

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:Atomic Weights (g.mol⁻¹)

H	1.01	B	10.81	C	12.01	O	16.00	F	19.00
Al	26.98	Si	28.09	Ti	47.88	Cu	63.54		

Constants and Conversions

Avagadro's number, N_A	=	$0.602 \times 10^{24} \text{ mol}^{-1}$
Boltzmann's constant, k	=	$13.8 \times 10^{-24} \text{ J.K}^{-1}$
Universal gas constant, R	=	$8.314 \text{ J. mol}^{-1} .\text{K}^{-1}$
1 eV	=	$0.16 \times 10^{-18} \text{ J}$
K	=	$^{\circ}\text{C} + 273$
Faraday, \mathcal{F}	=	$96.5 \times 10^3 \text{ C}$

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. Beryllium melts at 1252°C and silicon melts at 1414°C. They are completely soluble as liquids, but completely insoluble as solids. They form a eutectic at 1090°C containing 39% beryllium. Draw the thermal equilibrium diagram and label all fields. Explain, with the aid of sketches, what happens when liquid alloys containing (a) 90% beryllium, (b) 30% beryllium solidify completely during a slow cooling process. In each case determine the amount (%) of eutectic in the cooled solid.
2. (a) Above 882°C, titanium has a BCC structure with $a = 0.332$ nm. Below this temperature, the metal has a HCP structure with $a = 0.2978$ nm and $c = 0.4735$ nm. Determine the percent change in volume when titanium cools through 882°C (i.e. transforms from BCC to HCP).

(b) Describe the Charpy impact test. What relation, if any, is there between the measured impact energy and the stress-strain diagram obtained from tensile tests? What advantages, if any, would the impact test results have in comparison with the tensile test results?
3. The following data were obtained from a tensile test of high strength aluminum (7075-T5) alloy. (Note: kip = 10^3 lb). The test sample had an initial diameter of 0.505 inch. No appreciable "necking" (localised reduction in area) was observed during fracture.

<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: modulus of elasticity (psi), yield strength at 0.2% offset (psi), reduction in area (%), elongation (%), and tensile strength (psi).

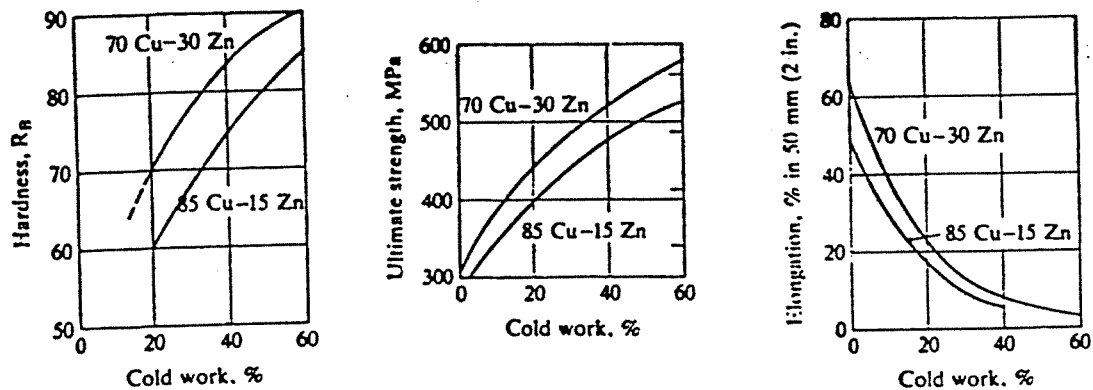


Fig 1 Effect of Cold Working on Mechanical Properties of Brasses

4. (a) Fig 1 shows the effect of cold working on the mechanical properties of brasses. A 50 mm diameter bar of 85%Cu-15%Zn brass is to be cold drawn to 12.5 mm diameter. Suggest a procedure to be followed if the mechanical properties to be obtained are tensile strength >415 MPa and ductility >10% elongation.

