For Questions 1- 30, select the BEST answer. Each correct answer is worth 1 mark.

1. In Figure 1, the bond length is obtained from:
   a) point A
   b) points B or E
   c) point C
   d) point D
   e) Cannot be answered without knowing the type of atomic bond

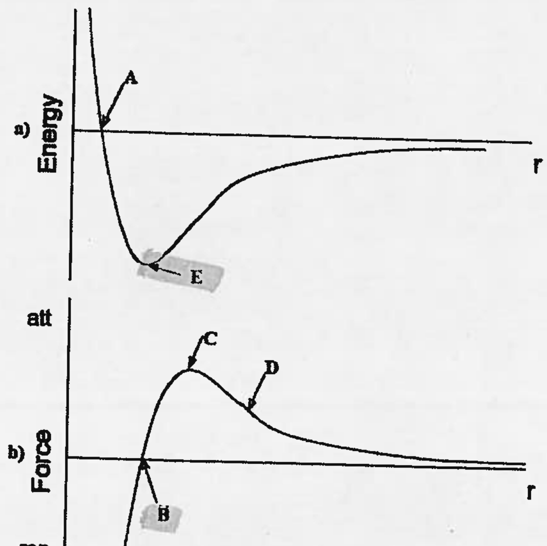

Figure 1

2. If the material modeled by the curves in Figure 1 had a stronger atomic bond, the point labeled E would definitely move:
   a) Left
   b) Right
   c) Up
   d) Down
   e) Cannot be answered without more information.

3. The crystal structure shown in Figure 2 is:
   a) BCC
   b) FCC
   c) HCP
   d) Metallic
   e) Ionic

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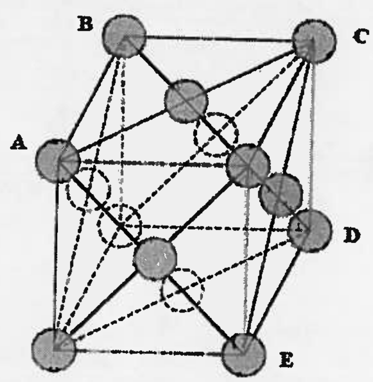


Figure 2

4. A close-packed direction for the unit cell in Figure 2 would be:
   a) A – B
   b) A – C
   c) A – D
   d) B – E
   e) There are no close-packed directions in this unit cell.

5. A close-packed plane for the unit cell in Figure 2 would be:
   a) A B C
   b) A B D
   c) A B E
   d) A C E
   e) There are no close-packed planes in this unit cell

6. The atomic weight of copper is 63.54 g/mol. 15 g of copper therefore contains:
   a) 6.32×10^{20} atoms
   b) 1.42×10^{23} atoms
   c) 2.55×10^{24} atoms
   d) 9.03×10^{24} atoms
   e) 5.74×10^{26} atoms.

$n = \frac{m}{M} = \frac{15}{63.54} = \square \times N_A$ (m: mass, M: molar mass)

$n = \frac{15}{63.54} \times 6.023 \times 10^{23}$

7. For the unit cell shown in Figure 3, the relationship between lattice parameter, a, and atomic diameter, D, is:
a) a=2D
b) a=D/√3
c) a= √2 D
d) a= 2D/√3
e) a = 4D/√3

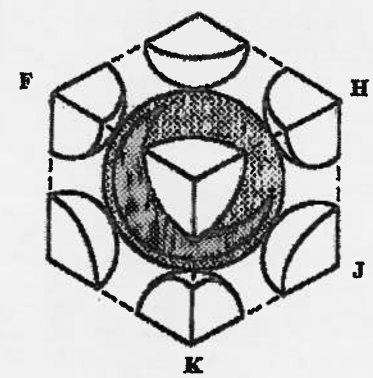


Figure 3

8. Which of the following is a "surface" defect?
a) A vacancy
b) An edge dislocation
c) A grain boundary
d) a, b, and c are all surface defects
e) None of the above

