

National Exams December 2016

**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- The lower skin panels of the wing of a 12 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. 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.

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2- 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  $\text{TiO}_2$  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 8.5 mole%  $\text{TiO}_2$  is used for this conversion.

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3- A composite made of hardened PVC plastic reinforced with E-glass fibers is being used as a structural material. The modulus of elasticity of E-glass is 75 GPa and for PVC is 2.5 GPa. If the PVC constitutes 70% 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  $500 \text{ mm}^2$  and is subjected to a longitudinal load of 50,000 N, calculate the corresponding strain.
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4- A ductile metal wire of uniform cross-section is loaded in tension until it just begins to neck. The curve of true stress  $\sigma$  vs. true strain  $\epsilon$  for this wire approximates to:

$$\sigma = 235 \epsilon^{0.37} \text{ MPa}$$

- 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  $0.1 \text{ m}^3$  of the wire to necking.
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5- 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? 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?

6- Floor beams of a transport airplane have been designed using an aluminum alloy containing 4.5 wt% Cu and 1.5 wt% Mg for a total weight of 95000 N. A customer has ordered the airplane but requested that its total weight be reduced by 10 percent for fuel saving purposes. An engineer in the design and analysis department has suggested that the weight saving objective can be accomplished by replacing the current aluminum alloy of the floor beams with another one containing 3 wt% Li and 1 wt % Cu. Is this possible? Answer the question by first determining the weight saving that will take place using the Al-Li alloy. Assume weighted averages of density and use the following densities for the mentioned materials:

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

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7- 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  $\Delta L$  the cross sectional dimensions are reduced by the amounts  $\Delta b$  and  $\Delta t$ . 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?

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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 phenolic.

- 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?
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