National Exams May 2003

**98-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.

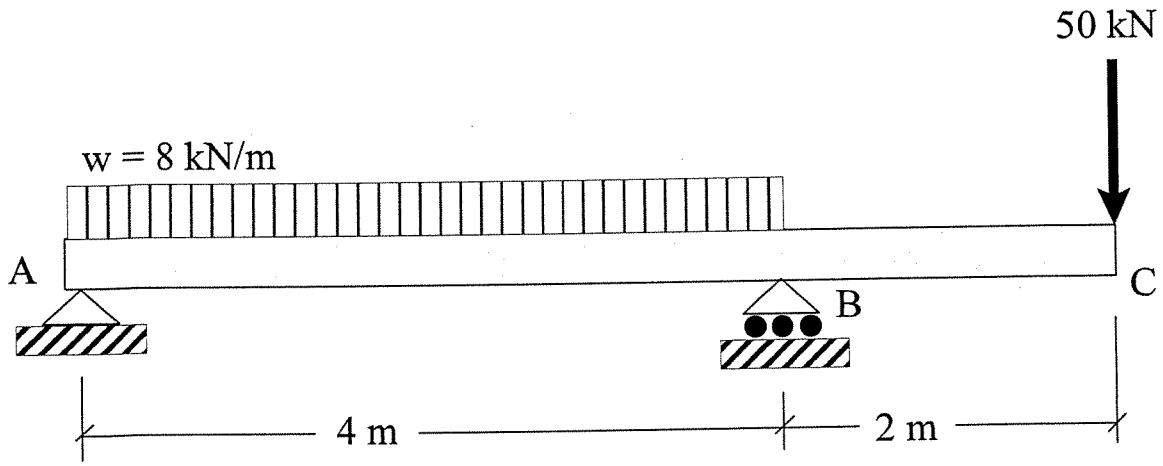
4. All questions are of equal value.

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

**Question 1**: A simply supported beam with a 2 m overhang supports a uniformly distributed load and an applied load at the end of the overhang as shown.

[20 marks] For this beam, determine the shear and moment throughout the beam as functions of x, and then sketch the shear force and bending moment diagrams. Remember to label points of maximum and negative bending moment, as well as any inflection points.

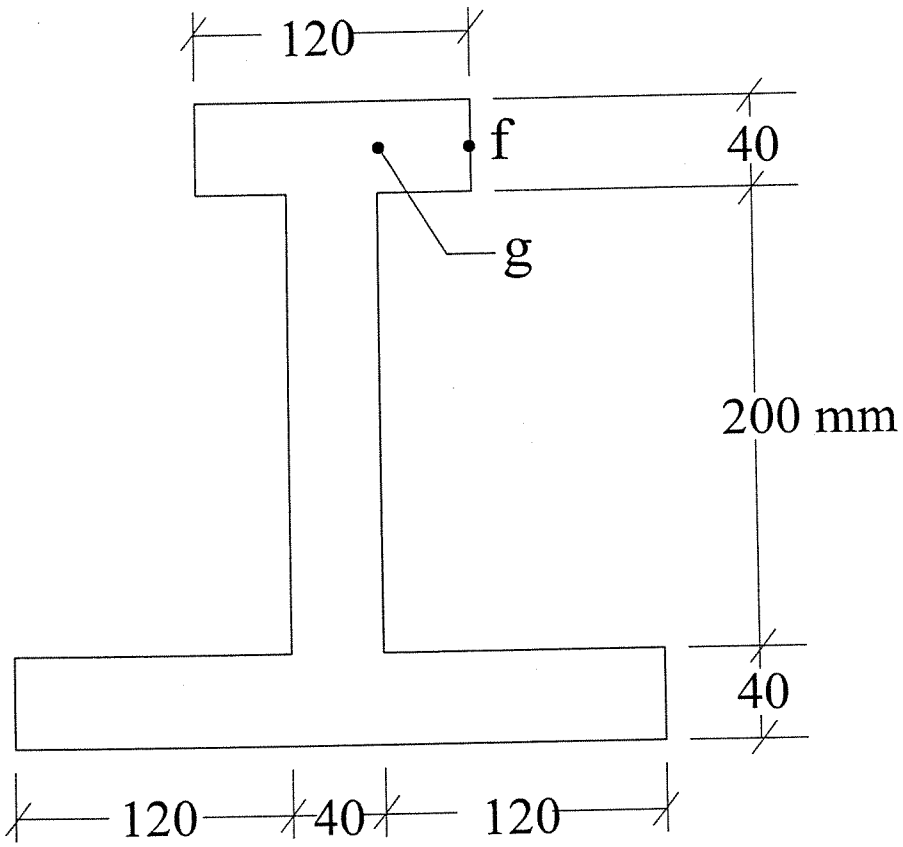
Note that **no credit** will be given for a solution using the principle of superposition, when combinations of existing solutions are used to find an answer.



