Version JAB/3

EGT1
ENGINEERING TRIPOS PART IB

Wednesday 11 June 2025 2.00 to 4.10

Paper 2

STRUCTURES

*Answer not more than **four** questions, which may be taken from either section.*

All questions carry the same number of marks.

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

Answers to questions in each section should be tied together and handed in separately.

*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.

SECTION A

1 A pin-jointed truss is shown in Fig. 1. All members have the same cross-sectional area A and are made of a linear elastic material with Young's modulus E. All members are initially unstressed and their self-weight can be neglected. A vertical load P is then applied at joint D, as shown in the figure.

(a) Find the number of redundancies. [2]

(b) Find all bar forces. [18]

(c) Find the horizontal displacement at point B. [5]

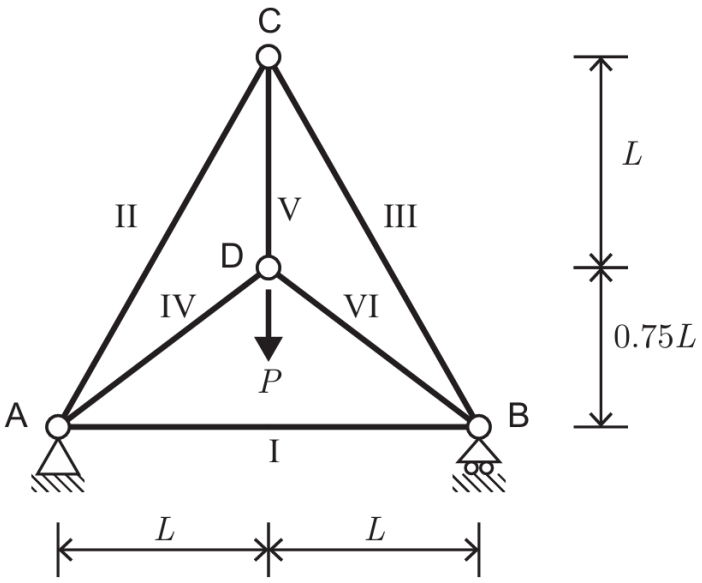

Figure 1

2 The weightless frame shown in Fig. 2 has a fixed support at A, a roller support at B, and a pin at D. All members have flexural rigidity EI, are axially rigid, and behave elastically. A horizontal point load is applied to member DB. The unloaded frame is unstressed.

(a) Sketch a feasible deflected shape for the frame. Annotate your diagram to highlight any salient points. [5]

(b) Calculate the reactions at A and B. [3]

(c) Draw the bending moment diagram for the frame. [5]

(d) Calculate the deflection at point B under the applied loads. [12]

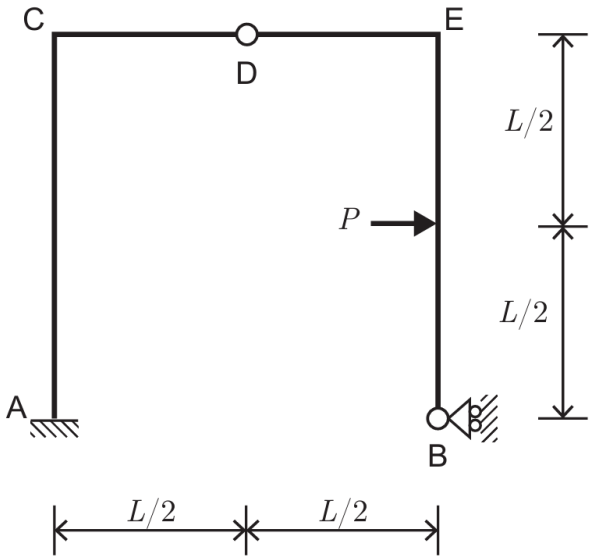

Figure 2

3 The cantilevered tube shown in Fig. 3 tapers linearly in circular cross-section from the base (where r_2 = 300 mm) to the tip (where r_1 = 100 mm). The radii r_1 and r_2 are measured to the centreline of the wall. The tube has constant thickness t = 5 mm, and span L = 5 m. It is loaded by a vertical force of 15 kN, which is eccentric relative to the axial centre line. The self-weight of the tube is negligible.

