قسم الهندسة الميكانيكية

ME 254
MATERIALS ENGINEERING
2nd Semester 1433/1434
Final Exam

(Three figures are attached in an external sheet, please give this sheet back with your answer sheet)

Question 1 (12 points)

a. State the conditions for complete substitutional solid solution.
b. Identify the three types of microscopic imperfections found in crystalline structures.
c. Calculate the radius of an iridium atom given that Ir has an FCC crystal structure, a density of 22.4 g/cm^3, and an atomic weight of 192.2 g/mol.
d. Calculate the number of vacancies per cubic meter in iron at 850^oC. The energy for vacancy formation is 1.08 eV/atom. Furthermore, the density and atomic weight for Fe are 7.65 g/cm3 and 55.85 g/mol, respectively.
e. Calculate the linear density for the [110] direction, and the planar density for the (110) plane for BCC unit cell.
f. Differentiate between the different types of cast iron.
g. State the types of diffusion mechanisms

Question 2 (10 points)

A cylindrical specimen of a stainless steel having a diameter of 10 mm and a gauge length of 40 mm is pulled in tension. Use the stress–strain curve shown in Fig. 3 to determine the following:

a) Compute the modulus of elasticity.
b) Determine the yield strength at a strain offset of 0.002.
c) Determine the tensile strength of this alloy.
d) What is the approximate ductility, in percent elongation?
e) Compute the modulus of resilience.
f) Compute the modulus of toughness
g) Determine the lateral strain at a load of 15 kN given that the Poisson's ratio, *v* is 0.3.
h) Determine the true stress and true strain at a load of 80 kN
i) Compute the strain hardening exponent, *n* and strength coefficient *k*.

Question 3: (5 marks)

a. write the eutectic and eutectoid reaction in Fe – C system, indicating the composition of each phase and the temperature at which the reactions take place.
b. For a hypoeutectoid steel of 0.3 wt% carbon, calculate the following:
    1. The amount of austenite and proeutectoid phase, just above the eutectoid temperature.
    2. The amount of ferrite and cementite just below the eutectoid temperature.
    3. The amount of eutectoid ferrite.

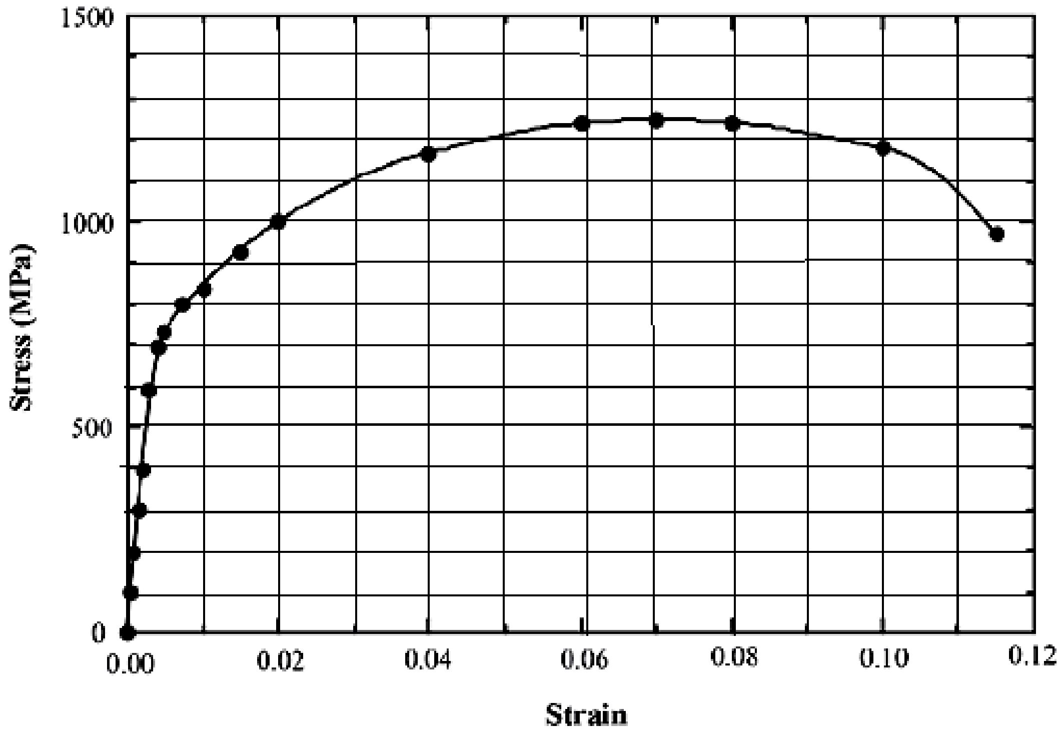
Question 4: (8 marks)

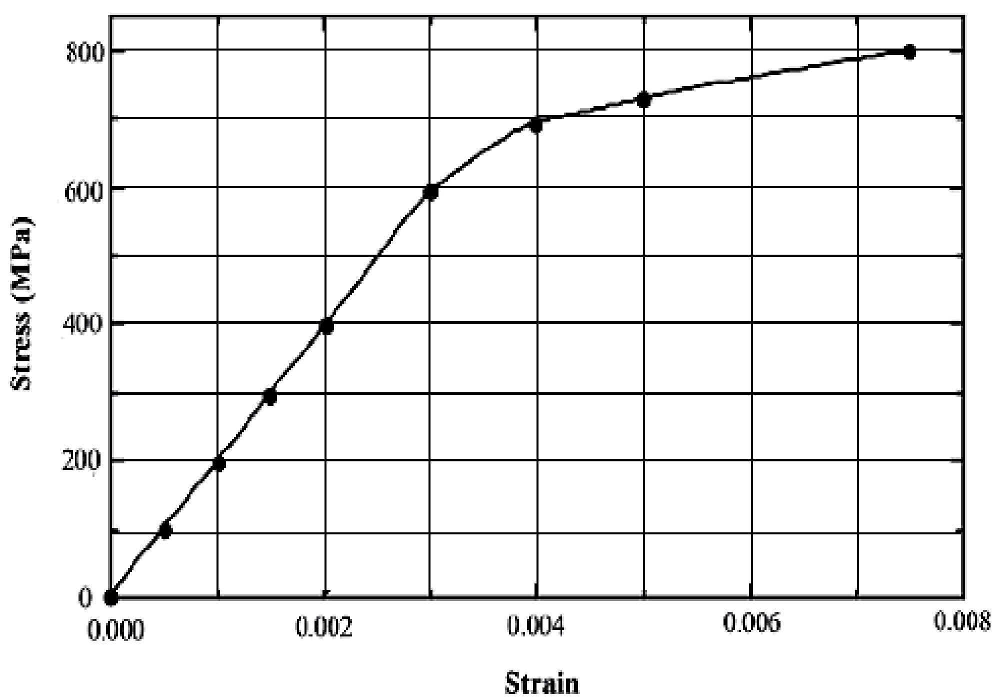
Using the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition (Figure 1), specify the nature of the final microstructure (in terms of microconstituents present and approximate percentages of each) of a small specimen that has been subjected to the following time–temperature treatments. In each case assume that the specimen begins at 800 °C and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.

1. Cool rapidly to 380 °C, hold for 10^3 s, then quench to room temperature.
2. Rapidly cool to 600 °C, hold for 10^4 s, then quench to room temperature.
3. Rapidly cool to 600 °C, hold for 1 s, rapidly cool to 450 °C, hold for 10 s, then quench to room temperature.
4. Reheat the specimen in part (2) to 700 °C for 20 h.
5. Rapidly cool to 300 °C, hold for 10^5 s, then quench to room temperature in water.
6. Cool rapidly to 665 °C, hold for 3000 s, then quench to room temperature.
7. Rapidly cool to 575 °C, hold for 5 s, rapidly cool to 350 °C, hold for 10^4 s, then quench to room temperature.
8. Rapidly cool to 320 °C, hold for 250 s, then quench to room temperature.

Question 5: (5 marks)

1. The maximum solubility of carbon in ferrite and austenite is
   (a) 0.022 and 2.14 wt% respectively (b). 3.0 and 4.2 wt% respectively (c) 0.76 and 6.7 wt% respectively.
2. If the atom of an element has the same protons and electrons but different neutrons we call it............
   (a) unstable (b) Ion (c) Isotope
3. The manner in which atoms, ions or molecules are specially arranged is ....
   (a) crystal structure (b) microstructure (c) atomic structure
4. The number of different possible combination of the lattice parameters are..
   (a) crystal system (b) phase system (c) dislocation system
5. Number of atoms centered on a direction divided by the length of this direction is ....
   (a) planer density (b) apparent density (c) linear density
6. Substances in which measured properties are independent of the direction are................................
   (a) isomorphism (b) isothermal (c) isotropic
7. Defects in which surface atoms are not bonded to the maximum number of nearest neighbors and become in higher energy is ....
   (a) linear defects (b) external surfaces defects (c) twin boundary defects
8. The strain fields that are exist around dislocations is...
   (a) strain rate (b) plain strain (c) lattice strain
9. The ability of the materials to absorb energy up to fracture known as ....
   (a) modulus of resilience (b) Hardness (c) toughness
10. If one solid phase transform into a liquid phase and another solid phase, we call it ....
    (a) Eutectic (b) Eutectoid (c) peritectic


