National Exams May 2010

**04-BS-6: Mechanics of Materials**

3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.

2. Candidates may use one of two calculators, the Casio or Sharp approved models.

   This is a Closed Book exam. However candidates are permitted to bring the following into the examination room:

   - ONE aid sheet 8.5" x 11" hand-written on both sides containing notes and formulae. **Example problems and solutions to problems are not allowed!**

3. Any five questions (out of 8 given) constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.

4. All questions are of equal value.

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**NOTE: The aid sheet must be handed in with the exam!**

*Your exam will not be marked if you do not hand in an aid sheet, unless there is a signed statement by the exam invigilator stating that no aid sheet was used for the exam.*

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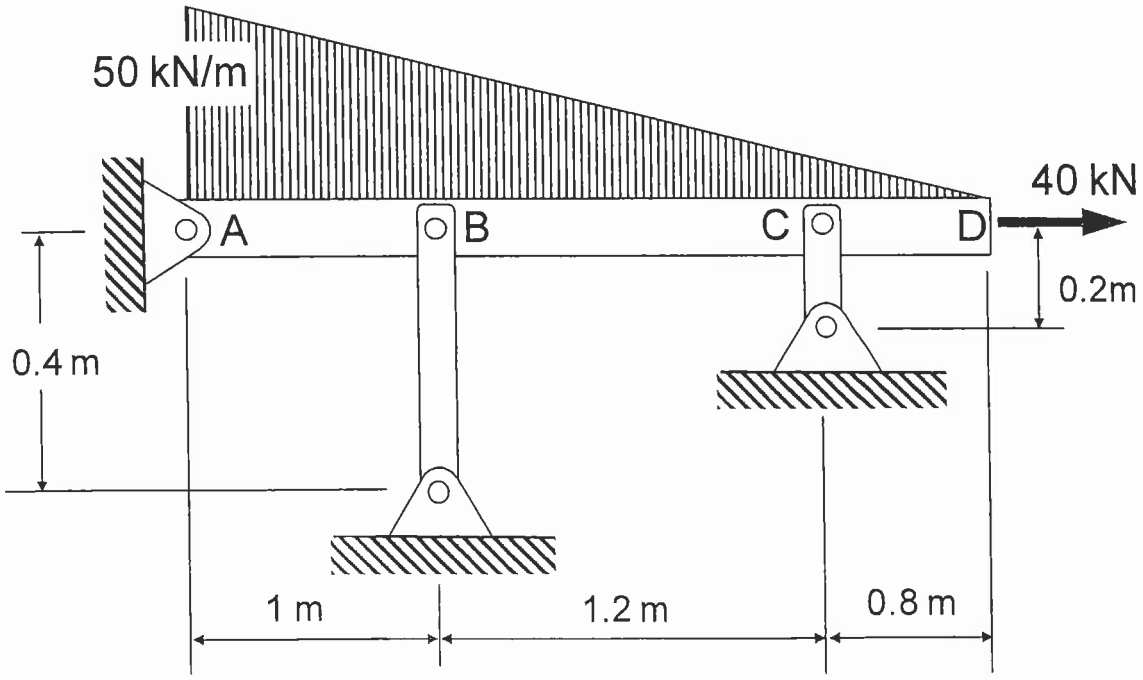
**Question 1:** A rigid bar ABCD is supported by a 30 mm diameter pin at A and two struts at points B and C. The strut at B is 0.4 m long while the strut at C is 0.2 m long. Both struts have the same cross-sectional area of 200 $mm^2$ and are made of aluminum with an allowable normal stress of 210 MPa and elastic modulus of 70 GPa. The rigid bar is loaded with a triangularly distributed load (maximum intensity of 50 kN/m) in addition to a 40 kN concentrated load acting in the horizontal direction at D.

