EGT1
ENGINEERING TRIPOS PART IB

Friday 8 June 2018 9 to 11.10

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*** *percentage 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.

SECTION A

1 (a) The cantilever of length ℓ and constant stiffness EI shown in Fig. 1(a) is subject to a distributed load that varies linearly from zero at its base to w at its tip.

(i) Write an equation to describe the variation in distributed load along the length of the cantilever in terms of x and ℓ. [2]

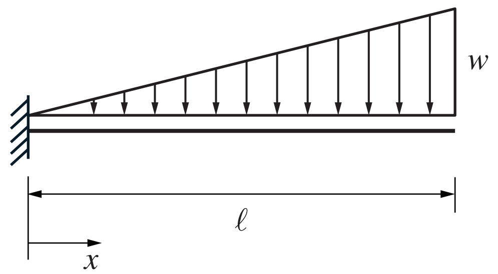
(ii) Find an expression for the vertical deflection of the tip of the cantilever. [8]

(b) An elastic frame ABCDE is shown in Fig. 1(b). All members have the same value of $EI = 200 \times 10^6\,\mathrm{N\,m^2}$. The beam ABC is connected to two columns, CD and BE. Column CD is rigidly connected at C and built-in at D. Column BE is pinned at B and E. Column CD is subject to a transverse wind load that varies linearly with height from zero at D to $10\,\mathrm{kN\,m^{-1}}$ at C. Use the Force Method by adding a pin at C to make the frame statically determinate.

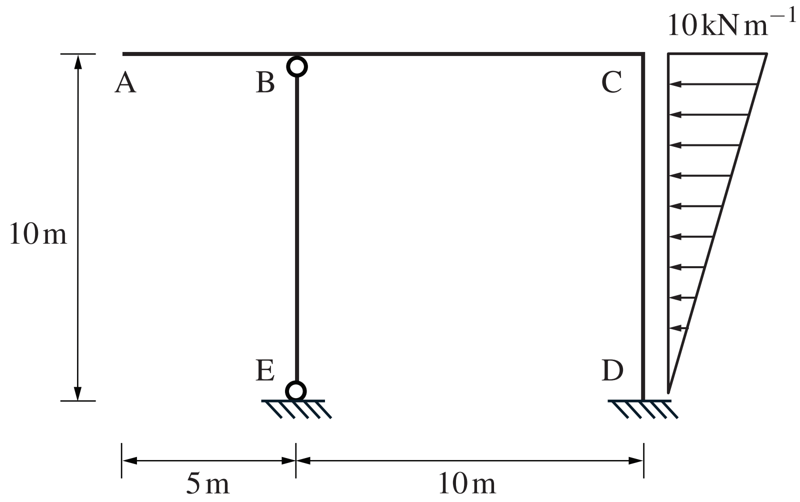
(i) Determine the axial forces throughout the frame. [5]

(ii) Determine the vertical and horizontal deflections at A. [4]

(iii) After construction it is found that column BE is 100 mm shorter than shown in Fig. 1(b). What is the corresponding change in moment at C? Comment on your result. [6]



(a)



(b)

Fig. 1

2 The circular hollow cantilever shown in Fig. 2 carries an eccentric point load of 25 kN applied at the tip. At the root of the cantilever are two points of interest, A and B.

(a) (i) Calculate the longitudinal normal stresses at both A and B. [4]

