Version MS/CYB/3

EGT2
ENGINEERING TRIPOS PART IIA

Thursday 30 April 2026 9.30 to 11.10

Module 3C1

MATERIALS PROCESSING AND DESIGN

Answer not more than ***three*** *questions.*

All questions carry the same number of marks.

The ***approximate*** *percentage of marks allocated to each part of a question is indicated in the right margin.*

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

10 minutes reading time is allowed for this paper at the start of the exam.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

You may not remove any stationery from the Examination Room.

1 Two pieces of mild steel are butt-welded together using a standard arc welding process. The metal surfaces to be joined are shaped to create a V-shaped cavity and the joint is made using molten steel filler. The result is a full-thickness weld with a weld bead on the upper surface, as shown in Fig. 1.

(a) Sketch what a *lap* weld would look like and explain why a *butt* weld configuration is preferred in this case. [10%]

(b) Describe the residual stress distribution around the butt weld, briefly explaining how it has formed. [15%]

(c) To avoid the formation of *martensite* in the heat affected zone, the entire part is subject to a post-weld heat treatment to 700°C for 30 minutes, followed by quenching.

(i) Explain why *martensite* may form and why it is a problem. [10%]

(ii) Consider the metal plates to be 30 mm thick and 150 mm wide. Refer to the table and British steel CCT diagram shown in Fig. 2 and Fig. 3, respectively. Would a quenching in oil from 700°C solve the problem? Why? [30%]

(d) Besides the presence of *martensite* discussed in part (c), what other common causes of failure could be envisioned and how could they be avoided? [15%]

(e) The weld joint is dipped in molten zinc to provide a layer of zinc on the surface.

(i) What is this intended to achieve, and how does it do it? [10%]

(ii) The steel was found to have formed cracks close to the weld during the hot-dipping process. What is the likely cause? [10%]

