National Exams December 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 0.35 kg magnesium sacrificial anode in a hot water heater is used up in 9 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.

2- 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.

3- Consider a homogeneous bar of length L and a rectangular cross section of width b and thickness t. When the bar is stretched by a small amount ΔL the cross sectional dimensions are reduced by the amounts Δb and Δt. If this corresponds to a case of perfect plasticity where the volume of the bar is the same before and after deformation, what is the Poisson's ratio for this material?

4- The lower skin panels of the wing of a 100 passenger commercial jet are made from aluminum 2024-T4. Those panels are subjected to fluctuating tensile loads while the airplane is in flight and fluctuating compressive loads when it is on the ground. An engineer recommended replacing this material with aluminum 7075-T6 on an extended version of that jet that weighs 30% more than the original design. Do you agree with this recommendation? Answer this question by comparing the main physical and mechanical properties of the two materials and the possible trade-offs resulting from the proposed replacement.

5- Advanced fiber-reinforced plastic (FRP) composites are now commonly used in aircraft manufacturing for both primary and secondary structural 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 mechanical properties, geometrical aspects, processing speeds, cost, and size.

6- 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 of each element, if 7.5 mole% TiO2 is used for this conversion.

7- 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:

$$\sigma = 338\ \varepsilon^{0.43}\ \text{MPa}$$

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 0.75 m^3 of the wire to necking.

8- The floor beams of a transport airplane weigh 70,000 N. They have been designed using an aluminum alloy (Alloy A) containing 5.5 wt% Cu and 1.5 wt% Mg and possessing a strength of 370 MPa. 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 fully 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