The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, SPRING 2009-2010

MECHANICS OF SOLIDS 2

Time allowed THREE Hours

Candidates may complete the front cover of their answer book and sign their desk card but must NOT write anything else until the start of the examination period is announced.

Answer FIVE questions

Only silent, self contained calculators with a Single-Line Display, or Dual-Line Display are permitted in this examination.

Dictionaries are not allowed with one exception. Those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination. Subject specific translation dictionaries are not permitted.

No electronic devices capable of storing and retrieving text, including electronic dictionaries, may be used.

DO NOT turn examination paper over until instructed to do so

ADDITIONAL MATERIAL: Graph Paper - 2mm

INFORMATION FOR INVIGILATORS: None

Turn over

The following formulae may be used without proof:

For beams in bending under elastic behaviour:

$$EI\frac{d^2y}{dx^2} = -M$$

$$\frac{\sigma}{y} = \frac{M}{I} = \frac{E}{R}$$

For shafts in torsion under elastic behaviour:

$$\frac{\tau}{r} = \frac{T}{j} = \frac{G\theta}{\ell}$$

For thick pressurised cylinders:

$$\sigma_r = A - \frac{B}{r^2} \text{ and } \sigma_\theta = A + \frac{B}{r^2}$$

$$\varepsilon_r = \frac{du}{dr} \text{ and } \varepsilon_\theta = \frac{u}{r}$$

1. For the cross-section shown in Fig. Q1 determine,

(a) the position of the centroid of area, G. [5 marks]

(b) the principal 2^{nd} moments of area (sketch the Mohr's circle showing points corresponding to the x and y axes and the principal axes) [10 marks]

(c) the orientation angle of the principal axes with respect to the y-axis (show on a sketch of the cross-section) [5 marks]

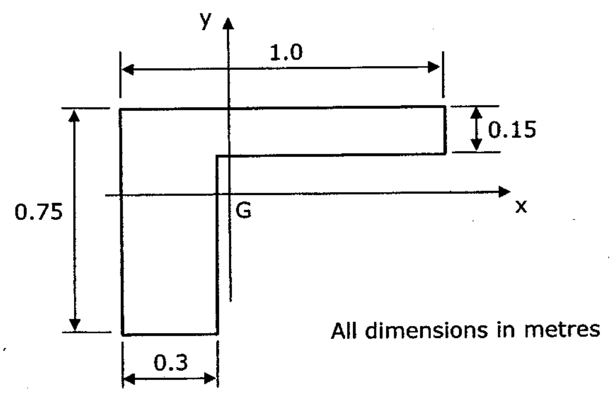


Fig. Q1

2. The simply-supported beam, ABC, span length 6 m, shown in Fig Q2, is subjected to a point load 60 kN, 1.5 m from the left end of the beam, and a uniformly distributed load of 20 kNm^{-1}, acting over the right half of the beam. Before loading, the beam has a prop 6 mm below its lower surface at mid span i.e. position B. After loading, the beam comes into contact with the prop.

Use Macaulay's method to determine:

(a) The reaction forces at both ends of the beam, A and C, and at the prop, B. [15 marks]

(b) The magnitude of the deflection of the beam at the point load. [5 marks]

[Assume EI = 4×10^7 Nm^2]

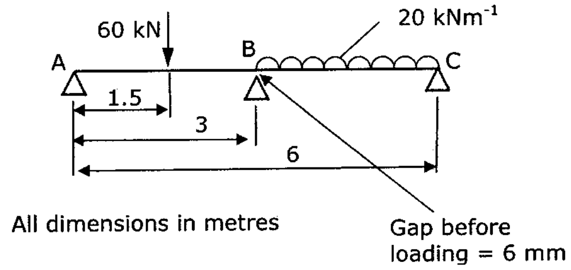


Fig Q2

3. The double channel, thin-walled section shown in Fig. Q3, has a uniform wall thickness throughout of 20 mm. All four flanges are of equal length, 0.2 m. The x-axis shown is an axis of symmetry. Determine:

(a) the 2nd moment of area about the x-axis [7 marks]

(b) the position of the shear centre for the section [13 marks]

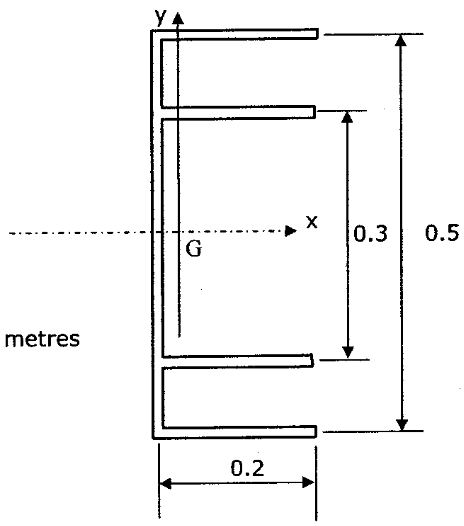


Fig Q3

Turn over

4. The slender steel support structure, ABC, shown in Fig. Q4, is rigidly supported in the ground and carries a vertical load of 250 N at its tip, A. The upright member, 6 m in height, supports a cantilevered semi-circular overhang of radius 1.5 m. All members in the structure are of hollow circular cross-section of outer diameter 100 mm and wall thickness 3 mm.

