MAY 2014 **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 of the eight (5 of 8) 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	10.8	C	12.0	N	14.0	O	16.0	Si	28.1
Cl	35.5	Ca	40.08	V	50.95	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
Calorie	$= 4.18$ J
Electron volt, eV	$= 0.16 \times 10^{-18}$ J
Kelvin, K	$= {}^{o}C + 273$

(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

Fick $J = -D\frac{\Delta c}{\Delta x}$ Boltzmann $\frac{n}{N} = Me^{-E/kT}$

Nernst $E = E_o + \frac{0.0592}{n}\log(C_{ion})$

Questions:

1. The following data were collected from a tensile test of a 12 mm diameter magnesium alloy sample.

Load (kN)	Gauge Length (mm)
0	30.00
5	30.0296
10	30.0592
15	30.0888
20	30.15
25	30.51
26.5	30.90
27	31.50 (maximum load)
26.5	32.10
25	32.79 (fracture)

After fracture, the gauge length was 32.61 mm and the diameter 11.74 mm. Plot the data and calculate the:

(i) 0.2% offset yield strength
(ii) tensile strength
(iii) modulus of elasticity
(iv) % elongation
(v) % reduction in area
(vi) engineering stress at fracture
(vii) true stress at fracture

2. (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.

3. (a) X-Ray crystallography studies of the metal vanadium show that it has a body centred cubic structure with a d_{110} interplanar spacing of 0.215 nm. Calculate the lattice constant and density of this metal. Marks will be awarded for a diagram supporting your calculations.

(b) What factors affect the diffusion rate in solid metal crystals?

4. (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?

5. (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 6 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 x 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?

6. (a) Explain how you would obtain the following microstructures in a 0.45% plain carbon steel: ferrite and pearlite; all martensite; all spherodite; all bainite.

(b) Cartridge brass CA260 (70Cu30Zn) is one of the most formable engineering alloys, making it ideal for deep drawing applications. Unfortunately, it is prone to corrosion due to "season cracking" (stress corrosion cracking) and "dezincification" (selective leaching). Describe these two types of corrosion and indicate how they can be minimized.

(c) "Weld decay" is commonly observed in austenitic stainless steels. It is intergranular corrosion. Describe why it occurs and how it can be minimised in these materials.

7. (a) Predict the coordination number for CaO given that the ionic radii are $Ca^{2+} = 0.100$ nm, $O^{2-} = 0.140$ nm.

(b) How do porosity and grain size affect the tensile strength of ceramic materials?

(c) Explain why statistical methods are often used to predict failure in ceramic materials. In particular, discuss how the Weibull distribution is employed.

Note: Do only **one** of parts a, b or c for a complete answer to question 8

8. (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) 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.

(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.