

National Exams December 2014

07-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** of the **eight** problems given constitute a complete paper.
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:

$$\sigma = 420 \epsilon^{0.33} \text{ MPa}$$

- 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 1 m^3 of the wire to necking.
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2- The lower skin panels of the wing of a 7-passenger business 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 25% more than the original design and will accommodate 12 passengers. Why in your opinion the engineer may have made 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.

3- A composite made of a plastic reinforced with continuous glass fibers is being used as a structural material. The modulus of elasticity of the glass fibers is 75 GPa and for the plastic material is 5 GPa. If the plastic constitutes 60% 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- assuming that the composite has a cross-sectional area of 500 mm^2 and is subjected to a longitudinal load of 75,900 N, calculate the corresponding strain.
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4- Discuss the following two applications where corrosion is an issue:

- a- Steel screws used as fasteners on aluminum siding experienced severe corrosion. Would you have expected this, why or why not? Explain why this might have occurred.
 - b- A brass faucet is connected to an iron pipe. Discuss this coupling from a corrosion viewpoint and explain which metal is likely to corrode and why?
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5- A barium-borate glass system ($\text{BaO} \cdot 4\text{B}_2\text{O}_3$) is converted into a glass-ceramic by remelting the glass and the addition of TiO_2 as a nucleating agent to the remelted 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 15 mole% TiO_2 is used for this conversion.

6- 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.

7- Floor beams of a transport airplane have been designed using an aluminum alloy containing 5 wt% Cu, 1.8 wt% Mg and 1 wt% Mn for a total weight of 10000 kg. A customer has ordered the airplane but requested that its total weight be reduced by 1500 kg for fuel saving purposes. Susan, a professional engineer in the design and analysis department suggested that it is possible to even exceed the 1500 kg weight reduction target by replacing the aluminum alloy of the floor beams with an aluminum-lithium alloy of comparable mechanical properties containing 6 wt% Li, 2 wt% Mg and 0.5 wt % Cu. Is she right? Answer the question by estimating the weight savings in kg (W_s) that will take place using the Al-Li alloy. Assume weighted averages of density and use the following densities for the mentioned materials:

$$\text{Al} = 2.70 \text{ g/cm}^3 \quad \text{Cu} = 8.92 \text{ g/cm}^3 \quad \text{Mg} = 1.74 \text{ g/cm}^3 \quad \text{Mn} = 7.47 \text{ g/cm}^3 \quad \text{Li} = 0.53 \text{ g/cm}^3$$

8- A box is to be placed on a bracket attached to the engine in an automobile. Two polymeric materials have been short-listed as primary candidates for this application, namely ABS and hardened PVC.

- a- Compare the two materials in terms of strength, impact resistance, manufacturing methods, chemical resistance, heat resistance and cost.
- b- What material would you select and why?