MAY 2013 **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	24.3	Al	27.0
Cl	35.5	Fe	55.9	Ni	58.7	Cu	63.54	Cs	132.9	Ta	181.0

(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
Faraday constant, F $= 96.5$ kC/mol

(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

Interplanar spacing $$d_{hkl} = \frac{a_o}{\sqrt{h^2 + k^2 + l^2}}$$

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

Questions:

1. (a) A 20ft long bridge suspension cable is to support a tensile load of 20,000 lb. The cable is manufactured by braiding a number of 3/16 in diameter wires made of 1080 steel. The stress in each wire must not exceed 70% of the yield strength of the steel. Additionally, the maximum allowable increase in length of the cable is ½ in. Assuming that the wires in the cable are equally loaded, calculate the number of wires needed.
($E_{steel} = 30 \times 10^6$ psi; $\sigma_y = 100{,}000$psi).

   (b) Explain how you would do an experimental measurement of the yield strength and Poisson's ratio for the steel used above.

2. (a) The radius of the cesium ion is 167 pm and the chlorine ion 181 pm, by calculation determine the 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 400 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. (a) A ½ in x 1/8 in nylon band is used to hold together stainless steel tubes. The minimum stress for holding the tubes tightly is 1200 psi. Relaxation test results showed that an initial stress of 1500 psi decreased to 1460 psi after 5 weeks. If the tubes will be stored for 1 year, what initial load must be applied to the band?

   (b) Glass fibres are used in nylon for reinforcement. If a glass/nylon composite contains 25% glass, what fraction of the load is carried by the glass fibres? State any assumptions that you have used in your calculations.
($E_{glass} = 10.5 \times 10^6$ psi; $E_{nylon} = 0.4 \times 10^6$ psi)

5. (a) An electrolyte is made by dissolving 40g of copper as Cu^{2+} in 2 litres of deionised water. Calculate the electrode potential of the copper half-cell in the electrolyte. (The standard electrode potential E^{o} for copper (Cu 6 $Cu^{2+} + 2e^{-}$) is +0.337 Volts).

(b) The electrolyte in part (a) is used to electroplate a 500 micron layer of copper on to a circular cathode of diameter 2.5 cm. At room temperature the recommended C.D. (current density) is 400 ASF (amp/ft^2). Calculate the current to be employed. How long will the process take?
(ρ_{Cu} = 8.96 g/cm^3)

6. 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.

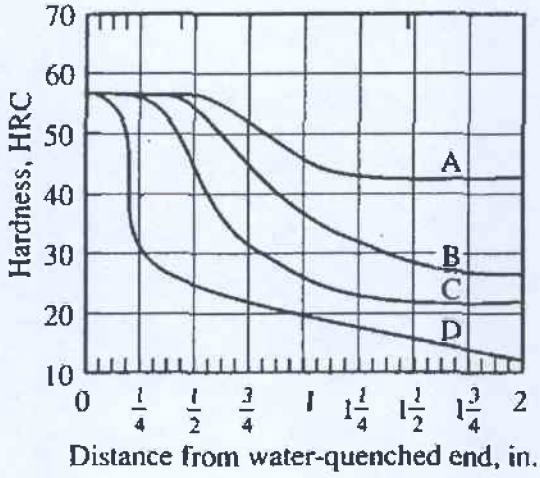
7. (a) Determine the ASTM grain size of a metal if 42 grains are counted in an circle of diameter 1.5 inches at a magnification ×300. Determine also the average grain diameter in mm (1 inch = 25.4 mm).

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

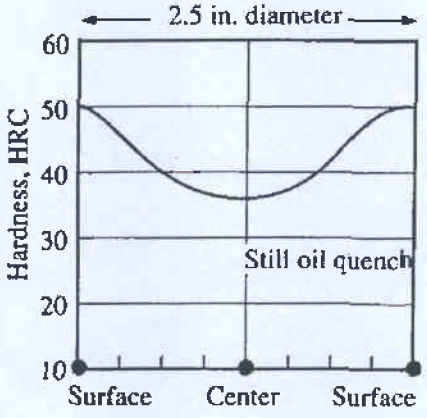
(c) The stretched alloy in part (c) is heated to 155°C for 2 hours and then cooled. What happens and why?

8. (a) What are the main constituents of concrete. Explain what happens when concrete cures. How does the water/cement ratio affect the properties of the concrete?

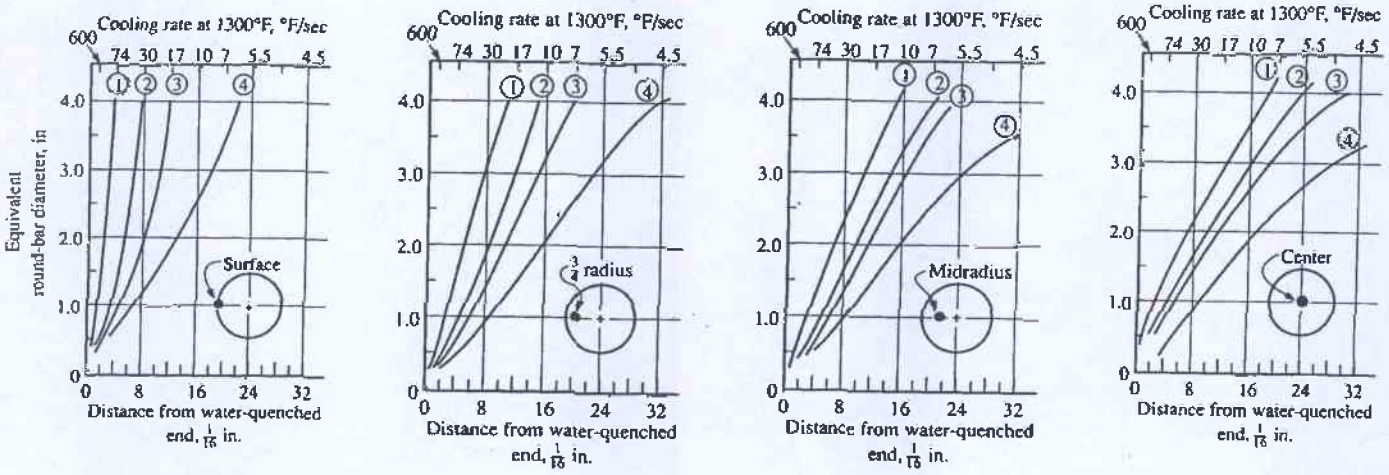
(b) An unidentified bar of steel of diameter 2½ in. is known to be made from one of four lots. The hardenability curves are given below for the four lots as well as the hardness traverse for the unknown bar. Which of the four steels is the unknown bar? (Explain your reasoning). Draw the hardness traverse for the unknown bar using surface, ¾ -radius, mid-radius, and centre positions shown on the figures below, if it were reheated and quenched in still water.



Hardenability Curves for the Four Steel Lots



Hardness Traverse for the Unknown Bar



Relationships between cooling rates in round bars and in Jominy locations. (1 = still water; 2 = mildly agitated oil; 3 = still oil; 4 = mildly agitated molten salt).