Universidad Carlos III de Madrid

EXAM

January 2013

Aerospace Materials I (2nd Year)

Surname: **Name:** **Group:**

Information:
- Read the questions carefully before answering.
- You have 2h 30min to complete the exam.
- The marks assigned to each of the questions are given at the beginning of the question.
- To pass the exam you need a minimum mark of 5 over 10.

1. **(1 mark)** a) Indicate the differences between covalent, ionic and metallic bonding in terms of: strength and directionality. b) Explain why metals are ductile and ceramics are brittle taking into account the atomic bonding.

2. **(2 marks)** Aluminium has an FCC structure and its atomic weight is 26.98 g/mol. Given that its linear density in the direction [111] is $1.43 \cdot 10^7$ at/cm, determine:
   a. The lattice parameter and the atomic radius for Aluminium.
   b. Its density in (g/cm^3).
   c. The planar density in the plane (101) in (at/cm^2).
   d. The linear density in [110] direction in (at/cm).

   Note: It is important to draw the indicated direction and planes in the cubic cell to justify your answers.

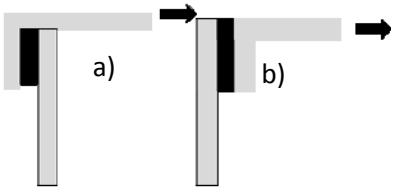
3. **(1 mark)**
   a) What are the most common types of fibre reinforcements in polymer matrix composites? Describe one method of processing a continuous fibre polymer matrix composite material.
   b) How do the properties of continuous fibre reinforced polymer matrix composites change with the direction of applied load (parallel and perpendicular to alignment direction)?

4. **(1 mark)**

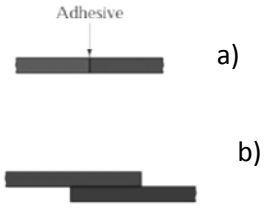
A. (0.5 marks) Draw energy-band diagrams showing donor or acceptor levels for the following:
   a) p-type silicon extrinsic semiconductor doped with boron impurity atoms.
   b) n-type silicon extrinsic semiconductor doped with phosphorus impurity atoms.

B. (0.5 marks) Indicate which of the following joint designs in adhesive joining is more appropriate and explain in each case why.

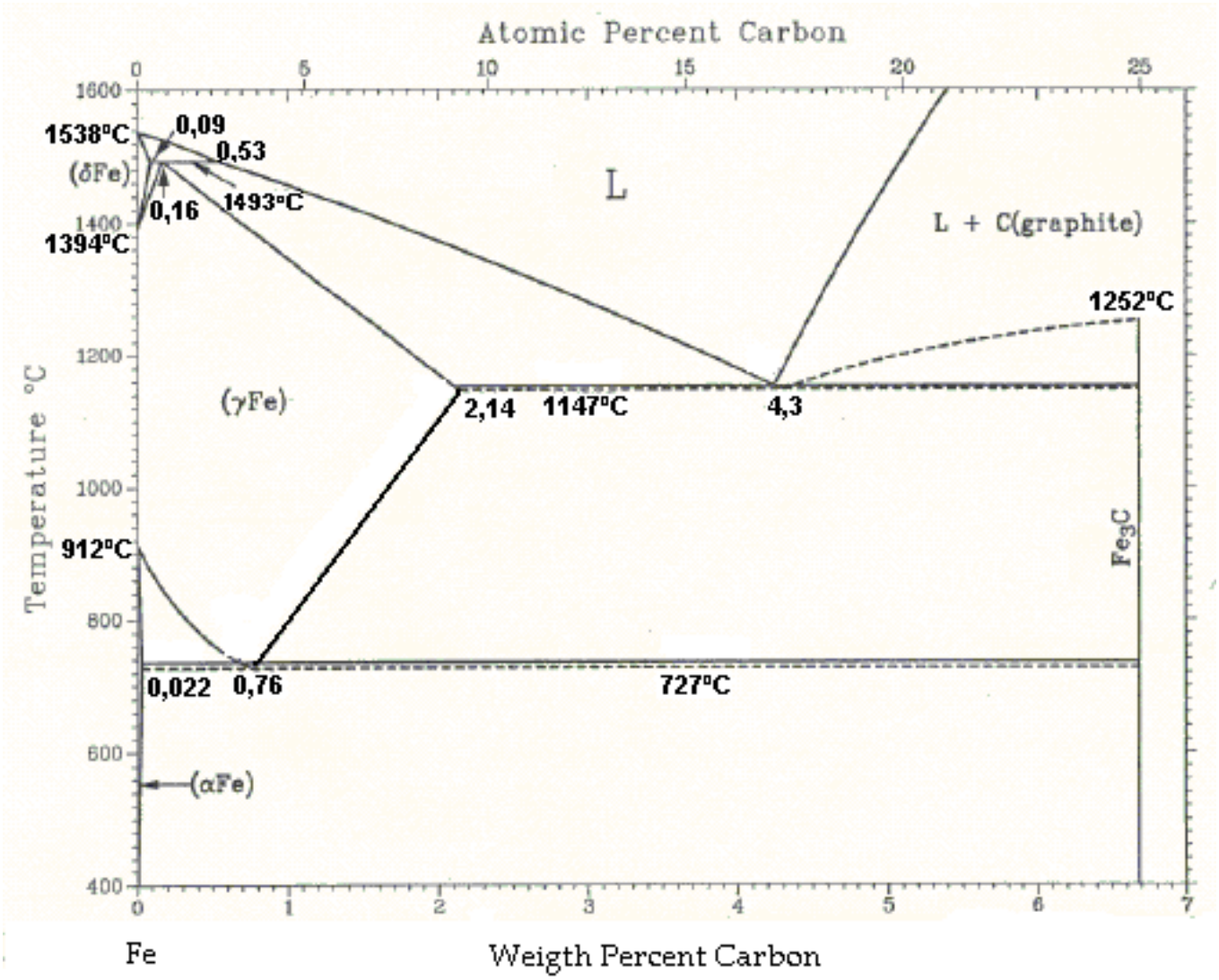
Case 1



Case 2



5. **(2 marks)** Consider the metastable Fe-C diagram of the figure. Answer the following questions:
    a. Name and fully describe the invariant reactions of the diagram.
    b. Indicate the maximum solubility of carbon in austenite at 1300 ºC, 1000 ºC, 730 ºC and 400ºC.
    c. At 1300 ºC, 1000 ºC, 730 ºC and 400 ºC, for an alloy of 0.3 (wt.)%C:
        i. Indicate the phases present, their mass fraction in the alloy and their chemical composition.
        ii. Indicate the microconstituents present, their mass fraction in the alloy and their chemical composition.
    d. At 400 ºC, consider 100g of the alloy and calculate the amount of pre-eutectoid ferrite (α') and the amount of ferrite inside the pearlite ($\alpha_{pearlite}$).
    e. If we add 8% of Ni to the alloy: how will the eutectoid temperature change with respect to the studied alloy? How much carbon will the pearlite have? Justify your answers.



6. (1 mark)