Using a strain energy method and assuming bending strain energy only, determine the vertical deflection of the tip, A, where the load is applied. [20 marks]

[assume E_{steel} = 209 GPa]

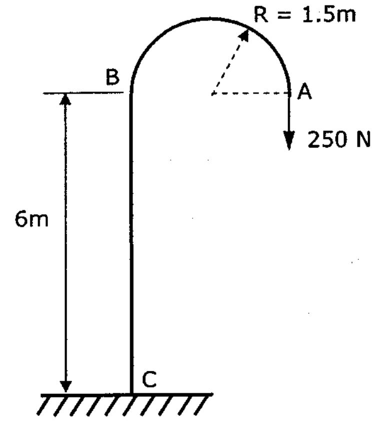


Fig. Q4

5. Two thick cylinders are machined so that one of them has an outside diameter of 150mm and an inside diameter slightly lower than 100mm. The other cylinder has an inside diameter of 50mm and an outside diameter slightly greater than 100mm. The larger cylinder is heated up and slid onto the smaller cylinder. When cooled down, the shrink fit causes a compressive hoop stress of -100MPa at the interface. Determine:-

i) The interface pressure [10 marks]

ii) The diametral interference between the two cylinders. [10 marks]

[E = 200 x 10^3 MPa and v= 0.3].

6. (a) Derive the equation for the buckling load of a pinned-pinned strut in terms of the Young's modulus, E, the second moment of area, I, and the length of the strut, l. [8 marks]

(b) The pin-jointed framework, ABC, shown in Fig Q6, is subjected to a vertical load P, at joint C.

If both bars are made of the same material, which has a yield stress of 100MPa (and behaves in an elastic-perfectly-plastic manner) and a Young's modulus of 200×10^3MPa, determine the maximum value of the load, P,that can be applied. [12 marks]

The cross-section of bar AC is square with dimensions 25mm x 25mm and the cross-section of bar BC is also square with dimensions 20mm x 20mm.

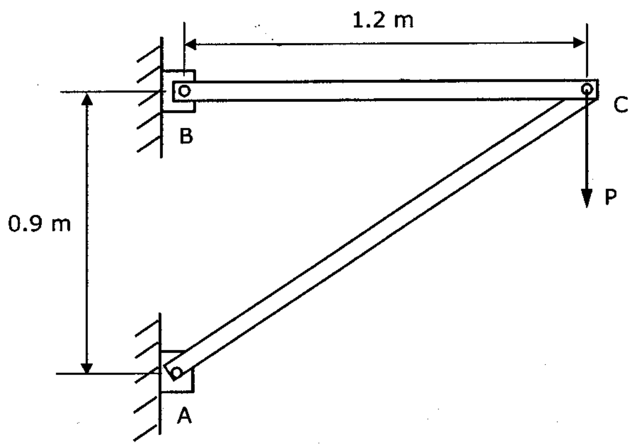


Fig. Q6

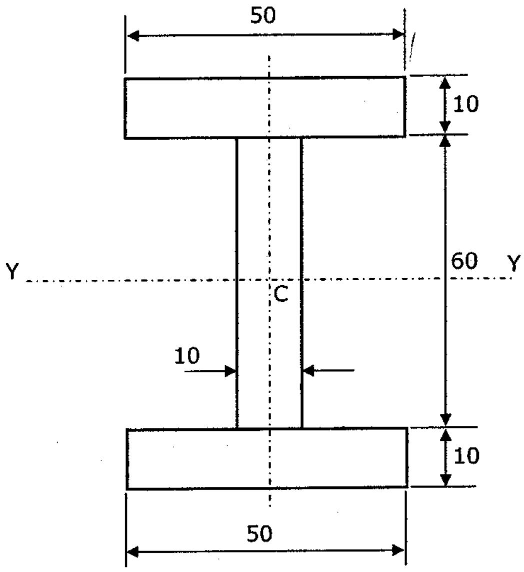
7. The cross-section of a straight I-section beam is shown in Fig. Q7. It is loaded in pure bending, about the Y-Y axis, until the whole of each flange has yielded, but the whole of the web remains elastic.

(a) Determine the bending moment required and the radius of the beam when this moment is applied. [10 marks]

Continued on next page
Turn over

(b) What is the residual radius when the moment is removed. [10 marks]

The material can be assumed to be elastic-perfectly-plastic with a yield stress of 300MPa and a Young's modulus of 200×10^3 MPa.



All dimensions in mm

Fig. Q7

8. (a) Describe, with the aid of diagrams, the elastic-perfectly-plastic material behaviour model, the isotropic hardening material behaviour model and the kinematic hardening material behaviour model. [6 marks]

(b) Describe in equation form and diagrammatically the Tresca and von-Mises yield criteria for 2-dimensional and 3-dimensional stress states. [6 marks]

(c) A solid circular bar having a diameter of 50mm is subjected to a combined loading consisting of an axial load, P, and a pure torque, T. The bar is made of a material with a yield stress of 100MPa and obeys the Tresca (maximum shear stress) yield criterion. If the magnitude of the axial load, P, is 160kN, what is the value of the torque, T, which will just cause yielding to occur. [8 marks]

End