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


800
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400
200
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Stress (MPa)
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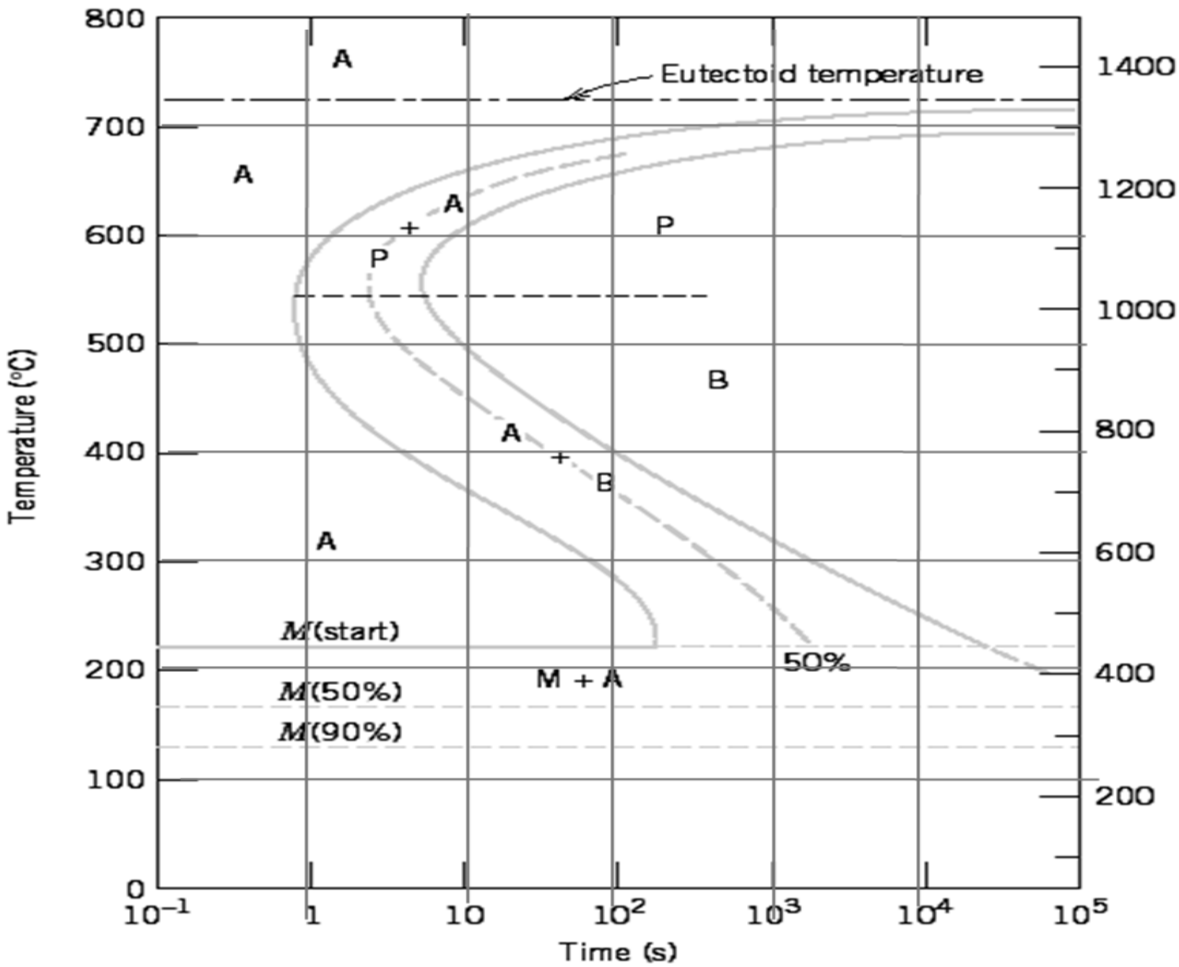
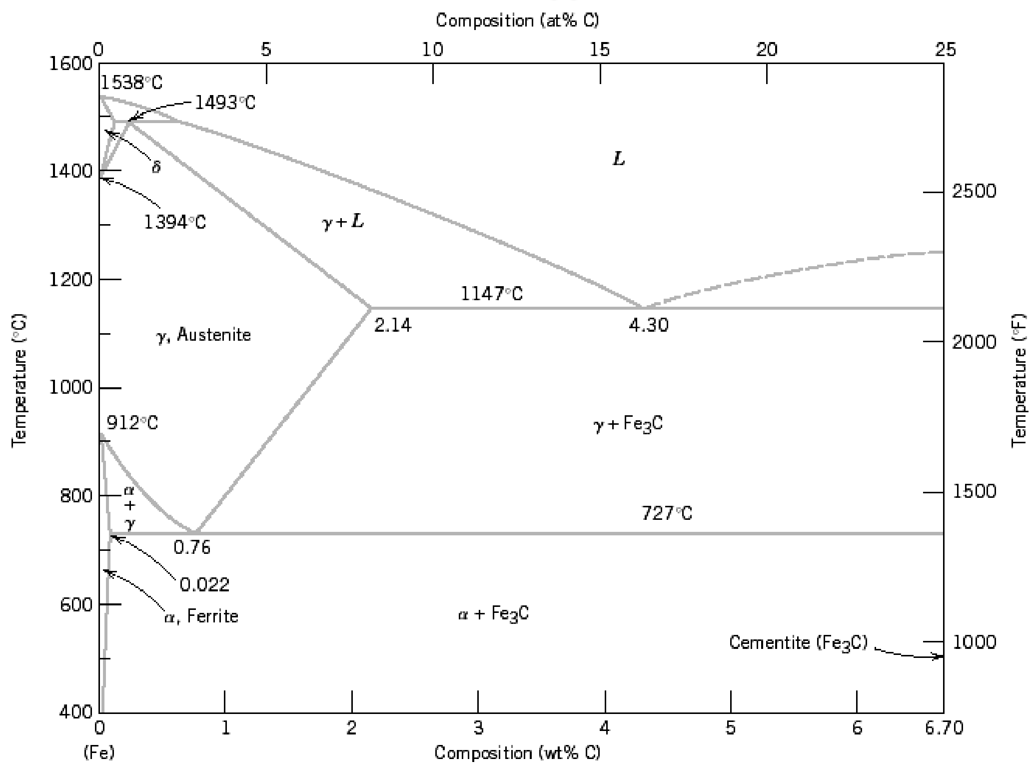
0.004
0.006
0.008
Strain



Eutectoid temperature
A
P
B
M(start)
M(50%)
M(90%)
M + A
50%
Temperature (°C)
Temperature (°F)
Time (s)



Composition (at% C)
1538°C
1493°C
δ
1394°C
L
γ + L
1147°C
2.14
4.30
γ, Austenite
912°C
γ + Fe3C
α + γ
727°C
0.76
0.022
α, Ferrite
α + Fe3C
Cementite (Fe3C)
(Fe)
Composition (wt% C)
Temperature (°C)
Temperature (°F)

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MATERIALS ENGINEERING
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Question 1

A) Choose the correct answer (2.5 marks)

11. Screw dislocation caused by ----------------
    a. Normal stresses b. Shear stresses c. Mixed
12. Diffusion is the phenomenon of material transport by----------------------
    a. dislocation motions b. atomic motions c. slipping
13. 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
14. The maximum solubility of carbon in ferrite and austenite is
    (a) 0.022 and 2.14 wt% respectively (b). 3.0 and 4.2 wt% respectively (c) 0.76 and 6.7 wt% respectively.
15. Single crystalline materials are usually -----------
    (a) Isotopic (b) anisotropic (c) neither

B) (6 marks)

1. Classify the following defects as point, line, or planar defect:
   a. A screw dislocation
   b. A vacancy
   c. A low angle boundary
   d. An edge dislocation
   e. An impurity atom.
   f. Self-interstitial atom

2. State the conditions for complete substitutional solid solubility.

3. A stress of 55 MPa is applied in the [001] direction of a BCC single crystal, calculate:
   a. The resolved shear stress acting on the (101) $[\bar{1}11]$ system and
   b. The resolved shear stress acting on the (110) $[\bar{1}11]$
   c. What would be the possible slip system?

Question 1 (6.5 marks)

1. What are the primary bonds existing in materials? Give an example for each bond.
2. Calculate the value of the density of FCC platinum? The atomic radius is 0.139*nm* and the atomic mass is 195*g/mol*. ($N_A = 6.02\times10^{23}$ *atoms/mol*)
3. Show for the body centered cubic crystal structure that the unit cell edge length ***a*** and the atomic radius ***R*** are related through $a = 4R/\sqrt{3}$.

4. Calculate the linear density for the [110] direction, and the planar density for the (110) plane for BCC unit cell
5. Explain the common crystal structure in metals and determine the number of atoms per unit cell and packing factor.

Question 3: (8 marks)

Using the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition (Figure 1), specify the nature of the final microstructure (in terms of microconstituents present and approximate percentages of each) of a small specimen that has been subjected to the following time–temperature treatments. In each case assume that the specimen begins at 760 °C and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.

9. Cool rapidly to 350 °C, hold for 10^3 s, then quench to room temperature.
10. Rapidly cool to 625 °C, hold for 10 s, then quench to room temperature.
11. Rapidly cool to 600 °C, hold for 4 s, rapidly cool to 450 °C, hold for 10 s, then quench to room temperature.
12. Reheat the specimen in part (c) to 700 °C for 20 h.
13. Rapidly cool to 300 °C, hold for 20 s, then quench to room temperature in water. Reheat to 425 °C for 10^3 s and slowly cool to room temperature.
14. Cool rapidly to 665 °C, hold for 10^3 s, then quench to room temperature.
15. Rapidly cool to 575 °C, hold for 20 s, rapidly cool to 350 °C, hold for 100 s, then quench to room temperature.
16. Rapidly cool to 350 °C, hold for 150 s, then quench to room temperature.

Question 4:

a) **(2 marks)**

Discuss briefly three strengthening mechanisms of metals, and the basic idea behind each.

b) (4 marks)

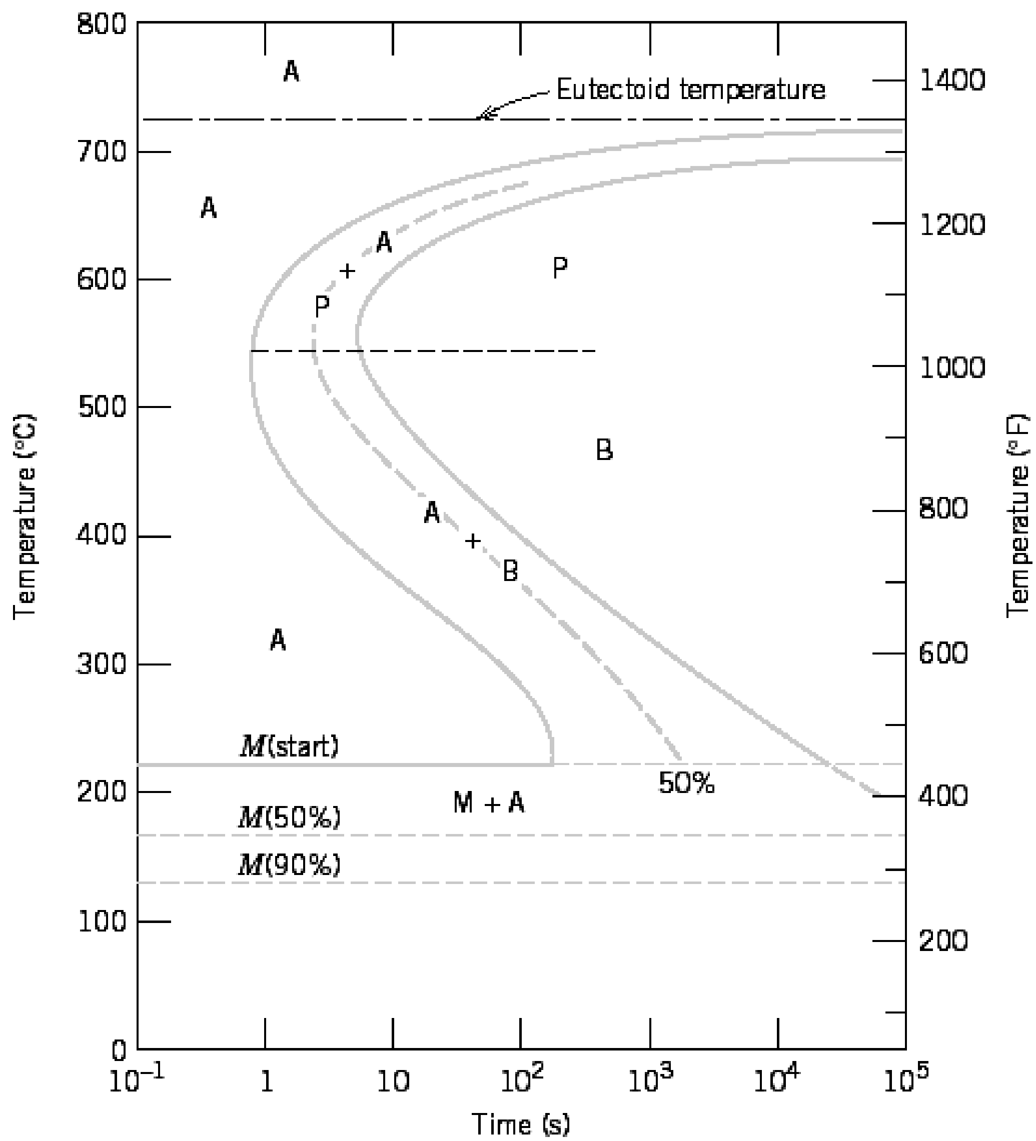
A specimen of ductile cast iron having a rectangular cross section of dimensions 4.8mm × 15.9mm is deformed in tension. Using the stress-strain diagram shown, answer the following (show your work on the stress – strain diagram supplied in the extra sheet):