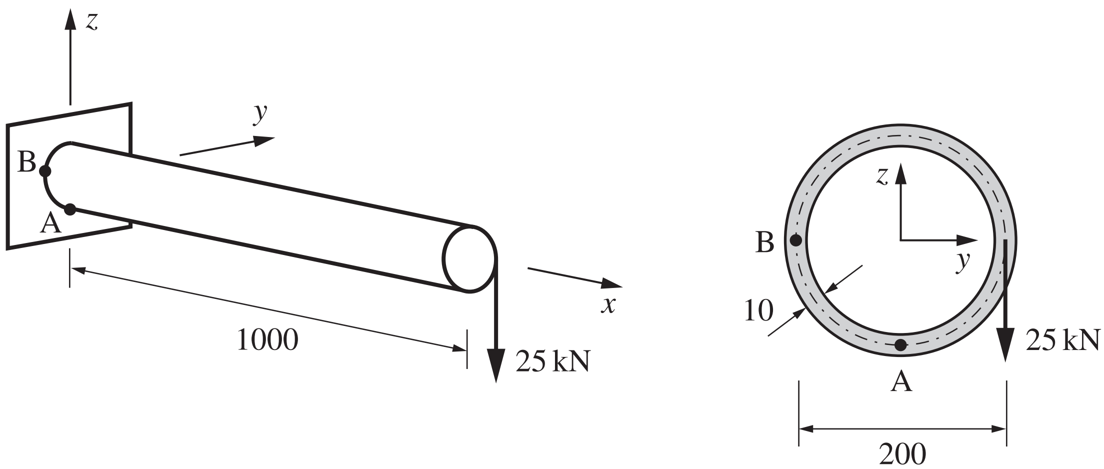
(ii) Calculate the total shear stresses at both A and B. [6]

(b) The beam is fabricated from a steel tube of yield strength 275 MPa.

(i) Calculate the factor of safety against failure, considering only points A and B. Use the von Mises yield criterion. [8]

(ii) Comment on your result in (i). [2]

(iii) For the loading arrangement shown in Fig. 2 use preliminary calculations to propose an alternative structural design that retains a reasonable factor of safety, whilst reducing the total volume of material used. [5]



(Not to scale: all dimensions in mm)

Fig. 2

3 A continuous beam ABC of total length 2ℓ rests on simple supports A and B and is supported by a vertical cable at C of length 0.5ℓ as shown in Fig. 3. The beam supports a uniform distributed load of intensity w. Prior to application of the uniformly distributed load there is no force in the cable nor is there any slack in the cable. The beam has a constant second moment of area I and the cable has a constant area A. All members have the same value of Young's modulus E.

(a) Sketch the deflected shape and the bending moment diagram of this continuous beam. [5]

(b) (i) Give the number of redundancies of the structure and show three distinct ways to make it statically determinate. [5]

(ii) For a structure without the cable CD find the vertical deflection at C. [8]

(iii) Use your results from (ii) to find the force in the cable. [7]