**Question 2**: The simply supported beam from Question 1 has a 4 m span with a 2 m overhang, and supports a uniformly distributed load of 8 kN/m in addition to a concentrated load of 50 kN at the end of the overhang. Assume an elastic modulus of E = 200 GPa and yield stress of $\sigma_y = 350$ MPa.

[18 marks] (a) determine the maximum normal stress and maximum shear stress in the beam.

[2 marks] (b) calculate the maximum shear stress at the points f and g indicated on the cross-section.

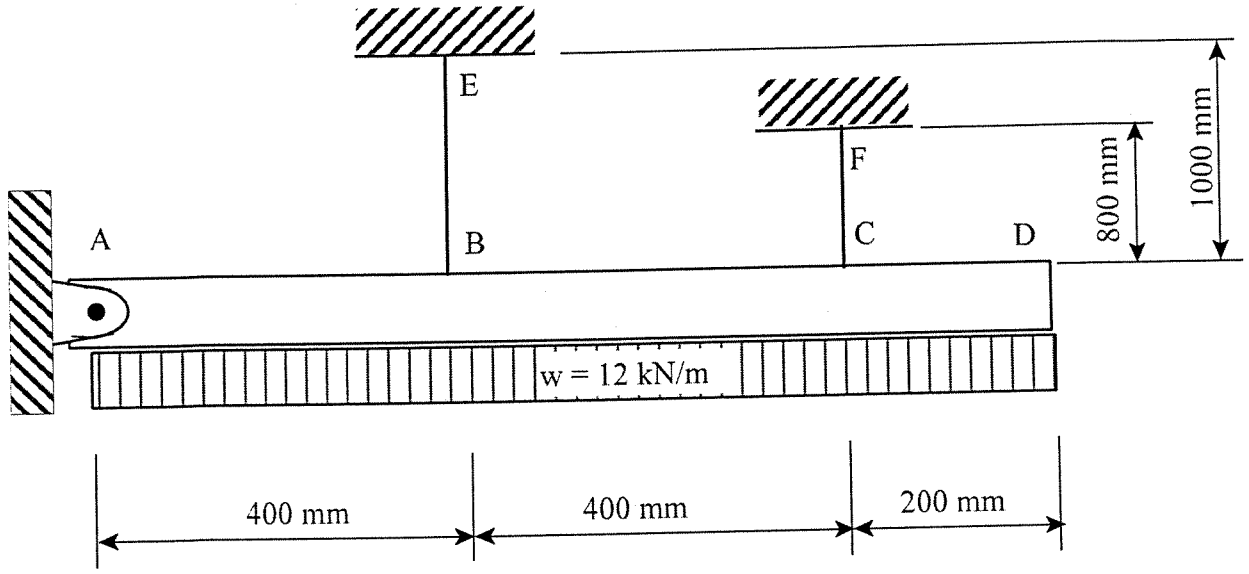


**Question 3**: A distributed load of $w = 12$ kN/m is placed on a rigid bar that is supported by a pin at A and two steel wires at B and C. Both wires have a diameter of 5 mm but different lengths as shown. The yield stress for the wires is $\sigma_y = 400$ MPa and the elastic modulus E = 200 GPa.

[12 marks] (i) determine the force in each of the two wires,

[4 marks] (ii) find the corresponding displacement at the end of the rigid bar (point D), and

[4 marks] (iii) compute the shear stress in the bolt at the pinned connection A, assuming that this bolt has a diameter of 25 mm and is in double shear.

