Summer Examinations 2015

ENG100715N

Module Title: Materials Science
Level: Four
Time Allowed: Two hours

Instructions to students:

- Enter your student number **not** your name on all answer booklets.
- Answer **four** out of **five** questions.
- All questions carry equal marks. Where a question has more than one part the division of marks is stated.
- Begin each answer on a separate page; label each page clearly with the number of the question you are answering.
- The use of a non-programmable calculator is permitted.
- Neither books nor notes may be taken into the examination.
- Students are permitted to remove this examination paper at the end of the examination.

<table>
<thead>
<tr>
<th>No. of Pages</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Questions</td>
<td>5</td>
</tr>
</tbody>
</table>
Answer four out of five questions.

**Question 1**

a. Sketch the stress-strain curve for low carbon steel in the normalised condition and on another drawing using the same scale sketch the stress-strain curve of the same metal after cold working. Indicate on each sketch i) the yield point ii) the ultimate tensile strength. Also show, on one of the curves, how you would calculate the plastic ductility from the stress-strain curve.

(10 marks)

b. Describe (or show using sketches) how the grain structure of a metal arises as result of cooling from the melt. Indicate how the grain structure is changed by cold working.

(8 marks)

c. Briefly describe how toughness can be measured in a laboratory test. For a 0.1% carbon steel, indicate graphically how the toughness value might be affected by temperature. What is the name of the transition that can occur? State two factors that could change the transition value.

(7 marks)

**Total: 25 marks**

**Question 2**

a. Calculate the maximum force required to produce a washer of diameter 30 mm, simultaneously with a 15mm dia hole from a steel sheet of thickness 2.0 mm with a shear strength of 430 MPa (or MN m\(^{-2}\)).

(10 marks)

b. What effect does metal ductility have on the appearance of the sheared edge of a component?

(2 marks)

c. If a sheared metal edge exhibited 30% penetration would it be more or less ductile than a metal edge that exhibited 10% penetration?

(3 marks)

d. Sketch and label a punch force/penetration graph and calculate the energy required to shear the circle in part (a) of this question.

(10 marks)

**Total: 25 marks**
Question 3

a. Name and draw out the three common crystal structures of metals (Hint: suggest use of small circles to represent atom centres) identify the following metals with each of these structures (iron at room temperature, aluminium, copper, zinc).

(10 marks)

b. Calculate the amount of atoms in a BBC unit cell and a FCC unit cell (show all working).

(5 marks)

c. A ferrous alloy component will be subject to high cyclic loading in service. What potential failure mechanism should be considered? Sketch a graph showing a typical failure under these conditions. How can the lifetime be increased or chances of failure reduced? Is there a safe stress for a ferrous material under these conditions. Would this be the case if the alloy were replaced by an Al alloy? If not explain why.

(10 marks)

Total: 25 marks

Question 4

a. Sketch the iron / carbon equilibrium diagram for the range room temperature to 1000°C and up to 1.5% Carbon. Name the phase areas and identify the eutectoid position and composition %.

(10 marks)

b. Draw (sketch) and label the phases for a 0.35% carbon steel, a 0.8% carbon steel and a 1.2% carbon steel in the normalised condition. How would the structure of the 0.35% carbon steel be altered if it had been hot worked?

(8 marks)

c. What non-equilibrium phase would be formed if a 0.35% carbon steel above were quenched from the austenitic phase region of the equilibrium diagram. Why does it not appear on the diagram? What are the two main (extreme) properties associated with this phase? What heat treatment processes could be carried out on the material to alter these two properties?

(7 marks)

Total: 25 marks
Question 5

a. Give a named example of a thermoset and of a thermoplastic polymeric material. Draw the typical chain arrangement in each case and explain how this influences the thermal and mechanical properties.

(10 marks)

b. Draw a graph of volume against temperature (suggested range -50°C to 200°C) for a) an amorphous thermoset polymer and b) a thermoplastic semi-crystalline polymer. Indicate what is happening at any changes in slope or discontinuities on the graphs. Also indicate on your graph the optimum working temperature range for use each of these polymers.

(8 marks)

c. With regards to mechanical properties, discuss the advantages of composite materials over traditional single component materials. What if any are the disadvantages of composite materials?

(7 marks)

Total: 25 marks