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UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING
FINAL EXAMINATIONS, DECEMBER 2001

First Year - Program 5

CIV 102H1F - STRUCTURES AND MATERIALS

Examiners - M.P. Collins and W.M. Onsongo

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2	
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4	
Total	

Permissible Aids: notebook, calculator and drafting instruments

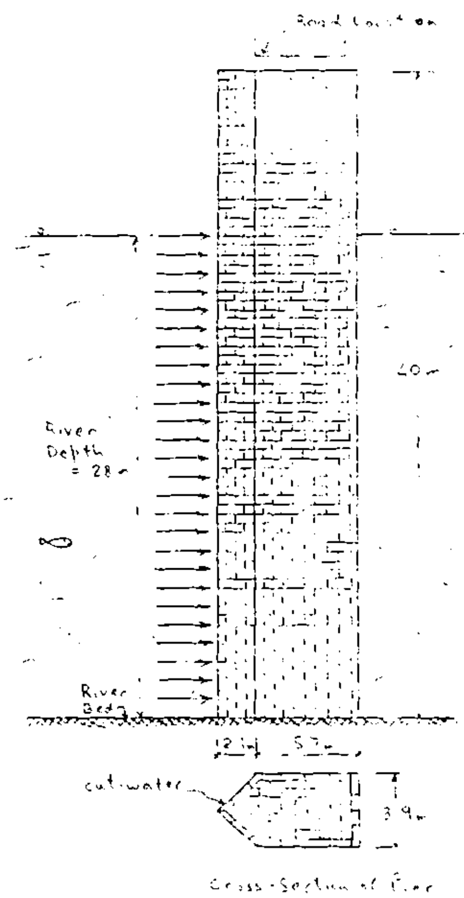
1. Through the miracle of time travel you find yourself in Spain during Trajan's reign. You are assisting Caius Julius Lacer design his great bridge across the Tagus River. He is concerned that during construction of the bridge, when the granite block piers are standing alone, a severe spring flood may damage or even destroy these stone towers. He asks you to check the tallest central pier for a river depth of 28 m and a river speed of 6 m/sec.

5 mks (a) If the granite blocks weigh 26 kN/m^3 in air, what will be the uniform compressive stress in the masonry at the base of the 40 m high pier caused by self weight when the river depth is 3 m?

5 mks (b) If the sharp "cut-water" on the pier reduces the drag coefficient to 0.85 what will be the uniform horizontal pressure caused by the 6 m/sec river velocity? Water has a density of 1000 kg/m^3.

10 mks (c) What is the moment at the base of the tower caused by the water pressure? Will this moment cause the blocks on the upstream side of the pier to separate?

5 mks (d) Estimate the river velocity, at a river depth of 28 m, which would destroy this stone block bridge pier.

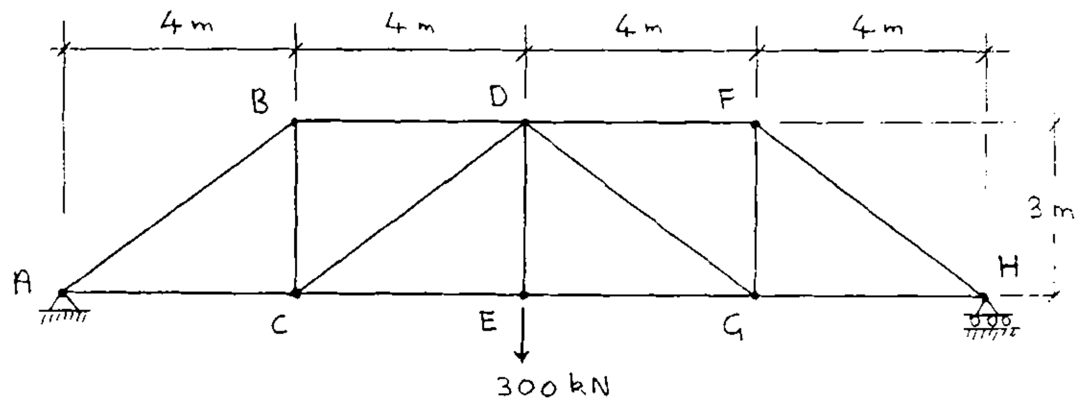


2. The steel truss shown below supports a point load of 300 kN applied at joint E.

10 mks (a) Calculate the axial force in each member of the truss due to the 300 kN load. Write your calculated forces adjacent to the appropriate members in the sketch below. Use the convention +ve for tension and −ve for compression.