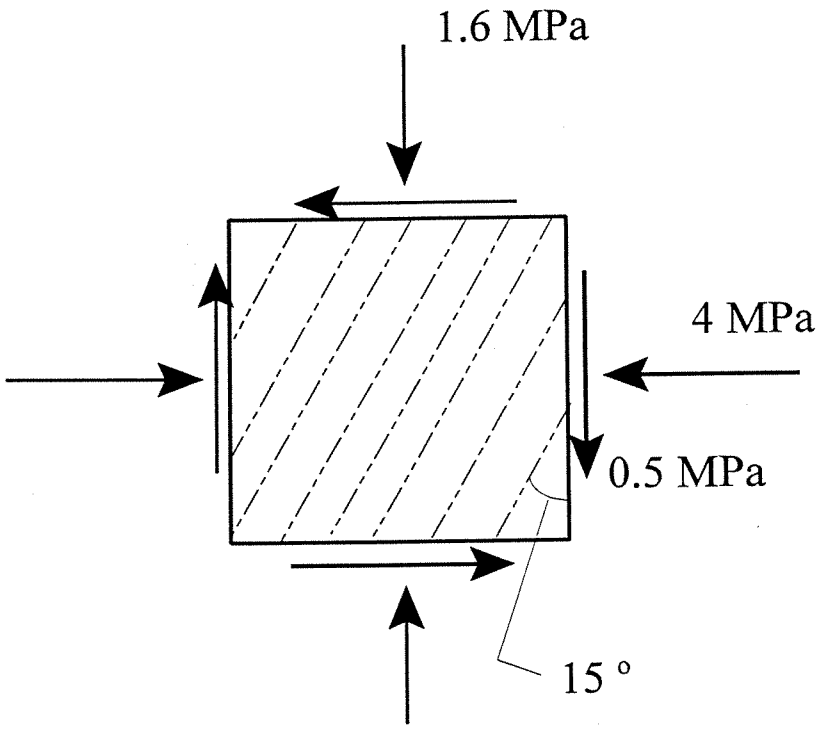


**Question 4:** The grain of a wooden member forms an angle of 15 ° with the vertical, and is subjected to the state of stress as shown below.

[18 marks] Use the Mohr's circle solution (*not* the transformation equations) to determine the normal stress perpendicular to the grain and the in-plane shear stresses acting along the grain. Show your answer on an inclined element.

[2 marks] Why is it necessary to calculate the stress acting along the grain?

Note that credit will **only** be given for a **solution using Mohr's circle**. Stress transformation equations can only be used to check your answer.