9. The energy of vacancy formation for copper is 0.9 eV/atom; the atomic weight and density of copper (at 20°C) are 63.5 g/mol and 8.9 g/cm³ respectively. The number of vacancies per cubic meter of copper at 20°C is closest to:
a) 2.8×10^{13} vacancies/m³
b) 2.2×10^{25} vacancies/m³
c) 3.0×10^{30} vacancies/m³
d) 4.4×10^{31} vacancies/m³
e) 2.5×10^{44} vacancies/m³

10. Which of the following best describes the material behaviour exhibited at the designated regions in the graph of Specific Volume versus Temperature shown in Figure 4?
a) (w) crystalline, (x) glassy, (y) supercooled liquid, (z) liquid.
b) (w) glassy, (x) crystalline, (y) supercooled liquid, (z) liquid.
c) (w) glassy, (x) single crystal, (y) liquid, (z) gas.
d) (w) linear, (x) crosslinked, (y) rubbery, (z) liquid
e) (w) crystalline, (x) leathery, (y) rubbery, (z) liquid .

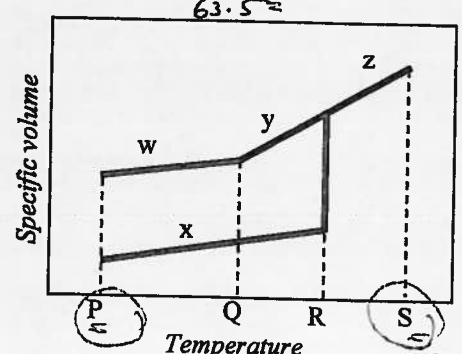


Figure 4

11. In Figure 4:
a) P refers to the Glass Transition temperature, T_g, and S is the Melting temperature, T_m.
b) P refers to the Glass Transition temperature, T_g, and R is the Melting temperature, T_m.
c) Q refers to the Glass Transition temperature, T_g, and S is the Melting temperature, T_m.
d) Q refers to the Glass Transition temperature, T_g, and R is the Melting temperature, T_m.
e) R refers to the Glass Transition temperature, T_g, and S is the Melting temperature, T_m.

12. The defect shown in Figure 5 is a representation of:
a) a vacancy
b) a screw dislocation
c) an edge dislocation
d) a substitutional impurity
e) a grain boundary

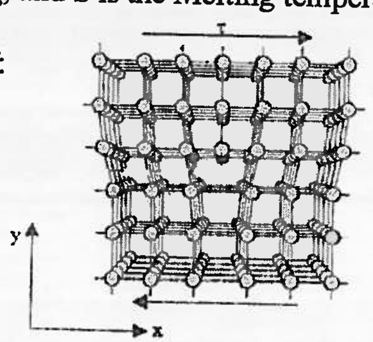


Figure 5

13. From the data provided in the accompanied table, the weight average molecular weight of the polymer is closest to (g/mol):
a) 32,000
b) 33,040
c) 36,240
d) 66,080
e) 72,080

Molecular Weight Range (g/mol)	Number fraction x_i	Weight fraction w_i
8,000-16,000	0.05	0.02
16,000-24,000	0.16	0.10
24,000-32,000	0.24	0.20
32,000-40,000	0.28	0.30
40,000-48,000	0.20	0.27
48,000-56,000	0.07	0.11

14. In polymer processing, the vulcanizing process is used to:
a) Inhibit branching during polymerization
b) Create cross-links in elastomers
c) Increase the crystallinity of thermoplastic polymers
d) Reduce the crystallinity of thermosetting polymers
e) Remove unwanted sulphur following the polymerization process.

15. In Figure 6, the bonding between points A-B would be:
a) ionic
b) covalent
c) metallic
d) van der Waals
e) hydrogen

16. In Figure 6, the bonding between chain fragments 1-1 and 2-2 would be:
a) ionic
b) covalent
c) metallic
d) van der Waals
e) There is no bond between fragments 1-1 and 2-2