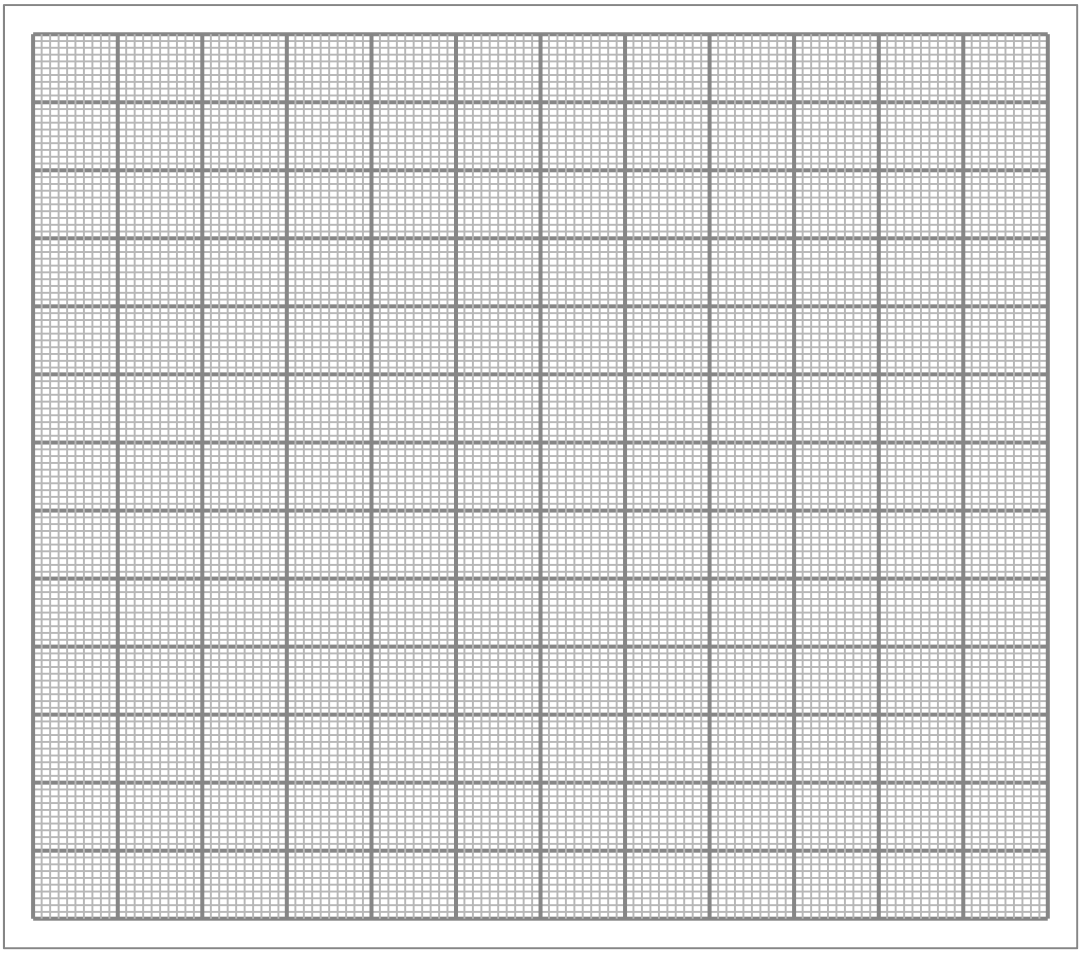
a) In ionic solids, explain what two main factors affect the packing of ions? Describe and draw the sodium chloride structure.

b) What are the basic steps in processing of ceramic products?

7. (2 marks) The following data was collected from a 12mm diameter test specimen of magnesium. After fracture, the gage length is 32.61 mm and the diameter is 11.74 mm.

a. Calculate the engineering stress and strain values and draw the stress-strain curve.
b. Calculate the yield strength and the tensile strength.
c. Calculate the modulus of elasticity and the modulus of resilience.
d. Calculate the % elongation and % reduction in area.
e. Calculate the engineering stress at fracture and the true stress at fracture.

Load (N)	**Gage length (mm)**	**Engineering stress**	**Engineering strain**
0	30.0000		
5000	30.0296		
10000	30.0592		
15000	30.0888		
20000	30.15		
25000	30.51		
26500	30.90		
27000 (maximum load)	31.50		
26500	32.10		
25000 (point of fracture)	32.79		



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EXAM

January 2014

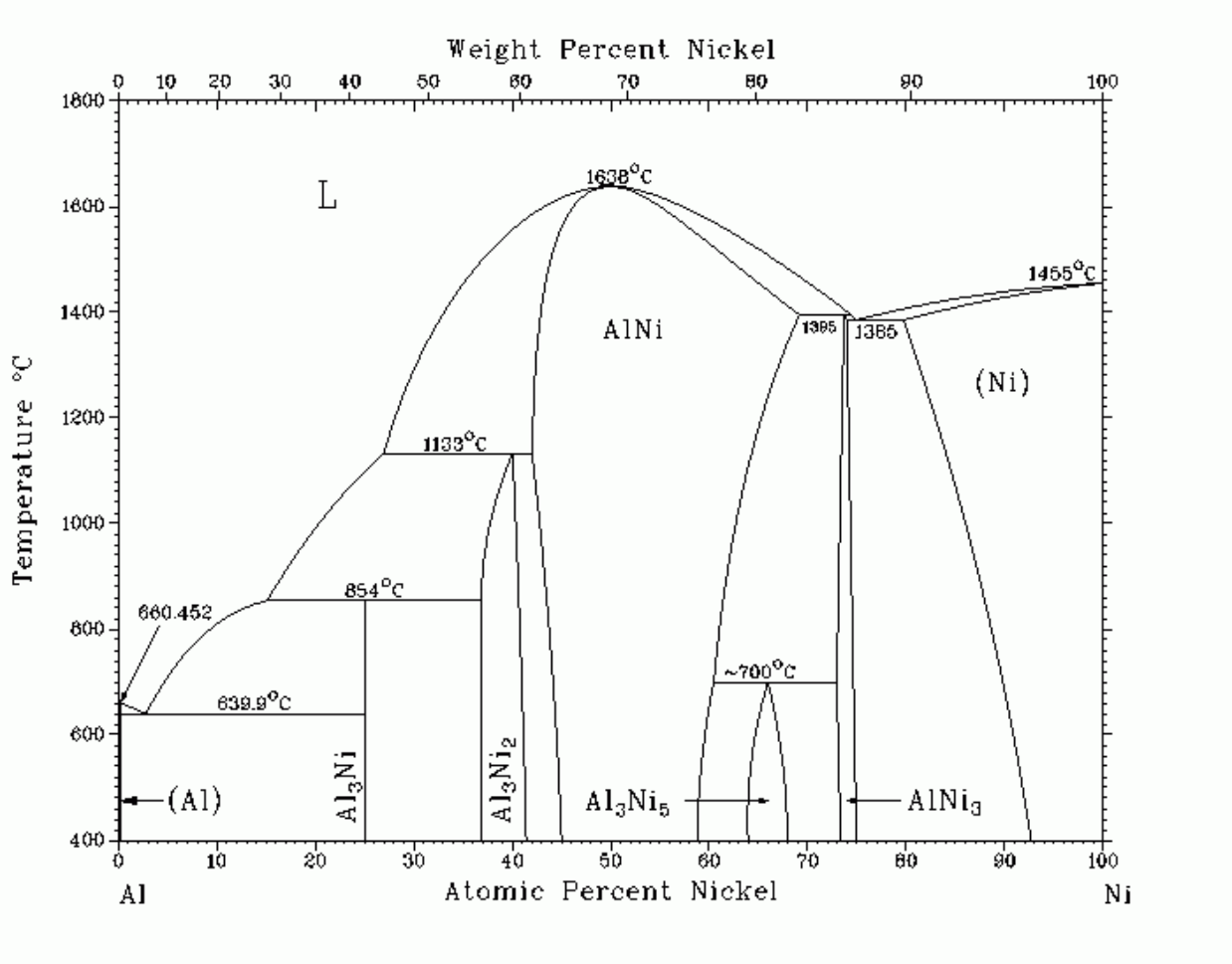
Aerospace Materials I (2nd Year)