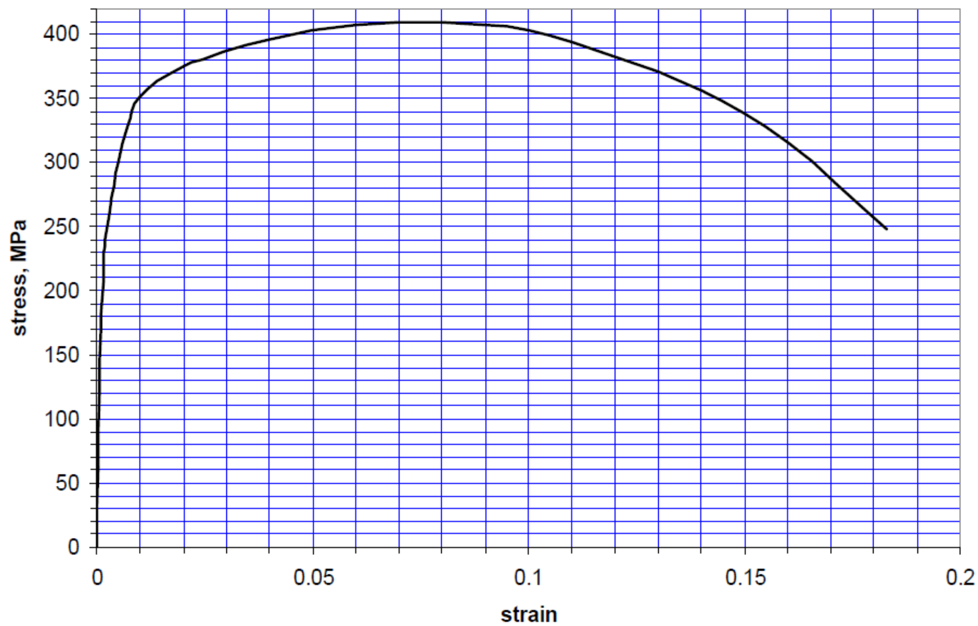
Compute the modulus of elasticity
Yield strength at a strain offset of 0.002
Determine the tensile strength of this alloy
What is the ductility, in percent elongation
Compute the modulus of resilience
Determine the lateral strain at a load of 10kN given that the Poisson's ratio, v is 0.3
Determine the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

Question 5: (8 marks)

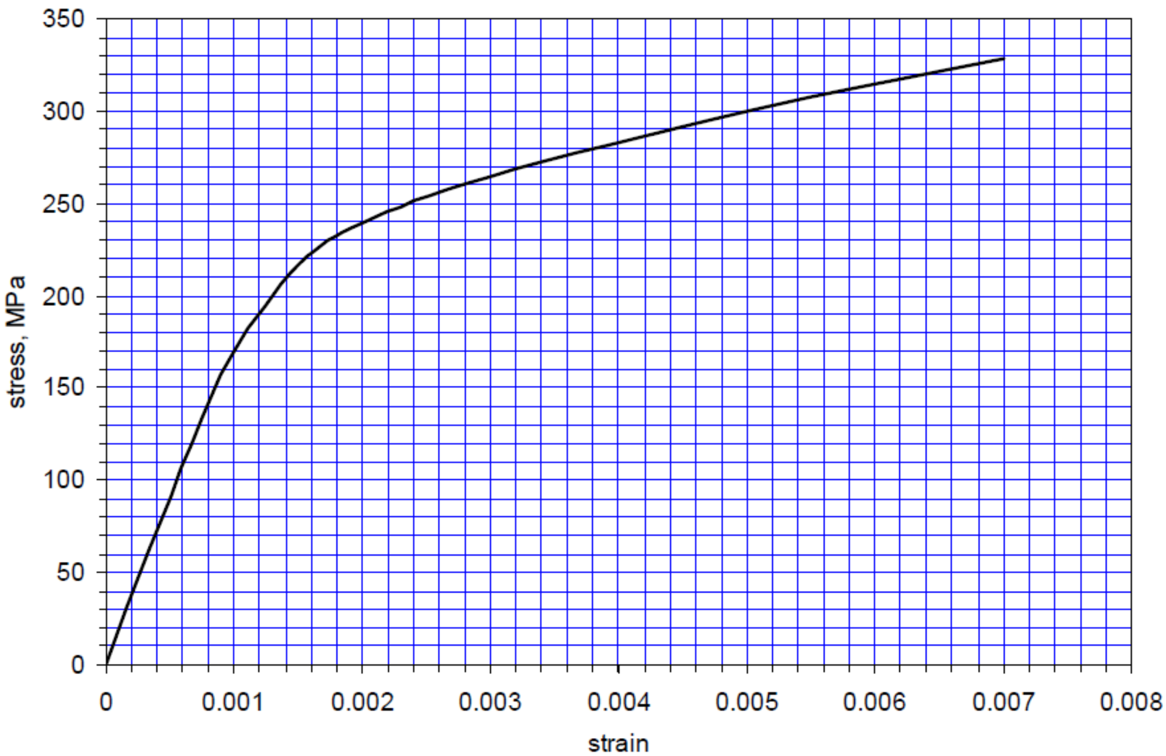
1. The weight fractions of total ferrite and total cementite in an iron–carbon alloy are 0.91 and 0.09, respectively. Is this a hypoeutectoid or hypereutectoid alloy? Why?

2. Discuss the mechanical properties and microstructure of pearlite, bainite, cementite, ferrite, austenite and martensite.
3. Define the following terms: Eutectic reaction, eutectoid reaction (apply to iron – carbon phase diagram).
4. Cite the phases that are present and the phase compositions for the following alloys:
   (a) 1 wt% C – 99 wt% Fe at (700 °C)
   (b) 2 wt% C – 98 wt% Fe at (900 °C)
   (c) 150 gram C and 5 kg Fe at (1200 °C)

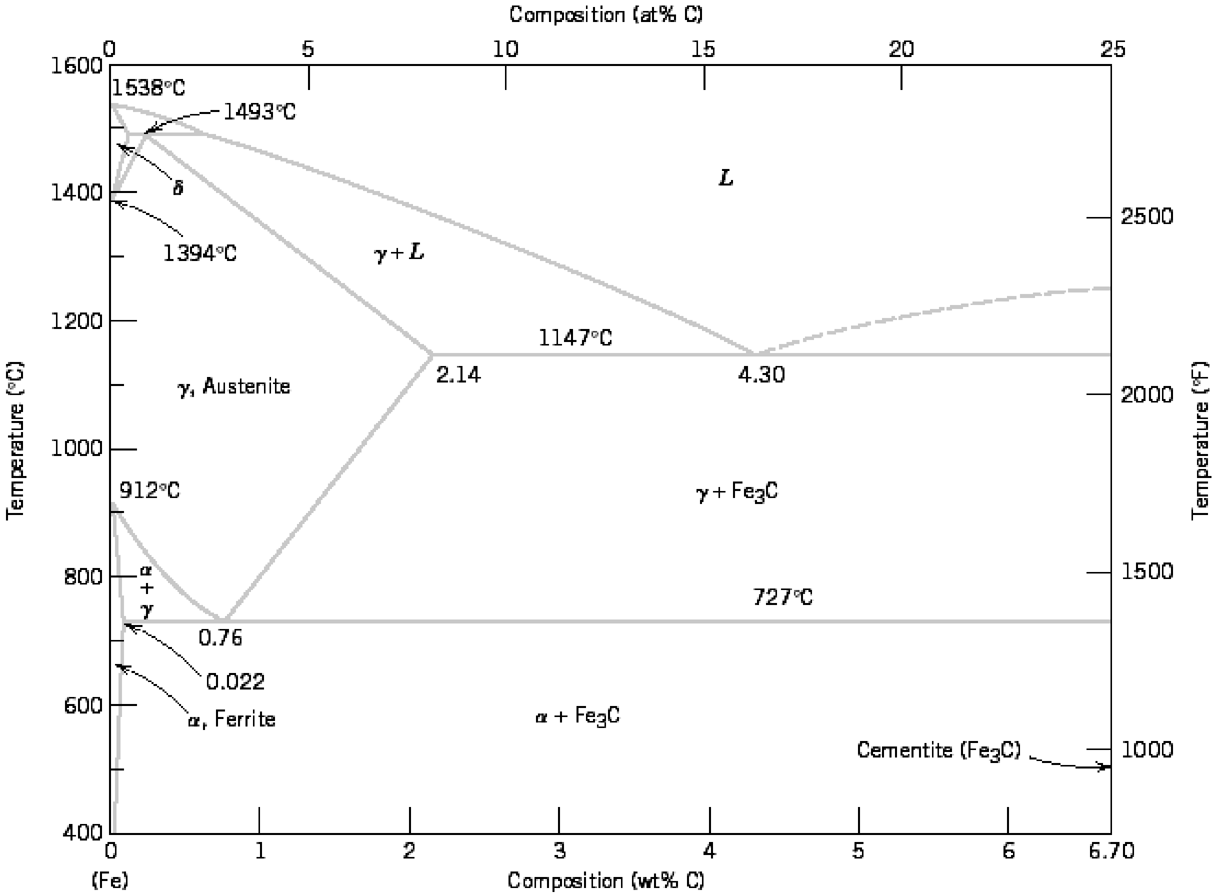




400
350
300
250
200
150
100
50
0
stress, MPa
0
0.05
0.1
0.15
0.2
strain



350
300
250
200
150
100
50
0
stress, MPa
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
strain



Composition (at% C)
0
5
10
15
20
25
1600
1538°C
1493°C
L
1400
δ
1394°C
γ + L
2500
1200
1147°C
2.14
4.30
γ, Austenite
2000
Temperature (°C)
Temperature (°F)
1000
912°C
γ + Fe3C
800
α
+
γ
727°C
1500
0.76
0.022
600
α, Ferrite
α + Fe3C
Cementite (Fe3C)
1000
400
0
1
2
3
4
5
6
6.70
(Fe)
Composition (wt% C)

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1st Semester 1431/1432
Final Exam

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Question 1

a)

1. Define the following terms: Isotope, Isotropic properties, atomic mass, Eutectic reaction, eutectoid reaction, and peritectic reaction.
2. Identify the three types of microscopic imperfections found in crystalline structures.
3. Differentiate between:
   Thermoplastic, thermosets and elastomers

b) A 90 wt% Ag–10 wt% Cu alloy is heated to a temperature within the **β** + liquid phase region. If the composition of the liquid phase is 85 wt% Ag, determine **(a)** the temperature of the alloy, **(b)** the composition of the **β** phase, and **(c)** the mass fractions of both phases. Use the given Cu-Ag phase diagram.

Question 2:

a)

1. Discuss briefly three strengthening mechanisms of metals, and the basic idea behind each.
2. Sketch the following direction and plane within a cubic unit cell

$[\bar{1}10]$ $(\bar{1}10)$

$[\bar{1}20]$ (310)

b) Consider a single crystal of BCC iron oriented such that a tensile stress is applied along a [010] direction.

1. Compute the resolved shear stresses along (110) plane and in $[1\bar{1}1]$ direction when a tensile stress of 52 MPa is applied.

2. If slip occurs on a (110) plane and a $[1\bar{1}1]$ direction, and the critical resolved shear stress is 30MPa, calculate the magnitude of the applied tensile stress necessary to initiate yielding.

