UNIVERSITY OF SASKATCHEWAN
COLLEGE OF ENGINEERING

ME 214.3 INTRODUCTION TO MATERIALS & MANUFACTURING

ALL SECTIONS
FINAL EXAM

OPEN BOOK **CALCULATORS ARE ALLOWED**

INSTRUVTOR: Prof. Q. Yang

LOCATION: STM 140

TIME: 9:00 am to 12:00 am, December 12, 2007

Candidates are to answer all questions.
You are to show your solution in the Examination Booklet.
State all necessary assumptions and give all the details.

NEATNESS and CLARITY will be considered in the marking of this examination

Note: - Make sure you have 5 problems in the exam

Question 1 (15 Marks)

(i) Distinguish between glass transition temperature and melting temperature. (2 Marks)
(ii) Give FOUR major industrial applications of engineering ceramics. (2 Marks)
(iii) Name the TWO main polymerization mechanisms used in the formation of synthetic polymers. (2 Marks)
(iv) Rank the strength and fracture toughness (room temperature) of a magnesium alloy, alumina, and a polycarbonate. (2 Marks)
(v) Compare the corrosion resistance, density, hardness, strength and electrical conductivity of steel and glass. (2 Marks)
(vi) Compare the corrosion resistance, density, hardness, strength, creep resistance and electrical conductivity of pure iron and polyethylene. (2 Marks)
(vii) Rank the following materials in a descending order of their thermal shock resistance. Give reason(s) for your answer (3 Marks).

Ceramic	σ_f (MPa) Fracture strength	E GPa Young's Modulus	ν Poission's ratio	α (μK^{-1}) Coefficient of thermal expansion	k ($Wm^{-1}K^{-1}$) thermalconductivity
A	850	310	0.27	3.2	17
B	240	220	0.27	3.2	15
C	500	410	0.24	4.3	84

Question 2 (16 Marks)

(a) Use a well-labeled sketch to distinguish between the fatigue behaviour of steel and that of aluminum. (2 Marks)
(b) Use labeled sketches only to show the variation of fracture toughness of metals with temperature T, grain size D, and yield strength σ_y. (3 Marks)
(c) Use labeled sketches only to describe the effect of the following factors on the fatigue life of an engineering component: (i) Surface defects, (ii) Shot peening, (iii) Carburizing. (3 Marks)
(d) Use sketch(s) ONLY to distinguish between *ductile* and *brittle* fracture. (2 Marks)
(e) Use line diagrams only to distinguish between the following types of polymers: (i) Linear homopolymer, (ii) Linear copolymer, (iii) Branched polymer, and (iv) Cross-linked polymer. (4 Marks)
(f) Use a labelled diagram to show the variation of *glass transition temperature* (T_g) versus *degree of polymerization* (*DP*) for polyethylene. (2 Marks)

Question 3 (25 marks)

(a) On unit cells (one for each) of a cubic crystal sketch (312), [121], (132), [312]. (2 marks for planes, 1 for directions) (6 Marks)
(b) An alloy contains 90 wt% Cu and 10% wt% Ag.
    (1) Please give the structure, composition and weight fraction of the phases presented at 700 ^oC. (7 Marks)

(2) On average how many of the nearest neighbour atoms of a Cu atom are Ag atoms for the phase rich in copper? (6 Marks)

(c) If a thick layer of Zn is plated onto Cu, the concentration profile of Zn (in at%) after holding for time t is given by

$$c_x = 50\left[1 - \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)\right]$$

where x is measured from the original interface and D is the diffusion coefficient. If it takes twelve hours at 800 ^oC for the concentration of Zn to reach 15 at % at a given distance from the original interface, how long would it take at 600 ^oC (4 Marks)?

(c) Would you expect the distance that Cu diffuses into Ni under the same conditions to be less than, about equal to or greater than the distance Ni diffuses into Cu? Give reasons. (2 Marks)

Question 4 (20 Marks)

(a) A cylindrical rod 30 mm. long and 10 mm. in diameter is made from steel whose tensile engineering stress-engineering strain curve can be represented by: (8 marks)

$\sigma = E\ \varepsilon$ for $\varepsilon < 0.001$

$\sigma = 200$ MPa for $0.001 < \varepsilon < 0.004$

$\sigma = 187 + 3230\ \varepsilon\ (1-\varepsilon)$ MPa for $0.004 < \varepsilon < 0.6$

fracture for $\varepsilon = 0.6$

where E is Young's modulus.

(i) If a 12 kN tensile load is slowly applied to the rod what would be the diameter (1 Mark)?
(ii) If the 12 kN load is then removed what would be the diameter (1 Mark)?
(iii) If a 24 kN tensile load is slowly applied to the rod what would be the diameter (1 Mark)?
(iv) If the 24 kN load is then removed what would be the diameter (1 Mark)?
(v) After fracture what would be the diameter of the uniform (un-necked) portion (1 Mark)?
(vi) If a 24 kN compressive load is slowly applied to the rod and then removed what would be the diameter (1 Mark)?
(vii) What are the yield strength and tensile strength of the steel (2 Mark)?

(b) There are a steel alloy 1040 and a glass (soda-lime): (6 Marks)

(i) Calculate the fracture strength of the glass materials due to the presence of a central crack of 0.2 mm long. Assume a geometric factor of 1.2. (2 Marks)
(ii) If a tensile stress of 200 MPa is applied to the materials, what is the maximum allowable length of cracks for the two materials without brittle fracture? (2 Marks)
(iii) Calculate the minimum flaw size required for the steel to yield rather than brittle fracture. (2 Marks)

(c) The blades of a jet turbine are to be manufactured using a special steel alloy. Since this is a new alloy, a laboratory creep test was conducted at 1000 °C on the blade alloy under constant stress conditions. A steady-state creep rate of 5×10^{-3} %/h was produced. The creep mechanism for this alloy is known to be dislocation climb with an activation energy of 200 kJ/mole. Each blade is 200 mm in length, has a uniform cross-section, and is to be operated at a temperature of 800 °C. There is an initial clearance of 2 mm between the outer tip of each blade and the turbine casing. Assuming the turbine is to operate under the same constant stress condition as in the laboratory steady state creep test, calculate how many hours the turbine can be operated for before the blades will need to be replaced. (6 Marks)

Question 5 (24 Marks)

(a) 100 kg of a copper-silver alloy are melted and then slowly cooled to just below the eutectic temperature, when the alloy consists of equal amounts of proeutectic α and eutectic mixture. The alloy is then remelted and silver is added. On slowly cooling to just below the eutectic temperature the alloy contains equal amounts of proeutectic β and eutectic mixture.
How much silver was added to the original 100 kg? (8 Marks)

(b) A micrograph of a slowly cooled plain carbon steel has 25% of the area proeutectoid phase, the remainder being pearlite. (8 Marks)
(i) What is the carbon content (3 Marks)?
(ii) In 100 kg of the steel how much ferrite and how much cementite are in the pearlite (3 Marks)?
(iii) Sketch the microstructure (2 Marks).

(c) A composite consists of 80 wt. % of aligned continuous fibres of tungsten in a copper matrix. What is the specific stiffness (Young's modulus/density) parallel and vertical to the fibre direction, respectively? (8 Marks)