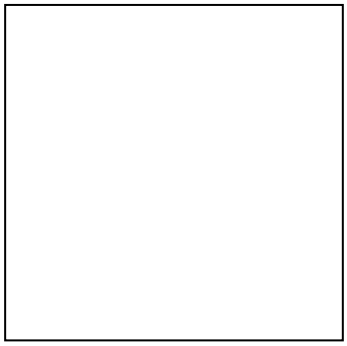
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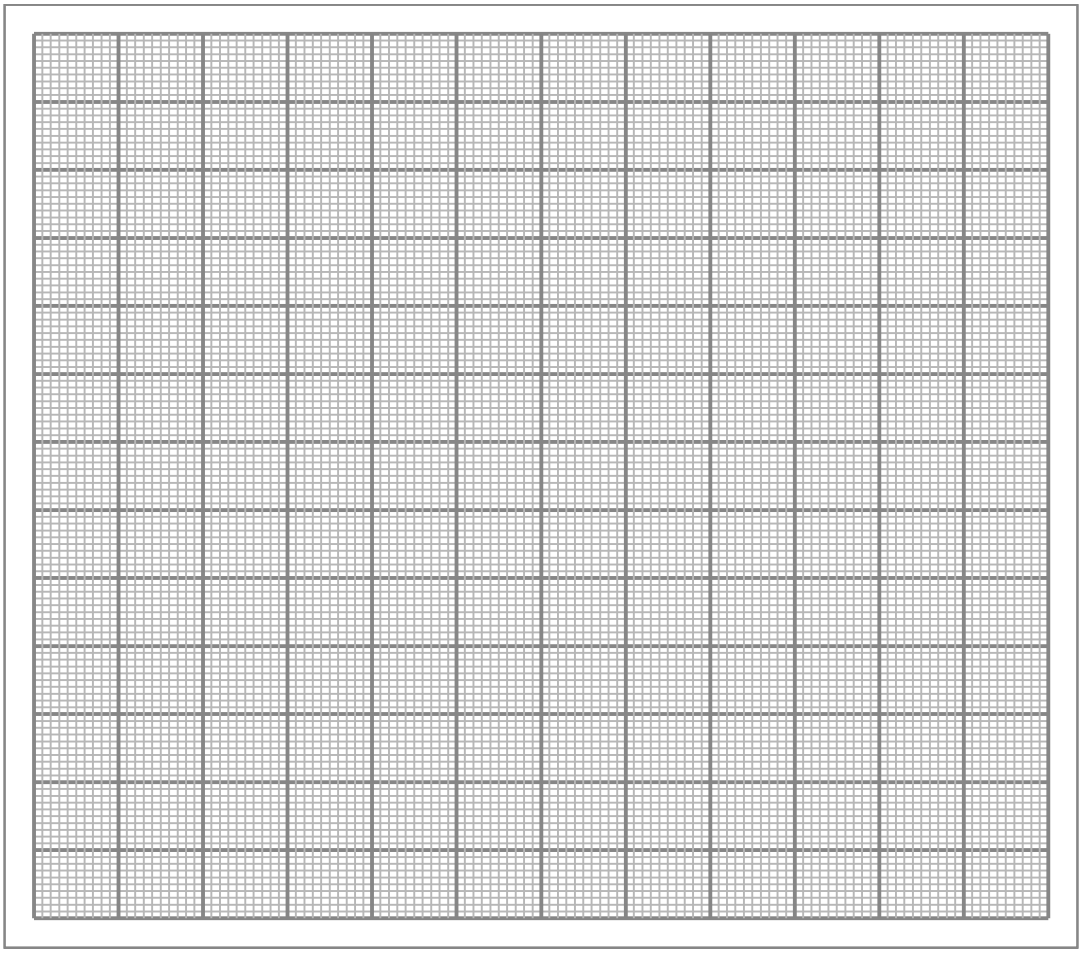
1. **(2 marks)** Use the following Al-Ni phase diagram to answer the questions.
   a) Determine the invariant reactions that take place at the following temperatures: 639.9ºC, 700ºC, 1133ºC, 1385ºC. For each reaction state its name, temperature and composition (in at% of Ni) of all phases involved in the reaction.
   b) For an alloy that has a 10 at% of Ni draw in the square provided a schematic sketch of the microstructure that would be observed at a temperature of 638ºC.
   c) For an alloy that has a 10 at% Ni indicate the quantity and composition of the phases present and the quantity of the microconstituents present at a temperature of 638ºC.
   d) Indicate which intermetallic compounds have congruent and incongruent melting.
   e) What is the maximum solubility of Al in Nickel and at what temperature is it observed.





2. **(2 marks)** The following data were collected from a 12 mm diameter test specimen of magnesium (l_o= 30.00 mm). After fracture, the gage length is 32.61 mm and the diameter is 11.74 mm. Poisson´s ratio for Mg is 0.29.
   a) Plot the engineering stress-strain curve. Determine the yield strength and the tensile strength.
   b) Calculate the modulus of elasticity and the modulus of resilience.
   c) Calculate the % elongation and the % reduction in area.
   d) Determine the engineering stress at fracture and the real stress at fracture. Calculate the real stress and the real strain for an engineering stress 176.8 MPa.
   e) Calculate the change in diameter when a tensile load of 10000 N is applied to this test specimen.

Load (N)	Gage Length (mm)	Stress (MPa)	Strain (mm/mm)
0	0000	0	0.0
5000	0.0296	44.2	0.000987
10000	0.0592	88.4	0.001973
15000	0.0888	132.6	0.00296
20000	0.15	176.8	0.005
25000	0.51	221.0	0.017
26500	0.90	234.3	0.030
27000	1.50 (max. load)	238.7	0.050
26500	2.10	234.3	0.070
25000	2.79 (fracture)	221.0	0.093



3. (1 mark)

a) What is the primary role of the matrix and the fibers, respectively, in a fiber reinforced composite?

b) What is the most common fiber product used in aeronautical technology for the fabrication of laminate structures? Describe briefly how it is manufactured.

4. (**1 mark)** What is the family of close packed directions for BCC and FCC structures respectively? How many octahedral and tetrahedral interstitial sites exist in the FCC structure? Determine de density of aluminum, which has and FCC structure, given that the interaplanar distance for planes (111) is 0.234 nm

DATA: M(Al)=26.98 g/mol ; N_A=6.022 x $10^{23}mol^{-1}$

5. (1 mark)

a) What are some common properties to most ceramic materials? What two main factors affect the packing of ions in ionic solids?

b) Describe briefly the basic steps in dry-pressing methods for producing such ceramic materials as technical ceramic compounds and structural refractories.

6. (1 mark) Polymers

Draw a characteristic stress-strain curve for a typical semi-crystalline polymer in the axis provided. Label the yield and tensile strengths on your curve. Does plastic deformation start in the crystalline or amorphous regions of a semicrystalline polymer? How does the amount of crystallinity affect the mechanical properties and the melting temperature of a polymer? Explain briefly.



7. **(1 mark)** Consider the following diffusion couples: (i) C in FCC Iron (ii) C in BCC Iron (iii) Fe in FCC Iron and (iv) Fe in BCC Iron.
    a) What will be the diffusion mechanism in each case?
    b) Where does C diffuse faster in FCC Iron or in BCC Iron? Explain your answer briefly.
    c) Will the activation energy for C diffusion in FCC Iron be higher or lower than that for Fe diffusion in iron?

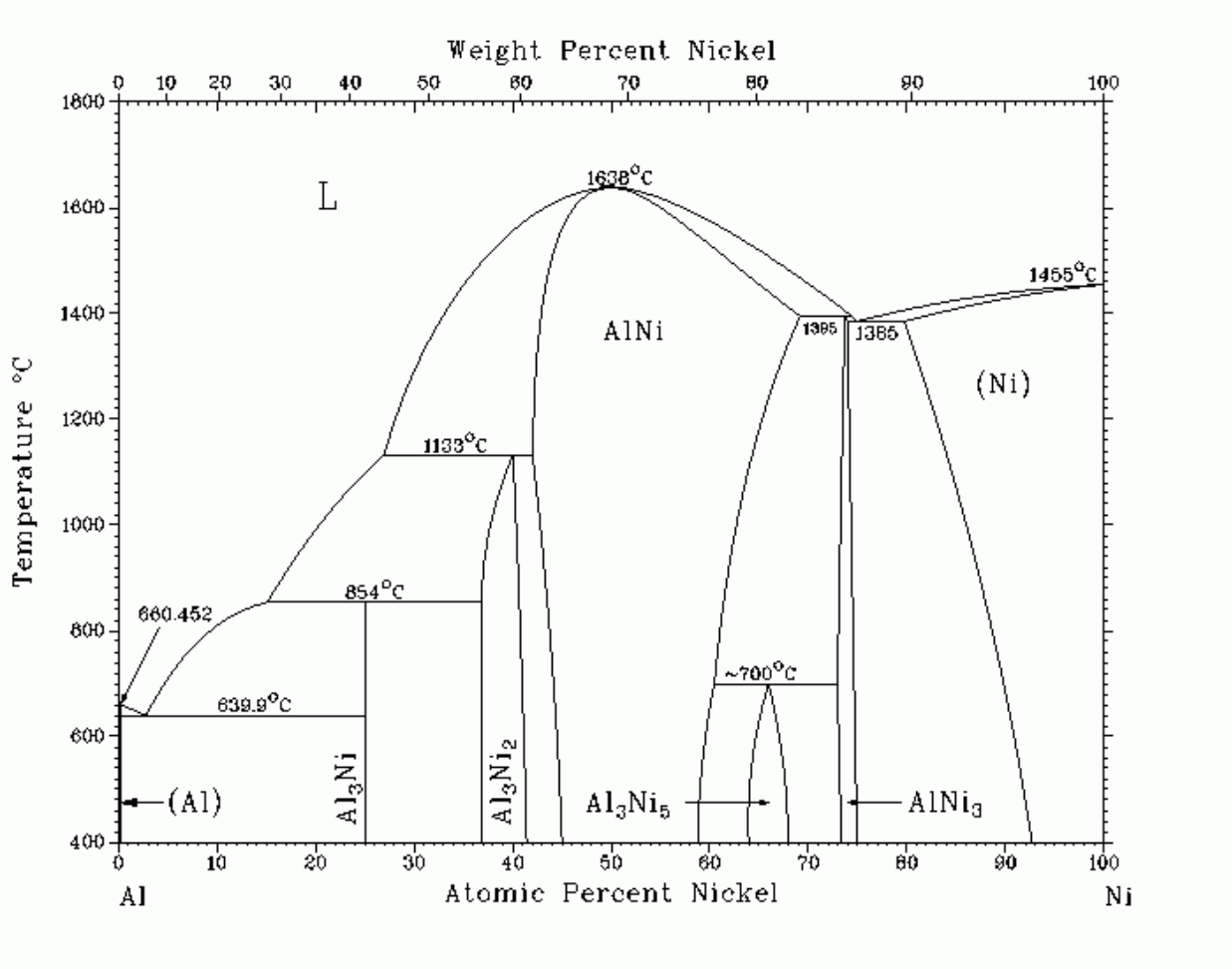
8. (1 mark)

a) Explain what type of semiconductors are (i) silicon doped with 1ppm Boron and (ii) silicon doped with 1ppm Indium. Assuming that they are both at the same temperature, which semiconductor will have higher conductivity? Explain. (Boron- column III A of the periodic table; Indium- column III A of the periodic table; B ion size < In ion size).

b) Calculate the electrical conductivity of silicon doped with 4.5×10^{21} Boron atoms/m^3 assuming complete dopant ionization.