Question 3:

a. Using the isothermal transformation diagram for Fe-C alloy of eutectoid composition. Specify the resulting microstructure from the following heat treatments: (Assume that, in each case, the specimen begins at 760 °C and that it attains a homogeneous austenite structure)

1. Cool rapidly to 370 °C, hold for 100 s, and then quench to room temperature.
2. Cool rapidly to 250 °C, hold for 10 s, then quench to room temperature.
3. Cool rapidly to 450 °C, hold for 10 s, rapidly cool to 250 °C hold for 1000 s then quench to room temperature.

b. Write the eutectic and eutectoid reaction in Fe – C system, indicating the composition of each phase and the temperature at which the reaction takes place.

c. For a hypoeutectoid steel of 0.4 wt% carbon, calculate the following:
1. The amount of austenite and proeutectoid phase, just above the eutectoid temperature.
2. The amount of ferrite and cementite just below the eutectoid temperature.
3. The amount of eutectoid ferrite.

Question 4:

a) Sketch the rock salt (NaCl) and Zinc blende (ZnS) unit cells.

b) Compute its theoretical density of NaCl giving that the atomic weight of Na and Cl are 22.99 and 35.45 g/mol respectively. Ionic radii of Na^+ and Cl^- are 0.102 nm and 0.181 nm respectively.

c) Consider a cylindrical specimen of some hypothetical metal alloy that has a diameter of 8.0 mm. A tensile force of 1000 N produces an elastic reduction in diameter of 2.8×10^{-4} mm. Compute the modulus of elasticity for this alloy, given that Poisson's ratio is 0.30.

Question 5: Choose the correct answer,

1. 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

2. Ceramic materials are hard and brittle because their atomic bonding is ………………

(a) Metallic bonding (b) ionic bonding (c) secondary bonding

3. Ductile iron contains carbon in the form of:

(a) graphite flakes, (b) graphite nodules, (c) cementite, (d) graphite rosettes.

4. The maximum solubility of carbon in ferrite and austenite is

(a) 0.022 and 2.14 wt% respectively (b). 3.0 and 4.2 wt% respectively (c) 0.76 and 6.7 wt% respectively.

5. Iron is allotropic it goes from ------------ when heated above 910 °C.

(a) BCC→ FCC (b) FCC→ HCP (c) FCC→BCC

6. Spheroidite is the ------------- of all known steels.

(a) most brittle (b) Softest (c) Strongest.

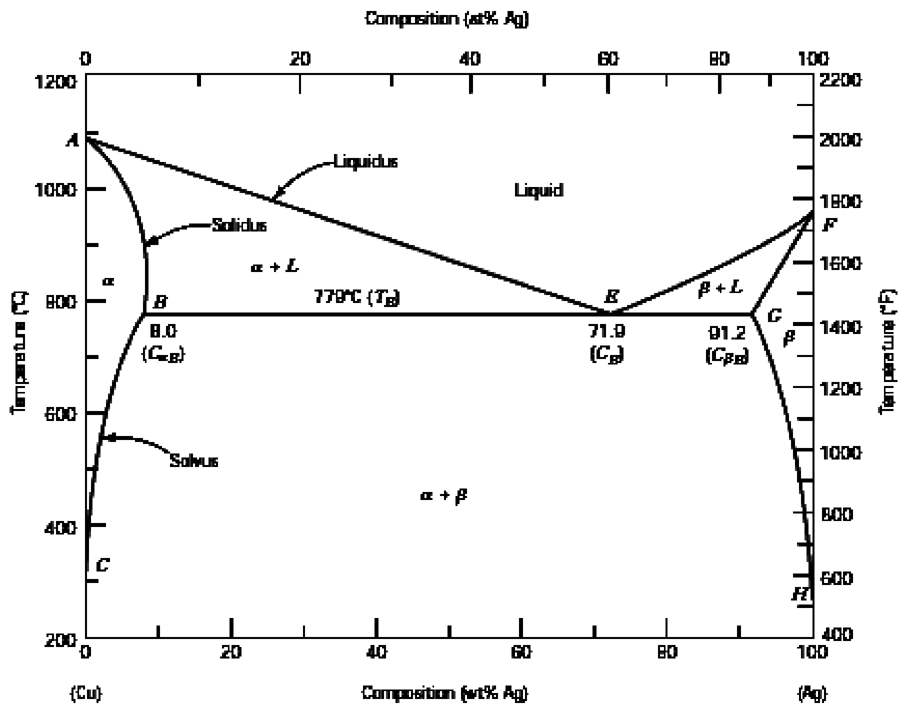
7. Single crystalline materials are usually -----------

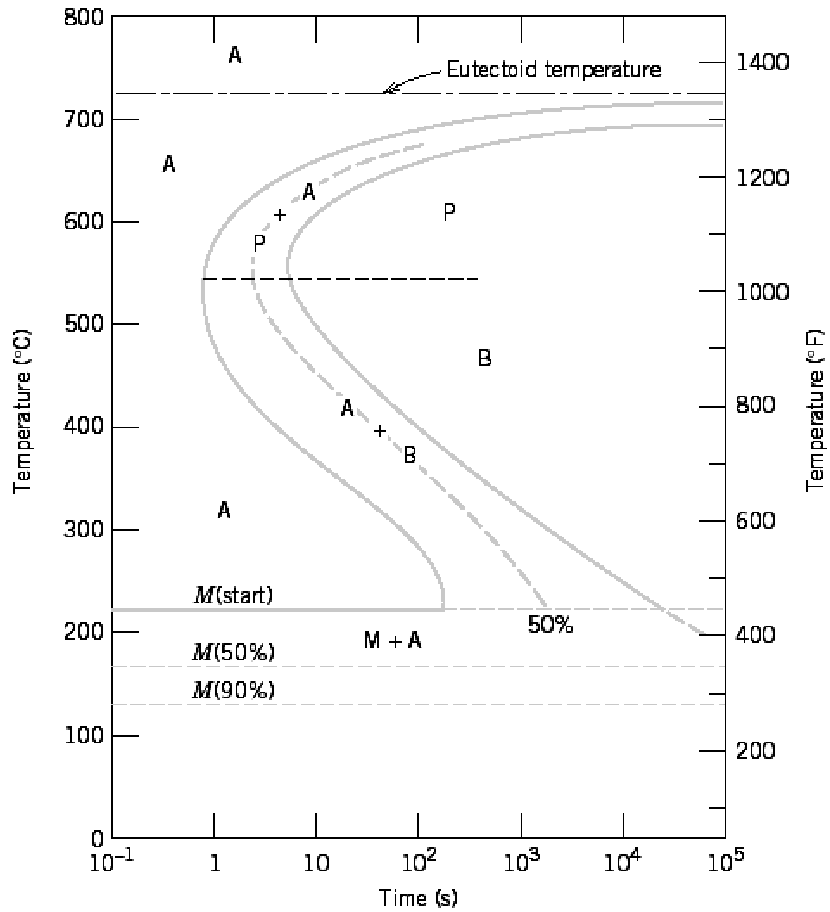
(a) Isotopic (b) anisotropic (c) neither

8. Brass is a solid solution alloy of ------ in Cu.
(a) Al (b) Pb (c) Zn (d) Sn.

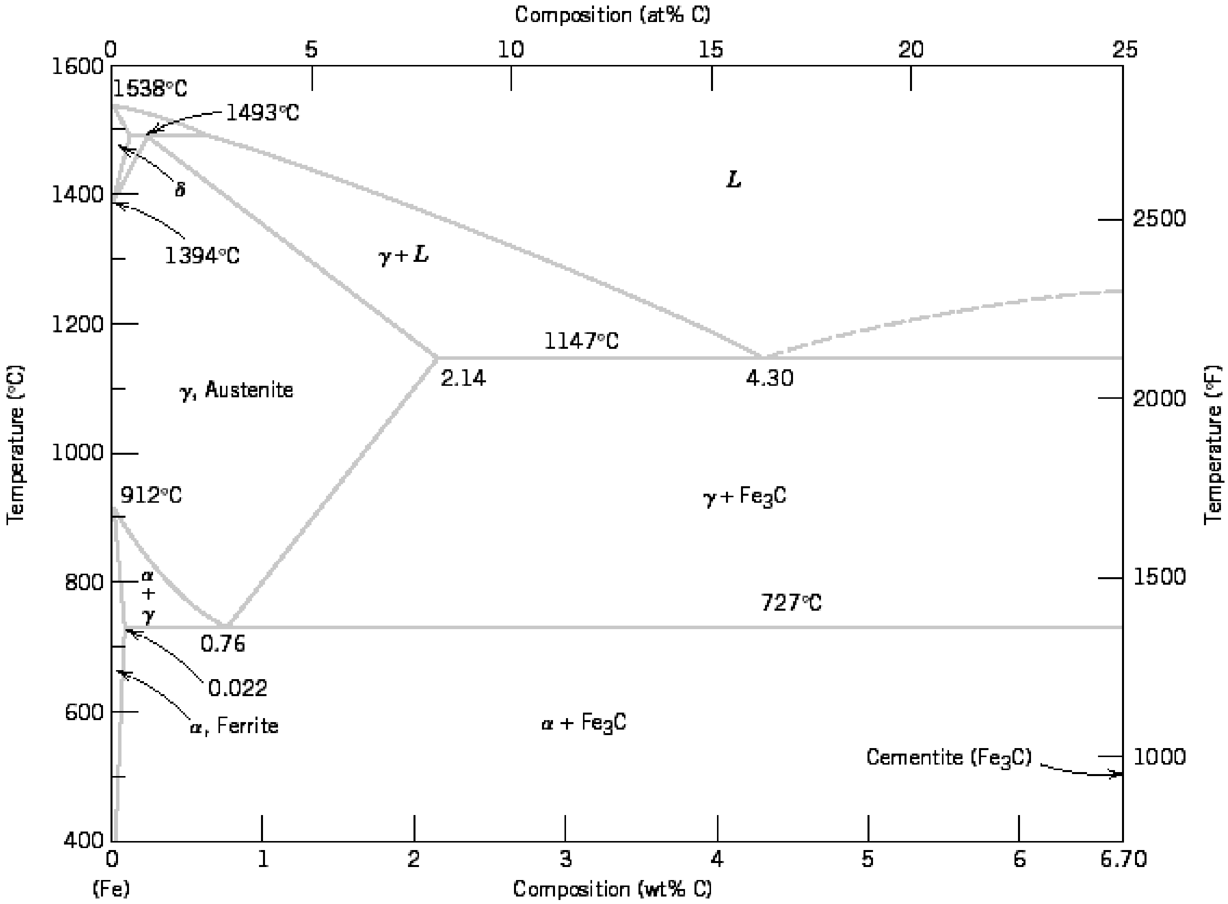
9. The major alloying element in 7075 Al alloy is--------.
(a) Al (b) Cu (c) Mg (d) Zn.

10. Surgery tools are made from:
(a) low carbon steel (b) tool steel (c) martensitic stainless steel (d) gray cast iron.





800
700
600
500
400
300
200
100
0
Temperature (°C)
1400
1200
1000
800
600
400
200
Temperature (°F)
10^{-1}
1
10
10^2
10^3
10^4
10^5
Time (s)
Eutectoid temperature
A
A
A
P
P
B
A
B
A
M(start)
50%
M + A
M(50%)
M(90%)



Composition (at% C)
0
5
10
15
20
25
1600
1538°C
1493°C
L
1400
δ
2500
1394°C
γ + L
1200
1147°C
2.14
4.30
γ, Austenite
2000
1000
Temperature (°C)
Temperature (°F)
912°C
γ + Fe3C
800
α
+
γ
727°C
1500
0.76
0.022
600
α, Ferrite
α + Fe3C
Cementite (Fe3C)
1000
400
0
1
2
3
4
5
6
6.70
(Fe)
Composition (wt% C)

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MATERIALS ENGINEERING
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Question 1

a)

4. Cite three criteria that are important in the materials selection process.
5. Briefly explain the concept of nanomaterials.
6. Briefly describe covalent and van der Waals bonds.

b) Consider 6.0 kg of austenite containing 0.45 wt% C, cooled to below 727 °C.