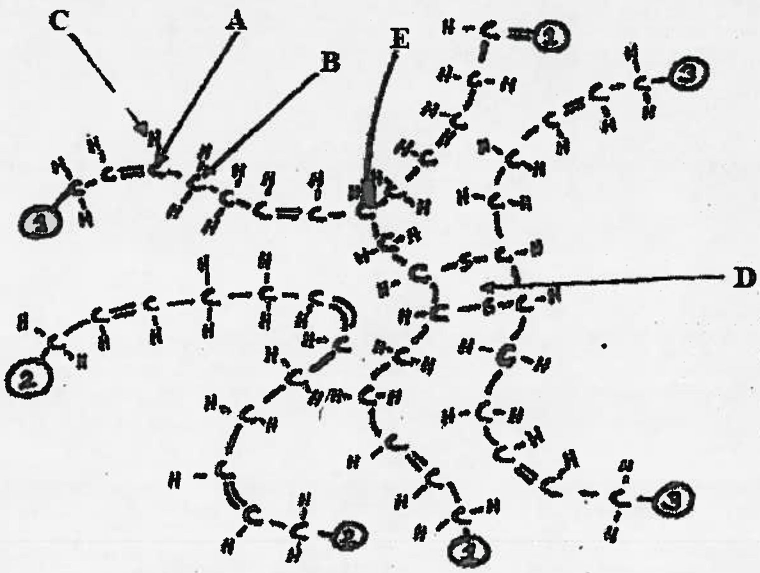


Figure 6

17. In Figure 6, the bonding between chain fragments 1-1 and 3-3 at the point "D" would be:
a) ionic
b) covalent
c) metallic
d) van der Waals
e) hydrogen

18. In Figure 6, the junction between the three parts of polymer chain "1" at the point E:
a) could never occur in reality
b) is termed vulcanizing
c) is termed esterification
d) is termed incipient crystallization
e) is termed branching

The resistance of two wires: one a metal and the other an intrinsic semiconductor is measured at different temperatures near room temperature. The expected behaviour for the resistance is: as the temperature increases, the resistance:

	Metal	Semiconductor
a)	increases	increases
b)	increases	decreases
c)	decreases	decreases
d)	decreases	increases

e) remains unchanged for both materials

20. The electrical conductivity (σ) of an n-type extrinsic semiconductor varies with temperature (T). Which diagram in Figure 7 is most similar to the expected behaviour?
a) A
b) B
c) C
d) D
e) none of the figures is representative of the real behaviour.

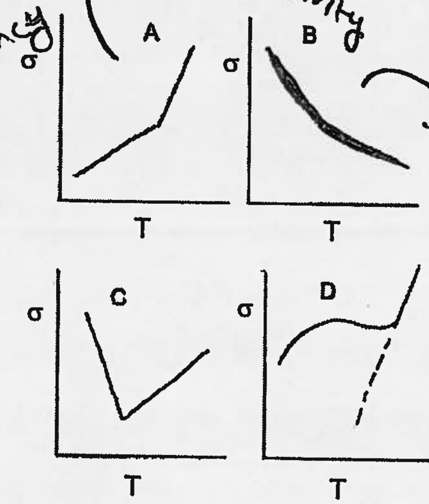


Figure 7

21. A p-type semiconductor has a band structure which
a) is similar to that of an insulator
b) is similar to that of a metallic conductor
c) is similar to that of a single atom
d) has a donor level in the band gap
e) has an acceptor level in the band gap

22. When you touch a piece of cold (-10 °C) metal with your bare hands it "feels" colder than a piece of plastic that is at the same temperature. This is because:
a) The plastic has higher thermal shock resistance than the metal
b) The metal has higher heat capacity
c) The metal has higher thermal conductivity
d) The plastic has a higher heat capacity
e) The plastic has a higher thermal conductivity

23. The coefficient of thermal expansion:
a) Is related to the asymmetry of the potential energy trough of the atomic bonding curve
b) Is generally highest for plastics, intermediate for metals and lowest for ceramics
c) Is the stress-free strain induced by heating a material by a unit of temperature
d) Can vary with direction in certain crystal structures
e) All the above

24. The stiffness (modulus of elasticity) of beryllium oxide (BeO) which has 5 volume % porosity is 310GPa. The modulus of elasticity of the nonporous material (0 % porosity) is:
a) 281.2 GPa
b) 243.3 GPa
c) 326.2 GPa
d) 310 GPa
e) 341.7 GPa

25. As the porosity of refractory ceramic bricks increases,
a) strength decreases and thermal insulation decreases.
b) strength increases and thermal insulation decreases.
c) strength decreases and thermal insulation increases.
d) strength increases and thermal insulation increases.
e) porosity does not affect the thermal conductivity of the ceramic materials.

