National Exams May 2017

16-Mec-B8 Engineering Materials

3 Hours Duration

NOTES:

1. If doubts exist as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. Any non-communicating calculator is permitted. This is an open book exam.

3. Any FIVE (5) questions constitute a complete exam paper. If more than five questions are attempted, only the first five as they appear in the answer book will be marked.

4. All problems are of equal value.

1- A ductile metal wire of uniform cross-section is loaded in tension until it just begins to neck. The curve of true stress σ vs. true strain ε for this wire approximates to:

$$\sigma = 303\ \varepsilon^{0.33}\ \text{MPa}$$

a- Assuming that the volume is conserved, derive a differential equation relating the true stress to the true strain at the point of necking.
b- Estimate the ultimate tensile strength of the metal and the work required to take 0.08 m^3 of the wire to necking.

2- Describe the heat treatment scheme that would provide the following property changes to 1080 steel: (refer your treatments to the appropriate time-temperature-transformation curve)

a- Pearlite to martensite
b- Pearlite to bainite
c- Mixture of 65% pearlite and 35% martensite to 100% tempered martensite
d- Martensite to fine pearlite
e- 100% pearlite to a mixture of 55% pearlite and 45% martensite

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3- A barium-borate glass system ($BaO.4B_2O_3$) is converted into a glass-ceramic by re-melting the glass and the addition of TiO_2 as a nucleating agent to the re-melted batch. Referring to the periodic table of elements to obtain the molecular weights of each component element, calculate the composition of the new glass-ceramic in weight percent, if 7 mole% TiO2 is used for this conversion.

4- The presence of carbon, while producing the necessary hardening of conventional high tensile steels, causes brittleness and distortion, which makes machining difficult and cold forming impracticable. Welded fabrication is also impracticable or very expensive. To overcome some of these difficulties, types of steel known as *maraging* steels were developed from which carbon is either eliminated entirely or present only in very small amounts. The hardening of maraging steels is achieved by the addition of other elements such as nickel, cobalt and molybdenum. What in your opinion are the main reasons for carbon to cause brittleness and the associated machining and welding difficulties of conventional steels? Also explain how the replacement of carbon with nickel, cobalt and molybdenum help alleviate these difficulties.

5- A 0.4 kg magnesium sacrificial anode in a hot water heater is used up in 8 years.

a- What is the anode reaction?
b- What is the average corrosion current supplied by the anode?

Use an electromechanical valence of 2 and an atomic mass of 24.3 amu for Mg.

6- Advanced fiber-reinforced plastic (FRP) composites are now commonly used in aircraft manufacturing for both primary and secondary load bearing applications. Present four different processing methods that may be used to consolidate FRP laminated components for such applications and, discuss the main advantages and disadvantages of each method in relationship to such considerations as mechanical properties, geometrical aspects, processing speeds, cost, and size.

7- A composite made of hardened PVC plastic reinforced with E-glass fibers is being used as a structural material. Assume the modulus of elasticity of E-glass is 75 GPa and for PVC is 2.3 GPa. If the PVC constitutes 72% per volume of the composite, calculate:

a- the modulus of elasticity of the composite,
b- the percentage of stress carried by the glass fibers, and
c- the axial strain, assuming that the composite has a cross-sectional area of 600 mm^2 and is subjected to a longitudinal load of 73,000 N.

8- Floor beams of a transport airplane have been designed using an aluminum alloy (Alloy A) containing 5 wt% Cu and 2 wt% Mg (possessing a strength of 370 MPa) for a total weight of 70,000 N. A customer has ordered the airplane but requested that its total weight be reduced by 8,000 N for fuel saving purposes. As a structural design engineer you suggest that the weight saving objective can be accomplished by simply replacing the aluminum alloy of the floor beams with another possessing similar mechanical properties yet lighter in weight. Two candidate aluminum alloys are proposed: Alloy B containing 4 wt% Li and 1 wt % Cu possessing a strength of 368 MPa and Alloy C containing 3 wt% Li and 3 wt% Mg possessing a strength of 340 MPa.

a- Assuming the alloy density is a simple weighted average of its individual constituents, what is the density of each alloy?
b- What is the volume of the floor beams?
c- What are the weight savings obtained using Alloys B and C and which one would you select to meet the customer requirements?
d- Which of the three alloys A, B or C is the best based on a strength to density material selection criterion?

Use the following densities for the mentioned constituent materials:
Al = 2700 Kg/m^3 Cu = 8920 Kg/m^3 Mg = 1740 Kg/m^3 Li = 530 Kg/m^3
