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

Instructions to students:

• Enter your student number not your name on all answer books.
• Answer all questions.
• The use of a non-programmable calculator is permitted.
• Mathematical formulae and graph paper will be provided.
• Students are permitted to remove this examination paper at the end of the examination.

No. of Pages: 3
No. of Questions: 4
Answer all questions.

**Question 1**

a. Describe 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. (7 marks)

b. Calculate the number of atoms in a Face Centre Cubic (FCC) unit cell and in a body centre cubic unit cell (BCC). Show all workings out. (6 marks)

c. Sketch and label the equilibrium diagram for the steel system for the range up to 1000°C and up to 1.5% Carbon. Name the phase areas. (12 marks)

**Total: 25 marks**

**Question 2**

a. What happens when mild steel is exposed to water and air? Make a sketch showing an anode and cathode and the rest of the circuit. Give the equations that govern the reaction of the metal with this environment. What similar and relatively inexpensive alloy could replace mild steel in this circuit to prevent or reduce corrosion? What mechanism protects the chosen material from corrosion damage? (10 marks)

b. This part is about expansion/contraction of a steel measuring tool. The following information may be of use in answering the question: Linear temperature coefficients - aluminium: 0.000023 (m/m°C), steel: 0.000016 (m/m°C), copper/alloy: 0.000017 (m/m°C).

A cutting machine has a bed of length 5 metres. This incorporates a steel rule which is 5 metres along its length when assembled at 20°C. Construction is designed for temperatures ranging from -40°C to +40°C.

i. What is the shortest length of the rule at minimum temperature -40°C? (5 marks)

ii. What is the length of the rule at +40°C? (5 marks)

iii. Suggest, with a reason, which of copper or aluminium would be the better alternative to steel for this application. (5 marks)

**Total: 25 marks**
Question 3

a. Describe using a diagram for a composite material the long and short fibre model to determine the critical fibre length. In your description relate to the common failure mechanism of composites.

(10 marks)

b. Draw (sketch) and label the phase or metallurgical structures for a 0.35% carbon steel, a 0.8% carbon steel and a 1.2% carbon steel in the normalised condition as viewed under an optical microscope at about 400x magnification. How would the structure of the 0.4% carbon steel be altered if it had been hot-worked.

(10 marks)

c. What non-equilibrium phase would be formed if a 0.4% carbon steel above were quenched from the austenitic (FCC) state. Why does it not appear on a equilibrium phase diagram? What are the two main (extreme) properties associated with this phase? What heat treatment process can be carried out on the material to alter these two properties?

(5 marks)

Total: 25 marks

Question 4

a. Name and draw a lattice diagram for the three common crystal structures of metals. Identify the following metals with each of these structures (iron at room temperature, aluminium, zinc).

(9 marks)

b. 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)

c. To determine hardness, tests can be carried out using a hardened steel balls or an industrial diamond indenter. Give advantages and disadvantages for both types

(5 marks)

Total: 25 marks

End of Paper