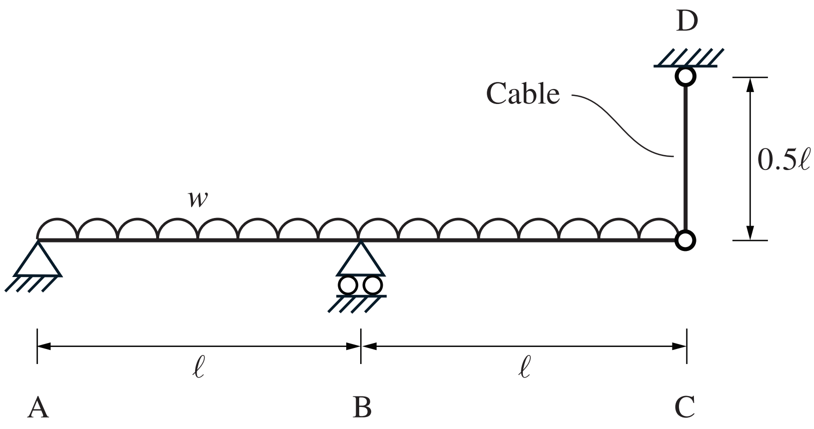


Fig. 3

SECTION B

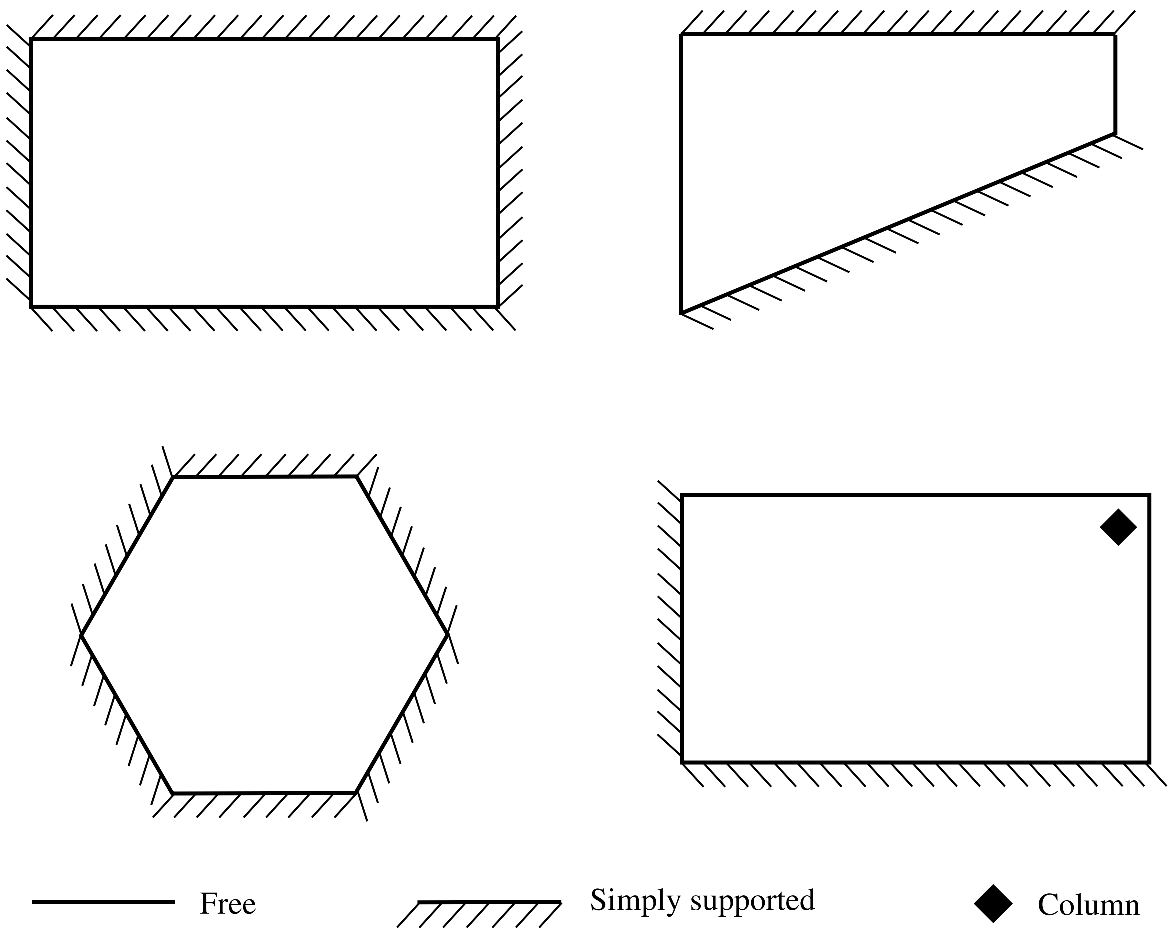
4 (a) The four ductile plates shown in plan view in Fig. 4(a) are subjected to uniform pressure loading. Sketch a likely collapse mechanism for each plate, and indicate the axes of rotation and any variable parameters to be used in a yield line analysis. [6]

(b) The ductile plate shown in plan view in Fig. 4(b) is simply supported along its edges AB, BC and CD and is free along DA. The plate is subjected to a uniform pressure p. The fully plastic moment per unit length is m for all yield lines.

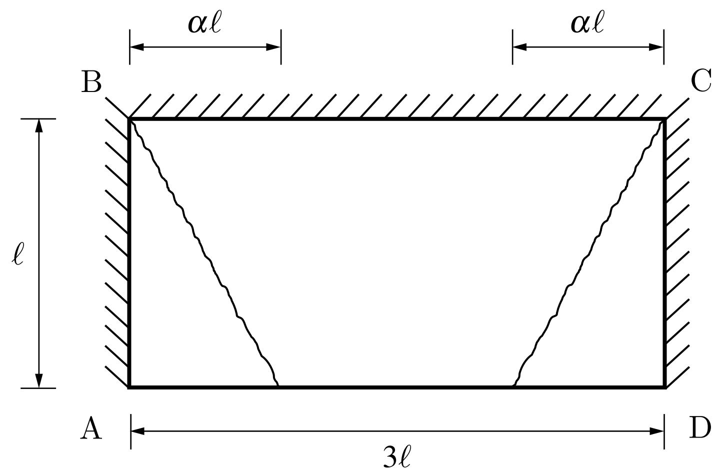
(i) Find the upper bound collapse pressure assuming the failure mechanism shown in Fig. 4(b). [10]