(DATA: μ_e=0.135 $m^2V^{-1}s^{-1}$; μ_h= 0.048 $m^2V^{-1}s^{-1}$; q_e=-1.6022×10^{-19}C)

1. **(2 marks)** Use the following Al-Ni phase diagram to answer the questions.
   a) Determine the invariant reactions that take place at the following temperatures: 639.9ºC, 700ºC, 1133ºC, 1385ºC. For each reaction state its name, temperature and composition (in at% of Ni) of all phases involved in the reaction.
   b) For an alloy that has a 10 at% of Ni draw a schematic sketch of the microstructure that would be observed at a temperature of 638ºC.
   c) For an alloy that has a 10 at% Ni indicate the quantity and composition of the phases present and the quantity of the microconstituents present at a temperature of 638ºC.
   d) Indicate which intermetallic compounds have congruent and incongruent melting.
   e) What is the maximum solubility of Al in Nickel and at what temperature is it observed.



a)

639.9ºC: EUTECTIC : L(4at%) -> (Al) (0at%) +Al_3Ni (25at%)

700ºC: PERITECTOID : AlNi(60at%) +$AlNi_3$ (73at%)-> Al_3Ni_5 (65at%)

1133ºC: PERITECTIC : AlNi(43at%) +L (26at%)-> Al_3Ni_2 (40at%)

1385ºC: EUTECTIC : L (77at%)-> $AlNi_3$ (75at%) + (Ni)(80at%)

b) Phases : (Al) (0at%Ni) Al_3Ni (25 at%) ; Microcostituents: primary Al_3Ni ; eutectic (Al + Al_3Ni)

$w_{Al} = \frac{C_{Al3Ni} - C_0}{C_{Al3Ni} - C_{Al}} = \frac{25-10}{25-0} = 0.6$; $w_{Al3Ni\ Total}$=0.4

$w_{Al3Ni\ primary} = \frac{C_o - C_E}{C_{Al3Ni} - C_E} = \frac{10-3}{25-3} = 0.32$; $w_{Al3Ni\ eutectic}$ =0.08

$$w_{eutectic} = w_{liq\ 639.9} = \frac{C_{Al3Ni} - C_o}{C_{Al3Ni} - C_E} = \frac{25-10}{25-3} = 0.68$$

d)Intermetallic compounds:

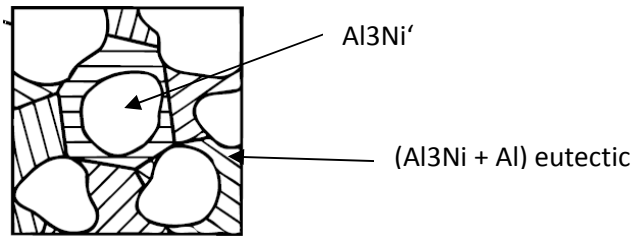
Al_3Ni: incongruent

Al_3Ni_2: incongruent

AlNi Congruent

Al_3Ni_5: incongruent

$AlNi_3$: incongruent



c)

d) About 18% of Al in Ni at1385ºC

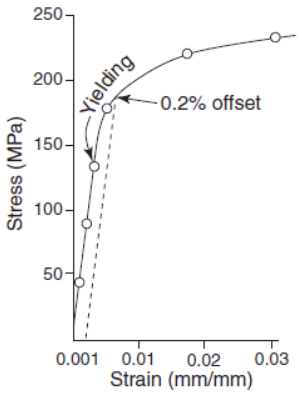
2. (2 marks) The following data were collected from a 12 mm diameter test specimen of magnesium (l_o= 30.00 mm). After fracture, the gage length is 32.61 mm and the diameter is 11.74 mm. Poisson´s ratio for Mg is 0.29.

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Solution: $S = F / [(\pi/4)(12\ \text{mm})^2] = F/113.1$

$e = (\ell - 30)/30$



Yield strength graphically 186MPa ; tensile strength graphically = 238.7MPa

b) $E = \frac{132.6-0}{0.00296-0} = 44800MPa = 44.8GPa$

From the figure yielding begins near 138 MPa Thus:

$U_r = \frac{1}{2}\sigma_y\varepsilon = \frac{1}{2} \cdot 138\ MPa\ * 0.00296 = 0.2MPa$ *OR*

$U_r = \frac{1}{2}\frac{{\sigma_y}^2}{E} = \frac{1}{2} \cdot \frac{138\ MPa^2}{44800MPa} = 0.21MPa$

c) $\%elongation = \frac{length\ after\ fracture - initial\ length}{initial\ length} x100 = \frac{32.61-30}{30} x100 = 8{,}7\%$

$\%R.A = \frac{initial\ area - final\ area}{initial\ area} x100 = \frac{\frac{\pi}{4}12^2 - \frac{\pi}{4}11.74^2}{\frac{\pi}{4}12^2} x100 = 4.3\%$

d) Engineering stress : 221MPa

Real stress at fracture: $\sigma_r = \frac{F}{A_r} = \frac{25000N}{\frac{\pi}{4}(11.74mm)^2} = 230MPa$

At 176.8 MPa:

$\sigma_r = \frac{F}{A_r} = \sigma_{eng}(1 + \varepsilon_{eng}) = 176.8MPa(1 + 0.005) = 177.684MPa$

$\varepsilon_r = ln(1 + \varepsilon_{eng}) = ln(1 + 0.005) = 0.004987$

e) $\upsilon = \frac{-\varepsilon_{\text{transverse}}}{\varepsilon_{\text{longitudinal}}} = -\frac{\varepsilon_y}{0.001973} = 0.29 \rightarrow \varepsilon_y = -0.29 * 0.001973 = -0.00057217$

$\varepsilon_y = \frac{\Delta\emptyset}{\emptyset_0} \rightarrow \Delta\emptyset = \varepsilon_y * \emptyset_0 = -0.00057217 * 12mm = -0.00686604$ ***contraction*** D_f = 11.933mm

3. (1 mark)

a) What is the primary role of the matrix and the fibers, respectively, in a fiber reinforced composite?
b) What is the most common fiber product used in aeronautical technology for the fabrication of laminate structures? Describe briefly how it is manufactured.

a)The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. The fibers provide strength by carrying most of the load The matrix forms the shape of the component ; transfers load into and out of the fibres , separates the fibres to prevent failure of adjacent fibers if one fails ,protects the fibre from the environment (degradation) ,keeps fibre orientation and provides the ductility and toughness.

b) Prepregs are the most common fiber form in aeronautical technology. Pre pegs are esin-impregnated fiber forms (tape or fabric), that deliver a consistent fiber/resin combination and ensure complete wetout. They are manufactured by impregnating fibers with a controlled amount of resin (thermoset or thermoplastic), using solvent, hot-melt or powder-impregnation technologies.: 1.Continuous fibers are aligned and subjected to surface treatment. 2. Fibers are coated by dipping in resin /solvent bath and a series of rollers ensure the correct amount of resin is impregnated .3 Tape is dried to evaporate the solvent and partially cured over cilinder. 4. The tape is protected by a baking paper and stored

4. (1 mark) What is the family of close packed directions for BCC and FCC structures respectively? How many octahedral and tetrahedral interstitial sites exist in the FCC structure? Determine de density of aluminum, which has and FCC structure, given that the interplanar distance for planes (111) is 0.234 nm

DATA: M(Al)=26.98 g/mol ; N_A=6.022 x 10^{23} mol^{-1}

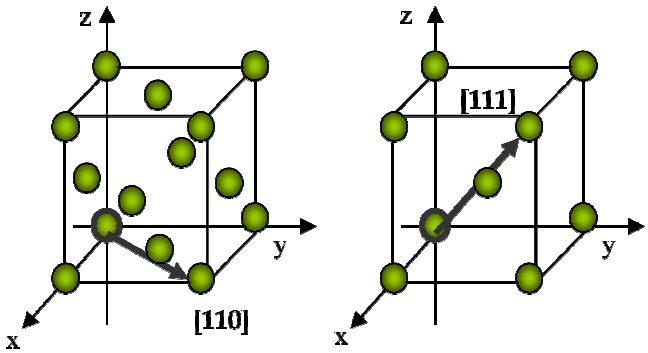
Close packed directions: FCC: <110> BCC: <111>

