National Exams May 2002

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:

   - Mechanics of Materials textbook by R.C. Hibbeler
     (or equivalent textbook based on the course outline)

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.

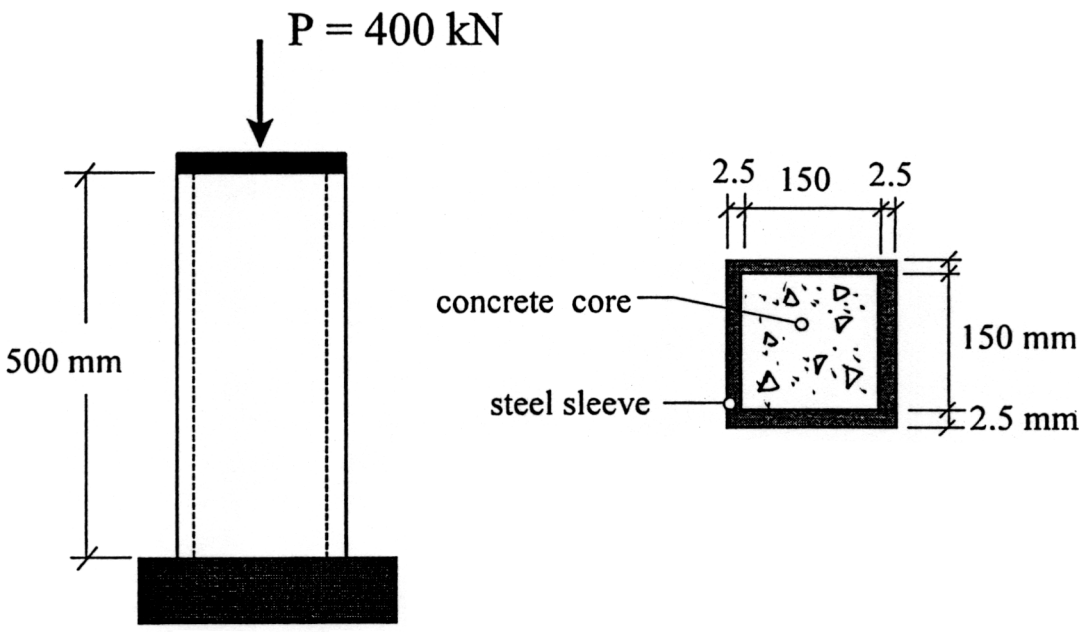
Question 1

A short column consists of a square concrete core (150 mm x 150 mm) and an outer steel sleeve (2.5 mm wall thickness) with the dimensions given. A load of P = 400 kN is applied to the composite column through a rigid steel bearing plate placed on top of the column as shown below. The structural steel has an allowable stress of 175 MPa and elastic modulus of 200 GPa, while the concrete has an allowable stress of 20 MPa and modulus of elasticity equal to 16 GPa. Determine