(a) Draw the shear and bending moment diagrams for the cantilever. Also draw a diagram indicating the variation of the torque along the cantilever. [3]

(b) Calculate the longitudinal normal stresses at the base of the cantilever. [3]

(c) Calculate the shear stresses near both end sections of the cantilever. [5]

(d) Assuming the cantilever is fabricated in steel with a yield stress of 275 MPa, calculate the factor of safety against yielding at both ends, using the Tresca criterion. [12]

(e) Suggest one way in which the structure might be optimised. [2]

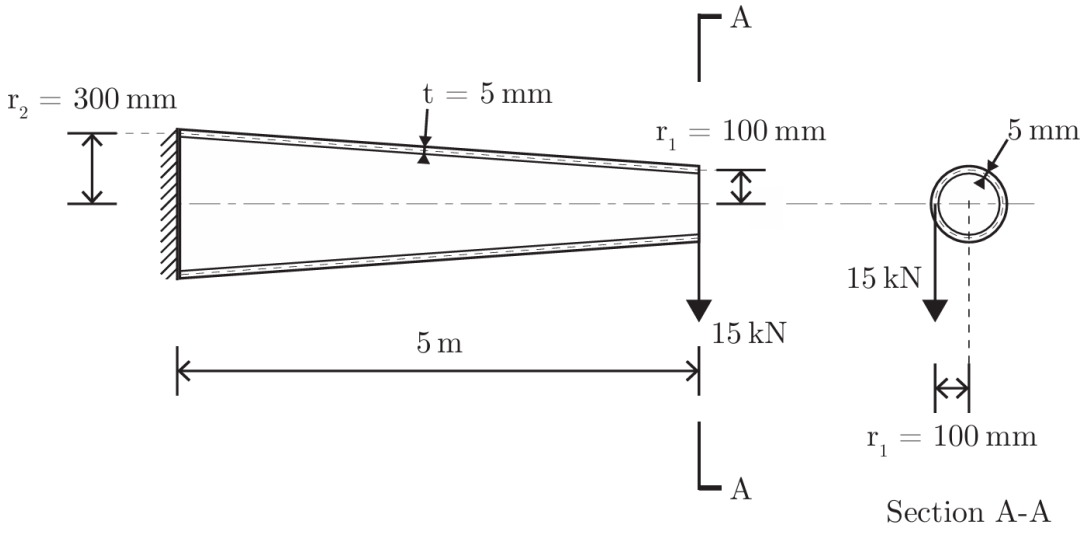

Figure 3

SECTION B

4 A warehouse is constructed from a number of identical steel frames with the dimensions and loading of each frame pictured in Fig. 4. The frames need to resist a lateral load P and two vertical loads, each of magnitude $2P$, placed on the horizontal roof beam. The self-weight of the frame can be neglected. The frame members are axially rigid.

As part of the design, a fire scenario needs to be considered. The fire (uniformly) heats the structure, gradually reducing the yield stress f_y and eventually causing a plastic collapse mechanism to form. At the time of collapse the fully plastic moment capacity of the columns is M_p, while that of the beam is αM_p, with $\alpha > 1$.

(a) Sketch the possible collapse mechanisms of the frame. Mechanisms which result in any of the applied forces generating negative work need not be considered. [4]

(b) If it is a design requirement that the collapse mechanism does not contain a sway component, to prevent the fire from spreading to neighbouring buildings, determine the limit(s) on α which need to be imposed. [12]

(c) For $\alpha = 1.5$, sketch the bending moment diagram at the time of collapse, indicating all salient values. [9]

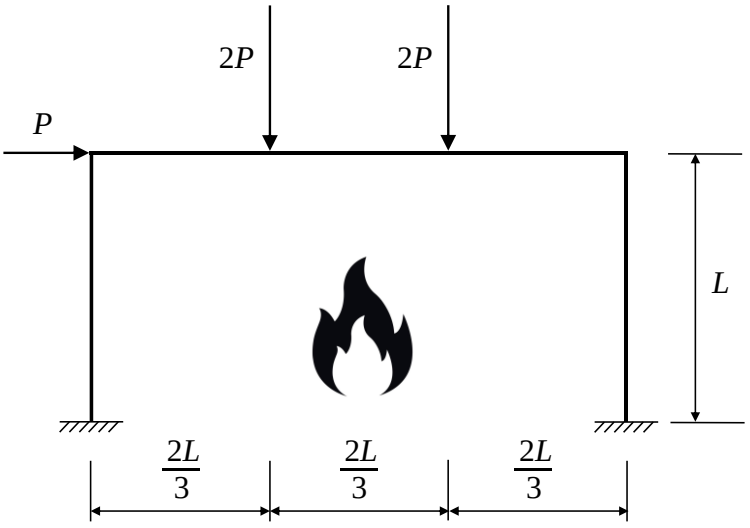

Figure 4

5 A steel frame has the dimensions and loading indicated in Fig. 5. A single cross-section is used for all frame members. The yield stress of the steel is f_y = 275 MPa. The self-weight of the frame may be neglected. The frame members are axially rigid.