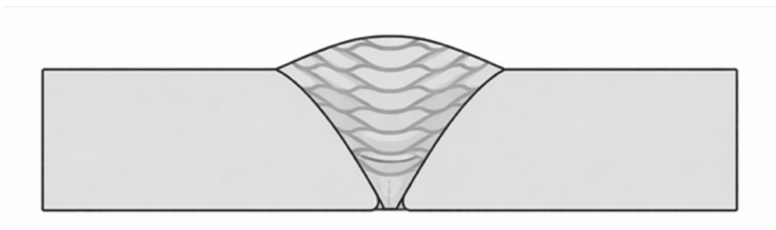

Fig. 1

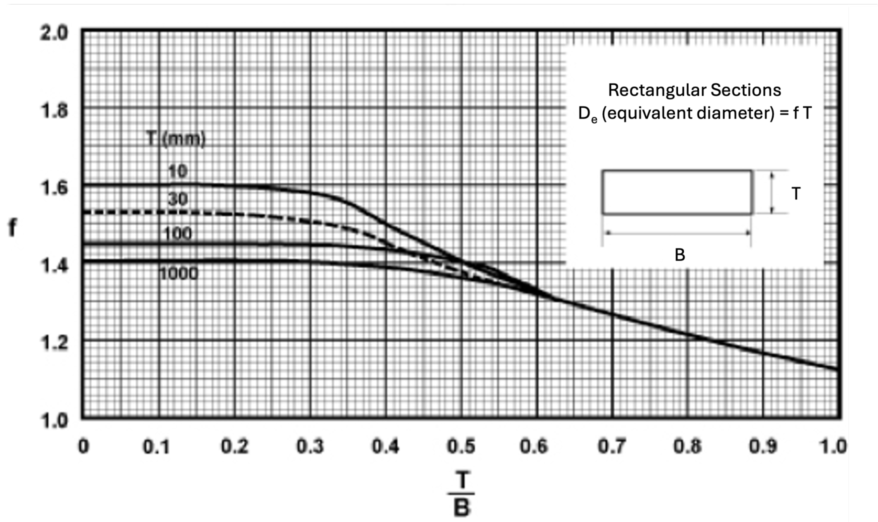

Fig. 2

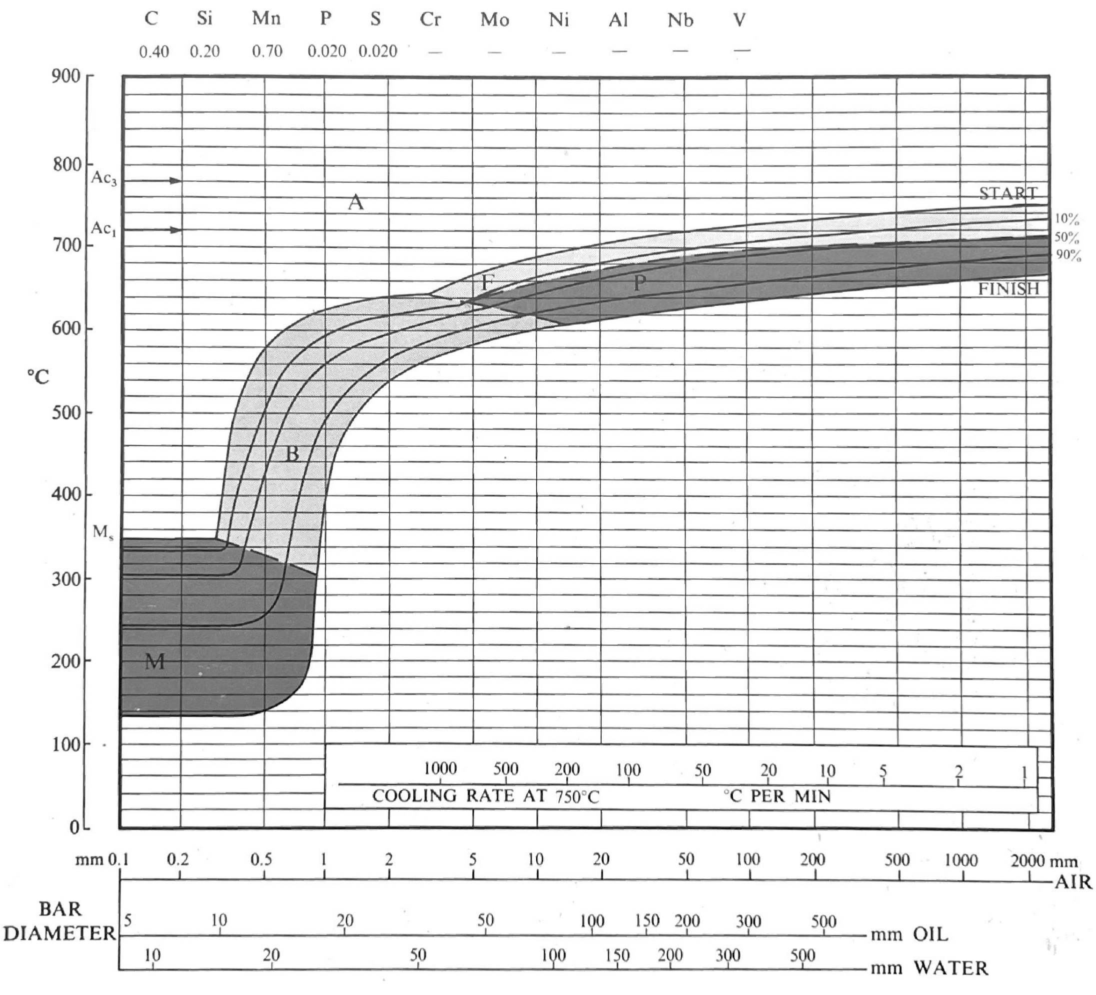

Fig. 3

 (TURN OVER

2 An aluminium bracket is to be produced using sand casting. The bracket is fed by a gating system consisting of a sprue, a runner, and one riser.

(a) Explain the role of the runner and riser in the sand casting process. What factors determine the size and placement of the riser in casting? [15%]

(b) List and briefly describe *three* common casting defects that could occur in casting and explain their likely causes. [15%]

(c) Fig. 4 shows a schematic drawing of the bracket and riser assembly (all other gating elements are omitted for simplicity). The bracket is roughly rectangular, with dimensions 100 mm × 70 mm × 20 mm. The riser is a cylindrical rod of diameter 25 mm and height 50 mm. *Chvorinov's* rule states: $t_s = C\,(V/A)^2$. Using *Chvorinov's* constant, $C = 2$ min/cm^2, estimate the solidification time, t_s, of the bracket and the riser. [10%]