[13 marks] (i) the forces carried by the concrete core and steel sleeve,

[4 marks] (ii) the corresponding displacement of the column, and

[3 marks] (iii) the maximum allowable load that can be carried by the column



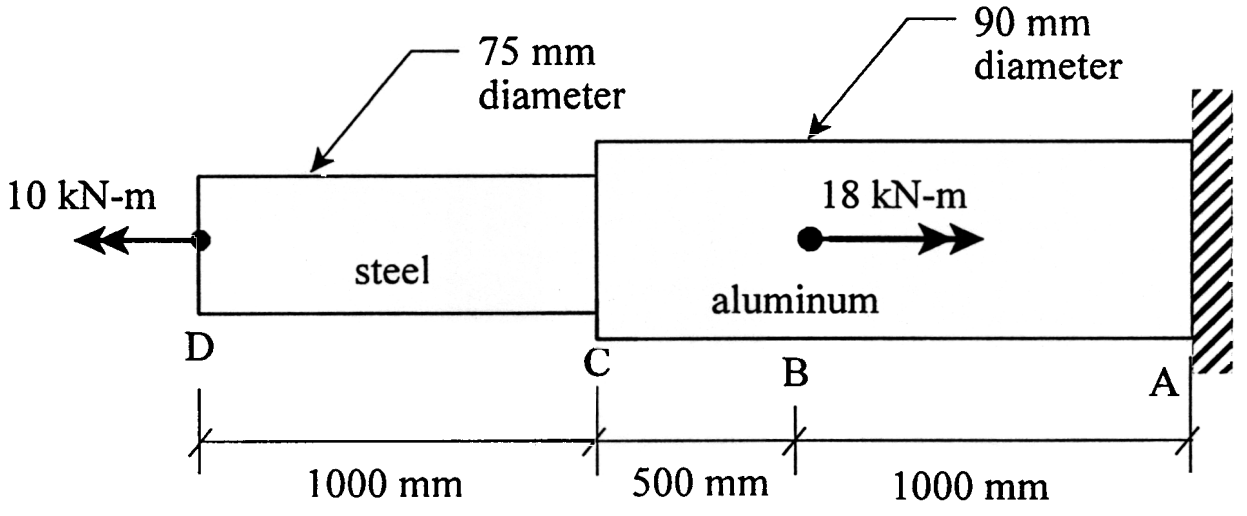
Question 2

A solid stepped shaft is made of steel (G = 80 GPa) and aluminum (G = 25 GPa). Two torques are applied to the shaft as shown, with the dimensions (diameter and length) given. The steel has a yield stress of τ_y = 150 MPa and the aluminum has a yield stress of τ_y = 100 MPa.

[5 marks] (i) draw a torque force diagram for this shaft (that is, show the variation of internal torque along the length of the shaft)

[10 marks] (ii) determine the maximum shear stress in the shaft for each material (steel and aluminum), and sketch the corresponding variation of shear stress along the shaft radius for each case

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

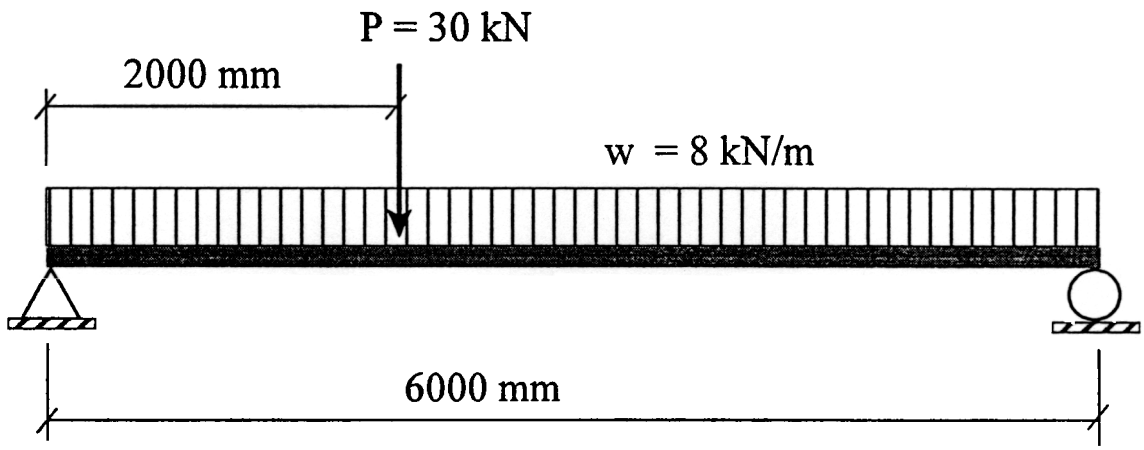


Question 3

[20 marks] Construct the shear force and bending moment diagrams for the simply supported beam which is subjected to both a uniformly distributed load (w = 8 kN/m) and a concentrated load (P = 30 kN) as indicated.

