The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS, AND MANUFACTURING

A LEVEL 2 MODULE, SPRING SEMESTER 2015-2016

MECHANICS OF SOLIDS 3

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 any 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

In this examination candidates are required to answer FOUR out of SIX questions. If a candidate answers more than the required number of questions, all questions will be marked and the highest marks will be used in the final examination mark.

ADDITIONAL MATERIAL: None

INFORMATION FOR INVIGILATORS:

Question papers should be collected in at the end of the exam – do not allow candidates to take copies from the exam room.

Turn Over

1. A statically indeterminate beam, with both ends built in at the walls, is subjected to a point moment a quarter span from the left as shown in Figure Q1. The beam has a length *L* and a flexural rigidity *EI*.

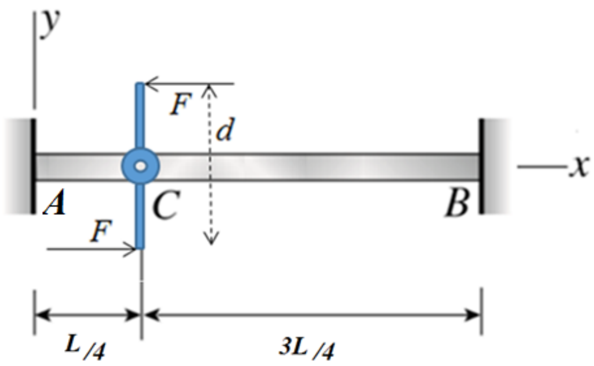


Figure Q1

(a) Determine the reactions acting at both supports (A and B).
[15 Marks]

(b) Calculate the vertical deflection of point C in terms of *EI*, *F*, *d* and *L*.
[5 Marks]

(c) Sketch the deflection of the beam based on your calculations.
[5 Marks]

2. The beam cross section shown in Figure Q2 is symmetrical about the y-axis, is made up of three rectangular sections (a, b and c) and is subjected to a Bending Moment, M, of 325Nm along the x-axis through the Centroid, C.

Determine:

(a) the position of C.

[5 marks]

(b) the 2nd Moments of Area and Product Moment of Area about the x-y axes through C.

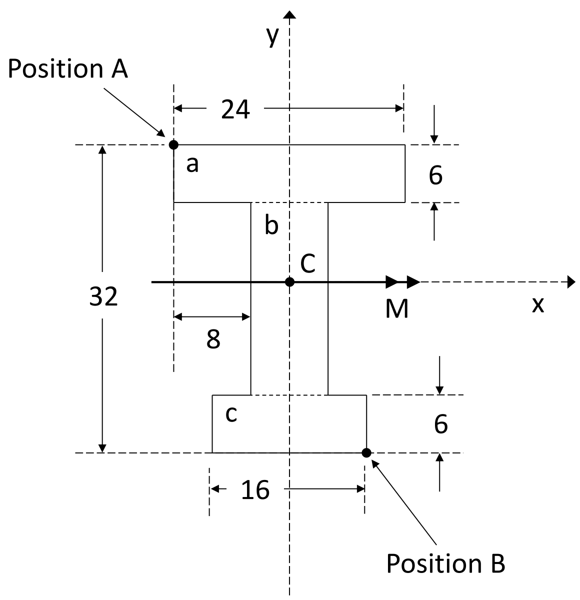
[5 marks]

(c) by calculation or by observation, the Principal 2nd Moments of Area, the direction of the Principal Axes and the direction of the Neutral Axis for the section.

[10 marks]

(d) the bending stresses at positions A and B.

[5 marks]



All dimensions in mm

Symmetrical about vertical centre line

Figure Q2

Turn over

3. A thick cylinder, with both ends closed, has an inner radius of 50mm and outer radius of 100mm. The cylinder is subjected to an internal pressure of 140MPa and external pressure of 20MPa. It may be assumed that end effects can be neglected.

   (a) Calculate the axial stress in the cylinder wall.

   [5 marks]

   (b) Determine the hoop stress at the inner radius and outer radius.

   [15 marks]

   (c) Sketch both the hoop stress and radial stress distribution through the thickness of the cylinder wall.

   [5 marks]

4. The cross-section shown in Figure Q4 carries a shear force, S = 45kN down the vertical centre line.

(a) Determine the position of the centroid, G, from the base of the section X-X.

[4 marks]

(b) Calculate the second moment of area of the section about the neutral axis (N.A.).

[5 marks]

(c) Determine the vertical shear stress at points A, B, C, D and G.

[12 marks]

(d) Sketch the vertical shear stress distribution along the vertical centre line of the section.

