The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, AUTUMN 2008-2009

SOLID MECHANICS 2

Time allowed TWO 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 FOUR 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

INFORMATION FOR INVIGILATORS: None

Turn over

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

   (a) the position of the centroid of area. [7 marks]

   (b) the principal 2nd moments of area. [12 marks]

   (c) the orientation angle of the principal axes with respect to the y-axis (show on a sketch of the cross-section] [6 marks]

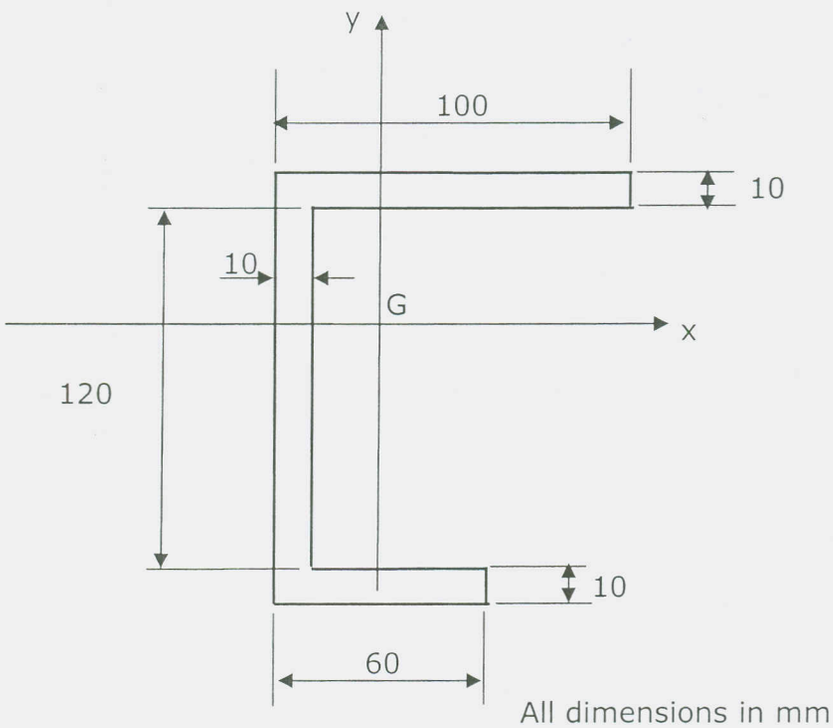


Fig Q1

2. The cross-section, shown in Fig Q2, is subjected to a bending moment, M = 1500Nm (as shown in vector form). The principal 2nd moments of area of the cross-section are,

$$I_p = 1.557 \times 10^{-6}\ m^4$$
$$I_q = 0.843 \times 10^{-6}\ m^4$$

The principal p-axis is inclined at an angle of 36.12° anti-clockwise to the y-axis.

Determine,

   (a) the angle of the neutral axis with respect to the x-axis (show on a sketch of the cross-section). [7 marks]

   (b) the magnitude of the bending stress at position A. [9 marks]

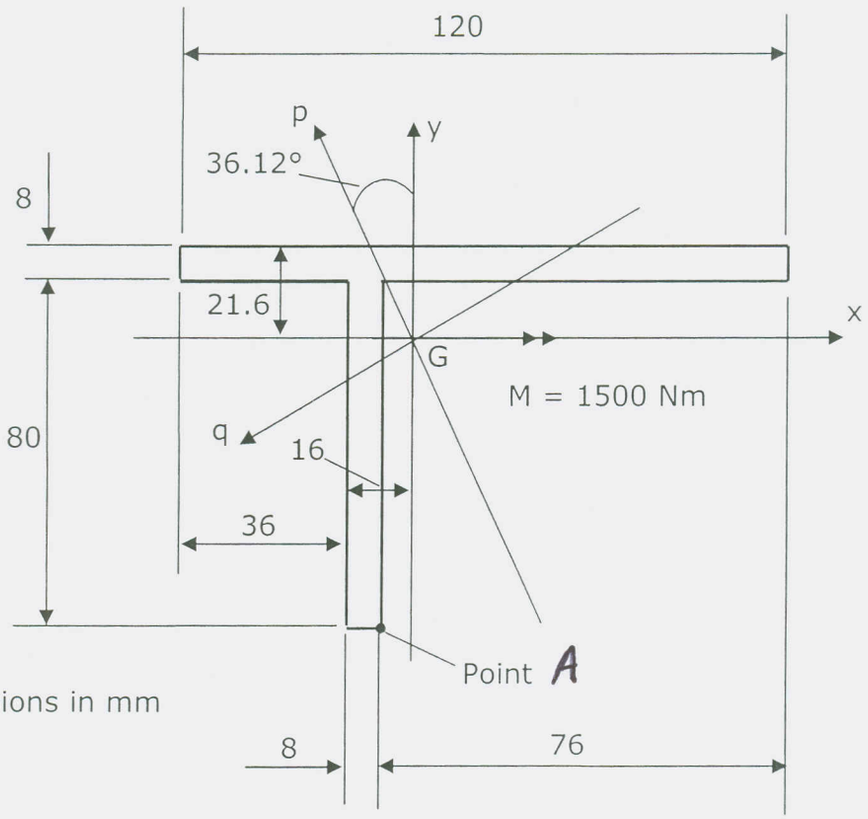
   (c) the location and magnitude of the maximum 'tensile' bending stress [9 marks]