[12 marks] (a) find the forces developed in the struts at B and C

[4 marks] (b) determine the vertical displacement at the end of the rigid bar (point D)

[4 marks] (c) compute the shear stress in the pin at A given that the pin is loaded in double shear

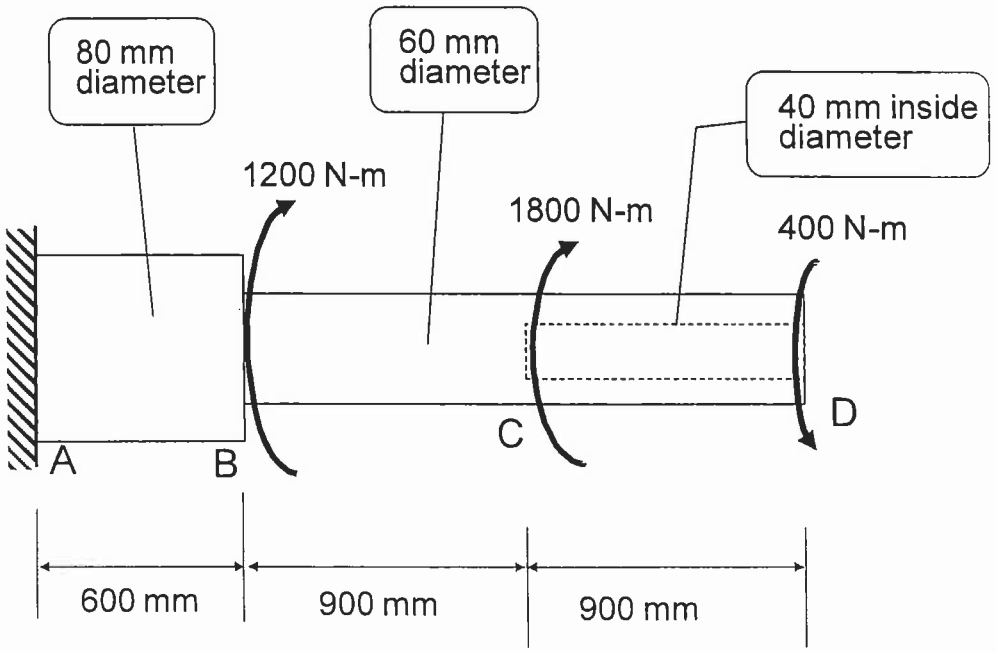


**Question 2:** A circular stepped shaft ABCD is subjected to three torques as indicated below. Part of the shaft (CD) is hollow as shown, and the entire shaft is made of steel with a yield stress of 150 MPa and shear modulus G = 80 GPa. Dimensions (diameter and length) and magnitude of the torques are given in the diagram.

[12 marks] (a) determine the maximum shear stress in the stepped shaft and sketch the corresponding variation of shear stress along the shaft radius at this point.

[6 marks] (b) find the angle of twist at the end of the shaft (point D) and give your answer in degrees.

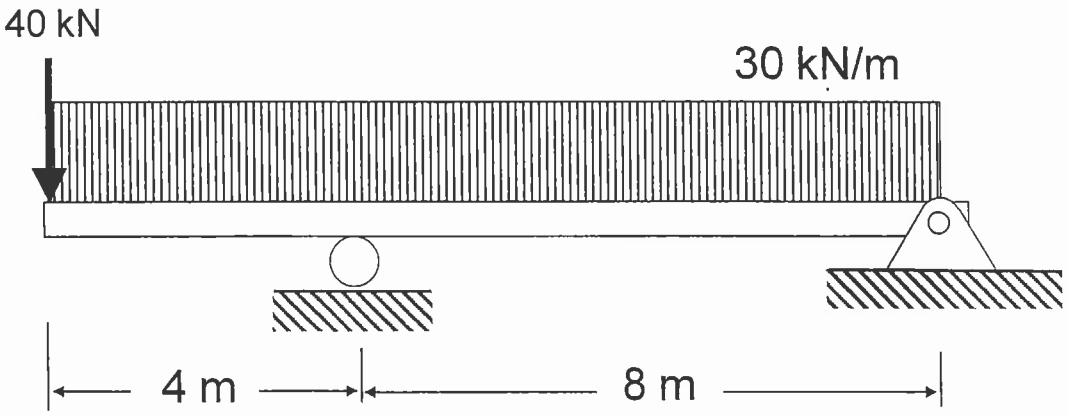
[2 marks] (c) compute the power that each segment of the shaft would transmit when it rotates at 900 rpm.