26. A rod of some material 0.20 m long elongates 0.20 mm on heating from 21 to 120°C. Determine the value of the linear coefficient of thermal expansion for this material.
a) 10×10^{-6} (°C)$^{-1}$
b) 15×10^{-5} (°C)$^{-1}$
c) 20×10^{-6} (°C)$^{-1}$
d) 1×10^{-3} (°C)$^{-1}$
e) 0.05×10^{-3} (°C)$^{-1}$

27. Tempering of glass by surface cooling is used in order to:
a) make it more transparent
b) make it more ductile
c) add colours
d) glaze ceramic products
e) make it more impact resistant

28. Which of the following determines the coordination number of a ceramic's crystal structure?
a) cation-anion mass ratio
b) cation-anion radius ratio
c) cation-anion electronegativity ratio
d) the wave length of the light emitted from its crystal
e) none of the above

29. Which of the following accompanies the ceramic sintering process:
a) diffusion
b) annealing
c) austenitizing
d) plasticizing
e) tempering

30. Which of the following statements about ceramics is true? Ceramic components are:
a) Usually cast in the molten state in a similar way to cast-irons.
b) Usually made from powder compacts which are sintered below their melting points.
c) Usually made from powder compacts which are then sintered just above their melting points.
d) Usually shaped after they have been sintered.
e) Exceedingly hard but capable of some plastic deformation at room temperature.

For **Questions 31 – 60**, decide whether the following statements are **True** or **False** and shade in the appropriate box on the **Answer sheet. Each correct answer is worth 0.5 marks.**

31. When determining Miller indices the plane must pass through the origin of the coordinate system.
32. The larger the number of slip systems available to a metal, the easier it is to deform.
33. A glass resembles an undercooled (or supercooled) liquid rather than a crystalline solid
34. Due to its high Modulus of Resilience, glass is used for making springs
35. Most hardness tests involve pressing a hard object into the surface of a test specimen and measuring the indentation that results.

36. If elements Si and N have electronegativities of 1.8 and 3.0, the material Si_3N_4 is approximately 70% ionic in character. F

37. If the length of the side of an FCC unit cell is "*a*" nm then the linear density on the [110] direction is $(\sqrt{2})/a$ atoms/nm. T

38. {100} represents the family of planes that make up the sides of the cube of the BCC unit cell and for the FCC unit cell it is the {110} family of planes.

39. The [100], [010] and [001] are equivalent in cubic unit cells. T

40. For powder pressing of ceramic pieces, degree of compaction is maximized when a mixture of large and small particles is used. T

41. Impurity atoms in ceramic materials may form substitutional and interstitial solid solutions. T

42. All ferrous alloys have similar microstructures. F

43. Ceramics are generally much stronger in tension than in compression. F

44. Heat capacity of metals is higher than that of ceramics. F

45. Increased hindering of dislocation motion makes a metallic material softer. F

46. Cementite is the proeutectoid phase in the hypereutectoid steels. T

47. The interstitial solid state diffusion of carbon atoms in FCC iron is slower than the substitutional solid state diffusion of iron atoms in FCC iron, all other factors being equal (including temperature). F

48. Pearlite is the name given to the combination of phases that form from the eutectic reaction in the iron-carbon system. F

49. Porosity decreases the thermal conductivity of ceramic and polymeric materials because the thermal conductivity of a gas phase that occupies pore space is extremely small relative to that of the solid material. Also, contributions from gaseous convection are generally insignificant. T

50. Increasing the degree of crystallinity of a semicrystalline polymer enhances its thermal conductivity because the vibrations and rotations of the molecular chains are more effective modes of thermal transport when a crystalline structure prevails. T

51. True stress and engineering stress are different, but true strain and engineering strain are the same. F

52. Grains, in metals, can be increased in size by heating and holding the material at high temperature and then slowly cooling it. F

