National Exams May 2010

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 **six** 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:

$$\sigma = 345\ \varepsilon^{0.42}\ \text{MPa}$$

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.

---

2. A composite made of a hardened plastic reinforced with E-glass fibers is being used as a structural material. The modulus of elasticity of E-glass is 72.5 GPa and for PVC is 2.5 GPa. If the PVC constitutes 65% 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 300 mm^2 and is subjected to a longitudinal load of 45,000 N, calculate the corresponding strain.

---

3. 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- 100% pearlite to a mixture of 50% pearlite and 50% martensite
b- Pearlite to bainite
c- Mixture of 75% pearlite and 25% martensite to 100% tempered martensite
d- Martensite to fine pearlite
e- Pearlite to martensite

---

4. A new aircraft program has been launched by an aircraft manufacturer to build the next generation of regional jets aiming to substantially exceed the range of its closest competitor for the same cabin capacity while hoping to maintain a strong hold on the market in terms of environmental friendliness of the aircraft and innovative use of aircraft structural materials.

The structural design engineers of the above aircraft are now choosing the materials for its primary load carrying structures. Their choice is between an advanced carbon fiber-reinforced polymeric composite, a conventional aircraft grade aluminum alloy and a new generation of lightweight advanced metallic alloys recently introduced to the market. Select your own set of five different selection criteria that you think would be of most relevance to this particular application and evaluate each of the three families of materials in terms of those criteria. In the end, what choice of materials would you recommend and why?

---

5. 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 a thermoplastic Acrylonitrile Butadiene Styrene (ABS) and a thermosetting polyimide.

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?

---

6. A barium-borate glass system ($BaO.4B_2O_3$) 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 10 mole% TiO2 is used for this conversion.

---

7. 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?

---

8. Floor beams of a transport airplane have been designed using an aluminum alloy containing 5 wt% Cu and 1.5 wt% Mg for a total weight of 9800 kg. A customer has ordered the airplane but requested that its total weight be reduced by 1000 kg for fuel saving purposes. An engineer in the design and analysis department has suggested that about 70% of that weight saving objective can be accomplished by replacing the aluminum alloy of the floor beams with an aluminum-lithium one containing 3 wt% Li and 1 wt % Cu. Is this possible? Answer the question by estimating the weight savings that will take place using the Al-Li alloy. Assume weighted averages of density and use the following densities for the mentioned materials:

Al = 2.70 g/cm^3 Cu = 8.92 g/cm^3 Mg = 1.74 g/cm^3 Li = 0.53 g/cm^3