**Question 3:** A simply supported beam with a cantilevered overhang supports a uniformly distributed load of 30 kN/m (acting in the downward direction) in addition to a concentrated 40 kN load at the end of the overhand as shown below.

[12 marks] (a) Determine the shear and moment throughout the beam as functions of x. This means that you need to give formula(s) for **V(x)** and **M(x)** along the length of the beam.

[8 marks] (b) Next construct the shear force and bending moment diagrams. Remember to label points of maximum and negative bending moment, as well as any inflection points. Show your work by indicating exactly how you obtained your answer.



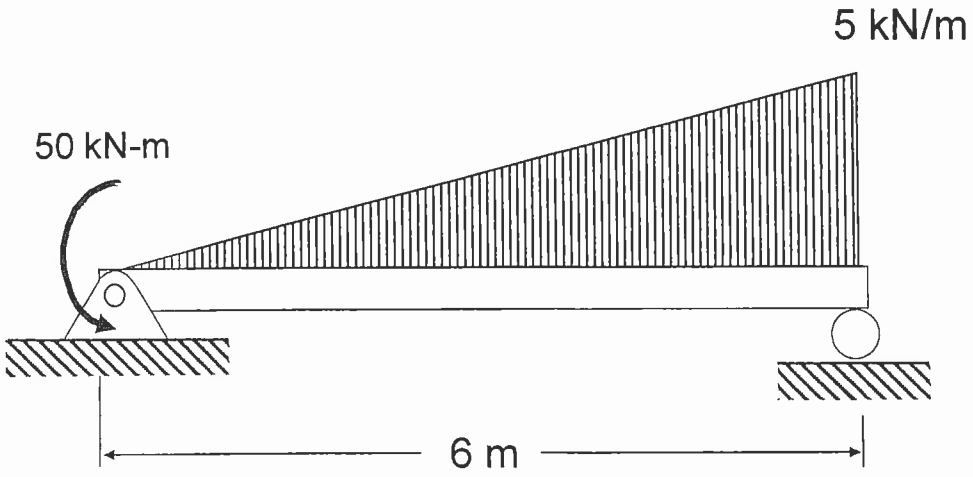

Remember that it is important you set this problem up correctly by calculating the correct reaction forces at the support(s).

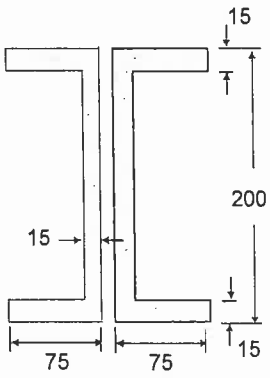
**No credit** will be given for a solution using the principle of superposition, when combinations of existing solutions are used to find an answer.

**Question 4:** A simply supported beam supports a triangularly distributed load (with a maximum intensity of 5 kN/m) and a concentrated couple at the end of the beam of 50 kN-m (see below). The beam is made up of two channel sections placed back to back as indicated by the cross-section shown. The beam is made from steel having an allowable normal stress of 240 MPa and elastic modulus of 200 GPa.

[18 marks] (a) determine the maximum deflection in the beam using the method of integration.

[2 marks] (b) recognizing that computation of deflection is a lengthy process using the method of integration, explain how you would compute the deflection of this beam in a design situation.



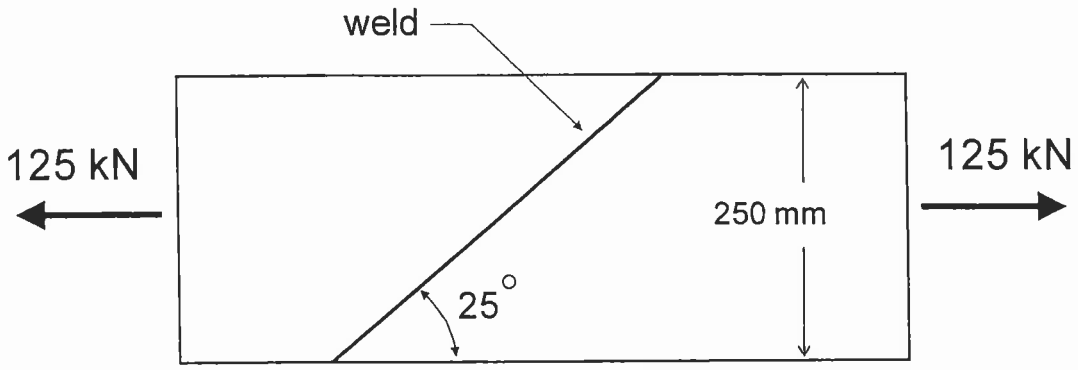

Beam Cross-Section
(all dimensions in mm)