[4 marks]

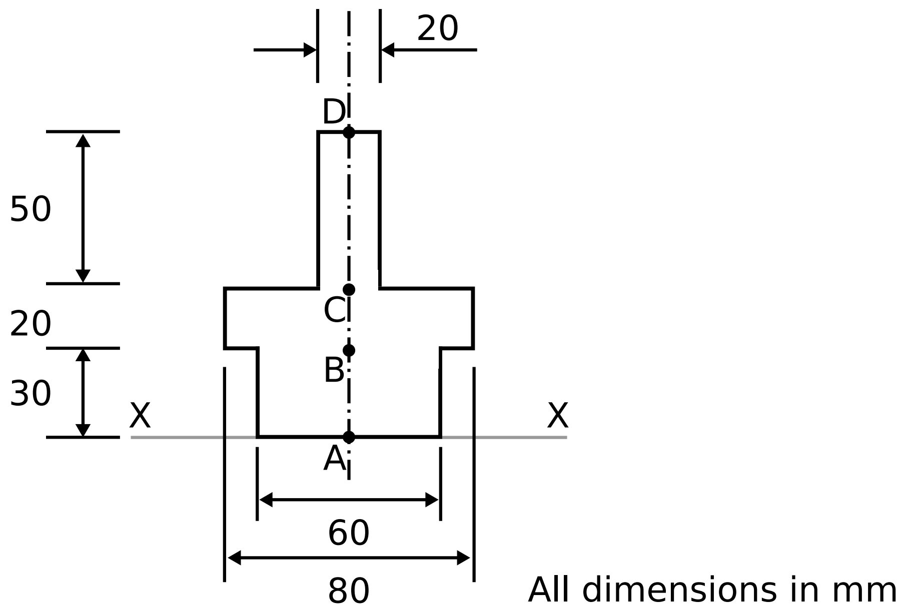


Figure Q4

Turn over

5. (a) Show that the buckling load, P, for a pinned-pinned ideal strut (i.e. initially straight with purely axial loading) under compression is given by:

$$P = \frac{n^2\pi^2 EI}{L^2}$$

where E is the Young's modulus, I is the second moment of area of the cross-section, and L is the length of the struts, n=1,2…

[7 marks]

(b) Show that buckling will occur if the compressive stress σ satisfies the following equation,

$$\sigma = \frac{\pi^2 E}{\left(\frac{l}{k}\right)^2}$$

and plot stress, σ, versus the slenderness ratio indicating the buckling and yielding collapse regions.

[10 marks]

(c) For an aluminum strut with the pinned-pinned end condition, Young's modulus, E=70GPa, square cross section is 30mm×30mm, and the yield stress, σ_y=230MPa, determine the maximum length required to prevent the strut failing by buckling.

[8 marks]

Note that the second moment of area could be defined as $I = Ak^2$, where k is the radius of gyration. The slenderness ratio is defined as l/k.

6. Figure Q6 shows a cantilevered bracket consisting of a straight section, AB, connected to a quarter-circular curved section, BC, and is made from a steel bar which is circular in cross section with a diameter, φ of 28mm, a Young's Modulus, E of 210GPa and a Shear Modulus, G of 77GPa. The bracket initially lies on the x-y plane and is built in to the wall at position A at a height of 0.25m above ground level as shown in Figure Q6. A point load, P of 500N is applied perpendicularly to the x-y plane at the free tip of the bracket (position C).

   Does the free tip of the bracket make contact with the ground (consider only bending for section BC)?

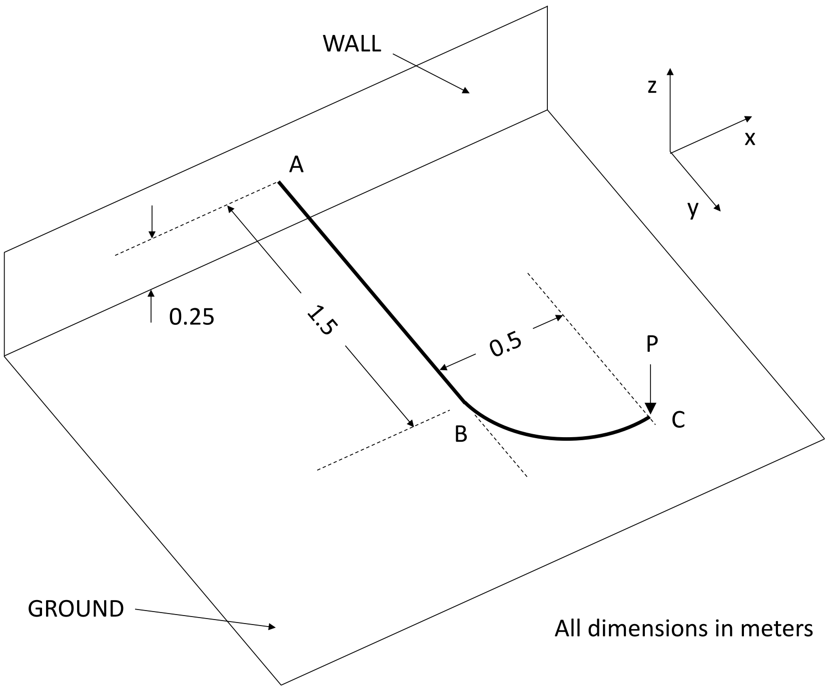


Figure Q6

The following trigonometric identities may be useful when solving for the deflections:

$$sin^2\phi + cos^2\phi = 1 \qquad cos2\phi = cos^2\phi - sin^2\phi \qquad sin2\phi = 2sin\phi cos\phi$$

[25 marks]

END