

04-BS-11 Properties of Materials

3 Hours Duration**Notes:**

- (i) If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumption made.
- (ii) Candidates may use one of two calculators, the Casio or Sharp approved models. This is a “closed book” examination.
- (iii) Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
- (iv) All questions are of equal value.

Information:(1) Atomic Masses (g.mol⁻¹)

H	1.01	C	12.01	N	14.01	O	16.00	S	32.1
Cl	35.5	Cr	52.0	Sn	118.7	Pb	207.2		

(2) Constants and Conversions

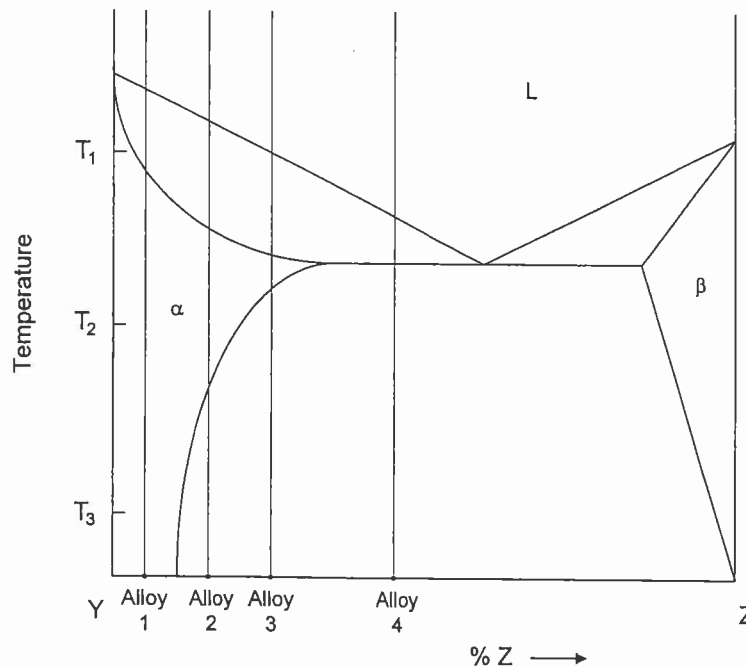
Avagadro's number, N _A	= 0.602 x 10 ²⁴ mol ⁻¹
Boltzmann's constant, k	= 13.8 x 10 ⁻²⁴ J. mol ⁻¹ .K ⁻¹
Universal gas constant, R	= 8.314 J. mol ⁻¹ .K ⁻¹

(3) Prefixes

tera	T	10 ¹²	milli	m	10 ⁻³
giga	G	10 ⁹	micro	μ	10 ⁻⁶
mega	M	10 ⁶	nano	n	10 ⁻⁹
kilo	k	10 ³	pico	p	10 ⁻¹²

Questions:

1. (a) The solubility of tin in solid lead at 200°C is 18% Sn. The solubility of lead in the molten metal at the same temperature is 43% Pb. What is the composition of an alloy containing 60% liquid and 40% solid α at 200°C?
- (b) Distinguish between coherent and incoherent precipitates.



- (c) Which of the alloys (1,2,3, and/or 4) in the figure above could be strengthened by age hardening? (Assume that β forms a coherent precipitate in α). Outline the complete procedure for the age hardening process.
2. (a) PVC (polyvinyl chloride) is usually used as a copolymer with PE (polyethylene) rather than as a homopolymer. Why? The copolymer is normally syndiotactic. Would you expect the copolymer to be crystalline? Thermoplastic or thermosetting? Explain your answers.
- (b) Name and describe the processing methods to make the following: polyethylene squeeze bottle, melamine dish, nylon fishing line, fiberglass boat hull.
- (c) A rubber contains 94% by weight polymerized chloroprene ($\text{CH}_2\text{CClCHCH}_2$) and 6% sulphur. What fraction of the chloroprene is crosslinked? Assume that all the sulphur is utilized in the crosslinking.

3. Chromium has a body centered cubic structure and atomic radius 0.1249 nm. Calculate the density ($\text{g}\cdot\text{cm}^{-3}$) of chromium. Sketch the unit cell. On your sketch show the (112) plane and [011] direction. What is the spacing (nm) between the (102) planes?
4. The following data were obtained from a tensile test of high strength aluminum (7075-T5) alloy. (Note: kip = 10^3 lb). All test samples had an initial diameter of 0.505 inch and an average final diameter of 0.390".

<u>Load (kips)</u>	<u>Gauge Length (inches)</u>
0	2.0000
4	2.0041
8	2.0079
10	2.0103
12	2.0114
13	2.0142
14	2.0202
16	2.0503
16.1	2.0990
15.6 (fracture)	2.1340

Using the supplied graph paper plot the engineering stress – strain curve. Use your plot to determine the following:

- (i) Modulus of elasticity (psi)
- (ii) Yield strength at 0.2% offset (psi)
- (iii) Reduction in area (%)
- (iv) Elongation (%)
- (v) Tensile strength (psi)

5. (a) Indicate whether the following statements about a 1080 steel are correct or incorrect and justify your answer.
- (i) The hardness of pearlite is a fixed value.
 - (ii) Martensite is obtained by the isothermal transformation of austenite.
 - (iii) Retained austenite indicates the quench was too rapid.
 - (iv) For maximum machinability the steel should be spherodised
- (b) Sketch and describe two types of dislocations.
- (c) Indicate whether the following statements are correct or incorrect, and justify your answer:
- (i) the presence of more dislocations increases the yield strength of an annealed metal.
 - (ii) dislocations move more readily in a solid solution alloy than in a pure metal.
 - (iii) a fine grained alloy will have a higher yield strength than a coarse grained alloy of the same chemical composition.
6. (b) Glass fibres in nylon provide reinforcement. If the nylon contains 10 vol% of E glass, what fraction of the applied force is carried by the glass fibres?
($E_{\text{glass}} = 10 \times 10^6$ psi, $E_{\text{nylon}} = 0.5 \times 10^6$ psi)
- (c) Using an appropriate sketch show that the minimum ionic radius ratio for 8-fold coordination is 0.732.

Note: Do only one of parts a, b or c for a complete answer to question 7

7. (a) Birchwood veneer is impregnated with a phenolic resin (specific gravity = 1.30) to ensure resistance to water and also to increase the hardness of the final product. Although dry birch weighs only 0.56 g.cm^{-3} , the true density of the wood-resin combination is 1.52 g.cm^{-3} . How many grams of the resin are required to impregnate 20 cm^3 of dry birchwood? What is the final bulk density?
- (b) A piping system used to transport a corrosive liquid is fabricated from 304 stainless steel. Welding of the pipes is required to assemble the system. Unfortunately, corrosion occurs and the corrosive liquid leaks from the pipes near the weld. Identify the problem and state what steps you would take to prevent corrosion in the future, while still using a welded 304 stainless steel construction.
- (c) The selection of engineering materials for component design is done by matching engineering properties of the material to the service conditions required of the component. Using this criterion perform a materials selection for an 8 lb sledge hammer for driving steel fence posts into the ground.