**Question 5:** Two steel plates 250 mm wide and 10 mm thick are welded together at an angle of 25 degrees to the horizontal axis as shown. The welded plate assembly resists an axial load of 125 kN.

[20 marks] Use the Mohr's circle solution (*not* the transformation equations) to determine the following:

(a) both the normal and shear stress acting on the weld. Make sure to show your answer on a properly orientated element.

(b) maximum in-plane shear stress (and associated normal stresses) acting on the steel plates. Once again, show your answer on a sketch of a properly oriented element and make sure to give the orientation of the corresponding planes.

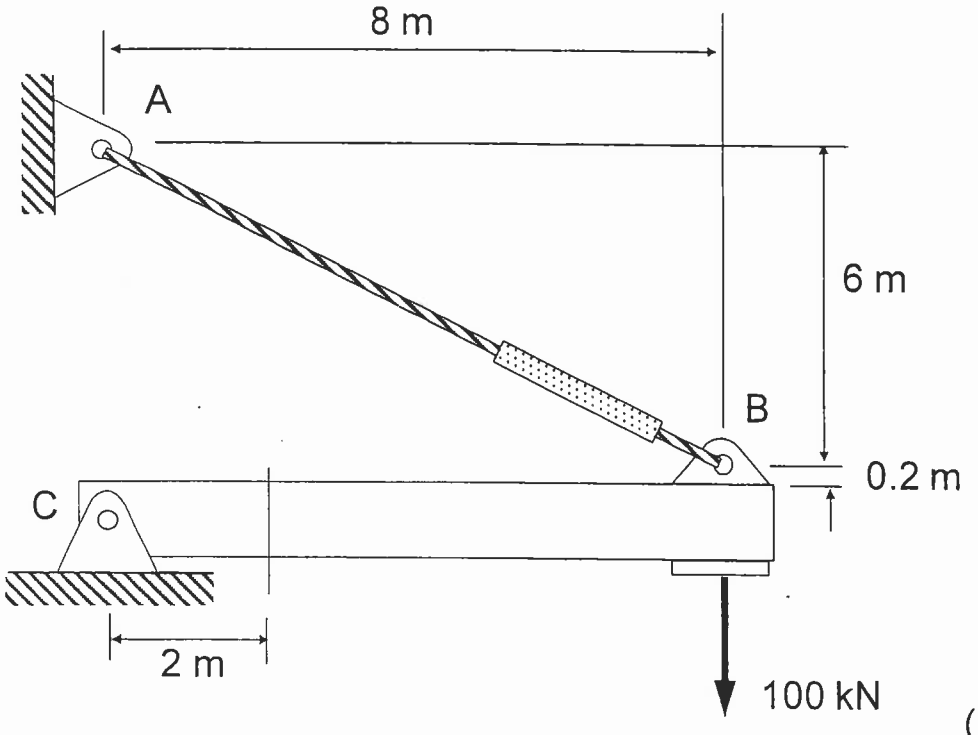


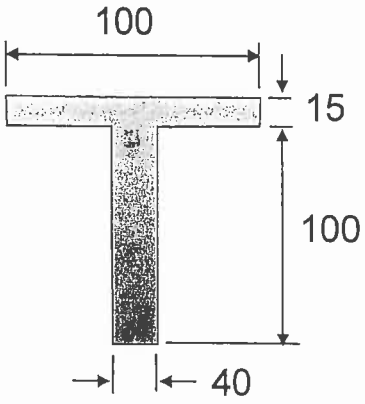

Note that credit will **only** be given for a **solution using Mohr's circle**. This means that you need to draw a Mohr's circle based on the stress components given in this problem. Remember to show numbers on your circle. Your **calculations** must be based on the geometry of your circle. So use your calculator. In other words, you are expected to use trigonometry to construct your Mohr's circle. Do not give a graphical solution that is scaled off! The stress transformation equations can only be used to check your answer.

