December 2019

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) Candidates are to attempt five, and only five, questions for a full 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	C	12.01	N	14.01	O	16.00	Na	22.99
Al	26.98	Si	28.1	Cr	52.00	Ni	58.71	Rh	102.90

(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 $= 8.314\ J.\ mol^{-1}.K^{-1}$
Angstrom, Å $= 1 \times 10^{-10}\ m$

(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}

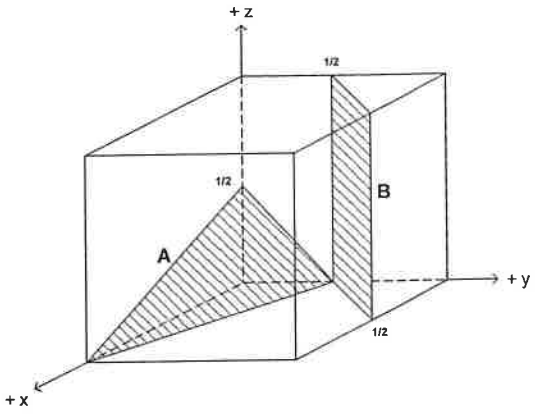
(4) Useful formulae

Crack Growth, $\frac{da}{dN} = C\,(\Delta K)^n$ Fracture Toughness, $K_{I_c} = f\sigma\sqrt{\pi a_c}$

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

Questions:

1. (a) Determine the Miller indices for the planes A and B shown at the right. Starting from the intersection point of the two planes, construct a [012] line.



(b) X-ray studies show the lattice constant of rhodium to be FCC with a lattice constant 3.796 Å. Calculate the density ($g.cm^{-3}$)

2. A complete stress-strain curve is often not determined in the daily gathering of data. From the information in the table below, determine the yield strength, tensile strength, modulus of elasticity, percent reduction of area, and percent elongation. The initial gauge length is 2.00 in, initial diameter 0.505 in, and diameter after failure 0.423 in.

Load (lb)	Gauge Length (in)
2000	2.001 (all elastic deformation)
6000	2.004 (all plastic deformation)
8500 (maximum)	2.300 (all plastic deformation)
7800 (failed)	2.450 (after failure)

3. (a) A 1.35 kg brick consists of 85% sand (SiO_2) and 15% sodium metasilicate ($Na_2SiO_3.9H_2O$). Sodium metasilicate is known to lose $6H_2O$ at 100°C. What will be the mass of the brick after heating at a temperature slightly above 100°C?

(b) Describe how bricks are made. What factors affect the final mechanical properties of the finished brick?

4. (a) Name and discuss the four primary bond types in solids. What role do they play in material properties?

(b) Describe some of the key physical and mechanical properties that must be considered in the design of an aircraft wing.

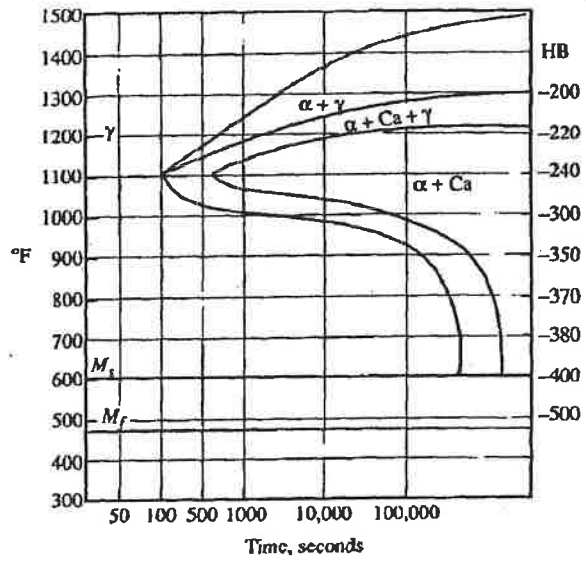


Fig 1. Temperature Time Transition Diagram for 1035 carbon steel

5. (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?

6. (a) 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.

(b) A stress of 4000 psi is applied to a fastener made of this copolymer. At a constant strain, the stress drops to 3500 psi after 100 hours. If the stress on the fastener must remain above 2500 psi in order for the part to function properly, determine the life of the fastener.

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 without changing the composition of the parts and without painting?