(b) A solid solution of copper in aluminum has 10^{26} atoms of copper per m^3 at point X, and 10^{24} copper atoms per m^3 at point Y. Points X and Y are $10 \mu m$ apart. What will be the diffusion flux of copper from X to Y at $500^\circ C$?

$$[D_{Cu \text{ in Al}} = 4 \times 10^{-14} \text{ m}^2/\text{sec} @ 500^\circ C]$$

5. (a) What is a substitutional solid solution? What factors favour this type of solid solution in metals?

b) 38 grains are observed in an area 2in x 1in at a linear magnification of X300. Calculate the ASTM grain size number.

c) Describe how you would recognise a fatigue failure.

6. (a) The melt index is the rate at which a polymer is extruded under prescribed conditions through a die of specified length and diameter (ASTM-D-1238). The units are grams of polymer extruded in 10 minutes.
- (i) How does the melt index vary with molecular weight of the polymer?
 - (ii) Explain why the weight average molecular weight would be more important as a measure of the melt index than would the number average molecular weight.
- (b) The degree of polymerization of polytetrafluoroethylene (PTFE or Teflon) is 8000. If all the polymer chains are of the same length, calculate:
- (i) The molecular weight of the chains
 - (ii) The total number of chains in 1200 g of the polymer.
- (c) Polytetrafluoroethylene can be used on components exposed to high temperatures. Explain why, as a thermoplastic, PTFE does not flow readily in high temperature service. Why does PTFE not burn readily? What is the structure of the mer? Suggest how it is attached to frying pans.
7. (a) B_2O_3 is added to silica to increase the chemical resistance and reduce the melting temperature. However, to assure that good glass-forming tendencies are retained the O:Si ratio must not exceed 2.5. Design such a glass (i.e. what is the maximum weight percent of B_2O_3 ?). State any assumptions made.
- (b) A 2 inch inside diameter, 12 ft long copper distribution pipe in a plumbing system is accidentally connected to the power system of a manufacturing plant, causing a current of 65 mA to flow through the pipe. The wall thickness of the pipe is 0.125 inch. Estimate the time required before the pipe begins to leak, assuming a uniform rate of corrosion. (Density of copper = 8.93 g. cm^{-3}).

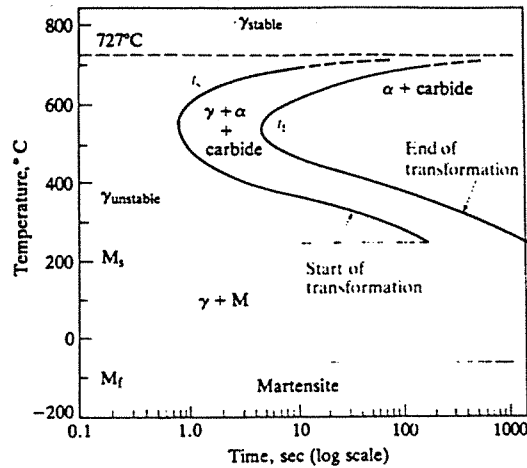


Fig 2 I-T Diagram for a 0.8% Carbon Steel

8. (a) Describe the Jominy test. What useful information does it provide?
- (b) Fig 2 shows the isothermal transformation curve for a eutectoid (0.8%) carbon steel. Thin sections of the steel are heated to 800°C for 1 hour, then heat treated as follows:
- (i) Quenched to 350°C, held for 750 s, and quenched to room temperature.
 - (ii) Quenched to 650°C, held for 500 s, and quenched to room temperature.
 - (iii) Quenched to 300°C, held for 10 s, and quenched to room temperature.
 - (iv) Quenched to 300°C, held for 10 s, quenched to room temperature, reheated to 400°C, held for 3600 s, cooled slowly to room temperature.

For each of the above cases describe the microstructure of the heat treated material and comment on the final mechanical properties obtained.