(a) Determine the number of redundancies *before* and *after* exploiting the symmetries of the system. [5]

(b) With P = 200 kN, use the *Lower Bound Theorem* of plasticity to determine the Universal Beam section (from the Data Book) with the lowest mass which can safely carry the loads. [20]

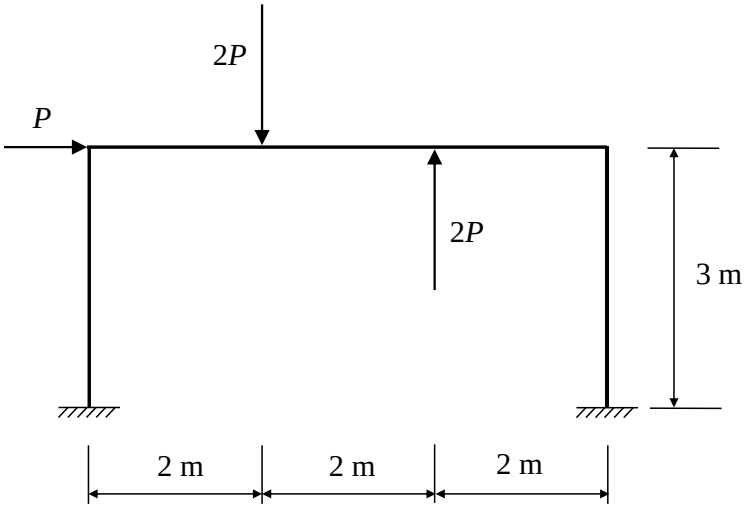

Figure 5

6 An engineer wants to write software code to investigate the geotechnical stability of a slope. They assume a slip line mechanism consisting of N (rigid) vertical strips, as illustrated in Fig. 6 for the case where $N = 4$. The angle α_i of the top surface of the i^{th} strip is given by:

$$\alpha_i = \begin{cases} \alpha & if \quad i = 1 \ldots N-1 \\ 0 & if \quad i = N \end{cases}$$

(a) Draw a vector diagram of the displacements of the N strips. [5]

(b) Write a general expression for the total energy dissipated along all slip lines, as a function of the widths Δ_i ($i = 1 \ldots N$), the lengths x_i ($i = 1 \ldots N$), the angles α_i ($i = 1 \ldots N$), the shear strength of the soil k, and the vertical displacement δ of the load P. [12]

(c) Write an expression for the work done by the load P and the self-weight of the soil. The density of the soil is ρ. The load P is a line load in the out-of-plane direction. [8]

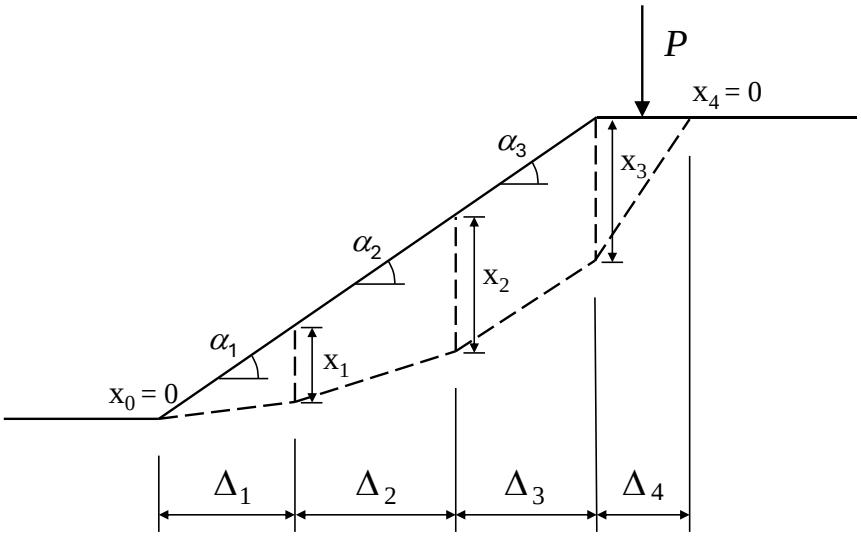

Figure 6

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