(ii) Use your result from (i) to determine the parameter α so that the upper bound collapse pressure is minimised. [5]

(iii) Suggest how you might obtain a lower bound estimate for the collapse pressure. [4]



(a)



(b)

Fig. 4

5 Figure 5 shows a frame structure carrying a horizontal load H and a uniformly distributed load w. The uniform fully plastic moment for the frame is M_p.

(a) Sketch *three* reasonable collapse mechanisms where plastic hinges occur at some subset of the five points marked A–E. [6]

(b) Find an upper-bound estimate of the collapse load for each of the three mechanisms sketched in part (a). [9]

(c) Consider that the hinge at D may no longer occur in the centre of the beam. For the relevant collapse mechanism sketched in part (a) determine the position of the hinge so that the corresponding upper bound is minimised. Assume that $w = H/(2\ell)$. [10]

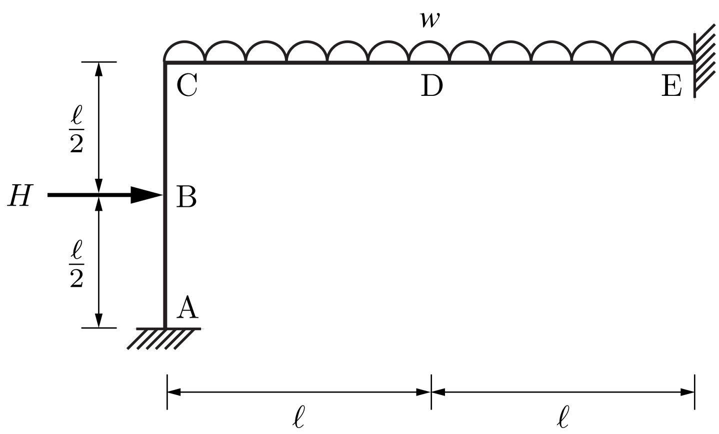


Fig. 5

6 (a) To find a lower bound on the collapse load, which of the three basic principles of structural analysis, namely equilibrium, compatibility and material law, have to be considered? [4]

(b) Figure 6 shows a universal beam UB 356x127x39 which is continuous over two 8 m spans. The structure is designed to carry two point loads W. The beam is made of structural steel with a yield stress of 355 MPa and is to be placed with the major axis orientated horizontally.

(i) Perform an elastic analysis to find the magnitude of the loads W when first yield occurs in the structure. [11]

(ii) Perform a lower bound analysis to find the maximum safe value of the magnitude of the loads W and sketch the overall bending diagram. [6]

(iii) Compute the vertical support reaction at E corresponding to the lower bound determined in (ii). [4]

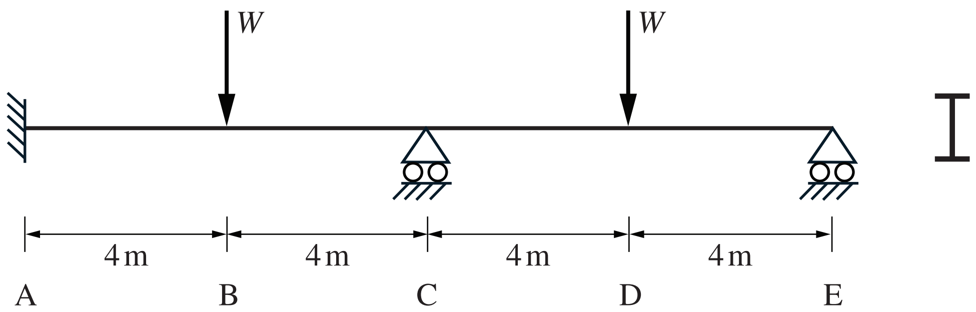


Fig. 6

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