MAY 2011 **NATIONAL EXAMINATIONS**

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
Al	26.98	Si	28.09	Fe	55.85	Cu	63.54

(2) Constants and Conversions

Avagadro's number, N_A $= 0.602 \times 10^{24}\ mol^{-1}$
Boltzmann's constant, k $= 13.8 \times 10^{-24}$ J/atom·K
Universal gas constant, R $= 8.314$ J/mol·K

(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 complete stress-strain curve is often not determined in the daily gathering of data. From the information in the table below, determine the yield strength, tensile strength, modulus of elasticity, percent reduction of area, and percent elongation. The initial gauge length is 2.00 in, initial diameter 0.505 in, and diameter after failure 0.423 in.

Load (lb)	Gauge Length (in)
2000	2.001 (all elastic deformation)
6000	2.004 (all plastic deformation)
8500 (maximum)	2.300 (all plastic deformation)
7800 (failed)	2.450 (after failure)

2. (a) Show that the minimum ionic radii ratio for three fold coordination is 0.155. Explain why this is a minimum and not a maximum value.

   (b) Calculate the linear and planar atomic densities for FCC nickel (a_o = 0.35167 nm) in the [112] direction and (111) plane, respectively.

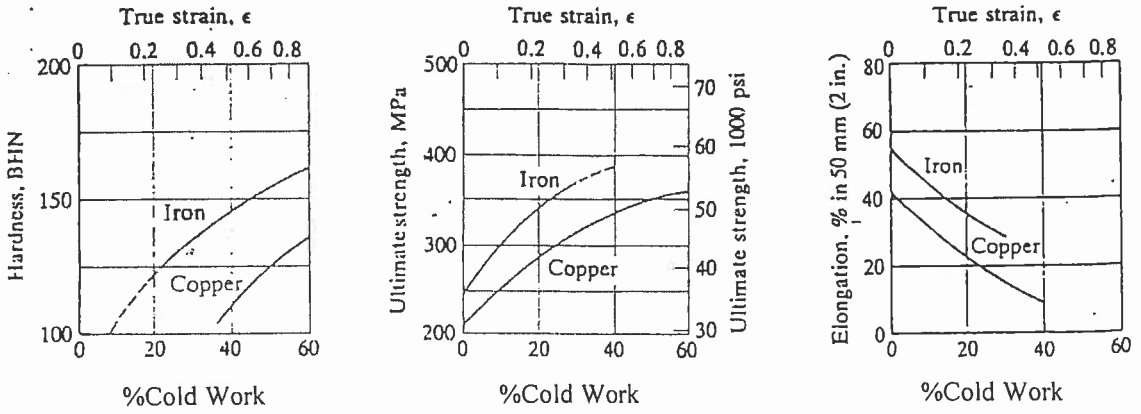

Fig 1. Cold Work vs Mechanical Properties (Iron and Copper)

3. (a) A copper wire must have a diameter 0.7 mm and an ultimate strength of >325 MPa (46,000 psi) together with a minimum ductility of 10% elongation in a tensile test. It is to be processed (drawing and annealing) from 10 mm diameter rod. Using the data in Fig 1, determine the diameter of the die to be used for the final cold draw?

   (b) What is a dislocation? Describe the role played by dislocations when a brass sheet is being cold rolled.

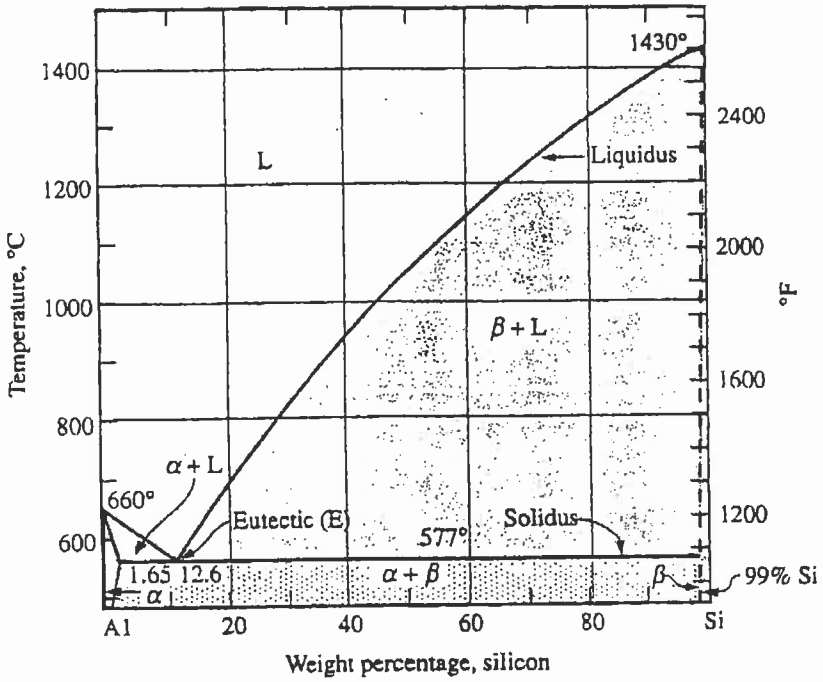

Fig 2 Aluminum – Silicon Phase Diagram

4. (a) Name and describe three types of imperfections found in crystals.

(b) Fig 2 shows the Aluminum - Silicon phase diagram. An automobile engine block is cast using a 20% Si - 80% Al alloy. At what temperature will the casting start to solidify? At what temperature is solidification complete? Assuming slow cooling describe the microstructures present at room temperature. How much (if any) of the microstructure will be eutectic?

5. (a) Sketch a schematic modulus vs temperature plot for amorphous polyethylene. On your sketch identify T_g and T_m (glass transition and melting temperatures). Indicate how the plot would change (if at all) should the polymer have:

(i) increasing crystallinity
(ii) increasing cross-linking

(b) A self lubricating bearing is made by sintering a cylinder of brass powder followed by impregnation with a mineral oil. Determine the percentage open and closed porosity (open-pore volume and closed-pore volume, respectively, divided by the bulk volume) in the bearing from the following data.

Dimensions:	2.00 cm diameter x 6.00 cm length
Mass, after sintering:	123.85 g
Mass, after oil impregnation:	126.80 g
Specific gravity of oil:	0.90
True density of brass:	8.47 g/cm^3

6. (a) Indicate whether the following statements about a 1080 steel are correct or incorrect. Justify your answer.

(i) The hardness of pearlite is a fixed value.
(ii) Martensite is obtained by the isothermal transformation of austenite.
(iii) The isothermal transformation curve is an equilibrium diagram.

(b) Some components are sold as being of "x-ray quality". That is, radiographs are used to determine the existence of flaws. Does this necessarily mean that we need not worry about brittle fracture in high-strength materials that have passed an x-ray examination? Explain.

(c) How would you distinguish between a brittle fracture and a fatigue failure?

7. (a) At the surface of a steel bar there is one carbon atom per 20 unit cells of iron. At 1 mm below the surface, there is one carbon atom per 30 unit cells. The diffusivity at 1000° C is 3×10^{11} m^2/s. The structure at 1000° C is FCC ($a_o = 0.365$ nm). How many carbon atoms diffuse through each unit cell per minute?

(b) Explain why the phenomenon for creep is so closely related to diffusion.

(c) Describe some general characteristics of creep resistant materials.