1. What is the proeutectoid phase?
2. How many kilograms each of total ferrite and cementite form?
3. How many kilograms each of pearlite and the proeutectoid phase form?
4. Schematically sketch and label the resulting microstructure.

Question 2:

a)

1. Explain why the properties of polycrystalline materials are most often isotropic.
2. Identify the three types of microscopic imperfections found in crystalline structures.
3. Name and describe the two atomic mechanisms of diffusion.

b)

1. If the atomic radius of lead is 0.175 nm, calculate the volume of its unit cell in cubic meters. Note that: Lead has an FCC crystal structure.
2. Within a cubic unit cell, sketch the following directions and planes:
   [111], [212], [301]
   (101), (211), (012)

Question 3:

a)

1. Write Fick's first law in equation form, and define all parameters.
2. Write Hooke's law, and note the conditions under which it is valid.
3. Name and briefly describe the two different hardness testing techniques

b) Using the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition (Figure 2), specify the nature of the final microstructure (in terms of microconstituents present and approximate percentages) of a small specimen that has been subjected to the following time–temperature treatments. In each case assume that the specimen begins at 760 °C and it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.

(1) Rapidly cool to 350 °C, hold for 10^4 s, and rapidly cooled to room temperature.
(2) Rapidly cool to 250 °C, hold for 10 s, and quench to room temperature.
(3) Rapidly cool to 600 °C, hold for 100 s, and quench to room temperature.

Question 4:

a)

1. Discuss briefly three strengthening mechanisms of metals, and the basic idea behind each.
2. Define the following terms: Eutectic reaction, eutectoid reaction, and peritectic reaction.
3. Sketch the rock salt (NaCl) and Cesium chloride (CsCl) unit cells, label the ions.

b) A cylindrical specimen of a stainless steel having a diameter of 12.8 mm and a gauge length of 50.8 mm is pulled in tension. Use the stress–strain curve shown in Fig. 3 to determine the following:

1. Compute the modulus of elasticity.
2. Determine the yield strength at a strain offset of 0.002.
3. Determine the tensile strength of this alloy.
4. What is the approximate ductility, in percent elongation?
5. Compute the modulus of resilience.

Question 5: Choose the correct answer,

1. 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

2. Ceramic materials are hard and brittle because their atomic bonding is ………………

(a) Metallic bonding (b) ionic bonding (c) secondary bonding

3. Cast iron (4.3% C) contains carbon in the form of:

(a) Graphite flakes, (b) graphite nodules, (c) cementite, (d) graphite rosettes.

4. The maximum solubility of carbon in ferrite and austenite is

(a) 0.022 and 2.14 wt% respectively (b). 3.0 and 4.2 wt% respectively (c) 0.76 and 6.7 wt% respectively.

5. Iron is allotropic it goes from ------------ when heated above 910 °C.

(a) BCC→ FCC (b) FCC→ HCP (c) FCC→BCC

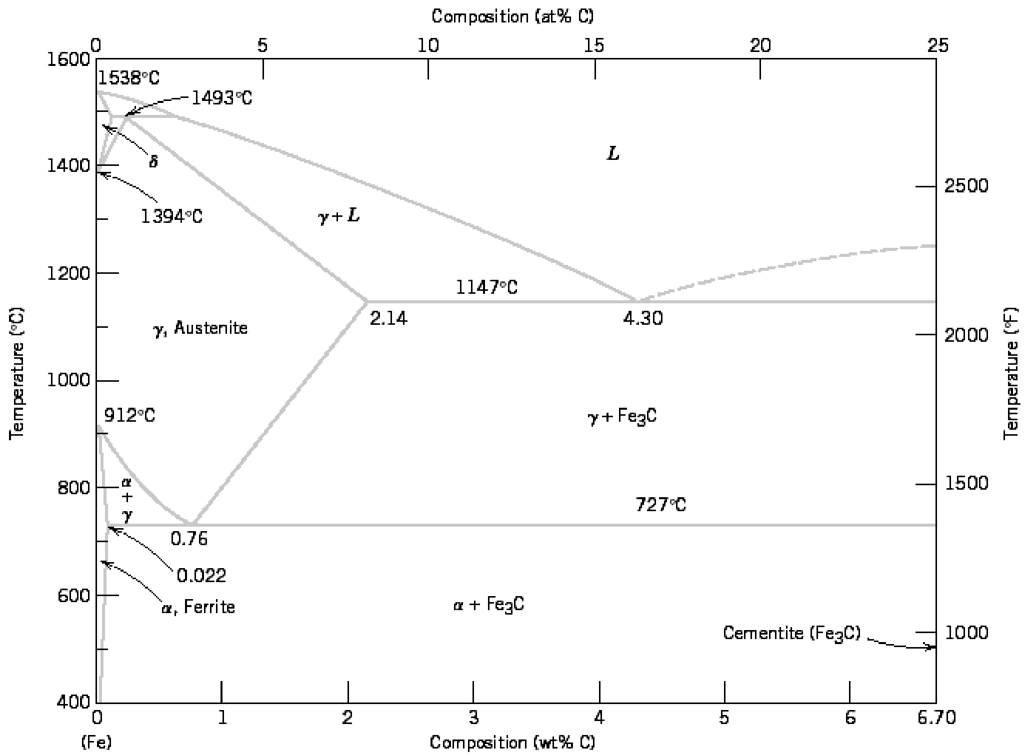
6. Spheroidite is the ------------- of all known steels.

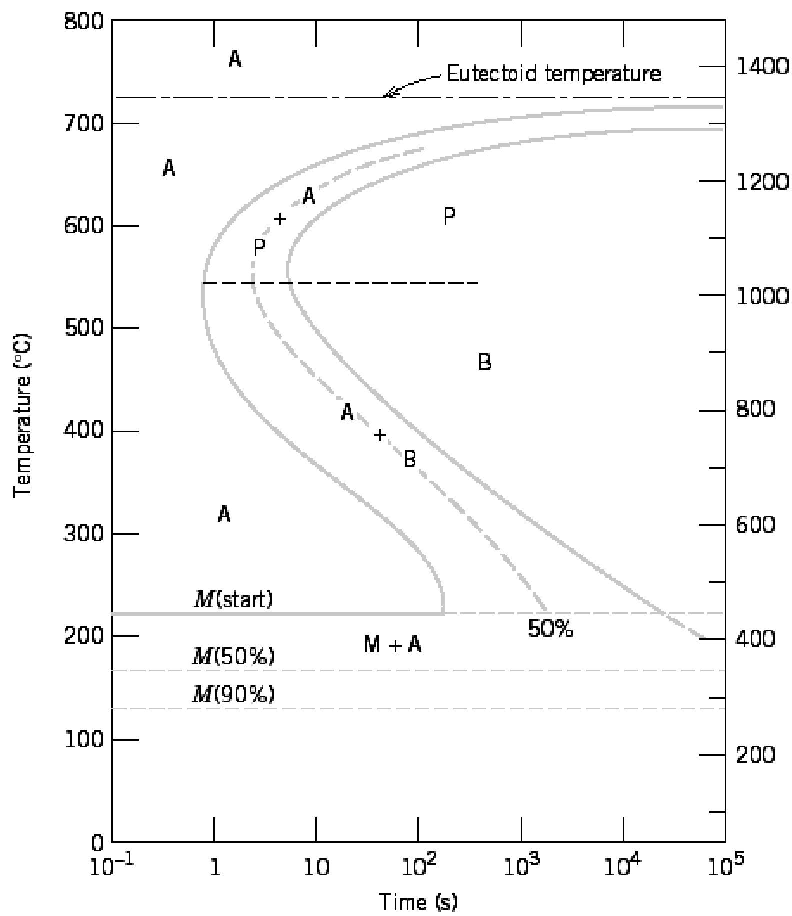
(a) most brittle (b) Softest (c) Strongest.

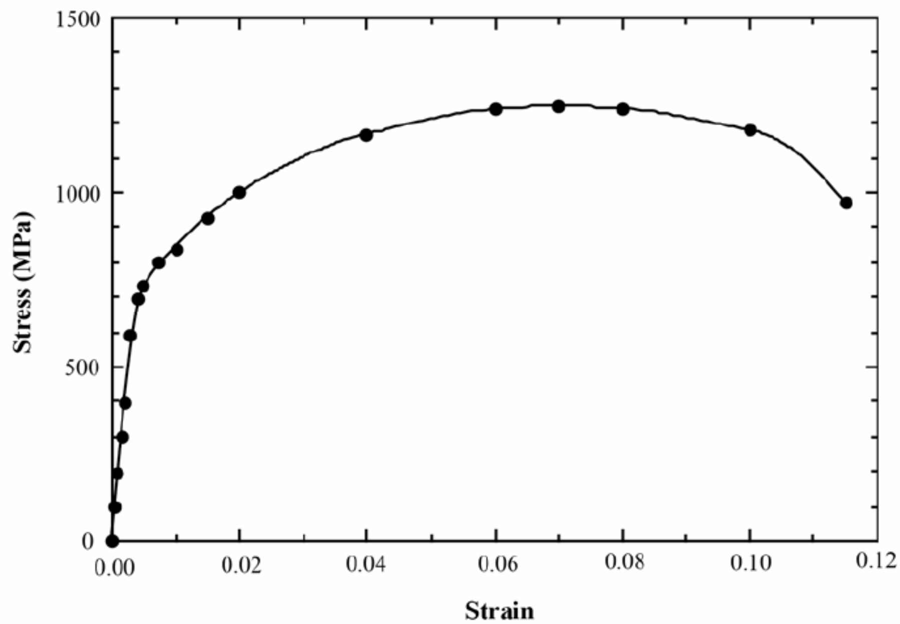
7. Single crystalline materials are usually -----------

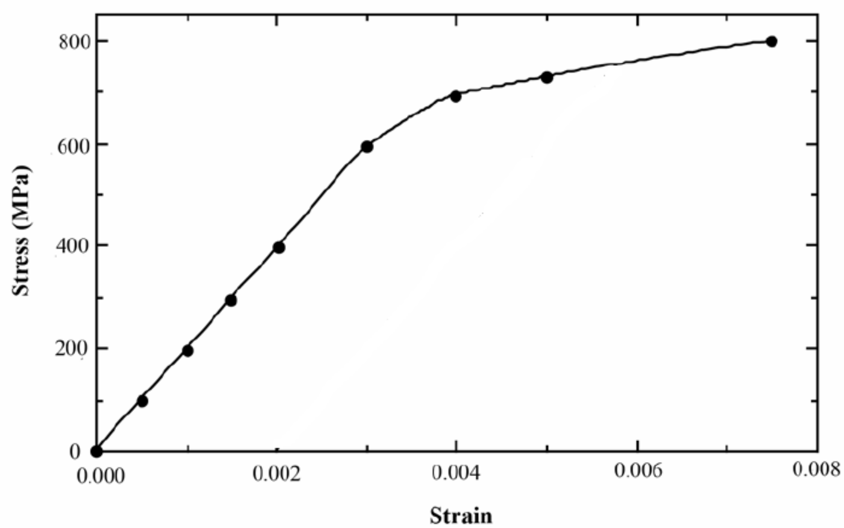
(a) Isotopic (b) anisotropic (c) neither

8. Brass is a solid solution alloy of ------ in Cu.
(a) Al (b) Pb (c) Zn (d) Sn.
9. The major alloying element in 7075 Al alloy is--------.
(a) Ni (b) Cu (c) Mg (d) Zn.
10. Surgery tools are made from:
(a) low carbon steel (b) tool steel (c) martensitic stainless steel (d) gray cast iron.