7 mks (b) If all members of the truss are made from the same hollow structural section, namely HSS 152 × 152 × 4.8, using a steel with a yield stress of 350 MPa, are the truss members safe under the 300 kN load? At what value of load at joint E will the truss be on the boundary between safe and unsafe?

8 mks (c) Calculate the deflection of joint E due to the 300 kN load.



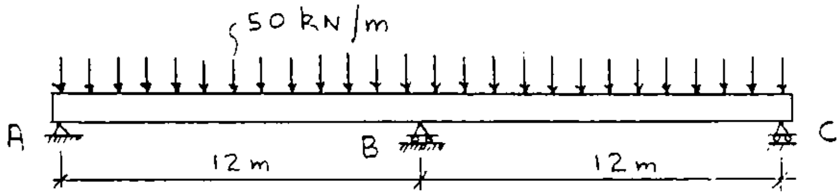
3. The W610 × 241 wide flange rolled steel beam shown below is continuous over two 12 m spans and supports a uniformly distributed load, which includes the beam's self weight, of 50 kN/m. The total downwards load of 1200 kN is resisted by the three rigid supports at A, B and C. To find out how much of the load is resisted by support B we must consider deformations.

5 mks (a) Calculate how far down point B would move if the support at B was removed. That is, find the midspan deflection of a 24 m span beam supported at A and C due to the downward load of 50 kN/m. Assume $E = 200000$ MPa.

5 mks (b) Calculate how far up joint B would move due to a 600 kN point load applied at B. That is, find the midspan deflection of a 24 m span beam supported at A and C due to an upwards point load of 600 kN applied at midspan.

5 mks (c) The actual deflection of point B is zero. Hence, the downwards deflection due to the 50 kN/m load must equal the upwards deflection due to the value of the support force at B. Is the support force at B equal to 600 kN? If not, what is the correct value of the support force at B?

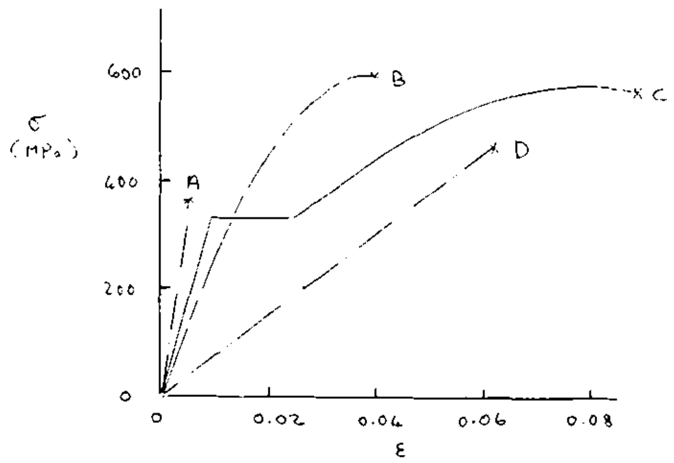
10 mks (d) Draw the shear force and bending moment diagrams for the two span beam. Calculate the highest tensile stress in the steel beam.



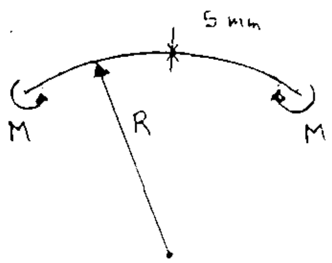
4. Display your understanding of structures and materials by making brief, insightful comments, illustrated where appropriate by calculations, on the following topics, issues, quotations or questions.

5 mks (a) Shown below are the stress-strain curves of four different materials. Based on these curves rank materials A, B, C and D on the basis of strength, stiffness, resilience and toughness.

Strongest					Weakest
Stiffest					Most Flexible
Most Resilient					Least Resilient
Toughest					Most Brittle



5 mks (b) To illustrate the concept of bending a professor uses a wooden metre stick 5 mm thick. If the wood fails at 80 MPa and E equals 12000 MPa, what is the smallest radius of the circular arc into which the stick can be bent just prior to failure?



5 mks (c) "firmitas, utilitas, venustas"

5 mks (d) "The Firth of Forth Bridge is the clumsiest structures ever designed by man … an American would have taken that bridge with the amount of money that was appropriated and would have turned back 50% to the owners."

5 mks (e) The buckling load of a long, thin plate with hinged edges (held against displacement) is

$$P_{cr} = \frac{4\pi^2 E}{12(b/t)^2} bt$$

For an aircraft structure a 3 m long and 1 m wide, thin plate with hinged edges is required to safely transmit a compressive force of 100 kN. What is the minimum safe thickness for an aluminium plate? What is the minimum safe thickness for a spruce plate? Which plate weighs less?