In compact structures is certain that:

Nº of tetrahedral sites =2n=8

Nº of octahedral sites =n=4

n = Nº atoms in the cell= 4 for FCC cells



$$\rho = \frac{n.M}{V.N_a} = \frac{(4).26.98 gr/mol}{(0.405.10^{-7} cm)^3 (6{,}022.10^{23} mol^{-1})} = 2.697 gr/cm^3$$

5. (1 mark)

a) What are some common properties to most ceramic materials? What two main factors affect the packing of ions in ionic solids?

b) Describe briefly the basic steps in dry-pressing methods for producing such ceramic materials as technical ceramic compounds and structural refractories.

a)High hardness

High Young's Modulus and high melting points (Strong bonds (covalent and /or ionic)

Limited electrical and thermal conductivity

Low thermal shock resistance ; low thermal and electrical conductivity

Refractory (Stability at high temperature Resistance to oxidation/corrosion (Chemical stability)

Brittle

The factors that affect the packing of ions are the relative size of the ions (define de coordination index) and their charge, in order to maintain electro neutrality

b) The basic process steps are: (i) mix ceramic powder (ii) compaction/pressing (iii) sintering. The most important processes are:

Dry pressing followed by sintering: simultaneous uniaxial compaction and shaping of ceramic particles in a die (followed by sintering)

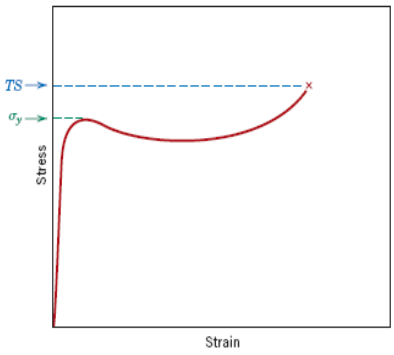
Cold isostatic pressing followed by sintering: simultaneous compaction and shaping of ceramic particles by pressure applied uniformly in all directions (followed by sintering)

Hot isostatic pressing: simultaneous compaction and shaping and sintering of ceramic particles by pressure applied uniformly in all directions

Sintering: the process in which fine particles of ceramic material become chemically bonded together at a temperature high enough for atomic diffusion to occur between particles

6. (1 mark) Polymers

Draw a characteristic stress-strain curve for a typical semi-crystalline polymer. Label the yield and tensile strengths on your curve. Does plastic deformation start in the crystalline or amorphous regions of a semicrystalline polymer? How does the amount of crystallinity affect the mechanical properties and the melting temperature of a polymer? Explain briefly.



Plastic deformation starts in the amorphous regions of the polymer with the elongation of amorphous tie chains. Then there is tilting of lamellar chain folds, followed by Separation of Crystalline block segments. Finally there is orientation of block segments and tie chains with tensile axis. Increasing the amount of crystallinity increases the strength of the polymer. Crystallinity increases strength by increasing intermolecular bonding. Also partially crystalline polymers exhibit a melting temperature (amorphous polymers exhibit only a glass transition temperature) Melting temperature increases with increasing amount of crystallinity due to increasing intermolecular bonding.

7. (1 mark) Consider the following diffusion couples: (i) C in FCC Iron (ii) C in BCC Iron (iii) Fe in FCC Iron and (iv) Fe in BCC Iron.

a) What will be the diffusion mechanism in each case?
b) Where does C diffuse faster in FCC Iron or in BCC Iron? Explain your answer briefly.
c) Will the activation energy for C diffusion in FCC Iron be higher or lower than that for Fe diffusion in iron?

a) C diffuses by interstitial diffusion and Fe by vacancy diffusion

b) C diffuses faster in BCC Fe than in FCC Fe. FCC Fe has a higher packing fraction than BCC Fe; hence, the activation energy is expected to be higher for diffusion in FCC Fe

c) Lower. C diffuses by interstitial diffusion and Fe by vacancy diffusion. The C atom is smaller than the Fe atom, and there are more interstitial sites available than vacancies, making interstitial diffusion easier than vacancy diffusion. This is reflected in the lower activation energy for C diffusion in Fe when compared to Fe diffusion in Fe.

8. (1 mark)

a) Explain what type of semiconductors are (i) silicon doped with 1ppm Boron and (ii) silicon doped with 1ppm Indium. Assuming that they are both at the same temperature, which semiconductor will have higher conductivity? Explain. (Boron- column III A of the periodic table; Indium- column III A of the periodic table; B ion size < In ion size).

b) Calculate the electrical conductivity of silicon doped with 4.5×10^{21} Boron atoms/m^3 assuming complete dopant ionization.

(DATA: μ_e=0.135 $m^2V^{-1}s^{-1}$; μ_h= 0.048 $m^2V^{-1}s^{-1}$; q_e=-1.6022x10^{-19}C)

B doped: extrinsic p-type semiconductor with acceptor level. Indium doped : extrinsic p-type semiconductor with acceptor level

The smaller the doping ion the stronger the attraction of the valance electron by the nucleus. Therefore in the band theory, this means that for p-type semiconductors, the smaller the doping ion the higher the attraction of the acceptor level, which would reduce Ea and therefore increase conductivity. $\sigma_{B\text{-}doped} > \sigma_{In\text{-}doped}$

$\sigma = n\,|q_e|\mu_h = (4.5 \times 10^{21}\ atoms/m^3) * (1.6 \times 10^{-19}\ A\ s) * 0.048\ m^2V^{-1}s^{-1} = 35\ \Omega^{-1}m^{-1}$

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1. (2 marks) The semiconductor GaAs has a Zinc Blende (ZnS) structure.

a. Describe the structure. What is the coordination index of GaAs?

b. What is the lattice parameter in nanometers for GaAs?

c. Calculate the volumetric density of GaAs expressed in g/ cm^3

d. Determine linear density (ions/mm) in the direction [111] and the planar density (ions/mm^2) in the plane (111)

e. Determine the packing factor

DATA: r_{Ga}=0.126 nm ; r_{As}=0.120 nm ; N_A=6.023x10^{23} at/mol ; M_{Ga}= 69.72 g/mol ; M_{As}= 74.96 g/mol

2. **(2 marks)** For a continuous and oriented fiber-reinforced composite, the moduli of elasticity of the fibers and matrix are 390 GPa and 3 GPa, respectively. If the volume fraction of fibers is 0.25, determine:
   a) The modulus of elasticity in the longitudinal and transverse directions.
   b) The weight percentage of the fibers and the matrix in the composite.
   c) The average density of the composite.

   A load of 25000 N is applied onto a cylindrical rod of 20 mm in diameter of this composite. Calculate:
   d) The fraction of the load carried by the fibers and matrix phases respectively.
   e) The stress acting on the fibers and matrix, respectively.

   DATA: ρ_m=1.29 g/cm^3, ρ_f=1.79 g/cm^3

3. (1 mark) Please construct a phase diagram having the following characteristics.

(a) The two components are "A" and "B"

(b) The melting point of A is 500^{o}C, and the melting point of B is 700^{o}C.

(c) The diagram contains only one compound, which is a line compound (exact stoichiometry formula) having the stoichiometry A_2B and a congruent melting point of 750^{o}C.

(d) One eutectic point appears at the component composition 80 at% A and 400^{o}C.

