The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, SPRING SEMESTER 2017-2018

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 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: Mechanics of Solids Formula Sheet

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.

1. A 3m long steel beam is simply supported at positions *A* and *C*, as shown in Figure Q1. It is subjected to a point load, P_o, and a point moment, M_o, at position *B*.

Determine the deflection and slope at position *B*. [25]

Assume $E = 200\ GPa$, $I = 2 \times 10^6\ mm^4$, $P_o = 5\ kN$ and $M_o = 2\ kNm$

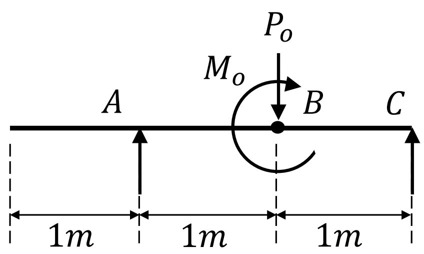
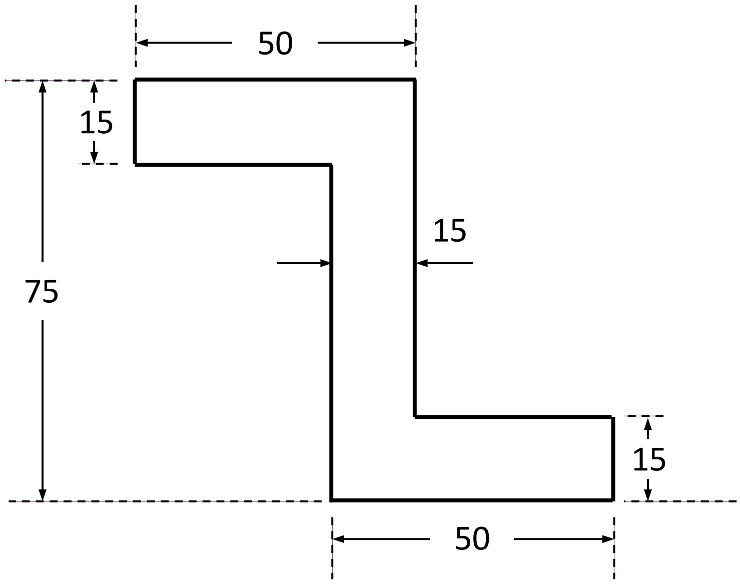


Figure Q1

2. Figure Q2 shows the cross-section of a beam.



All dimensions in mm

Figure Q2

Determine:

(a) The position of the Centroid of Area, C. [6]

(b) The Principal 2nd Moments of Area. [13]

(c) The orientation of the Principal Axes with respect to the x-y co-ordinate system (show on a sketch of the cross-section). [6]

3. A steel flywheel of diameter 1.0 m with a 0.1 m diameter bore is required for a rotating machine.

(a) At 5000 rpm, determine the radial and hoop stresses at the bore and at radial positions of 0.15, 0.3 and 0.5 m and sketch the distribution of both stresses in the flywheel. [15]

(b) Determine the maximum operational rotational speed (in rpm) of the flywheel if the maximum hoop stress is limited to 240 MPa. [10]

Assume ρ = 7900 kg m^{-3}, and ν = 0.3.

4. The thin walled channel cross-section shown in Figure Q4 is subjected to a vertical shear load of 5kN.

(a) Determine the horizontal shear stress in the flange at a = 0 and 28 mm. [8]

(b) Determine the vertical shear stress distribution in the web at y = 0 and 18 mm. [8]

(c) Determine the position of the shear centre on the N.A. from O. [9]

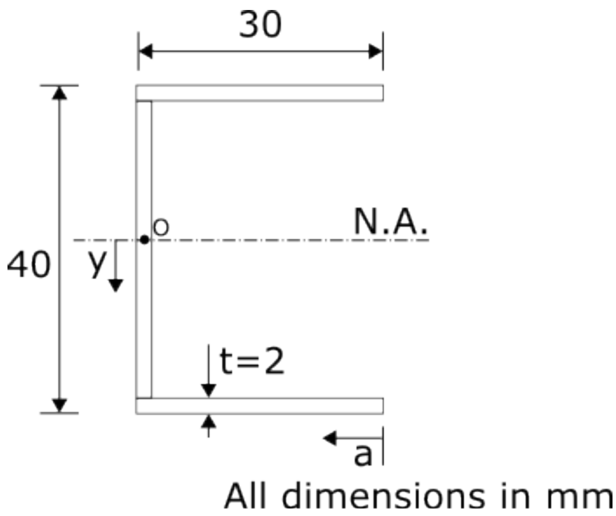


Figure Q4

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 strut, n=1,2… [7]

(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]

(c) For an steel strut in the fixed-fixed end condition, determine the maximum length required to prevent the strut failing by buckling.

Assume:

- Young's modulus, *E* = 200GPa
- The cross section of the beam is a square of 45mm × 45mm
- Yield stress, σ_y = 250MPa

[8]

6. The bent uniform bar, shown in Figure Q6, has a circular cross-section of 40mm diameter and is subjected to a vertical load, P, of 16kN at one end and clamped at the other end.

Considering bending strain energy only, determine the vertical and horizontal deflections at the position of the applied load. [25]

Assume E = 225GPa, L = 0.75m and θ = 55°

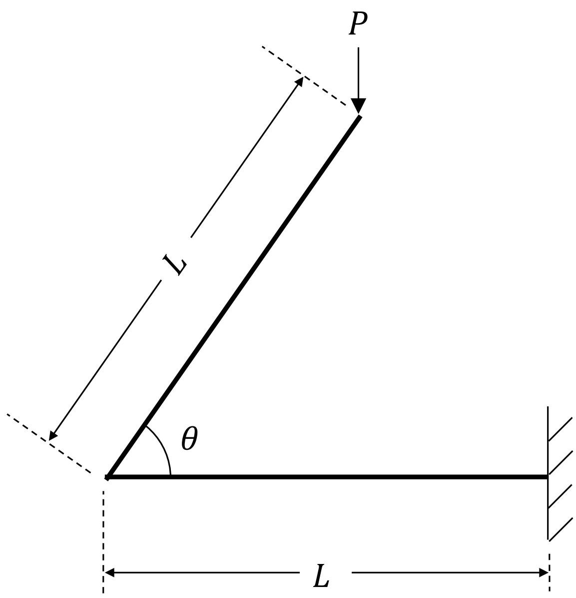


Figure Q6