UNIVERSITY OF SASKATCHEWAN
COLLEGE OF ENGINEERING

MECHANICAL ENGINEERING (M.E.) 214

ALL SECTIONS
FINAL EXAM
OPEN BOOK **CALCULATORS ARE ALLOWED**

TIME: 3 HOURS **DECEMBER 2004**

Candidates are to answer all questions.
You are to show your solution in the space below the question.
The reverse side of the page may be used if required.
State and justify all necessary assumptions.

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

NAME: _____
(First Name) (Last Name)

Name of Lecturing Professor: _____

Student Number: _____

Examination Room: _____

Marks

1._____
2._____
3._____
4._____
5._____
6._____

TOTAL._____

There are 10 marks for each question.

Note:
- make sure you have 6 problems in the exam
- the questions are of equal value

Question 1

(a) On unit cells (one for each) of a cubic crystal sketch
(112), [210], (120), [121].

(b) Calculate the distance between atom centers at room temperature for (i) chromium and (ii) nickel along [011].

Question 2 (a) The tensile engineering stress-engineering strain curve for an alloy whose Young's modulus, E, is 200 GPa can be represented by:

$\sigma = E\ \varepsilon$	for $\varepsilon < 0.001$
$\sigma = 180$ MPa	for $0.001 < \varepsilon < 0.004$
$\sigma = 167 + 3230\ \varepsilon\ (1 - \varepsilon)$ MPa	for $0.004 < \varepsilon < 0.6$
fracture	for $\varepsilon = 0.6$

A cylindrical rod of this material 100 mm. long and 5 mm. in diam is loaded in tension to 250 MPa

(i) What is the elastic strain?

(ii) What is the plastic strain?

(iii) Assuming that plastic deformation is a constant volume process, what is the diameter of the bar after the 250MPa stress has been removed?

(iv) Sketch the broken rod and determine the diameter of the uniform section

Question 3

A one metre long tensile member is required to carry a static load of 320 kN and is to be cut from stock of 10 mm thickness. Two steels of this thickness are in available: a mild steel with a yield strength of 450 MPa and a K_{IC} of 90 MPa $m^{1/2}$ and a 1040 steel which has been heat-treated to give a yield strength of 950 MPa and a K_{IC} of 45 MPa $m^{1/2}$. A non-destructive testing program can ensure that no flaw (edge crack) greater than 5 mm will be present. The weight of the member should be a minimum possible.

Select a steel and the width of the member to ensure that the resulting stress is no greater than one-half of the yield strength and that fast fracture will not occur.

(Assume Y = 1.12)

Question 4

(a) A metallurgical process in a steel containing Ni takes 17 minutes to complete at 950^{o}C but only 9.6 minutes at 1000^{o}C. Professor S argues that the rate of the process (which is diffusion controlled) is determined by the diffusion of Ni in Fe, whereas Professor Y says that it is the diffusion of C in Fe which is important. Determine which, if any, is correct.

(b) If a thick layer of metal A is plated onto metal B, the concentration profile of A (in at%) after interdiffusion 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. If the diffusivity for A in B is the same as that for B in A and is equal to 1.2×10^{-14} m^2/s at 500 ^{o}C determine the concentration of A at 5 μm from the interface after holding for 5 hour at 500 ^{o}C.

[Note that erf(-z) = - erf(z)]

Question 5

(a) At 500 ^{o}C an alloy of A and B with 40 wt% B has a mass fraction of α phase of 0.57 the remainder being β phase. At the same temperature an alloy containing 70 wt% B has a mass fraction of α phase of 0.14 the remainder being β phase.
What are the compositions of the α and β phases at this temperature?

(b) For a plain carbon steel containing 0.4 % carbon slowly cooled from austenite, what fraction of the total ferrite is in the pearlite?

Question 6

(a) What is the average molecular weight of a polytetrafluoroethylene polymer with a degree of polymerization of 500? What would be the ratio of the coiled length to the extended length of an average molecule?

(b) What is the minimum relaxation time for polymer strapping if no more than 2% stress relaxation in 4 hours can be tolerated before re-tightening becomes necessary? Would you expect the relaxation time to be longer or shorter at a lower temperature?

(c) A composite with a copper matrix reinforced with continuous aligned tungsten wires has an isostrain (longitudinal) modulus of 300 GPa. What would be the isostress (transverse) modulus?