National Exams May 2019

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 current density of 1.1 microamperes /cm^2 is measured to flow when iron corrodes in a dilute salt electrolyte.

a) How much iron thickness, in millimeters, will be lost in a year (mm/year)?
b) What would the current density in microamperes /cm^2 have to be if the thickness loss was 0.01 mm/year

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2- A piece of steel is being carburized at a temperature where the steel has a face-centered cubic crystal structure. The carbon concentration at the steel surface is 3.8 atomic percent. At 2.5 mm below the surface the carbon concentration is 1.0 atomic percent. Assume a constant carbon concentration gradient as the carbon diffuses interstitially inward from the surface. If the diffusivity of carbon in the steel at this carburizing temperature is 2.9×10^{-11} m^2/s, calculate the inward flux of carbon atoms into the steel using Flick's first law.

3- Consider a pure silicon wafer 150 mm in diameter and 0.5 mm thick.

a) How many atoms are there in the wafer?
b) If the wafer is alloyed with 10^{16} phosphorous atoms per cm^3 what is the atomic fraction of phosphorous in silicon?

4- 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.

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

6- 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?

7- 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 mass of 7,000 Kg. A customer has ordered the airplane but requested that its total mass be reduced by 800 Kg for fuel saving purposes. An engineer suggested that the mass saving objective can be accomplished by simply replacing the aluminum alloy of the floor beams with another possessing similar mechanical properties yet with lower density. 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 mass 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 its specific property in terms of strength to density ratio?

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

8- 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:

$$\sigma = 307\ \varepsilon^{0.37}\ MPa$$

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 0.07 m^3 of the wire to necking.