Composition (at% C)
0
5
10
15
20
25
1600
1538°C
1493°C
δ
L
1400
1394°C
γ + L
2500
1200
1147°C
2.14
4.30
γ, Austenite
2000
Temperature (°C)
Temperature (°F)
1000
912°C
γ + Fe3C
800
α
+
γ
727°C
1500
0.76
0.022
600
α, Ferrite
α + Fe3C
Cementite (Fe3C)
1000
400
0
1
2
3
4
5
6
6.70
(Fe)
Composition (wt% C)


800
A
Eutectoid temperature
1400
700
A
A
1200
+
600
P
P
1000
500
B
Temperature (°C)
Temperature (°F)
400
A
+
B
800
A
300
600
M(start)
50%
200
M + A
400
M(50%)
M(90%)
100
200
0
10−1
1
10
10²
10³
10⁴
10⁵
Time (s)


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


800
600
400
200
0
Stress (MPa)
0.000
0.002
0.004
0.006
0.008
Strain

ME 254
MATERIALS ENGINEERING
1st Semester 1432/1433
Final Exam

(Three figures are attached in an external sheet, please give this sheet back with your answer sheet)

Question 1

a) Choose the correct answer (4 marks)

16. In complete solid solution -------------- structure will be obtained
    a. new b. no new c. amorphous
17. Screw dislocation caused by ----------------
    a. Normal stresses b. Shear stresses c. Mixed
18. Diffusion is the phenomenon of material transport by----------------------
    a. dislocation motions b. atomic motions c. slipping
19. 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
20. 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
21. The maximum solubility of carbon in ferrite and austenite is
    (a) 0.022 and 2.14 wt% respectively (b). 3.0 and 4.2 wt% respectively (c) 0.76 and 6.7 wt% respectively.
22. Spheroidite is the ------------- of all known steels.
    (a) most brittle (b) Softest (c) Strongest.
23. Single crystalline materials are usually -----------
    (a) Isotopic (b) anisotropic (c) neither

b) (8 marks)

1. Calculate the fraction of atom sites that are vacant for copper at its melting temperature of 1357 K. Assume the energy for vacancy formation of 0.90 eV/atom. $K = 8.62 \times 10^{-5}$ eV/atom.k
2. What are the miller indices of the slip directions : a) on the (111) plane in an FCC unit cell b) on the (110) plane in a BCC unit cell.
3. Consider the simple cubic crystal structure which has a cubic unit cell with atoms positions at each of the eight corners. The atoms touch one another along the edges. The slip system for this crystal structure is (100) [010]. A single crystal is stressed in tension along the [110] direction and yielded at a stress level of 13 MPa. Calculate the critical resolved shear stress.
4. Identify the types of microscopic imperfections found in crystalline structures.

Question 3: (8 marks)

Using the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition (Figure 1), specify the nature of the final microstructure (in terms of microconstituents present and approximate percentages of each) of a small specimen that has been subjected to the following time–temperature treatments. In each case assume that the specimen begins at 760 °C and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.

17. Cool rapidly to 350 °C, hold for 10^3 s, then quench to room temperature.
18. Rapidly cool to 625 °C, hold for 10 s, then quench to room temperature.
19. Rapidly cool to 600 °C, hold for 4 s, rapidly cool to 450 °C, hold for 10 s, then quench to room temperature.
20. Reheat the specimen in part (c) to 700 °C for 20 h.
21. Rapidly cool to 300 °C, hold for 20 s, then quench to room temperature in water. Reheat to 425 °C for 10^3 s and slowly cool to room temperature.
22. Cool rapidly to 665 °C, hold for 10^3 s, then quench to room temperature.
23. Rapidly cool to 575 °C, hold for 20 s, rapidly cool to 350 °C, hold for 100 s, then quench to room temperature.
24. Rapidly cool to 350 °C, hold for 150 s, then quench to room temperature.

Question 4:

a) **(2 marks)**

Discuss briefly three strengthening mechanisms of metals, and the basic idea behind each.

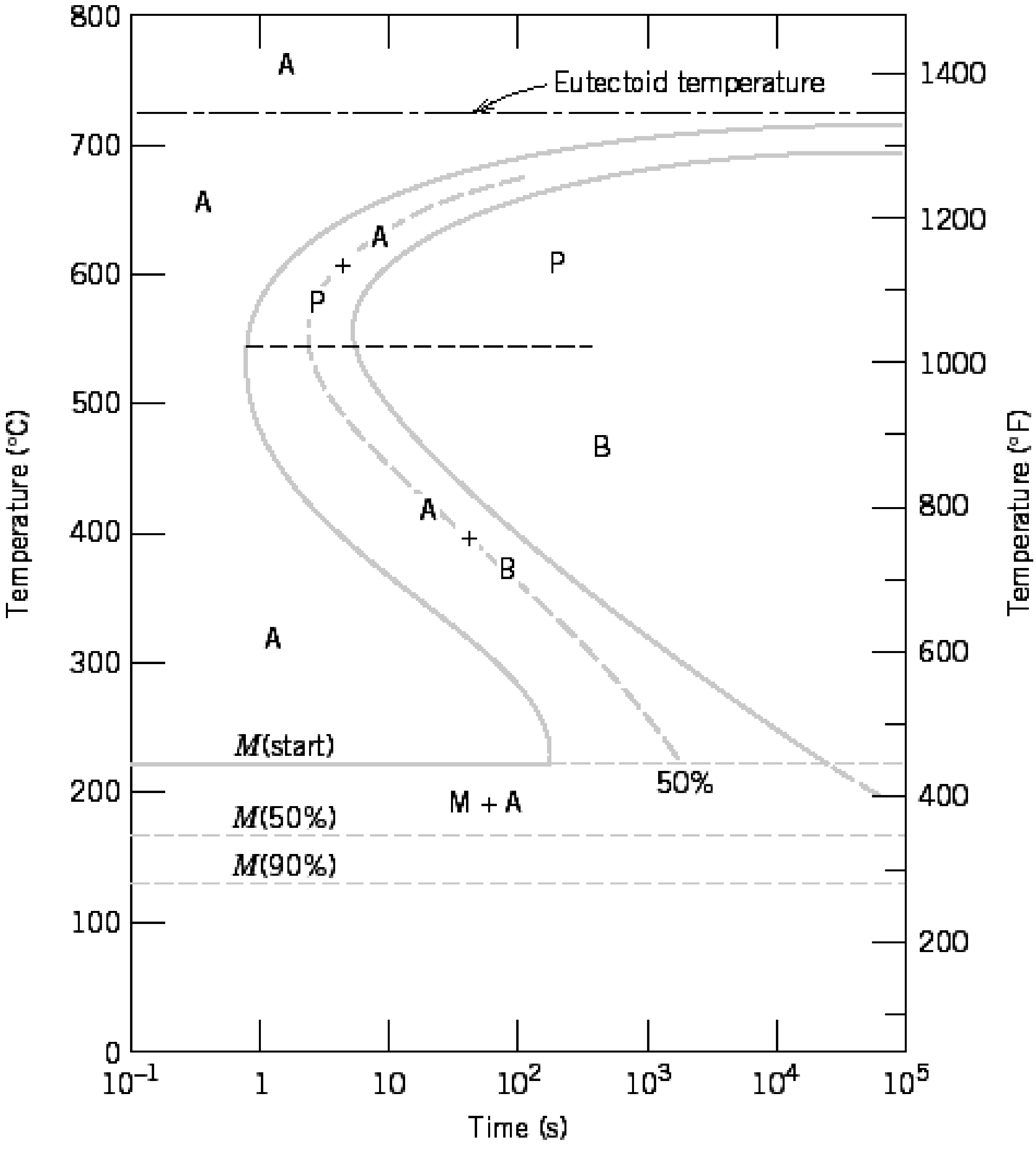
b) (10 marks)

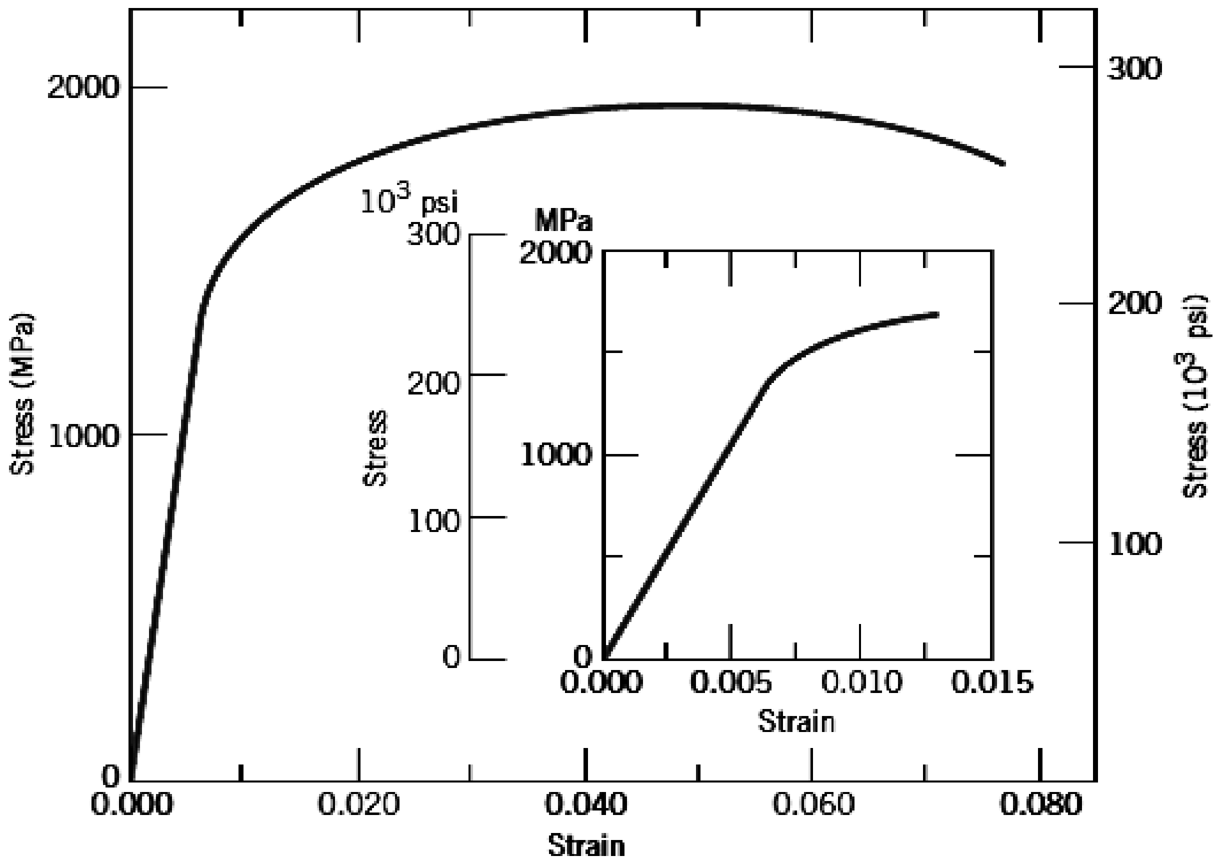
Consider a cylindrical specimen of a steel alloy (Figure2) 8.5 mm in diameter and 80 mm long that is pulled in tension. Determine:

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. Compute the modulus of resilience
5. Compute the modulus of toughness
6. Determine the change in diameter at a load of 55 kN given that the Poisson's ratio, v is 0.3
7. Determine the true stress and true strain at a load of 44.5 kN
8. Compute the value of strain hardening exponent (n) and strength coefficient (k).