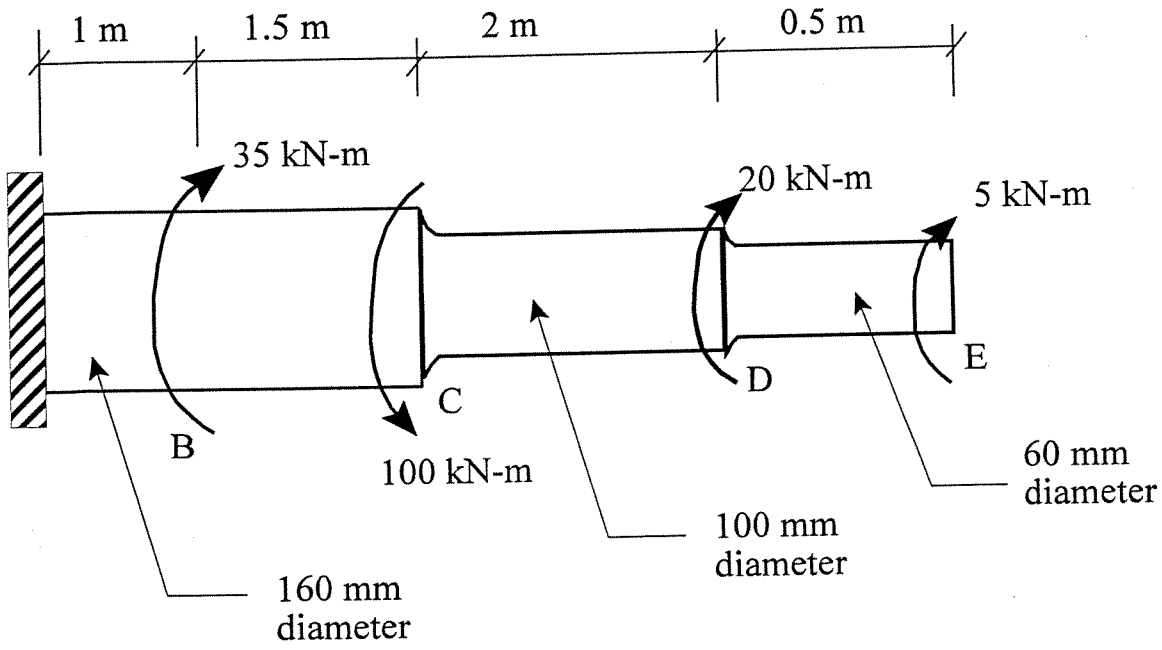


**Question 5:** A solid stepped shaft with a shear modulus of G = 80 GPa and yield stress of $\tau_y$ = 150 MPa has the dimensions shown. The applied torques are as indicated in the figure.

[12 marks] (i) determine the maximum shear stress in the shaft, and sketch the corresponding variation of shear stress along the shaft radius.

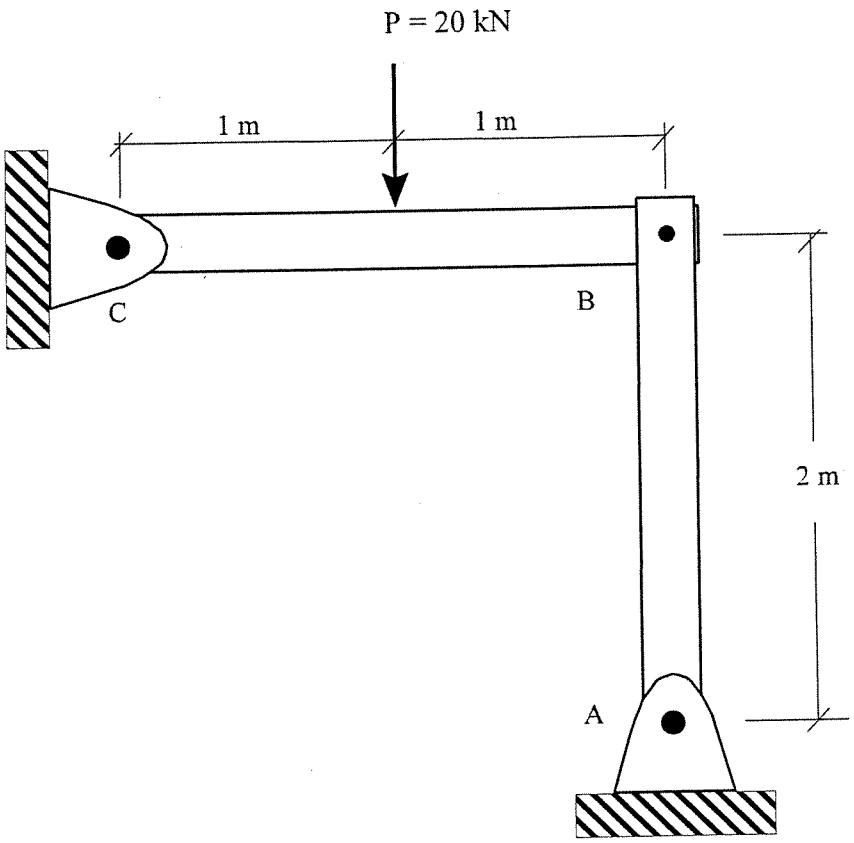
[6 marks] (ii) find the angle of twist at the end of the shaft and give your answer in degrees.

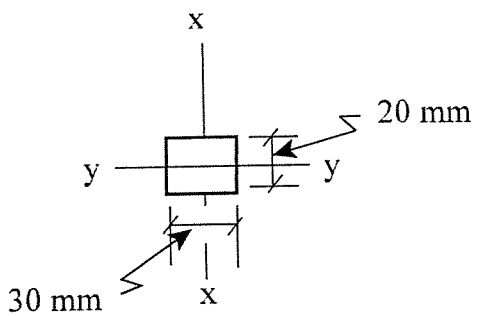
[2 marks] (iii) indicate whether the shaft will fail, assuming that the step in the shaft at C and D is constructed with a fillet having a radius sufficient to reduce the torsional stress concentration factor to a value of 1.3.