continued on next page

The co-ordinate transformation equations for a set of axes, p-q, angled θ anticlockwise to the x-y axes, are,

$$p = x\cos\theta + y\sin\theta$$

$$q = -x\sin\theta + y\cos\theta$$



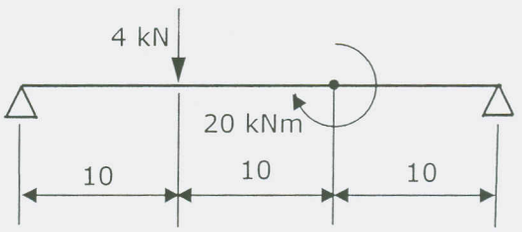
All dimensions in mm

Fig. Q2

3. The simply-supported steel beam, span length 30 m, shown in Fig Q3, is subjected to a point load of 4 kN, 10 m from the left end of the beam, and a clockwise point moment of 20 kNm, 10 m from the right end of the beam. The beam has a solid rectangular cross-section, 200 mm wide and 150 mm deep.

Use Macaulay's method to determine the magnitude of the deflection of the beam at the point load. [25 marks]

[Assume E_{steel} = 210 GPa]



All dimensions in metres

Fig Q3

4. (a) Show that the shear stress in a beam of solid circular section, radius R, subjected to a shear force S, is given by the following equation:

$$\tau = \frac{4S}{3\pi R^2}\left\{1-\left(\frac{y}{R}\right)^2\right\}$$

[12 marks]

(b) Hence, calculate the required radius to prevent yield at Section A'-A' (considering shear stress only) in the simply-supported beam of uniform circular section shown in Fig Q4, under the uniformly-distributed load of 3 kN/m. Use a shear yield stress of 100 MPa. [13 marks]

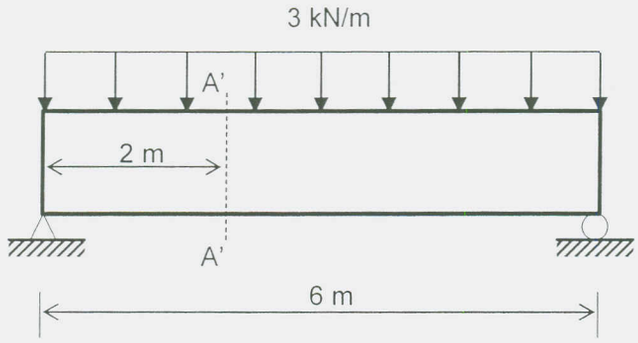


Fig Q4

5. A hollow shaft with an internal diameter (D_i) of 20 mm and an external diameter of (D_o) of 30 mm is fixed at one end to a rigid support structure and subjected to a combined load of (i) a torque about the Y-axis of T, (ii) a bending moment about the Z-axis of $2T$, and (iii) an axial load parallel to the Y-axis of $3T/D_o$. The yield stress of the shaft material is 1000 MPa.

(a) Determine the maximum and minimum principal stresses and the maximum shear stress in the shaft at point A in terms of T. [17 marks]

(b) Using the maximum shear stress yield criterion, determine the maximum allowable value of T. [8 marks]

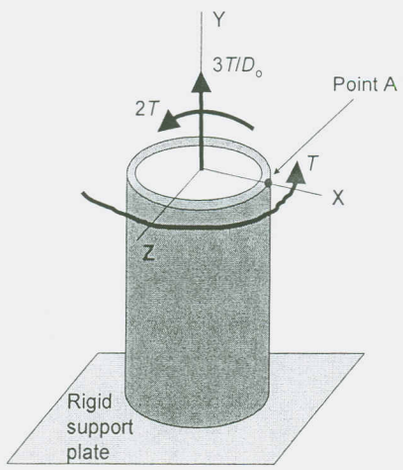


Fig Q5

6. (a) Derive an expression for the strain energy in a prismatic member of polar second moment of area, J, shear modulus, G, and length, L, subjected to a torque, T. [7 marks]

(b) Derive an expression for the strain energy in a uniform section beam of length, L, with Young's modulus, E, second moment of area, I, subjected to a bending moment, M. [7 marks]

(c) The bent cantilever shown in Fig Q6 has a circular hollow section, D_i = 10 mm, D_o = 20 mm for section AB and a circular hollow section D_i = 20 mm, D_o = 30 mm for section BC. L_1 is 200 mm and L_2 is 400 mm. The material is steel with E = 200 GPa, G = 70 GPa. The load is 1 kN. Determine the vertical deflection at point A. [11 marks]

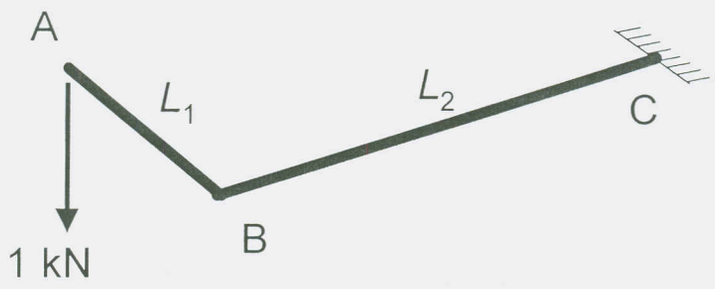


Fig Q6

End