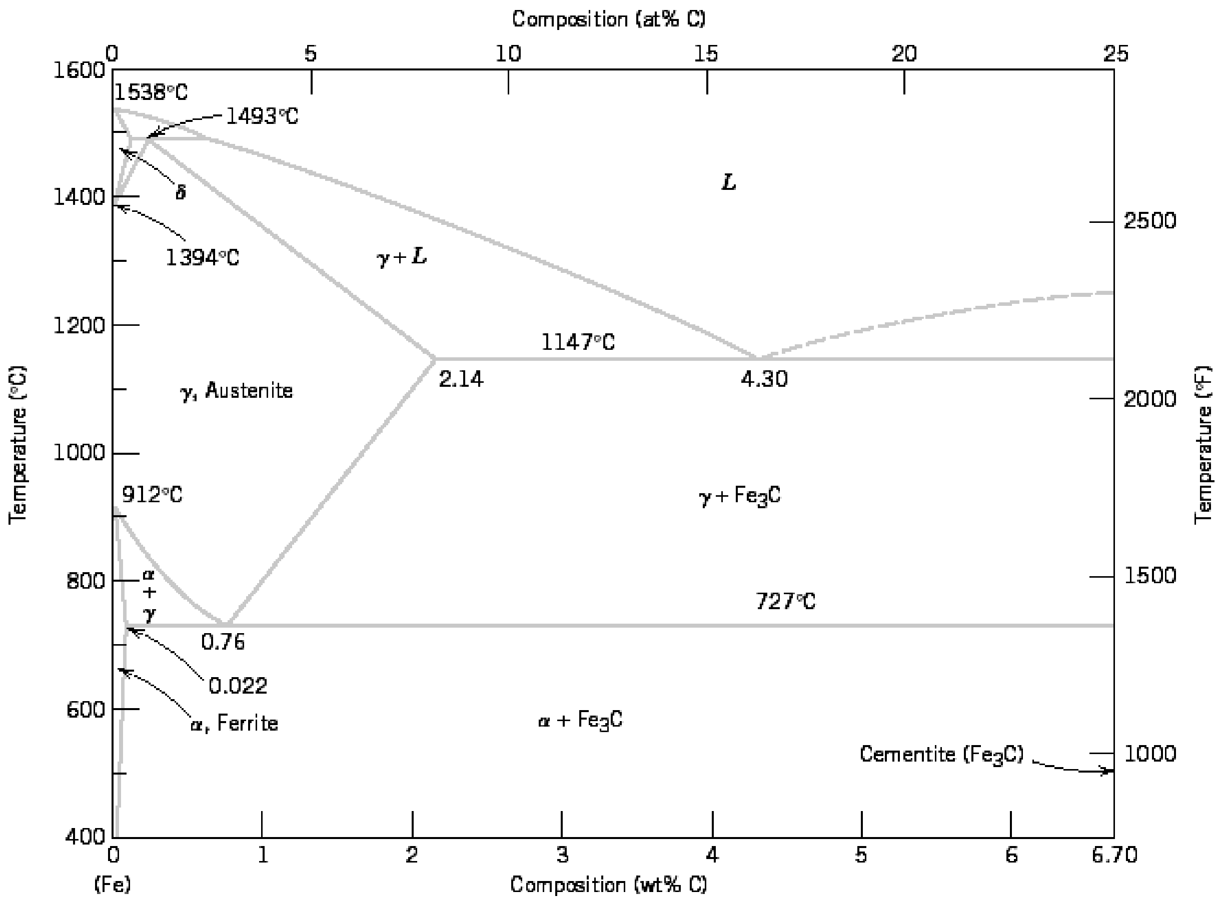
Question 5: (10 marks)

5. The mass fractions of total ferrite and total cementite in an iron–carbon alloy are 0.91 and 0.09, respectively. Is this a hypoeutectoid or hypereutectoid alloy? Why?
6. Discuss the mechanical properties and microstructure of pearlite, bainite, cementite, ferrite, austenite and martensite.
7. Define the following terms: Eutectic reaction, eutectoid reaction (apply to iron – carbon phase diagram).
8. Consider 6.0 kg of austenite containing 0.45 wt% C, cooled to below 727 °C.
   a)How many kilograms each of total ferrite and cementite form?
   b)How many kilograms each of pearlite and the proeutectoid phase form?


800
700
600
500
400
300
200
100
0
Temperature (°C)
1400
1200
1000
800
600
400
200
Temperature (°F)
A
Eutectoid temperature
A
A
P
P
A
B
A
B
A
M(start)
50%
M + A
M(50%)
M(90%)
10−1
1
10
10²
10³
10⁴
10⁵
Time (s)



2000
1000
0
Stress (MPa)
300
200
100
Stress (10^3 psi)
0.000
0.020
0.040
0.060
0.080
Strain
10^3 psi
300
200
100
0
Stress
MPa
2000
1000
0
0.000
0.005
0.010
0.015
Strain



Composition (at% C)
0
5
10
15
20
25
1600
1538°C
1493°C
L
δ
1400
2500
1394°C
γ + L
1200
1147°C
2.14
4.30
γ, Austenite
2000
Temperature (°C)
Temperature (°F)
1000
912°C
γ + Fe3C
800
α
+
γ
1500
727°C
0.76
0.022
600
α, Ferrite
α + Fe3C
Cementite (Fe3C)
1000
400
0
1
2
3
4
5
6
6.70
(Fe)
Composition (wt% C)

ME 254
MATERIALS ENGINEERING
1st Semester 1433/1434
Final Exam

قسم الهندسة الميكانيكية

(Three figures are attached in an external sheet, please give this sheet back with your answer sheet)

Question 1

A) Choose the correct answer (2 marks)

24. Screw dislocation caused by ----------------
 a. Normal stresses b. Shear stresses c. Mixed
25. Diffusion is the phenomenon of material transport by----------------------
 a. dislocation motions b. atomic motions c. slipping
26. 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
27. The maximum solubility of carbon in ferrite and austenite is
 (a) 0.022 and 2.14 wt% respectively (b). 3.0 and 4.2 wt% respectively (c) 0.76 and 6.7 wt% respectively.

B)(6 marks)

1. Classify the following defects as point, line, or planar defect:

g. A screw dislocation	h. An edge dislocation
i. A vacancy	j. An impurity atom.
k. A low angle boundary	l. Self-interstitial atom

2. State the conditions for complete substitutional solid solubility.

3. A stress of 55 MPa is applied in the [001] direction of a BCC single crystal, calculate:

d. The resolved shear stress acting on the (101) $[\bar{1}11]$ system and
e. The resolved shear stress acting on the (110) $[\bar{1}11]$
f. What would be the possible slip system?

Question 2 (8 marks)

6. What are the primary bonds existing in materials? Give an example for each bond.
7. Calculate the value of the density of FCC platinum? The atomic radius is 0.139*nm* and the atomic mass is 195*g/mol*. ($N_A = 6.02\times10^{23}$ *atoms/mol*)
8. Show for the body centered cubic crystal structure that the unit cell edge length ***a*** and the atomic radius ***R*** are related through $a = 4R/\sqrt{3}$.
9. Calculate the linear density for the [110] direction, and the planar density for the (110) plane for BCC unit cell

10. Explain the common crystal structures in metals and determine the number of atoms per unit cell and packing factor.
11. State the different types of polymer additives and state two processing techniques for polymers.

Question 3: (6 marks)

Using the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition (Figure 1), specify the nature of the final microstructure (in terms of microconstituents present and approximate percentages of each) of a small specimen that has been subjected to the following time–temperature treatments. In each case assume that the specimen begins at 760 °C and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.

25. Cool rapidly to 350 °C, hold for 10^3 s, then quench to room temperature.
26. Rapidly cool to 625 °C, hold for 10 s, then quench to room temperature.
27. Rapidly cool to 600 °C, hold for 4 s, rapidly cool to 450 °C, hold for 10 s, then quench to room temperature.
28. Reheat the specimen in part (c) to 700 °C for 20 h.
29. Rapidly cool to 300 °C, hold for 20 s, then quench to room temperature in water. Reheat to 425 °C for 10^3 s and slowly cool to room temperature.
30. Rapidly cool to 575 °C, hold for 20 s, rapidly cool to 350 °C, hold for 100 s, then quench to room temperature.

Question 4:

a) **(2 marks)**

Discuss briefly three strengthening mechanisms of metals, and the basic idea behind each.

b) (8 marks)

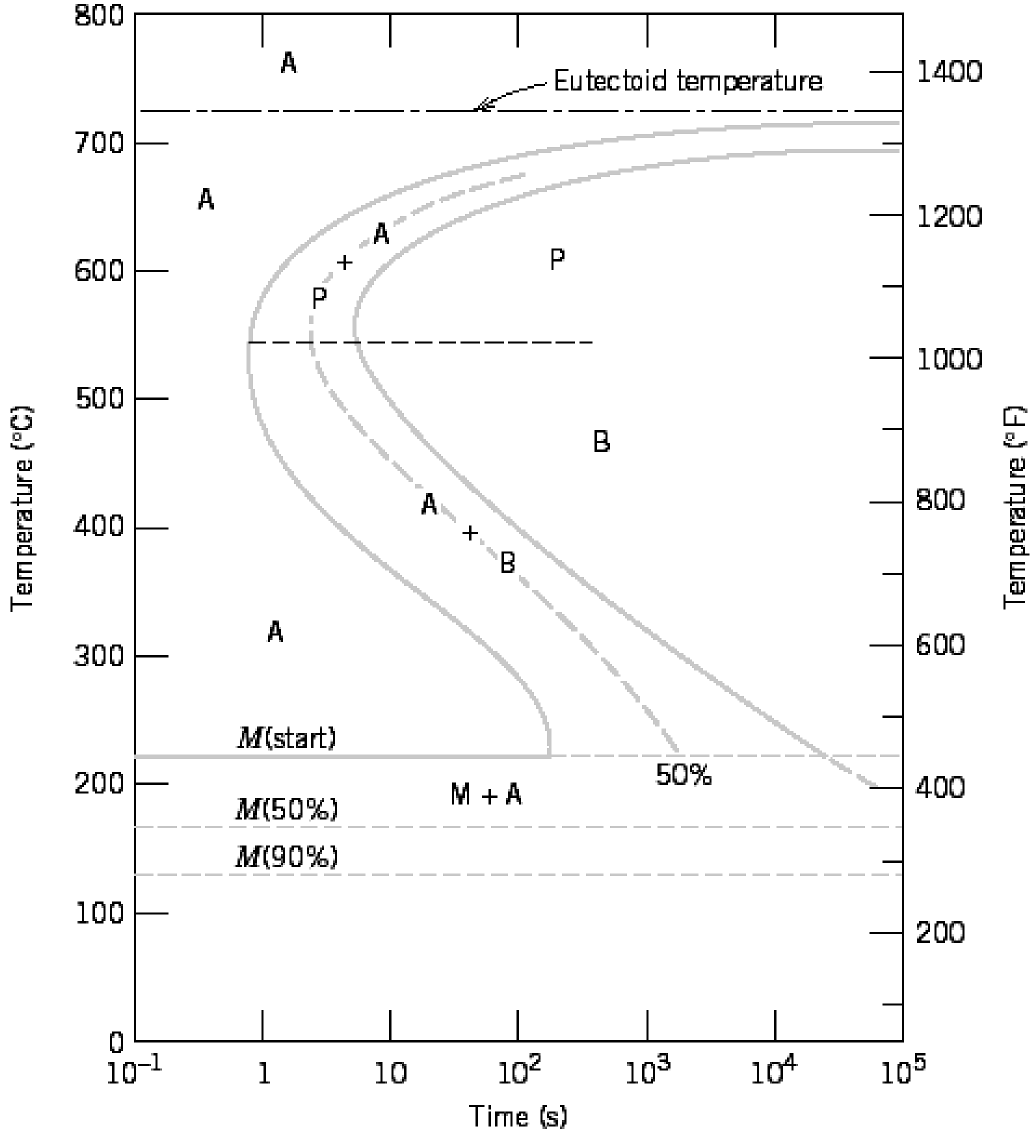
A specimen of ductile cast iron having a rectangular cross section of dimensions 4.8mm × 15.9mm isdeformed in tension. Using the stress-strain diagram shown, answer the following (show your work onthestress – strain diagram supplied in the extra sheet):