(d) With reference to the different types of defects found in casting, which one is likely to be found in this casting and how could it be avoided? [15%]

(e) Explain the physical origin of microsegregation in cast aluminium alloys and how it affects the composition and properties in different regions of the casting. [20%]

(f) Sketch the grain structure that you expect to see across the cross-section of the (defect-free) aluminium bracket in Fig. 4. Label the different zones that you might find and explain the thermal and solidification conditions that produce them. [25%]

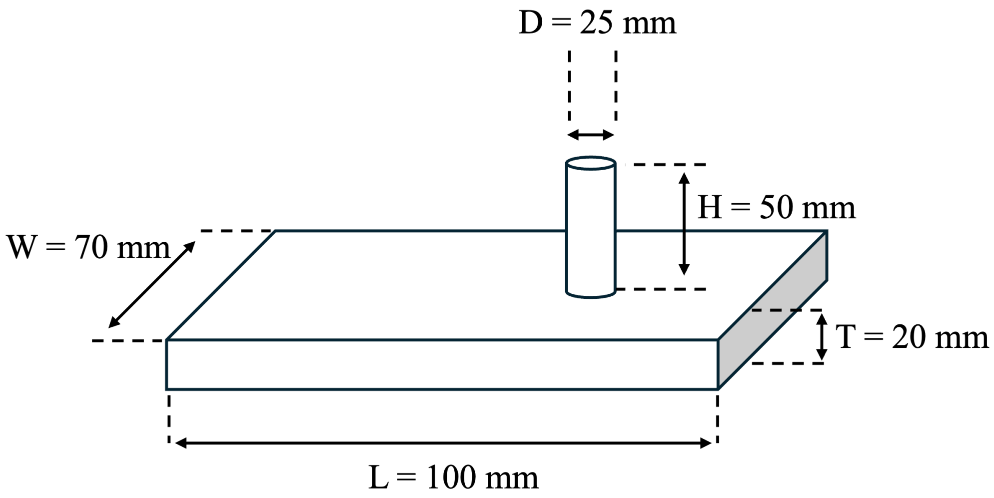

Fig. 4

3 (a) You are tasked with manufacturing two-litre plastic bottles for carbonated drinks and two-litre plastic bottles for milk.

(i) Briefly describe which process you would choose to make the two products and discuss your choice. [10%]

(ii) What polymers would you use in both cases and why? [10%]

(iii) Discuss the extent to which these bottles can be recycled at end-of-life, and describe how this can be achieved. What are the environmental benefits of recycling these polymers in terms of carbon footprint and resource management? [15%]

(b) Carbon fibre reinforced plastic is to be used for manufacturing a monocoque shell for a racing car. The design specifies using a high-volume fraction of uniaxially aligned carbon fibres in epoxy resin.

(i) Outline the composite manufacture and assembly process that you would recommend. Then, discuss a possible alternative manufacturing process and the corresponding drawbacks. [20%]

(ii) What is meant by a *balanced lay-up* and why would it be important for this application? [10%]

(iii) What difficulties would you expect to encounter in joining other parts (e.g. engine, side panel) to the monocoque? [10%]

(c) Over time, the composite suffers progressive damage because of occasional impacts, cyclic loading, and exposure to the environment (especially liquids and high temperatures). Discuss the type of damage that you will expect to see, making reference to how the composite has been designed to resist damage. To what extent can the damage be detected?

[25%]

4 (a) Define *Additive Manufacturing* (AM) and explain how it differs from traditional *Subtractive Manufacturing* techniques. [10%]

(b) Discuss the importance of AM in aerospace product development. [10%]

(c) Describe the working principle of *Powder Bed Fusion* (PBF) technology. [15%]

(d) PBF technology includes both laser-beam or electron-beam processes.

(i) Explain how and why the surface quality of parts produced by these two processes differ. [10%]

(ii) Explain how and why residual stresses in parts produced by these two processes differ. [10%]

(iii) Explain how and why the microstructure of a part made of high carbon steel may change when produced by laser-beam or electron-beam PBF processes. [20%]

(e) (i) Discuss the pros and cons of producing copper parts using either laser-beam or electron-beam PBF processes. [15%]

(ii) Which of these two processes would you chose to make copper parts with complex internal channels and why? [10%]

END OF PAPER

THIS PAGE IS BLANK