DEC 2010

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 <u>or</u> 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)   <u>Atomic Masses (g.mol^{-1})</u>

H	1.01	C	12.01	N	14.01	O	16.00
Al	26.98	Ti	47.90	Pb	207.19		

(2)   <u>Constants and Conversions</u>

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

(3)   <u>Prefixes</u>

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) Above 882°C, titanium has a BCC structure with a = 0.332 nm. Below this temperature, the metal has a HCP structure with a = 0.2978 nm and c = 0.4735 nm. Determine the percent change in volume when titanium cools through 882°C (i.e. transforms from BCC to HCP).

   (b) Describe the Charpy impact test. What relation, if any, is there between the measured impact energy and the stress-strain diagram obtained from tensile tests? What advantages, if any, would the impact test results have in comparison with the tensile test results?

2. (a) What is a substitutional solid solution? What factors favour this type of solid solution in metals?

   (b) 38 grains are observed in an area 2in x 1in at a linear magnification of X300. Calculate the ASTM grain size number.

   (c) Describe how you would recognise a fatigue failure.

3. Analysis of a sample of polyacrylonitrile $(CH_2 \cdot CH \cdot CN)_n$ gives the following data for six chain length groups:

| Number of chains	Mean molecular weight of chains $(g.mol^{-1})$
10,000	3,000
18,000	6,000
17,000	9,000
15,000	12,000
9,000	15,000
4,000	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.

4. (a) Show that the minimum cation-anion radius ratio for four-fold coordination is 0.225.

   (b) Calculate the lattice constant a_o (nm) for lead (which has an FCC structure). Use your value to find the planar density of atoms (atom.mm^{-2}) on the (110) planes, and the linear density of atoms (atoms.mm^{-1}) in the [111] direction.

5. A 15 mm diameter tensile bar of an aluminum alloy is pulled in a tensile test with the following results:

Load (kN)	Gauge Length (mm)
0.0	60.0000
10.0	60.0469
20.0	60.0938
30.0	60.1407
35.0	60.2100
37.5	60.3000
40.0	60.6000
42.5	61.2000
45.0 (maximum)	63.0000
44.2 (fracture)	63.9000

After fracture, the gauge length is 63.66 mm and the diameter is 14.5 mm. Plot the data and calculate the:

   (i) 0.2% offset yield strength
   (ii) tensile strength
   (iii) Young's modulus of elasticity
   (iv) % elongation
   (v) % reduction in area
   (vi) engineering fracture stress
   (vii) true fracture stress
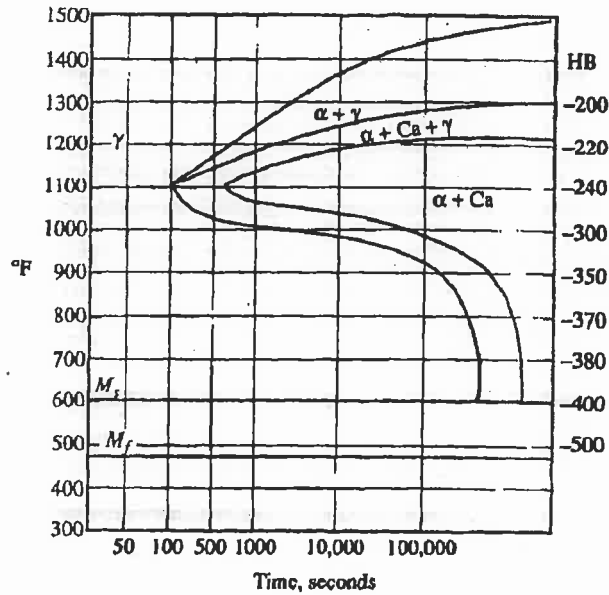
Temperature Time Transition diagram for 1035 carbon steel

6. (a)   Fig 2 shows the TTT diagram for a 0.35% carbon steel. The hardness data are for fully transformed structures. The symbol Ca is for carbide.

     (i)   A foundry finds that castings made of this steel are hard and unmachinable (400 HB) in the as-cast condition. Name two possible microstructures that could be responsible.

     (ii)   The same foundry hears that a competitor is annealing its castings with a cycle called an *isothermal anneal*. This involves heating of the castings, followed by isothermal transformation to a structure of 250 HB max. Draw a time-temperature chart giving this result, labelling *temperatures* and isothermal transformation *time* accurately.

  (b)   A tank is made of low alloy steel with a yield strength 600 MPa and plane strain fracture toughness 120 MPa.m$^{1/2}$. The steel is exposed to a stress not exceeding 70% of the yield strength. Calculate the minimum size of crack to cause failure. What methods are available to detect cracks of this size?

7. (a) Indicate whether the following statements are correct or incorrect and justify each answer.

   (i)   A high concentration of oxidising acid may render a metal more corrosion resistant.

   (ii) When an etched microstructure is observed under the microscope, the grain boundaries were anodic during the etching process.

   (iii) Oxygen dissolved in water has no effect on the corrosion rate of iron that is exposed to water.

   (iv) Aluminum rivets in a steel structure should have longer life against corrosion than steel rivets in an aluminum structure.

   (b) In recent years automobile manufacturers have used galvanised steel sheet in body parts to combat corrosion. Considering the principal corrosive to be a dilute NaCl solution, write the ion-electron equations for the corrosion taking place before this changeover (in ordinary steel) and after (in galvanised steel).

   (c) A sign manufacturer makes small signs of 18% Cr, 8% Ni, 0.08% C stainless steel by welding letters to a plate of the same material, using a weld rod of the same material. Corrosion occurs ¼ in from the weld.

   (i)   Write the ion-electron equations.

   (ii) Why is the stainless steel not "stainless"?

   (iii) What could be done to prevent the corrosion <u>without</u> changing the composition of the parts and without painting?