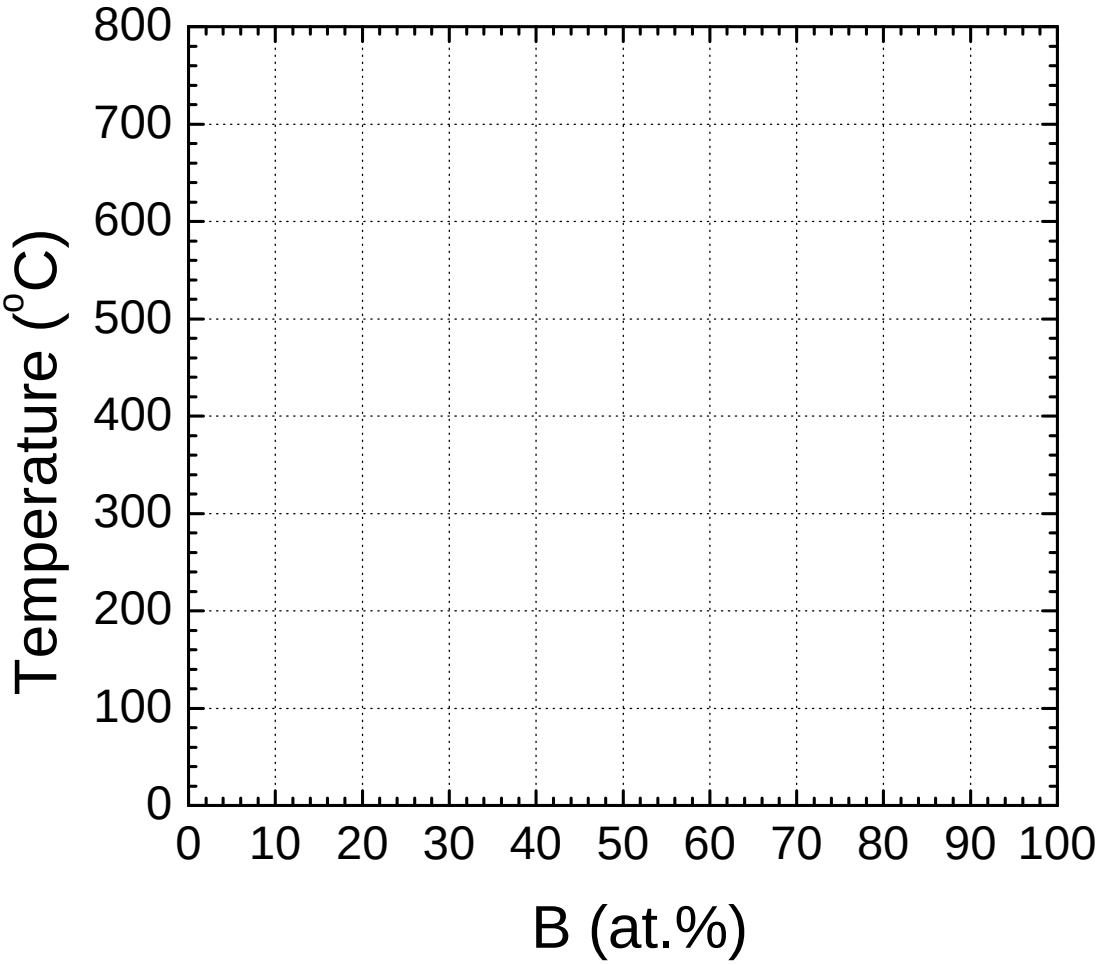
(e) Another eutectic point appears at the component composition 75 at% B and 600^{o}C.

(f) The maximum solubility of B in A occurs at the eutectic temperature and it is 10 at.% (α-phase)

(g) The maximum solubility of A in B occurs at the eutectic temperature and it is 5 at.% (β-phase).

(h) The solubility of A in B and B in A are zero at RT.

Label all the regions on the diagram.



4. (**1 mark**) Order the following materials in terms of (a) hardness and (b) elastic modulus: Aluminium; Aluminium oxide; Epoxy Resin; Low Density Polyethylene. Justify your answer.

5. **(1 mark)** a) Match the following glass transition temperatures (Tg) to the correct polymer. Explain how can the Tg temperature be increased in each case. Justify your answer.

Tg: -110 ºC ; 80 ºC ; 140 ºC

Polymers: Polyethelene (PE) ; Polyvinyl chloride (PVC); epoxy resin

b) When a bag of semicrystalline plastic deforms (i.e. polyethylene), it will offer greater resistance to deformation. Explain briefly why this behavior occurs.

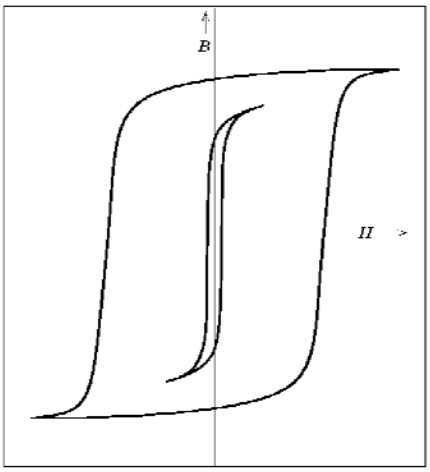
6. (1 mark)

A. **(0.5 marks)**Describe briefly the steps in the production of an adhesive joint. What are the most important considerations in a design of an adhesive joint? Include sketches, where appropriate.

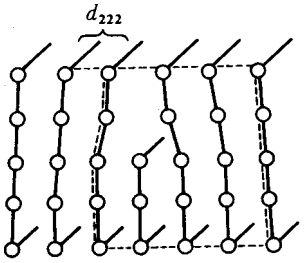
B. **(0.5 marks)**Label which of schematic diagrams of magnetic induction (B) versus magnetic strength (H) is representative of:

   a. Hard ferromagnetic material
   b. Soft ferromagnetic material

   What is an application that requires a soft magnetic material? What is an application that requires a hard magnetic material. Explain briefly how grain size of a material affects the hysteresis cycle of a magnet.



7. **(1 point)** Suppose we have a BCC structure with a lattice parameter of 4.0 Å, containing the dislocation shown in figure. Determine the direction (Miller indices) and the length of the Burgers vector.



8. **(1 point)**
   a. Name three of the strengthening mechanisms (for metals) discussed in this course.
   b. In general, what is the key objective at the microscopic level for all of these strengthening mechanisms?
   c. For one of the mechanisms listed in part (a), explain how it works. Include sketches, where appropriate

Universidad Carlos III de Madrid

EXAM

January 2015

Aerospace Materials I (2nd Year)

Surname: **Name:** **Group:**

Information:

- Read the questions carefully before answering. Use the space given for answering each question.
- You have 2h 30min to complete the exam.
- The marks assigned to each of the questions are given at the beginning of the question.
- To pass the exam you need a minimum mark of 4 over 10.

1. (2 marks) In the figure, two crystallographic planes are represented. They correspond to a cubic unit cell of a ceramic material with the following formula A_xB_y that has density of 5.92 gr/cm^3.

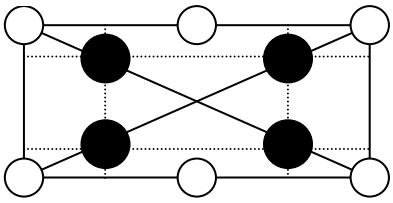
a) Determine and describe the type of structure and indicate its stoichiometry. What is the coordination index (C.I) for the ion A?
b) Determine the lattice parameter of the unit cell and the molecular weight of ion B
c) Determine the radius of ion B and calculate the packing factor
d) Calculate the linear density in the direction [111]

DATA: r(A^{m+})=0.086 nm; M(A)=91.224 g/mol ; N_A=6.023x10^{23} mol^{-1}

Ion A: ○

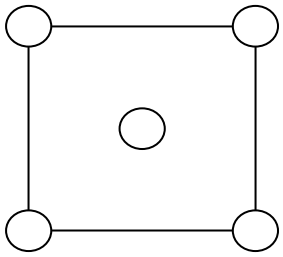
Ion B: ●

(110)/($\bar{1}\,\bar{1}\,0$)