53. During cooling from the 100% liquid phase, an alloy of eutectic composition goes through a two-phase – {pro-eutectic solid + liquid} region before transforming to two solid phases at the eutectic temperature. F

54. Toughness is the energy to break a unit volume of material and it is represented by the area under the stress strain curve so tough materials have a combination of strength and plastic deformation T

55. In steady state diffusion the flux of the diffusing species is proportional to the concentration gradient of the species. T

56. The coefficient of diffusion decreases with the increase in the temperature. F

57. For noncrystalline ceramics, plastic deformation occurs by the motion of dislocations. F

58. Ceramics often fracture above their theoretical strength because of their strong ionic bonding. F

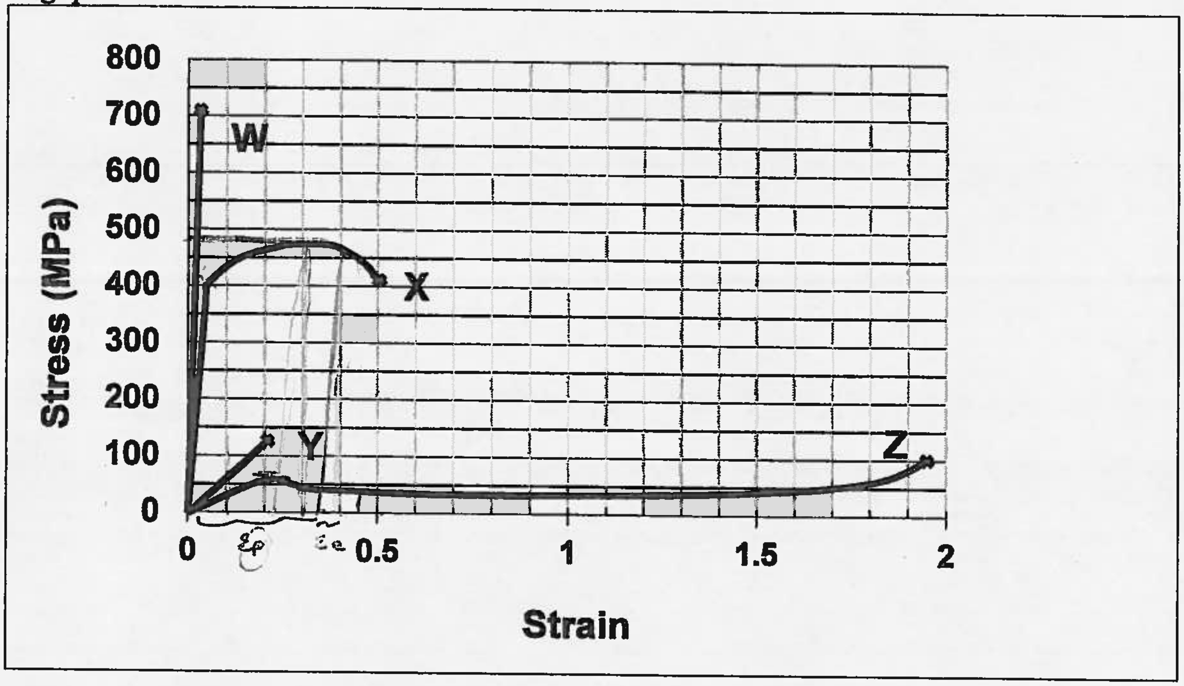
59. A combination of two or more metals, one of which is intentionally added to the base metal, is called allotropy F

60. Thermosets are usually stiffer than thermoplastics because of the strong covalent bonding of the cross-links in the thermosets. T

Attempt all questions: Where appropriate put your final answer in the answer box provided

Question 61: *{10 marks}*

The Figure below shows the tensile stress-strain behaviour for 4 different materials, W, X, Y and Z. Using the figure and your knowledge of the behaviour of different types of materials answer the following questions.



i) Which of the materials groups (metals, ceramics, thermoplastics, thermosets) does each material likely belong in?