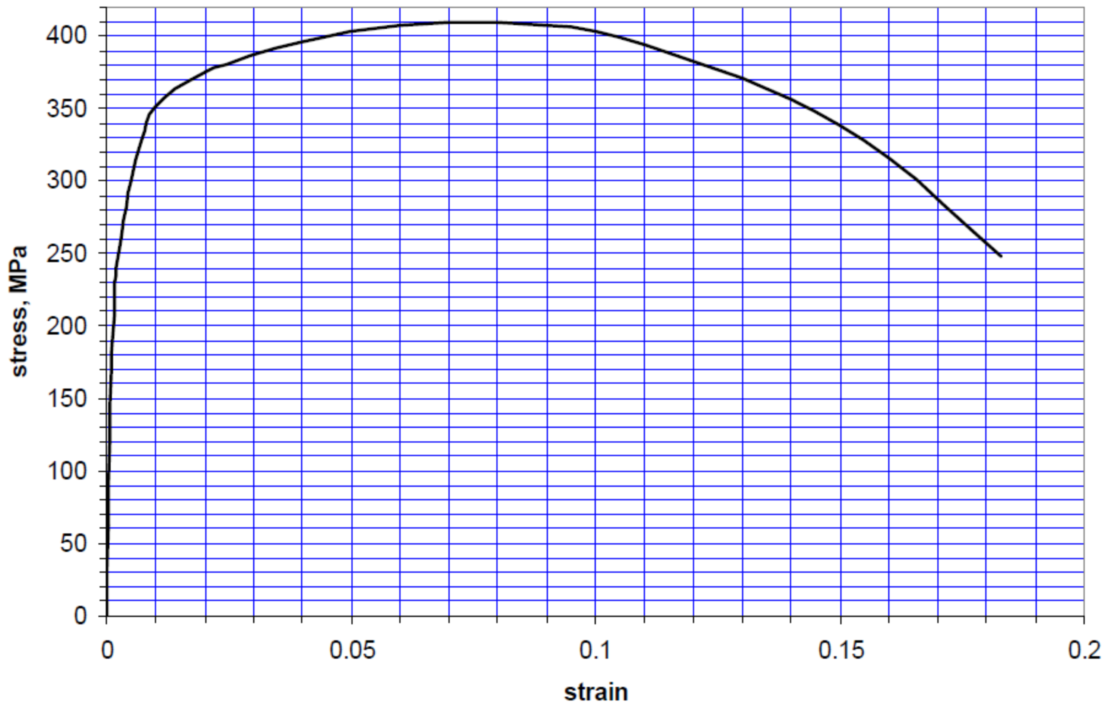
1. Compute the modulus of elasticity
2. Yield strength at a strain offset of 0.002
3. Determine the tensile strength of this alloy
4. What is the ductility, in percent elongation
5. Compute the modulus of resilience
6. Determine the lateral strain at a load of 10kN given that the Poisson's ratio, *v*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

Question 5: (8 marks)

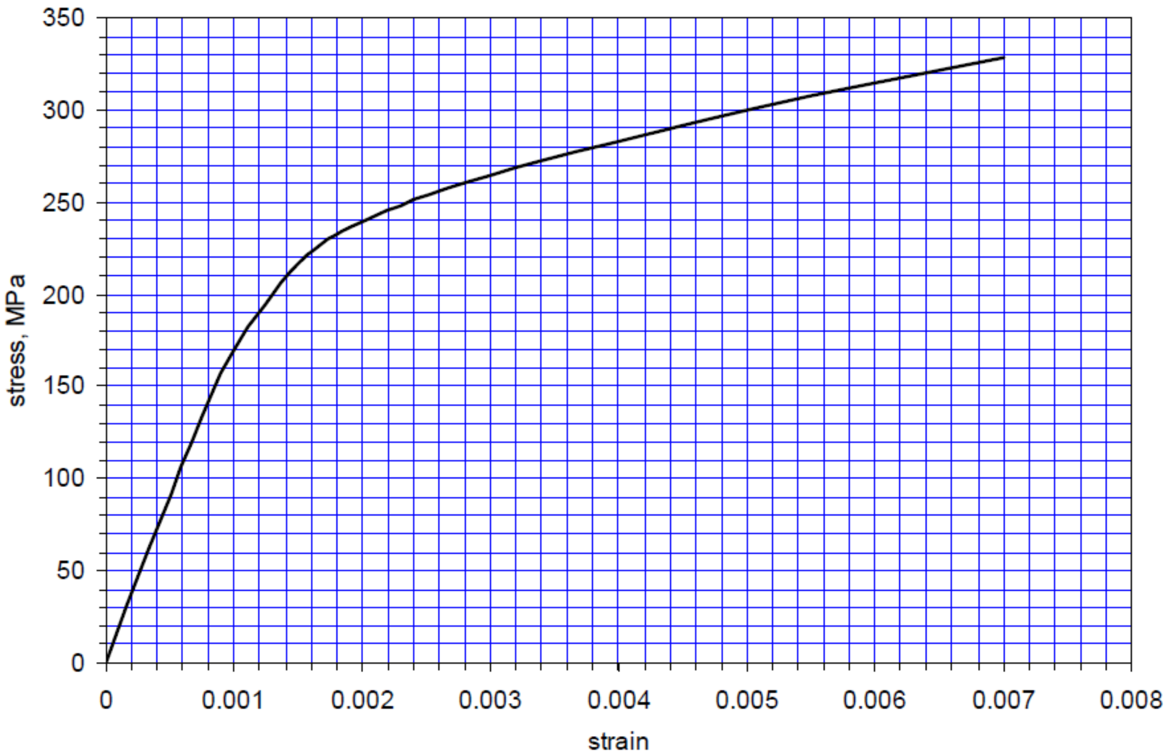
9. Discuss the mechanical properties and microstructure of pearlite, bainite, cementite, ferrite, austenite and martensite.
10. Define the following terms: Eutectic reaction, eutectoid reaction (apply to iron – carbon phase diagram).
11. Cite the phases that are present and the phase compositions and weight fractions for the following alloys:
    (a) 1 wt% C – 99 wt% Fe at (700 °C)
    (b) 2 wt% C – 98 wt% Fe at (900 °C)

(c) 150 gram C and 5 kg Fe at (1200 °C)

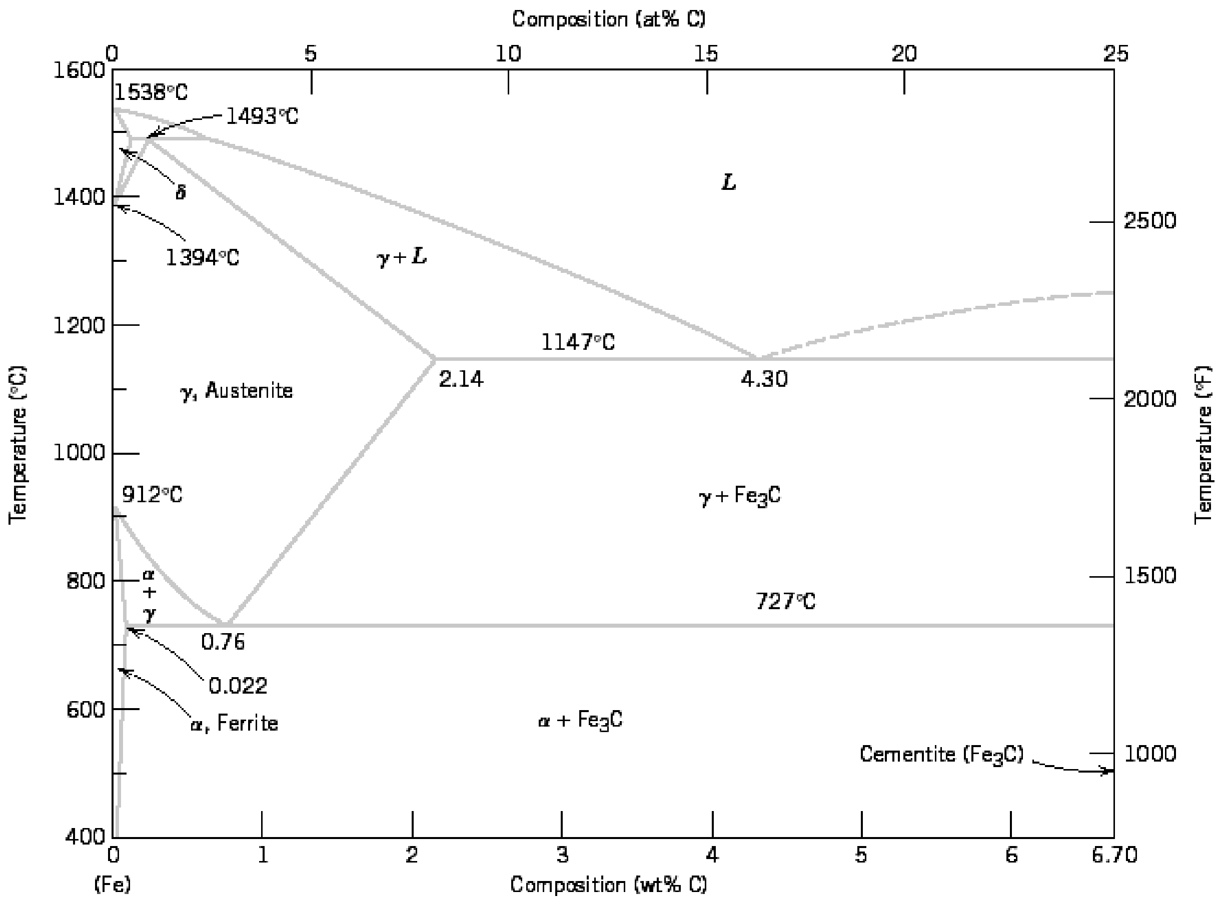




stress, MPa
0
50
100
150
200
250
300
350
400
0
0.05
0.1
0.15
0.2
strain



stress, MPa
0
50
100
150
200
250
300
350
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
strain



Composition (at% C)
0
5
10
15
20
25
1600
1538°C
1493°C
L
δ
1400
2500
1394°C
γ + L
1200
1147°C
2.14
4.30
γ, Austenite
2000
Temperature (°C)
Temperature (°F)
1000
912°C
γ + Fe3C
α
+
γ
800
1500
727°C
0.76
0.022
600
α, Ferrite
α + Fe3C
Cementite (Fe3C)
1000
400
0
1
2
3
4
5
6
6.70
(Fe)
Composition (wt% C)