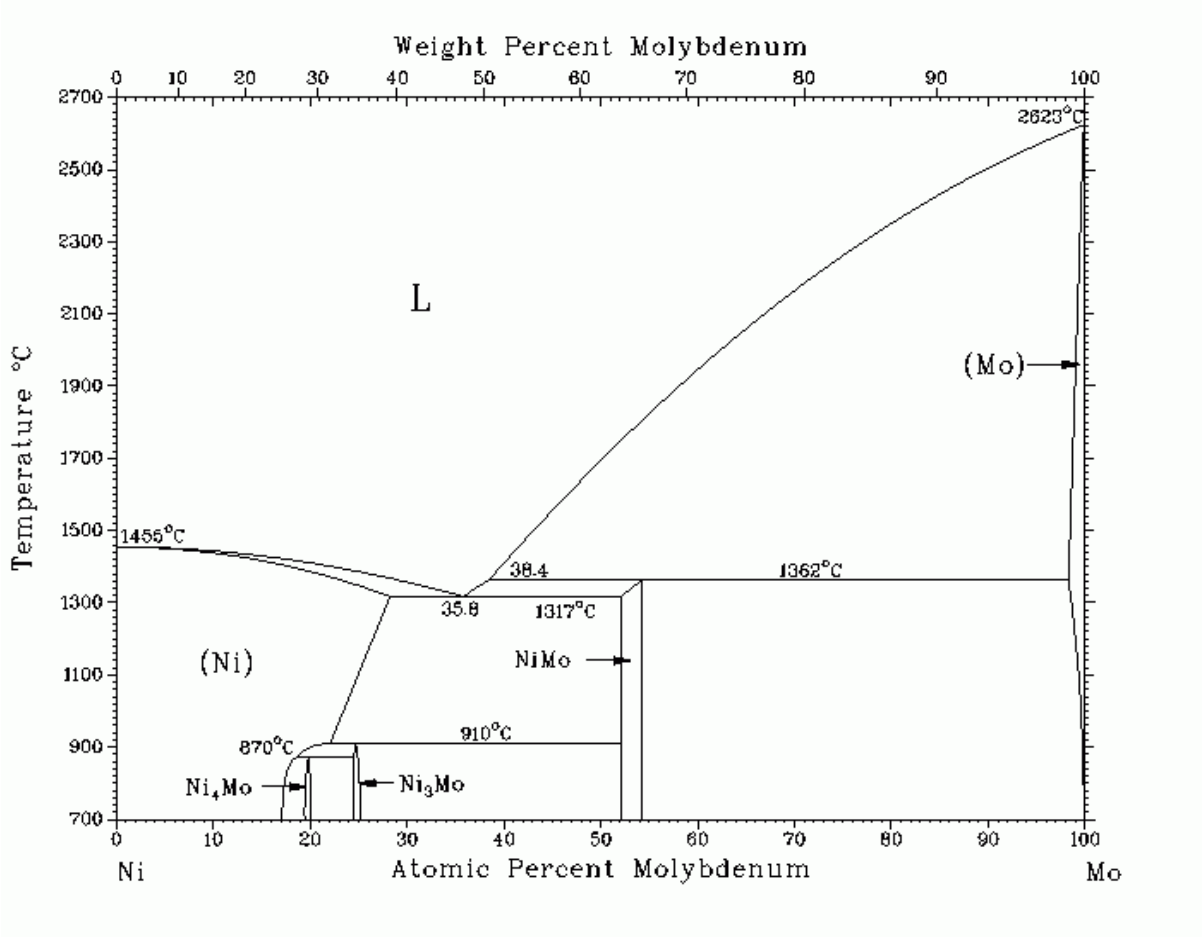


0.731 nm

(010)



2. (2 marks) Use the following phase diagram to answer the questions.

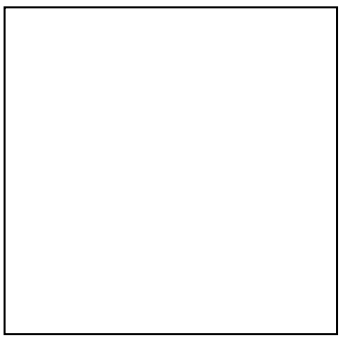


a) **(0.8 marks)** Mark as true (T) or false (F) the following statements

	NiMo melts congruently
	NiMo is an intermetallic compound
	At 870ºC the reaction of Ni-20at%Mo alloy is eutectoid
	At 1362ºC the reaction of Ni-54at%Mo alloy is eutectic
	Maximum solubility of Mo in (Ni) is about 28at%
	Maximum solubility of Ni in (Mo) is 15at%
	The microconstituents of Ni-60at%Mo alloy at 1300ºC, are proeutectic (Mo), and eutectic ((Mo)+ NiMo)
	At 910ºC the reaction of Ni-25at%Mo alloy is peritectoid

b) **(0.8 marks)** Determine the quantity and composition of the phases present and the quantity of the microconstituents present for a Ni-34at%Mo alloy at: (i) 1318ºC and (ii) 1316ºC

c) **(0.4 marks)** Draw in the square provided a schematic sketch of the microstructure at a temperature of 1316ºC for a Ni-34at%Mo alloy



3. **a) (0.5 marks)** How does the amount of crystallinity in a thermoplastic affect (i) its density, (ii) its tensile strength and (iii) its melting temperature? Explain briefly.

   b) (0.5 marks) Describe briefly the main differences between thermosetting and thermoplastic polymers with respect to (i) structure and (ii) temperature stability.

4. **(1 mark)** Answer the following questions and explain briefly:
   - **a)** What is GLARE? Describe its components.
   - **b)** In what applications it is used?
   - **c)** What material does it substitute? What are its main advantages?

5. **(1 mark)** Two FCC-type crystalline structures are given. Both of them have defects characterized by an extra plane of atoms. In one of these structures, the extra plane of atoms is parallel to plane (110) and in the other one is parallel to plane (100). Determine and justify: The type of defect in each structure, direction of Burger´s vector and the magnitude as a function of atomic radius. In which structure is slipping easier? (Consider the same atomic radius for both structures).

6. **a) (0.5 marks)** Explain briefly the difference between prepolymerized and polymerizing adhesives and give an example of each. Which of the two types is high resistance adhesive?

b) (0.5 marks) What are the main types of charge carriers in the following:

i. Intrinsic semiconductors
ii. p-type extrinsic semiconductors
iii. n-type extrinsic semiconductors

7. **(1 mark)** Which factors affect the diffusivity of a material? How?

8. Answer the following questions:

a) **(0.3 marks)** Draw the stress-strain curve of an Al alloy with the yield strength σ_Y=210MPa, the ultimative tensile strength of σ_{UTS}=250MPa and a fracture stress of σ_f=160MPa at %EL=4%.

b) **(0.3 marks)** Briefly describe the main difference between elastic and plastic deformation macroscopically and microscopically.

c) **(0.4 marks)** The Al material given above will be used for a tube-shaped retainer. The inner diameter has to be 10mm. For the application a safety factor of n=2 is given. The static load is F=12000N. Calculate the outer diameter of the retainer.

Universidad Carlos III de Madrid

EXAM

June 2015

Aerospace Materials I (2nd Year)

Surname: **Name:** **Group:**

Information:

- Read the questions carefully before answering. Use the space given for answering each question.
- You have 2h 30min to complete the exam.
- The marks assigned to each of the questions are given at the beginning of the question.
- To pass the exam you need a minimum mark of 4 over 10.

1. (1 mark) For the following pair of polymers, do the following: (1) state whether it is possible to decide if one polymer has a higher tensile strength than the other; (2) if this is possible, note which has the higher tensile strength and then cite the reasons for your choice; and (3) if it is not possible to decide, then state why not.

a) Syndiotactic polystyrene having a number-average molecular weight of 600,000 g/mol and Isotactic polystyrene having a number-average molecular weight of 500,000 g/mol.

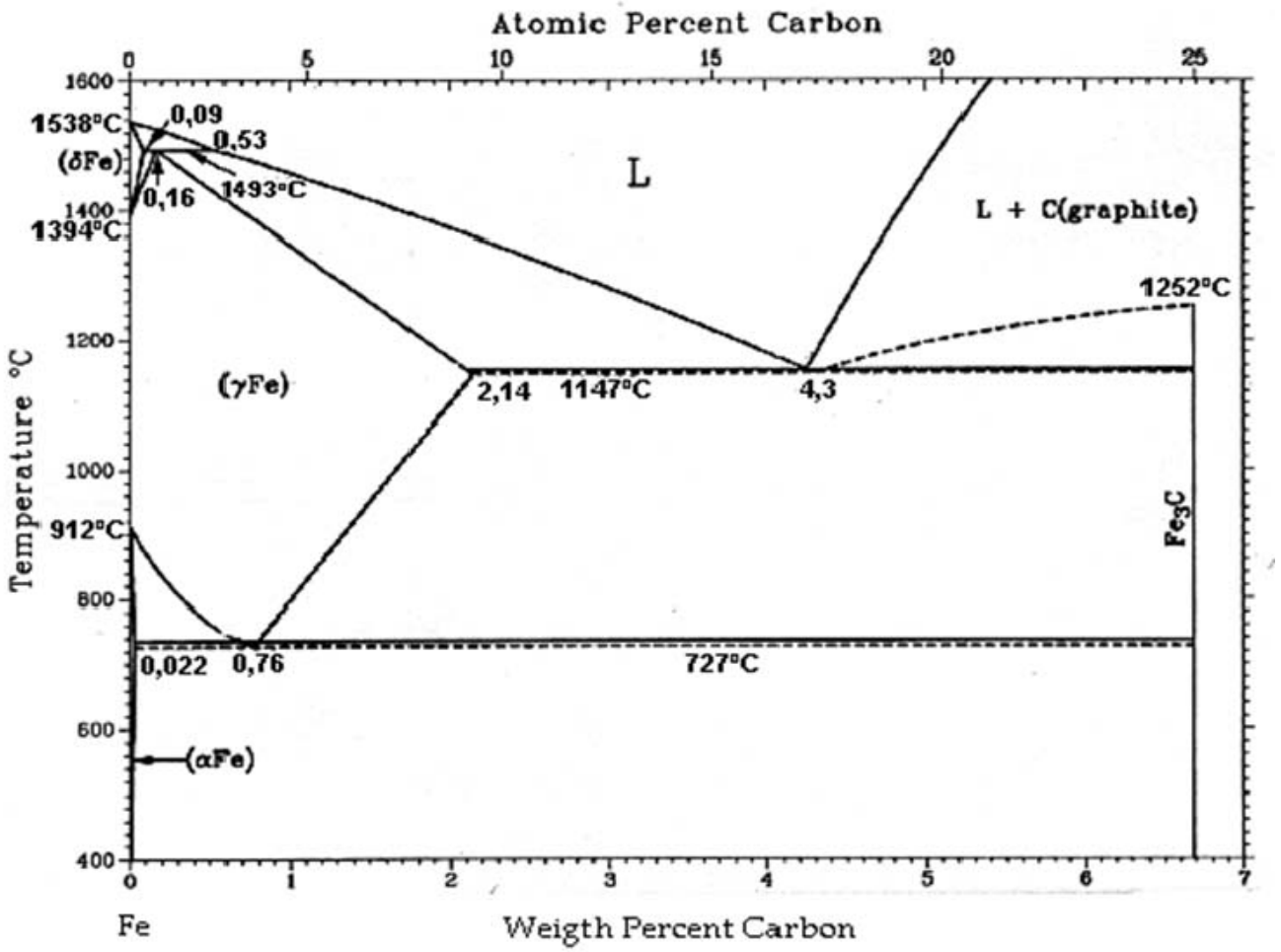
b) Poly(styrene-butadiene) random copolymer having a number-average molecular weight of 100,000 g/mol and 10% of the available sites crosslinked and Poly(styrene-butadiene) random copolymer having a number-average molecular weight of 120,000 g/mol and 15% of the available sites crosslinked.

