MAY 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	C	12.01	N	14.01	O	16.00	Na	23.0
Cl	35.5	Al	27.0	Fe	55.9	Sn	118.7	Pb	207.2

(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

Diffusion, $J = -D\frac{\Delta c}{\Delta x}$ $D = D_0 \exp\left(\frac{-Q}{RT}\right)$ $\frac{dc}{dt} = D\frac{d^2c}{dx^2}$

Boltzmann, $\frac{n}{N} = Me^{-E/kT}$ Nernst, $E = E_o + \frac{0.0592}{n}\log(C_{ion})$

Questions:

1. 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

2. (a) Using a sketch show how the modulus varies with temperature for a partially crystalline nylon. How would the curve change if the degree of crystallinity increases? Decreases?

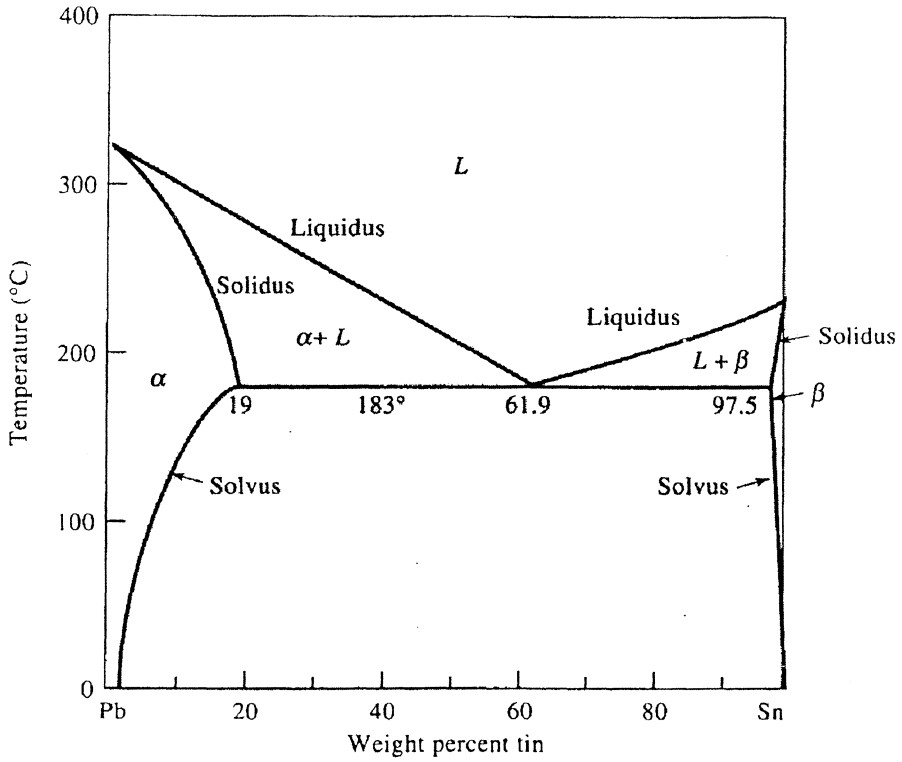
(b) A self lubricating bearing is made by sintering a cylinder of brass powder followed by impregnation with a mineral oil. Determine the percentage open and closed porosity (open-pore volume and closed-pore volume, respectively, divided by the bulk volume) in the bearing from the following data.

Dimensions:	2.00 cm diameter x 6.00 cm length
Mass, after sintering:	123.85 g
Mass, after oil impregnation:	126.80 g
Specific gravity of oil:	0.90
True density of brass:	8.47 g/cm^3

3. (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.
(The density of lead is 11.36g.cm^{-3}).

4.



Lead - Tin Phase Diagram

(a) A 30% Sn alloy of lead-tin is slowly cooled from a temperature of 350°C. Determine the:

(i) Composition of the first solid to form.
(ii) The freezing range of the alloy.
(iii) Amounts and compositions of each phase at 184°C.
(iv) Amounts and compositions of each phase at 182°C.
(v) Amounts and compositions of each phase at 25°C.

(b) Repeat part (a) but for an 80% Sn alloy.

5. (a) At the surface of a steel bar there is one carbon atom per 20 unit cells of iron. At 1 mm below the surface, there is one carbon atom per 30 unit cells. The diffusivity at 1000° C is 3 x 10^{11} m^2/s. The structure at 1000° C is FCC (a_o = 0.365 nm). How many carbon atoms diffuse through each unit cell per minute?

(b) Explain why the phenomenon for creep is so closely related to diffusion.

(c) Describe some general characteristics of creep resistant materials.

6. (a) Indicate, with reasons, whether the corrosion rate of a piece of iron placed in tap water is increased or decreased by doing the following:

(i) Adding NaCl to the water
(ii) Using a dry cell battery to impose electron flow *into* the iron
(iii) Placing nickel in contact with the iron
(iv) Adding chromate ion to the water
(v) Freezing the water

(b) Why are some stainless steels prone to corrosion after welding?

(c) In concentration cells corrosion occurs at the region having the lower concentration. Explain.

7. (a) Indicate whether the following statements about a 1080 steel are correct or incorrect. Justify your answer.

(i) The hardness of pearlite is a fixed value.
(ii) Martensite is obtained by the isothermal transformation of austenite.
(iii) The isothermal transformation curve is an equilibrium diagram.
(iv) The hardness of martensite will be the same as from a 1040 steel.

(b) Some components are sold as being of "x-ray quality". That is, radiographs are used to determine the existence of flaws. Does this necessarily mean that we need not worry about brittle fracture in high-strength materials that have passed an x-ray examination? Explain.

(c) How would you distinguish between a brittle fracture and a fatigue failure?

(d) You wish to attach aluminum sheet to the frame on the 20^{th} floor of a high rise building. You select rivets made of an age-hardenable aluminum alloy. The rivets must be soft and ductile in order to close without cracking. After the rivets are attached, they must be very strong. Design a method for producing, using, and strengthening the rivets.