

May 2009

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	B	10.81	C	12.01
O	16.00	F	19.0	Si	28.1	Cu	63.54

(2) Density of copper = 8.93 g.cm⁻³

(3) Constants and Conversions

Avagadro's number, N _A	= 0.602 x 10 ²⁴ mol ⁻¹
Boltzmann's constant, k	= 13.8 x 10 ⁻²⁴ J. mol ⁻¹ .K ⁻¹
Universal gas constant, R	= 8.314 J. mol ⁻¹ .K ⁻¹
Faraday's constant, F	= 96.5 kC. mol ⁻¹

(4) 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

Questions:

1. (a) Sketch the face centered cubic (FCC) unit cell. Using your sketch show that $a = 2R\sqrt{2}$, and hence, or otherwise, determine the packing factor for copper that has this structure.
- (b) Determine the atomic radius (nm) of copper.
- (c) Calculate the planar density (atom/mm²) for the (100) and (110) planes of copper.

2. (a) Determine the ASTM grain size of a metal if 24 grains are counted in a circle of diameter 2 inches at a magnification $\times 400$. Determine also the average grain diameter in mm (1 inch = 25.4 mm).
- (b) Show that the minimum ionic radii ratio for three fold coordination is 0.155. Explain why this is a minimum and not a maximum value.
- (c) After being stretched in a forming process, the yield strength of a sheet of aluminum alloy increases from 350 MPa to 600 MPa. Account for the increase.

3. (a) Using a diagram show that for a single crystal the resolved shear stress τ in the slip plane (Schmid's law) is:

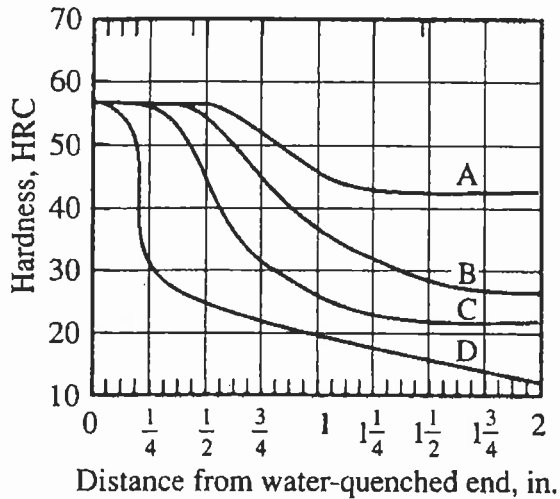
$$\tau = \sigma \cos \phi \cos \lambda$$

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

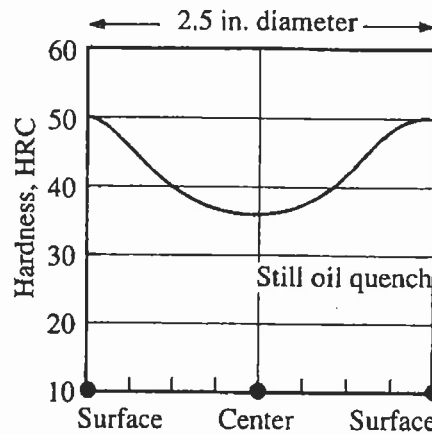
- (b) A force of 875 lb is applied to a 0.15 in diameter nickel wire having a yield strength of 45,000 psi and a tensile strength of 55,000 psi. Determine whether the wire will
 - (i) deform plastically
 - (ii) experience necking

4. 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.
5. (a) The melt index is the rate at which a polymer is extruded under prescribed conditions through a die of specified length and diameter (ASTM-D-1238). The units are grams of polymer extruded in 10 minutes.
- (i) How does the melt index vary with molecular weight of the polymer?
 - (ii) Explain why the weight average molecular weight would be more important as a measure of the melt index than would the number average molecular weight.
- (b) The degree of polymerization of polytetrafluoroethylene (PTFE or Teflon) is 8000. If all the polymer chains are of the same length, calculate:
- (i) The molecular weight of the chains
 - (ii) The total number of chains in 1200 g of the polymer.
- (c) Polytetrafluoroethylene can be used on components exposed to high temperatures. Explain why, as a thermoplastic, PTFE does not flow readily in high temperature service. Why does PTFE not burn readily? What is the structure of the mer? Suggest how it is attached to frying pans.
6. 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.
7. A 2 inch inside diameter, 12 ft long copper distribution pipe in a plumbing system is accidentally connected to the power system of a manufacturing plant, causing a current of 65 mA to flow through the pipe. The wall thickness of the pipe is 0.125 inch. Estimate the time required before the pipe begins to leak, assuming a uniform rate of corrosion.

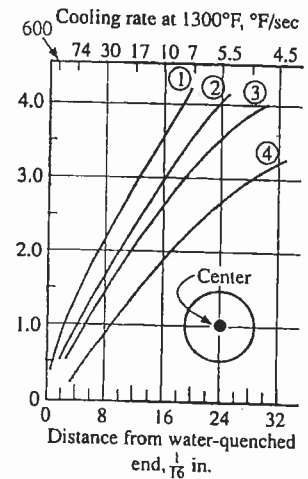
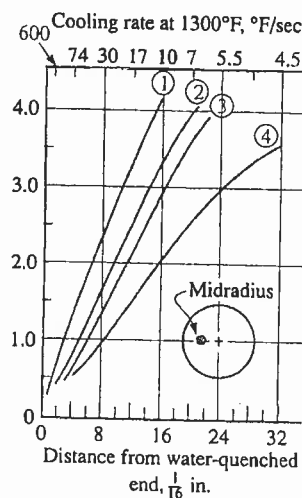
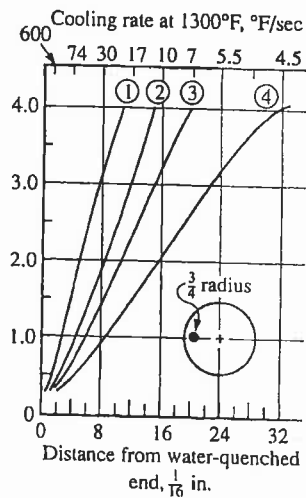
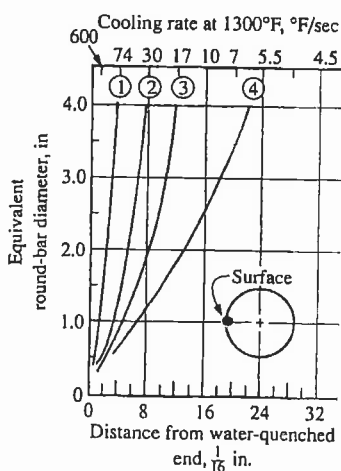
8. An unidentified bar of steel of diameter 2½ in. is known to be made from one of four lots. The hardenability curves are given below for the four lots as well as the hardness traverse for the unknown bar. Which of the four steels is the unknown bar? (Explain your reasoning). Draw the hardness traverse 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).