DEC 2016

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	1.01	Be	9.01	N	14.01	O	16.00
Si	28.1	Cr	52.0	Fe	55.85	Cu	63.54

(2) Constants and Conversions

Avogadro's number, N_A	$= 0.602 \times 10^{24}$ mol^{-1}
Boltzmann's constant, k	$= 13.8 \times 10^{-24}$ $J. mol^{-1} .K^{-1}$
Universal gas constant, R	$= 8.314$ $J. mol^{-1} .K^{-1}$
Faraday's constant	$= 96.5$ $kC. mol^{-1}$

(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 formulae

Interplanar spacing, $d_{(hkl)} = \dfrac{a_o}{\sqrt{h^2 + k^2 + l^2}}$ Nernst, $E = E_o + \dfrac{0.0592}{n} \log(C_{ion})$

Faraday, $w = \dfrac{ItM}{nF}$ Stress relaxation, $\sigma = \sigma_o e^{-t/\lambda}$ and $\lambda = \lambda_o e^{-Q_n/RT}$

Questions:

1. Chromium has a body centered cubic structure and atomic radius 0.1249 nm. Calculate the density (g.cm^{-3}) of chromium. Sketch the unit cell. On your sketch show the (112) plane and [011] direction. What is the spacing (nm) between the (102) planes?

2. (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 minimum 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.

3. Beryllium melts at 1252 °C and silicon melts at 1414 °C. They are completely soluble as liquids, but completely insoluble as solids. They form a eutectic at 1090 °C containing 39% beryllium. Draw the thermal equilibrium diagram and label all fields. Explain, with the aid of sketches, what happens when liquid alloys containing (a) 90% beryllium, (b) 30% beryllium solidify completely during a slow cooling process. In each case determine the amount (%) of eutectic in the cooled solid.

4. (a) A ½ in x ⅛ 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.

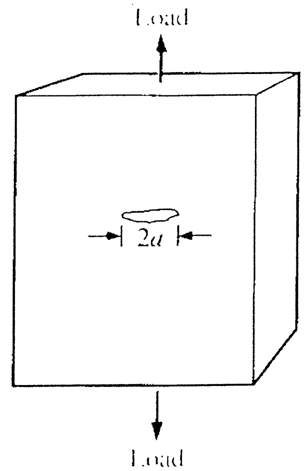
   ($E_{glass} = 10.5 \times 10^6$ psi; $E_{nylon} = 0.4 \times 10^6$ psi)

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 ($Cu \rightarrow Cu^{2+} + 2e^-$) 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?

   (Density of copper = 8.96 g/cm^3)

6. A large panel has a central crack through the thickness of $2a = 0.2$ in. as shown at the right. The panel is 20 in wide and 0.5 in thick and is made of a material of fracture toughness, $K_{Ic} = 24{,}000\,\text{psi}\sqrt{\text{in}}$. The panel is cyclically loaded between zero stress and 13,000 psi. Calculate the:



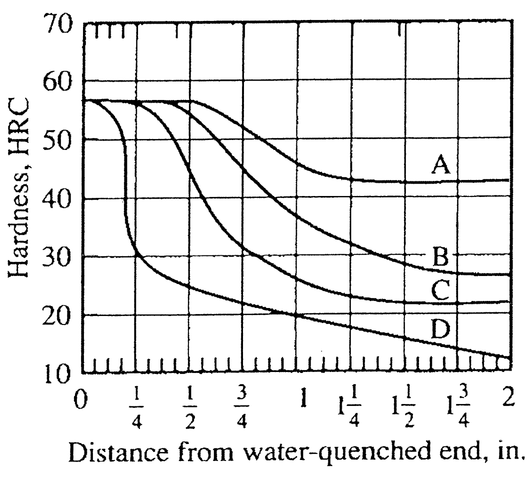
(i) length of crack at which failure occurs

(ii) number of fatigue cycles it takes to cause failure of the panel.

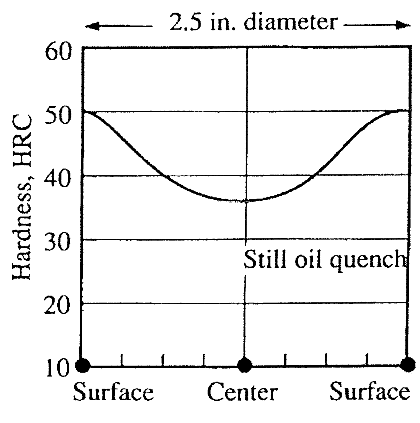
Hint: For a centre cracked panel, $K_{Ic} = \sigma\sqrt{\pi a}\,Y(a/w)$ and you may assume $Y(a/w) = 1$ as $a \ll w$. The growth of fatigue follows the law $\frac{da}{dN} = C(\Delta K)^m$ where $C = 1.8\times10^{-18}$ in/(cycle.psi $\sqrt{\text{in}}$), $\Delta K = K_{max} - K_{min}$, and $m = 3.0$.

7. (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?

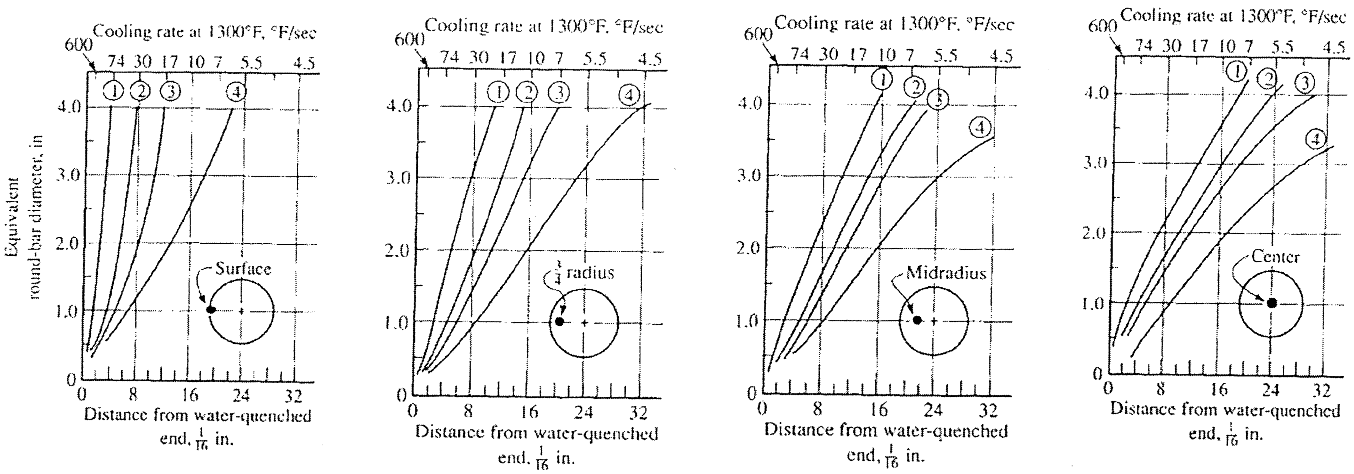
(b) An unidentified bar of steel of diameter 2½ in. is known to be made from one of four lots. The hardenability curves are given below for the four lots as well as the hardness traverse for the unknown bar for a heat and still oil quench. Which of the four steels is the unknown bar? (Explain your reasoning).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



Hardenability Curves for the Four Steel Lots



Hardness Traverse for the Unknown Bar



<u>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).</u>