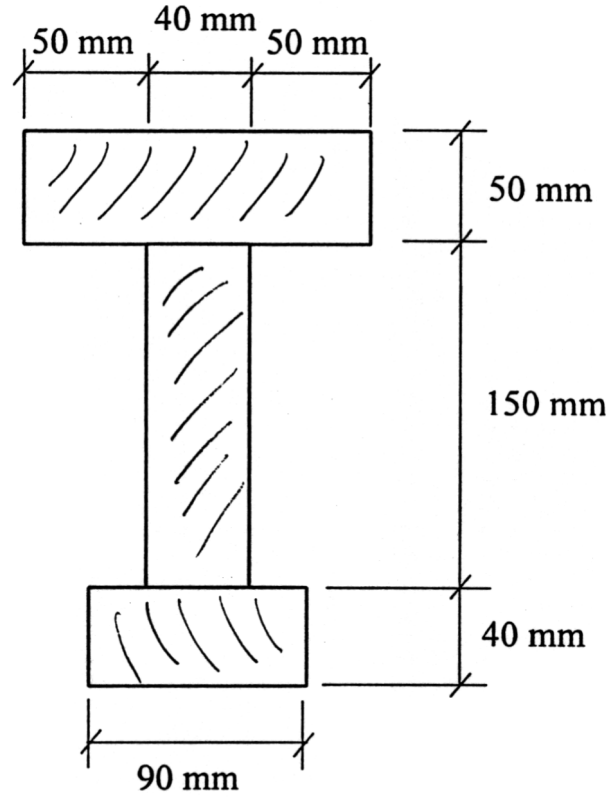
Determine the shear and bending moment throughout the beam as a function of x. That is, give expressions for V(x) and M(x), and draw the corresponding shear force and bending moment diagrams. Remember to label all critical points and show your work by indicating exactly how you obtained your answers.

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



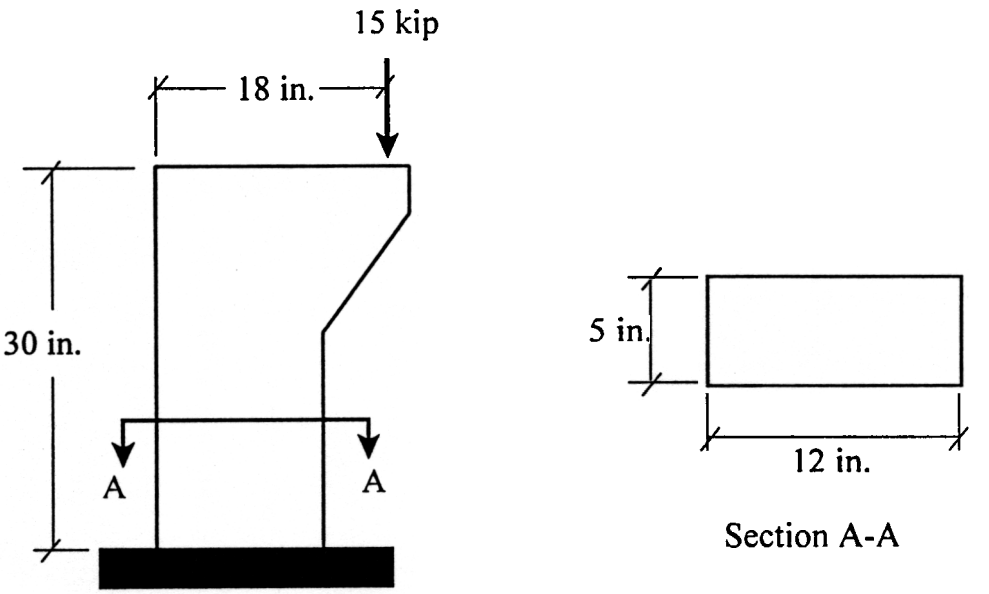
Question 4

[20 marks] A wood beam is made by gluing together three planks to form a built up section as shown in the figure below. The beam is simply supported and spans 3 m, with a concentrated load of P = 10 kN applied at midspan. Determine whether the beam will fail given allowable stresses for the wood of σ_{all} = 12 MPa and τ_{all} = 1000 kPa, while the allowable shear stress for the glue joints is given as τ_{all} = 650 kPa.



