

# 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<sup>-1</sup>)

H	1.01	B	10.81	C	12.01	O	16.00	Mg	24.31
Si	28.08	Ni	58.71	Cu	63.54				

#### (2) Constants and Conversions

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

#### (3) Prefixes

tera	T	$10^{12}$	milli	m	$10^{-3}$
giga	G	$10^9$	micro	$\mu$	$10^{-6}$
mega	M	$10^6$	nano	n	$10^{-9}$
kilo	k	$10^3$	pico	p	$10^{-12}$

**Questions:**

1. (a) In a tensile test an extensometer is used to obtain accurate values for the sample gauge length  $l$ . Show that the true strain  $\epsilon_T$  is given by:

$$\epsilon_T = \ln\left(\frac{l}{l_0}\right) \quad \dots\dots (1)$$

The true strain can also be determined by monitoring the diameter  $d$ . Show that if the specimen volume remains constant the true strain is given by:

$$\epsilon_T = 2 \ln\left(\frac{d_0}{d}\right) \quad \dots\dots (2)$$

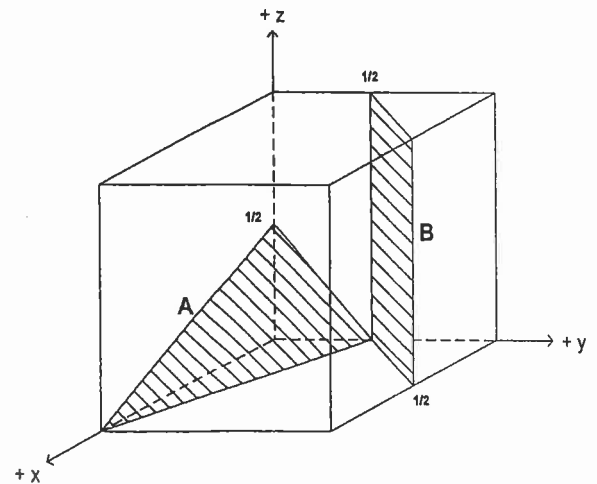
Which of the two expressions is more valid during necking? Why? ( $l_0$  and  $d_0$  are the initial sample gauge length and diameter, respectively).

- (b) Describe the Brinell hardness test. This hardness test gives a closer correlation to tensile strength of structural steels than other hardness tests. Explain. Why does this correlation not exist for heat treated steels?

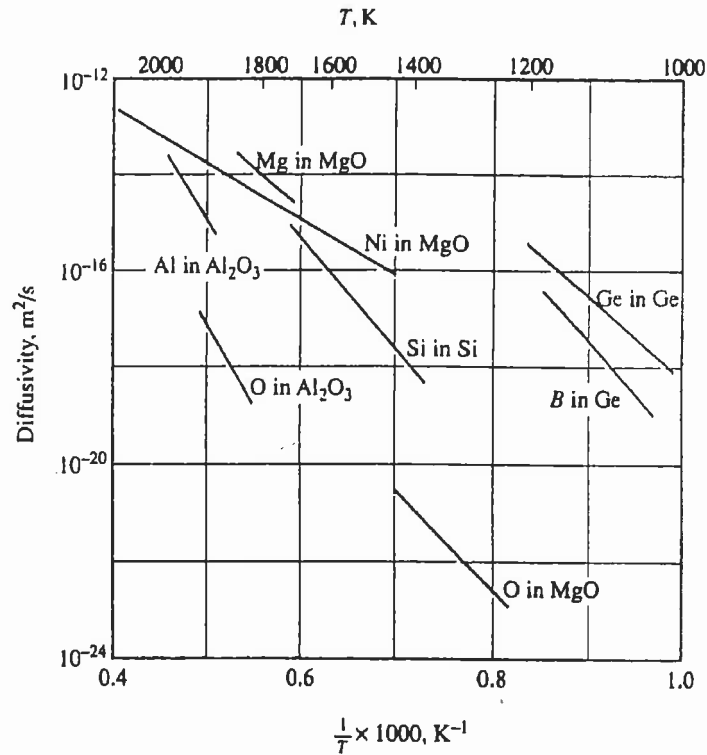
2. (a) Determine the Miller indices for the planes A and B shown at the right.

- (b) Determine the lattice constant  $a_0$  for copper, given that its density is  $8.93 \text{ g.cm}^{-3}$ .

- (c) At what temperature will there be 10,000 times as many vacancies as the number present at room temperature in pure copper. The energy of vacancy formation in copper is  $83.7 \text{ kJ/mol}$ . The following identity may be of use:



$$\frac{n_v}{n_0} = \exp\left\{\frac{-Q}{RT}\right\}$$



**Fig 1 Diffusivity data for some nonmetallic systems**

3. (a) Refer to Fig 1 above.
- At a given temperature, why would you expect the diffusivity of oxygen in MgO to be less than that of Mg in MgO? Explain.
  - Similarly, at a given temperature, why does the diffusivity of Mg in MgO lie close to, but higher than that of Ni in MgO?
  - Show that the units of diffusivity are  $\text{m}^2/\text{s}$ .
- (b) Discuss some methods that are employed to improve the fracture toughness of ceramic materials.

4. (a) A common copolymer is produced by including both ethylene and propylene monomers in the same chain. Calculate the molecular weight of the polymer using 1 kg of ethylene ( $C_2H_4$ ) and 3 kg of propylene ( $C_3H_6$ ), giving a degree of polymerization of 4500.
- (b) A 60 cm long solid connecting rod of diameter 10 mm consists of borosilicate glass fibres oriented lengthwise in polystyrene. If the rod contains 75% glass and 25% plastic, determine the increase in length of the rod when an axial load of 500N is applied. State all assumptions made.

<u>Material</u>	<u>Density, g.cm<sup>-3</sup></u>	<u>Young's Modulus, GPa</u>
Glass	2.40	70
Polystyrene	1.05	2.8

5. (a) It is possible to purify a metal by using the knowledge that the composition of the first solid to form is not the same as the composition of the liquid from which it first forms. The method is known as "zone refining". Use a phase diagram to explain how this might work.
- (b) Show that the minimum cation to anion ratio for 6-fold coordination is 0.414.
6. (a) An insulating brick (true specific gravity = 2.71) weighs 1.69 kg dry, 2.27 kg when the open pores are saturated with kerosene, and 1.30 kg when suspended in kerosene (specific gravity = 0.82). Calculate the:
- (i) True volume, apparent pore volume, and bulk volume ( $cm^3$ ).
- (ii) Closed porosity (%).
- (b) A stress of 4000 psi is applied to a polymer serving as a fastener in a complex assembly. At a constant strain, the stress drops to 3500 psi after 100 hours. If the stress on the fastener must remain above 2500 psi in order for the part to function properly, determine the life of the assembly.
7. (a) Investigation of an automobile accident revealed that an axle for a rear wheel was broken. The axle could have failed by fatigue thus causing the accident, or have failed in impact as a consequence of the accident. What features of the axle and fracture surface would you look for in an attempt to establish the cause of failure?
- (b) What nondestructive testing method(s) might be helpful in detecting a crack that is parallel to the surface of a steel plate?
- (c) A welded austenitic stainless steel pipe corroded badly in the HAZ parallel to the weld. Explain why this corrosion occurred and what you could do to prevent this from happening again?