Group	metals	ceramics	thermoplastics	thermosets
Material	X	W	Z	Y

ii) Rank the materials in order of increasing Young's Modulus:

Z Y X W ⇒ slope

iii) Which of the materials shows the highest toughness? X area under

iv) Which of the materials shows the highest ductility? Z

v) What is the tensile strength of the metal? 475 MPA

vi) Materials X and Y are both strained to a value of 0.1. Which one yields first? X

vii) Materials X and Z are both strained to a value of 0.45. Will either or both show necking? X and Z

viii) If a sample of material X is strained to a value of 0.4 and the load is then removed what will happen to the sample? 0.05 wich is the Elastic strain will recover wille the rest is Palstic deformation remains

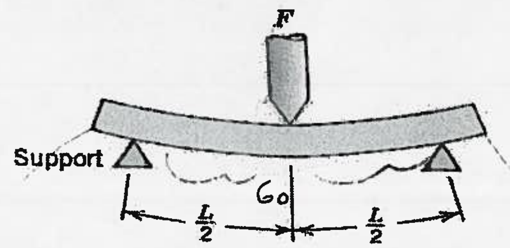
i) Which of these materials would be the best one to use for a crash barrier separating highway lanes? X

ii) Which of these materials would be the best one to use for a bottle that may get dropped on a hard floor (eg. shampoo, ketchup)? Z

Question 62: *{10 marks}*

A design of a measurement instrument requires a small ceramic beam, 5mm high x 10mm wide x 80mm long which will be supported in a 3-point loading configuration (lower span 60mm with the load applied through the height) and then the deflection of the beam under applied external loads will be measured and used to determine the magnitude of the applied load. The material of choice is alumina (Al_2O_3). In its **fully dense** form this alumina has a 3-point flexure strength of 700MPa and a Young's Modulus of 393 GPa.

d b L



a) What is the minimum applied load that will likely cause the fully dense beam to fracture?

$\sigma_{fs} = \frac{3 F_f L}{2bd^2}$

$700\times10^6 = \frac{3 F \, 60\times10^{-3}}{2 (10\times10^{-3}) \times (5\times10^{-3})^2}$

350

$F_f = \frac{\sigma_{Fs} \times 2bd^2}{3L}$

F = 1944 N

Minimum load = 1944N

b) If the actual alumina material supplied has 5% porosity what will be the new value of the fracture load in part (a) (n = 3.75 and σ_0 = 700 MPa)?

$\sigma_{fs} = 700 \exp(-3.75 \times 0.05)$

580 MPA

580 is 700 N

$\sigma_F = \frac{3 F_f L}{2bd^2}$

$F = \frac{580\times10^6 \times 2 \times 10\times10^{-3} \times (5\times10^{-3})^2}{3 (60\times10^{-3})}$

Minimum load = 1611 N

c) How else will 5% porosity affect this beam's performance under load?

it will effect the elastic modules by $E = E_0(1 - 1.9P + 0.9P^2)$

stiffness

d) How would such an alumina beam be manufactured?

