MAY 2017 **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	C	12.0	N	14.0	O	16.0	Mg	24.31	Al	27.0
Cl	35.5	Fe	55.85	Ni	58.7	Cu	63.54	Cs	132.9		

(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
Calorie	= 4.18 J
Kelvin, K	= °C + 273
Ton	= 2000 lb

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

Grain Size, $\mathcal{N} = 2^{n-1}$

Questions:

1. (a) Using a diagram show that the resolved shear stress in the slip plane (Schmid's law) is:

$$\tau = \sigma \cos \phi \cos \lambda$$

where, ϕ = angle between the applied force and the normal to the slip plane,
λ = angle between the applied force and the slip direction,
σ = applied tensile stress

What orientations would yield the maximum value for resolved shear stress? Express this maximum value as a function of the applied tensile stress.

(b) A force of 3 tons is applied to a ⅜ in diameter nickel wire having a yield strength of 49,000 psi and a tensile strength of 58,000 psi. Determine whether the wire will

(i) deform plastically
(ii) experience necking

2. (a) The radius of the cesium ion is 167 pm and the chlorine ion 181 pm, by calculation determine the coordination number and crystal structure (i.e. fcc, bcc, or sc) of cesium chloride. Use your results to calculate the lattice constant of cesium chloride. (Hint: cesium and chlorine are both monovalent).

(b) Use the results from part (a) to calculate the density of cesium chloride.

(c) Using sketches explain how you would, using an X-ray diffractometer, verify the results in part (a) of this question.

3. (a) Show that the units of the diffusion constant, D, are cm^2/s.

(b) A 300 micron layer of MgO is deposited between layers of nickel and tantalum to provide a diffusion barrier that prevents high temperature reactions between the two metals. At 1400°C, nickel ions are created and diffuse through the MgO ceramic to the tantalum. Determine the time it would take for one micron (1 μm) of nickel to be removed. At 1400°C , the diffusion constant of nickel in MgO is 9×10^{-12} cm^2/s, and lattice constant of nickel is 3.6×10^{-8}cm.

4. Analysis of a sample of polypropylene $(CH_2 \cdot CH \cdot CH_3)_n$ gives the following data for six chain length groups:

Number of chains	Mean molecular weight of chains ($g.mol^{-1}$)
5,000	3,000
20,000	6,000
18,000	9,000
15,000	12,000
8,000	15,000
3,000	18,000

Determine the weight average and number average molecular weights for this polymer. Based on the weight average molecular weight find the degree of polymerization.

5. (a) Determine the ASTM grain size of a metal if 42 grains are counted in an circle of diameter 1.5 inches at a magnification ×300. Determine also the average grain diameter in mm (1 inch = 25.4 mm).

(b) Explain why stretching a sheet of aluminum alloy increases its yield strength from 350 MPa to 600 MPa.

(c) The stretched alloy in part (c) is heated to 155°C for 2 hours and then cooled. What happens and why?

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) Describe the Jominey test. What useful information does it provide?

(c) Gas porosity in castings can cause service failures. What are some of the common causes of this porosity? How can the castings be checked for porosity?

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

(b) What are glass network modifiers? How do they affect the silica-glass network? Why are they added to silica glass?

(c) What factors must be considered when designing a fibre reinforced composite?