Question 5

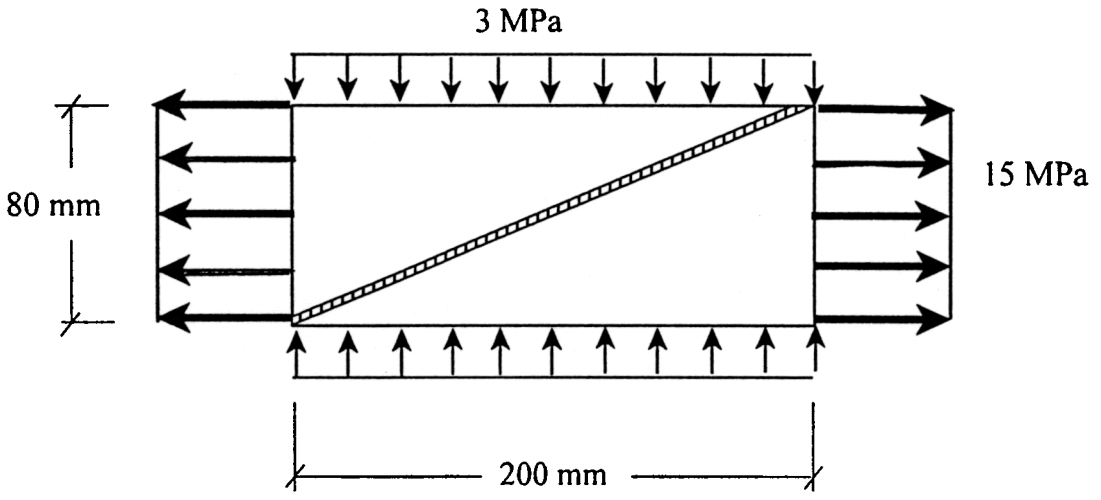
[20 marks] The pier below has a rectangular cross-section and supports a 15 kip load. Determine the distribution of normal stress at section A-A.



Question 6

[20 marks] A thin rectangular plate with in-plane dimensions of 80 mm x 200 mm is formed by welding two pieces of triangular plate as shown in the figure below. The plate is subjected to a compressive stress of 3 MPa in the short direction and a tensile stress of 15 MPa in the long direction. Use Mohr's circle to determine the stresses in the weld. Make sure to show your answer on a properly orientated element.

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.

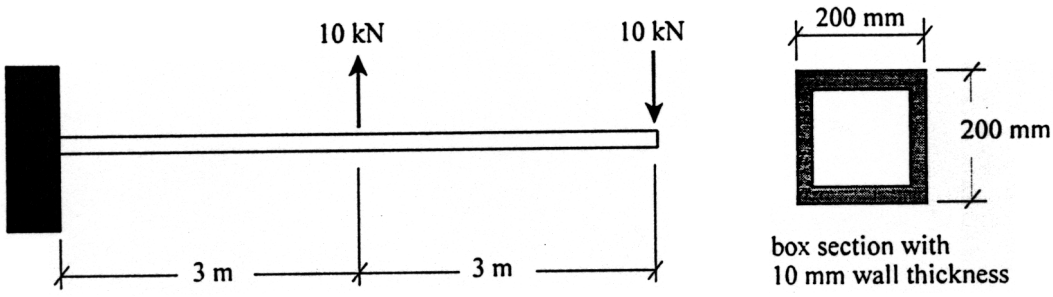


Question 7

[20 marks] A 6 m long cantilever beam is subjected to two 10 kN concentrated loads acting in opposite directions as shown in the figure below. The beam is made of a hollow steel box section (with a 10 mm wall thickness) having the dimensions given.

Using the method of integration, determine the vertical deflection and slope at the free end of the beam.

Does this beam satisfy deflection criteria given that the maximum allowable deflection is equal to L/180 for a structural steel cantilever beam?



Question 8

[20 marks] The horizontal member ABC supports a uniformly distributed load of 30 kN/m and is pin-supported at A and B. The inclined member DB is a structural steel pipe with an outside diameter of 100 mm. Assume that this compression member is pinned at both ends and consider in-plane buckling only.

Determine the wall thickness needed for the steel pipe in order to prevent column buckling. Use a safety factor with respect to buckling of FS = 3, and assume that the allowable normal stress in the steel σ_{all} = 175 MPa.