**Question 6:** A 100 kN force is applied at the end of a T-shaped beam (CB) supported by a
**[20 marks]** pinned connection at C and a 19 mm diameter steel cable (AB) at B. Note that the connection of the cable to the T beam at point B is eccentric as shown while the pinned connection at C is located at the centroid of the member.

(a) compute the distribution of normal stress in the T-beam at a section located 2 m from the support at C, and show this distribution in a sketch

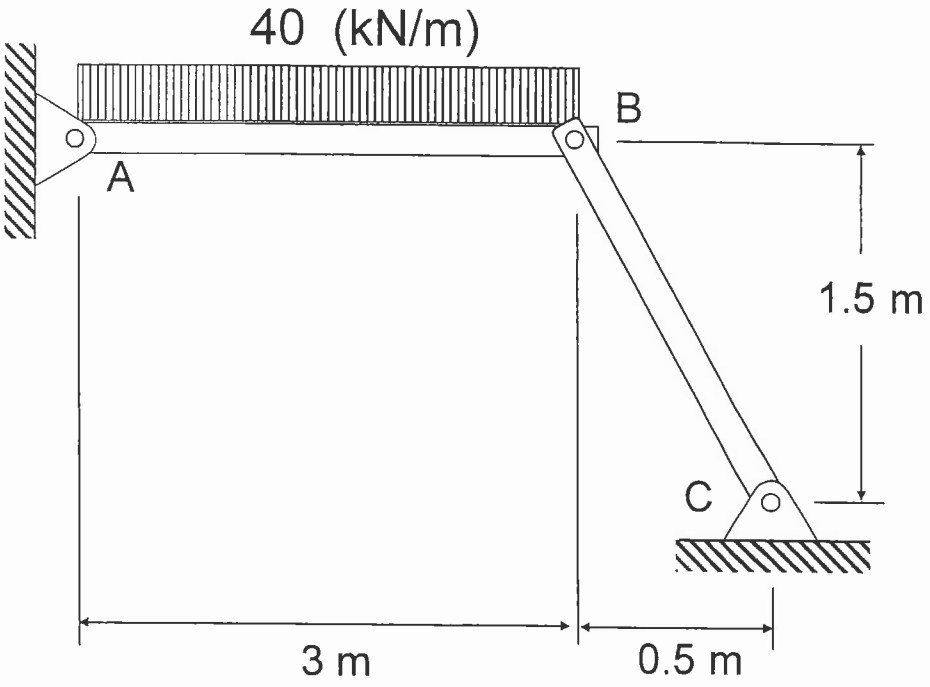
(b) compute the maximum shear stress in the T-beam at the same section located 2 m from the support at C




beam cross-section
(all dimensions in mm)

**Question 7:** [20 marks] The horizontal member in the structure below supports a uniformly distributed load w = 40 kN/m. The horizontal member is propped up by an inclined strut. The strut has a square cross section 120 mm x 120 mm and is made from steel having a yield strength of 300 MPa and elastic modulus of 200 GPa. Assume the strut is pinned at both ends. Determine the factor of safety against buckling of the strut. Consider buckling in the plane of the structure only.



**Question 8:** The cantilevered beam shown below is a composite member made of a rectangular concrete section (200 mm by 450 mm in cross-section) reinforced with a 10 mm thick steel plate at the top. Bending is about the horizontal axis. The concrete has an allowable normal stress of 3 MPa in tension and 15 MPa in compression while the steel has an allowable normal stress of 240 MPa. The elastic modulus of the concrete is 25 GPa while that of the steel is 200 GPa.

[18 marks] Determine the maximum load that can be carried by the beam given that it supports a uniformly distributed load as indicated.

[2 marks] Explain why the steel plate needs to be bonded to the concrete section to ensure composite behaviour.