c) Isotactic polystyrene that has a density of 1.12 g/cm^3 and a weight-average molecular weight of 150,000 g/mol and Syndiotactic polystyrene that has a density of 1.10 g/cm^3 and a weight-average molecular weight of 125,000 g/mol.

2. **(2 marks)** Use the Fe-C phase diagram to answer the questions.
   a) **(0.5 marks)** Mark as true (T) or false (F) the following statements:

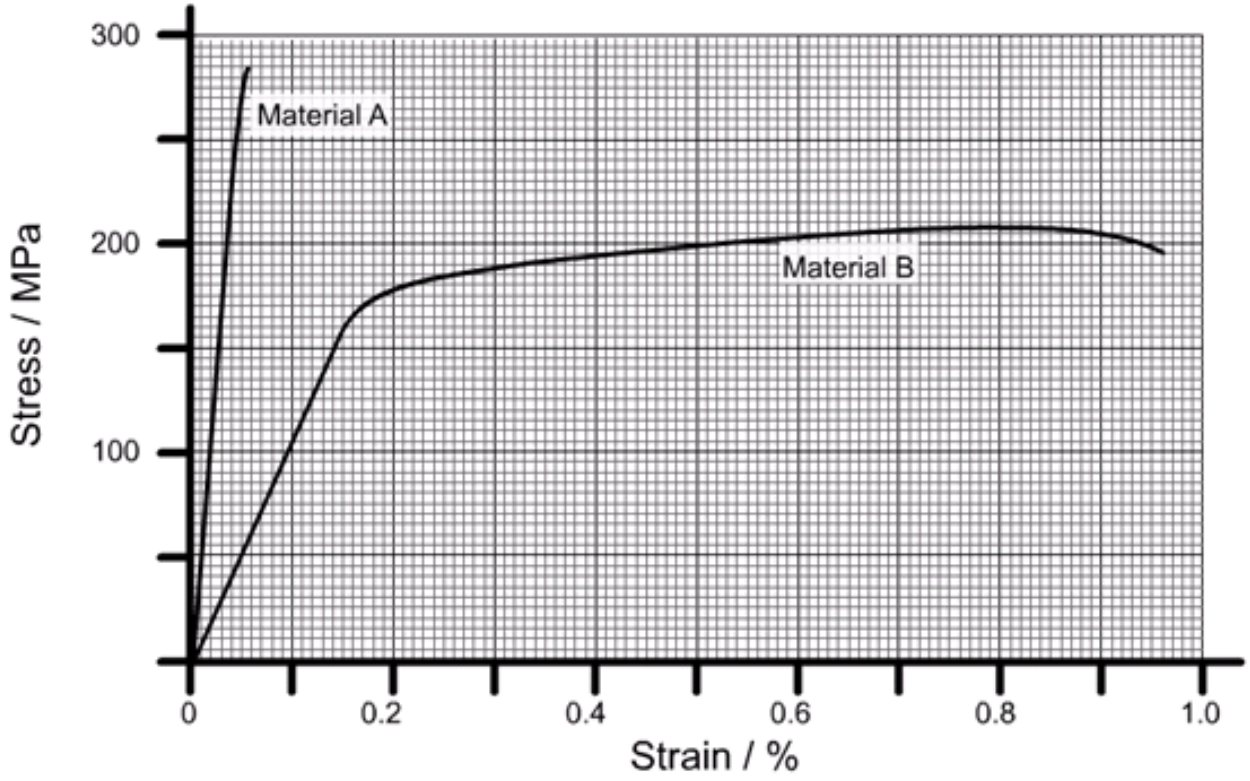
	Pure Iron has three allotropic modifications
	Cementite melts congruently
	At 1493ºC the reaction is monotectic
	Maximum solubility of C in α phase of Fe at 727ºC is 0.022%
	Microconstituents of an alloy with 3 wt%C at 1000ºC are primary austenite and cementite

   b) **(0.5 marks)** For an alloy with 0.5 (wt.)%C at 727+ΔTºC, indicate the phases present, their mass fraction and their chemical composition
   c) **(0.5 marks)** Consider 250g of an alloy with 1.3 wt% C and calculate the amount of cementite in each microconstituent at 600ºC
   d) **(0.5 marks)** If we add 8% of Mn to the alloy from part c): how will the eutectoid temperature change with respect to the studied alloy? How much carbon will the pearlite have? Justify your answers.



3. **(2 marks)** A cylindrical rod 3m long and having an initial diameter of 20 mm is subjected to a tensile load of 65000 N and experiences a change in diameter of 0.014 mm, recovering its initial diameter when the load is removed. For this kind of alloy Poisson's ratio is ν= 0.36.
   a) Calculate the length of the cable when it's holding the load mentioned above
   b) Plastic deformation for this alloy begins when it is holding a weight of 26608 kg. Calculate the tensile strength of this alloy. Assuming a safety factor of 2, can it be considered that the rod is working under safe conditions?
   c) Calculate the elastic modulus and the modulus of resilience of this alloy
   d) Calculate the elastic modulus and yield stress for the Materials A and B that have the stress-strain curves represented below. Can Material B replace the alloy rod? Explain why.
   e) If the alloy rod is substituted by Material B and is subjected to the same load calculate the final length of the rod

DATA: g_o=9.8 m/s^2



4. **(1 mark**) Answer the following question and explain briefly:
   a) What are Bravais lattices and how many are there?
   b) What are the 3 most common structures of metallic materials and which one has the smallest packing factor?
   c) For closed packed structures, what is the relation between number of possible interstitial sites (n) and number of atoms in the cell (N) for both types of interstitials?
   d) Is the solubility of Carbon higher in ferrite or austenite? Why?

5. **(1 mark)** Answer the following question and explain briefly:
   a) What are typical materials used as matrices in ceramic matrix composites (CMC)?
   b) What are the advantages of CMCs?
   c) What is the role of the reinforcements in CMCs?
   d) Name and describe a manufacturing method applicable only to CMCs?

6. **(1 marks) a)** Define a ceramic material. What structural defects are the main causes of failure of polycrystalline ceramic materials? Distinguish between traditional and engineering ceramics and give an example of each. **b)** What is the sintering process of ceramic materials? What occurs to the ceramic particles during sintering?

7. **(1 mark)** Lattice energy for binary ionic compounds depends on the values of some fundamental constants and other parameters that are a function of the nature of the ions.
   a) Enumerate at least two parameters and briefly explain their influence.
   b) In the following table you may find the values of the melting point (ºC), lattice energy (Kcal/mol), hardness (Moh's scale) as well as the formula of several binary compounds. Match each compound with the correct values of T_m, lattice energy and hardness.
   Data r(Na) > r (K), r(Mg) > r(Ba)

Compound	T_m	Lattice energy	Hardness
NaCl	776	747	6.5
KCl	1923	164	2.5
MgO	801	183	3.3
BaO	2800	940	2.25

Compound	T_m	Lattice energy	Hardness
NaCl			
KCl			
MgO			
BaO			

8. **a) (0.5 marks)** For a metallic conductor explain how is electrical resistivity affected by (i) increasing temperature and (ii) impurities, alloying additions, dislocations and grain boundaries

b) (0.5 marks) Explain the relationship between superconducting materials and magnetism. Define the T_c (critical temperature in a superconductor). What is the Meissner effect?