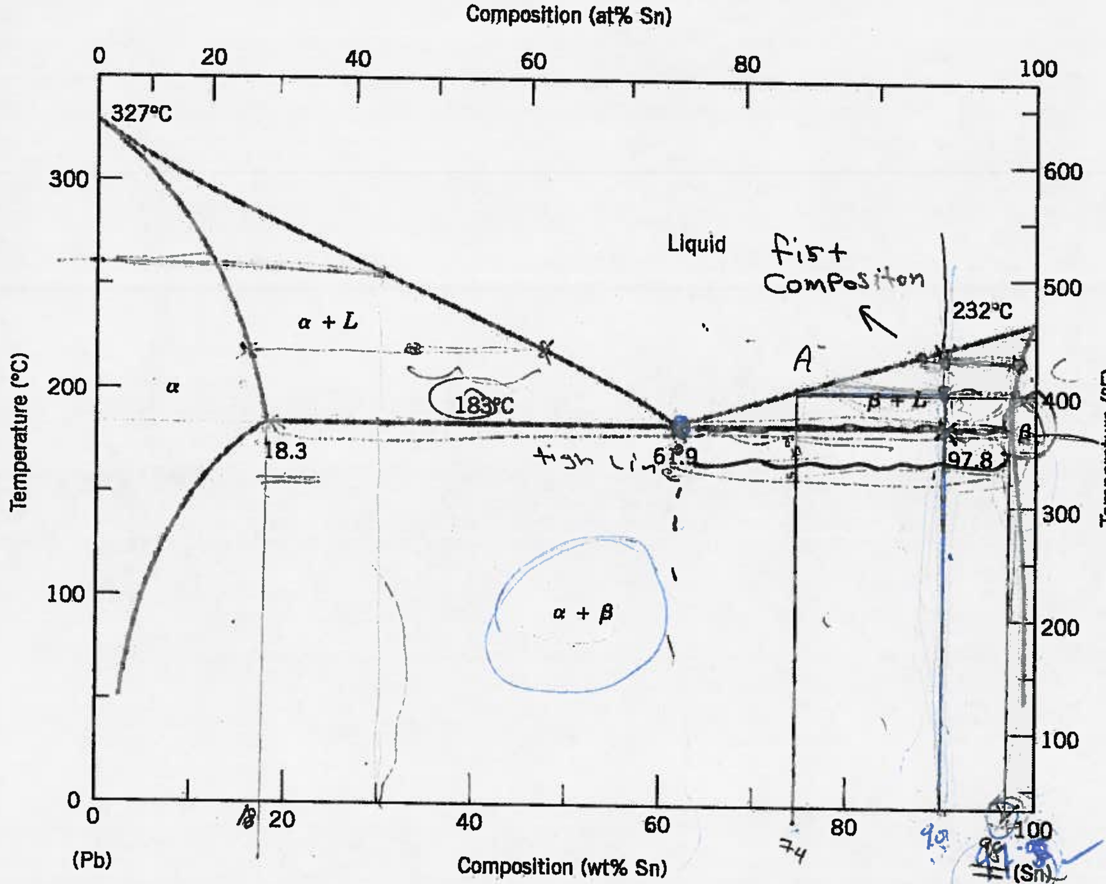
it can be casted

by casteing the ciramic

slip casting

Question 63: *{20 marks}*

Shown below is the equilibrium phase diagram for the lead-tin system. Alloys from this system are commonly used as "solders" which are melted and used to join two other metal pieces together. Using this diagram answer the following questions, putting your answers in the boxes where indicated.



i) Why is the eutectic composition commonly used as a solder for joining electronic components?

*Low temp Point + it is totaly Liq befor it become solid.

ii) At what temperatures does freezing begin (first solid forms, T_1) and finish (last liquid freezes, T_2) for the following two alloys?

a. An alloy with overall composition 61.9 wt% Sn (balance Pb) — T_1= 183 T_2= 183

b. An alloy with overall composition 30 wt% Sn (balance Pb) — T_1= 260 T_2= 183

iii) For an alloy with an overall composition (C_0) of 90 wt% Sn what is the composition of the first solid to form?

98 wt% Sn

iv) For 50kg of an alloy with an overall composition (C_0) of 90 wt% Sn that is cooled from the liquid phase and held at 200°C what is the weight of solid?

$W_\beta = \frac{AB}{AC} = \frac{90-74}{98-74} = 0.66$

$m_\beta = 50 kg \times 0.545 = 27.27 kg$

33.3 kg

v) For 50kg of an alloy with an overall composition (C_0) of 90 wt% Sn that is cooled from the liquid phase to a temperature just below the eutectic temperature what are the weights of the two phases?

~~$W_\alpha = \frac{97.8-90}{97.8-18.3} \times 50 =$~~

~~$W_\beta = \frac{90-18.3}{97.8-18.3} \times 50 =$~~

$W_\alpha = \frac{98-90}{98-18.3} = 0.1 \times 50 = 5\text{kg}$

$W_\beta = 50 - 5\text{ kg} = 45$ $\quad \frac{90-18.3}{98-18.3} =$

5kg α
45kg β

vi) For 50kg of an alloy with an overall composition (C_0) of 90 wt% Sn that is cooled from the liquid phase to a temperature just below the eutectic temperature what is the weight of the proeutectic (primary) phase?

$W_\beta = \frac{90-61.9}{98-61.9}$

38.9 kg

vii) Schematically sketch and label the microstructure of an alloy of 61.9 wt% Sn cooled slowly from 300°C to room temperature.