MAY 2018 **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	1.0	B	10.81	C	12.0	O	16.0
Si	28.01	Fe	55.85	Cu	63.54	Ag	107.87

(2) Constants and Conversions

Avagadro's number, N_A = 0.602×10^{24} mol^{-1}
Boltzmann's constant, k = 13.8×10^{-24} J/atom·K
Kelvin, K = °C + 273
1 inch = 25.4 mm

(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}

(4) Useful equations

Diffusion, $J = -D\frac{\Delta c}{\Delta x}$ $D = D_0 \exp\left(\frac{-E}{kT}\right)$ $\frac{dc}{dt} = D\frac{d^2c}{dx^2}$

Nernst, $E = E_o + \frac{0.0592}{n}\log(C_{ion})$ Hall-Petch, $\sigma_y = \sigma_o + Kd^{-½}$

Questions:

1. (a) X-ray data gives the lattice constant of silver to be 0.4073 nm and its structure face centered cubic. Calculate the density ($g.cm^{-3}$) and atomic radius (nm) of silver.

   (b) Determine the planar density and packing fraction for silver in the (100), (110), and (111) planes. Which, if any, of these planes is close packed?

2. (a) Calculate the average molecular mass for a thermoplastic which has the following mass fractions f_i for the molecular mass ranges listed below:

Molecular mass range, g/mol	f_i	**Molecular mass range, g/mol**	f_i
0-5,000	0.02	20,000-25,000	0.25
5,000-10,000	0.11	25,000-30,000	0.13
10,000-15,000	0.18	30,000-35,000	0.06
15,000-20,000	0.22	35,000-40,000	0.03

   (b) How does the amount of crystallinity in a thermoplastic affect its density and tensile strength? Explain.

   (c) In general how does the processing of thermoplastics into the desired shape differ from the processing of thermosetting plastics?

3. (a) A 3" x ¼" strip of annealed C26000 brass (70Cu-30Zn) is cut into nine 6" lengths. Each strip is put through a rolling mill with the distance between the rolls set from 0.250" down to 0.050" in intervals of 0.025". (Thus the first sample is rolled at 0.250", the second at 0.225", and so on). The hardness of each sample is then measured using a Rockwell superficial tester (similar to regular Rockwell except lighter loads are used, thus better for thinner materials). Sketch the graph of hardness vs cold work. Explain the nature of the graph.

   (b) The sample that was rolled to 0.100" is now cut into seven (7) approximately equal pieces. Each piece is annealed for 10 minutes in a vacuum furnace. The temperature of the furnace is varied from 100°C to 700°C in intervals of 100°C. (Each piece is annealed at <u>one</u> temperature). After annealing the pieces are water quenched, dried and then their hardness measured using the same hardness tester. Sketch the graph of hardness vs annealing temperature and explain the nature of the graph.

4. (a) One end of a copper wire is immersed in an electrolyte of 0.03 *M* Cu^{2+} ions and the other in one of 0.002 *M* Cu^{2+} ions, with the two electrolytes being separated by a porous wall.

(i) Which end of the wire will corrode?
(ii) What will be the potential difference between the two ends of the wire when it is just immersed in the electrolytes?

The standard electrode potential E^o for copper ($Cu = Cu^{2+} + 2e^-$) is +0.337 Volts.

(b) At the surface of a steel bar there is one carbon atom per 40 unit cells of iron. At 2 mm below the surface, there is one carbon atom per 50 unit cells. The diffusivity at 1000°C is 3×10^{-11} m^2/s. The structure at 1000 °C is face centred cubic ($a_o = 0.365$ nm). How many carbon atoms diffuse through each unit cell per minute?

5. (a) Glass fibres in nylon provide reinforcement. If the nylon contains 15 vol% of E glass, what fraction of the applied force is carried by the glass fibres?
($E_{glass} = 10.2 \times 10^6$ psi, $E_{nylon} = 0.65 \times 10^6$ psi)

(b) Using an appropriate sketch show that the minimum ionic radius ratio for 4-fold coordination is 0.225.

6. (a) What would be the ASTM grain size number for a steel with an average grain diameter of 30 μm?

(b) Yield stresses for a steel have been measured for samples of different grain sizes.

d, μm	σ_y, MPa
60.5	160
136	130

By determining the Hall-Petch coefficients, calculate the yield stress for a steel of grain diameter 30 μm.

7. (a) Boric oxide B_2O_3 is added to silica SiO_2 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) What are cermets? How are they made and where would they typically be used?