**Question 6**: Determine if the frame can support a load of P = 20 kN if the factor of safety with respect to buckling of member AB is 3. Assume that AB is made of steel and is pinned at its ends for x-x axis buckling and fixed at its ends for y-y axis buckling. E = 200 GPa and $\sigma_y$ = 360 MPa.

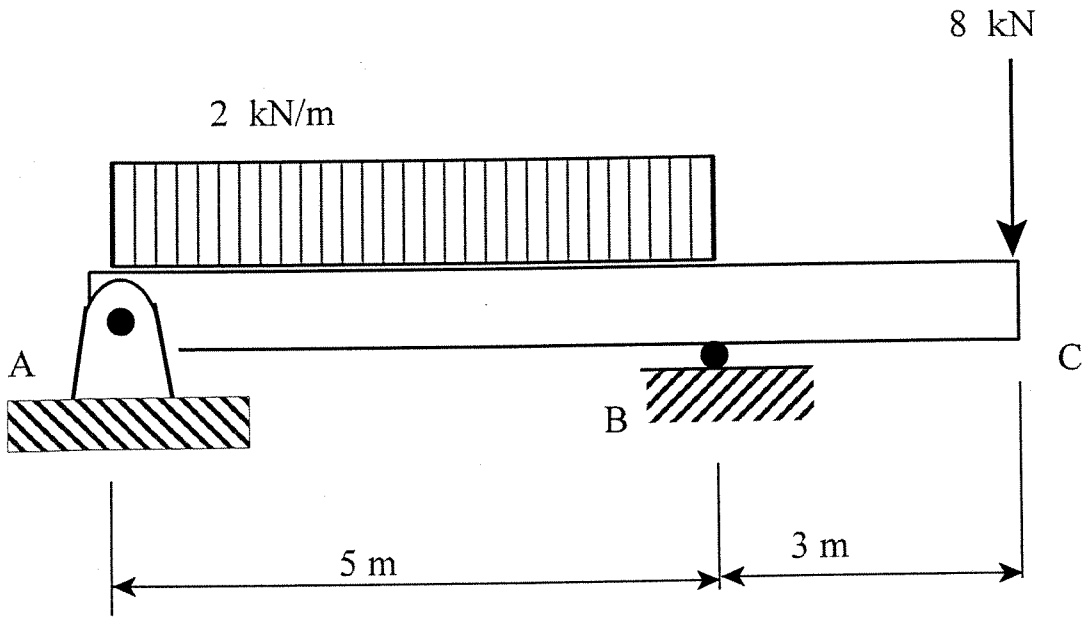
[20 marks]



**Question 7** A beam with constant EI is subjected to the loading shown.

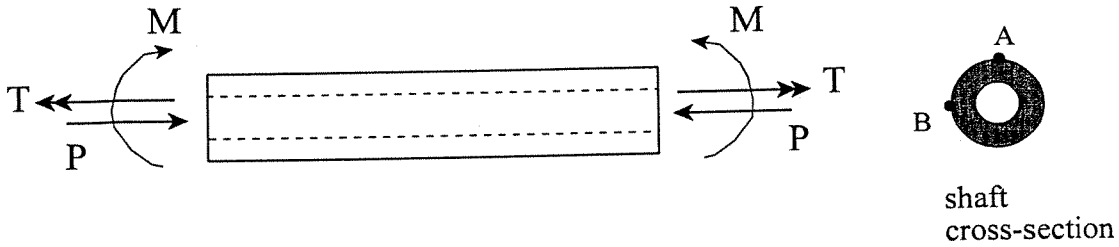
[20 marks] Using the method of integration, determine the slope at A, deflection at C, and sketch the deflected shape of the structure.




Note: since your answer depends on having the correct expression for the bending moment M(x), it is important that you set this problem up correctly by calculating the correct support reaction forces.

**Question 8:** A generator shaft of hollow circular cross-section (outside diameter of 200 mm and inside diameter of 160 mm) is subjected to the combined action of a torque T = 25 kN-m , axial compressive load P = 725 kN, and moment M = 5 kN-m as indicated in the figure below.

[20 marks] Determine the stress components on an element of material located at the outside surface of the shaft at points A and B.




shaft
cross-section

Note: $A_{circle} = \pi r^2$ and $I_{circle} = \pi r^4 / 4$