National Exams December 2008

**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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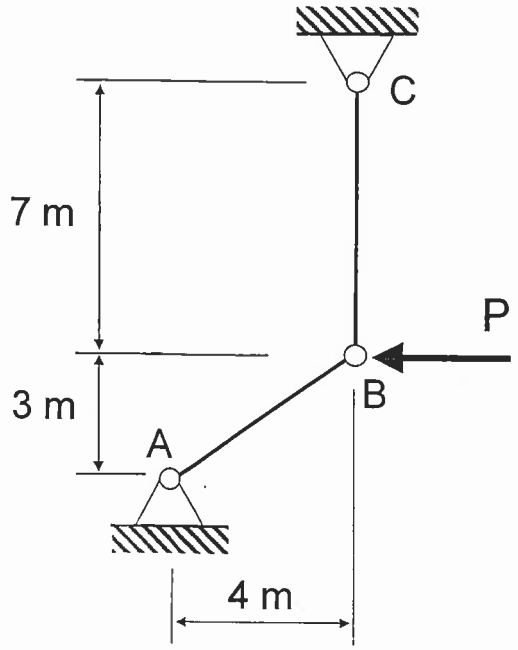
**Question 1:** A simple pin connected truss shown below is made of 80 mm diameter rods and supports a horizontal load P. The two rods are made of steel with a yield strength of 350 MPa and elastic modulus of 200 GPa.

[20 marks] Determine the largest load P the structure can support.

Consider in-plane buckling only and use a factor of safety of 2 for the Euler buckling load. The safety factor for yielding of the steel is 1.5.



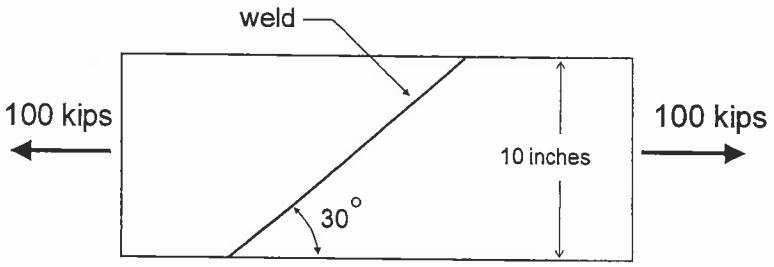

Note: $A_{circle} = \pi r^2$ and $I_{circle} = \pi r^4 / 4$

**Question 2:** Two steel plates 10 inches wide and ½ inch in thickness are welded together at an angle of 30 degrees to the horizontal axis as shown. The welded plate assembly resists an axial load of 100 kips.

[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.



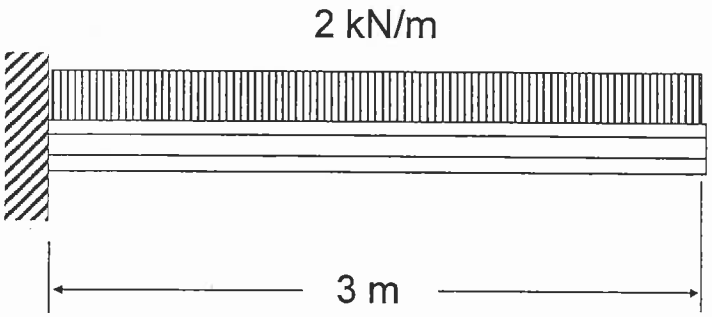

1 kip = 1000 lbs

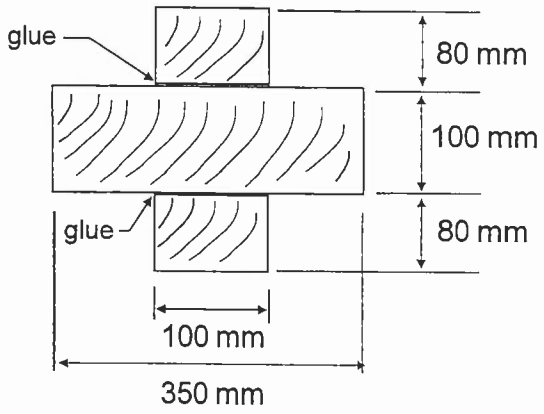
Note that credit will **only** be given for a **solution using Mohr's circle**. This means that you need to draw a Mohr's circle based on the stress components given in this problem. Remember to show numbers on your circle. Your **calculations** must be based on the geometry of your circle. So use your 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 3:** A cantilevered beam (fixed at the base on the left side) supports a uniformly distributed load of 2 kN/m. The beam is made of wood and built up with three boards that are glued together as shown in the cross-section. The wood has an allowable normal stress of 8 MPa, allowable shear stress of 1 MPa and elastic modulus of 10 GPa. The glue can withstand an allowable shear stress of 1.2 MPa.

[18 marks] Determine whether the beam can support the loading shown given that the maximum moment and shear are at the base of the cantilever.

[2 marks] Explain the advantage of gluing the three wooden pieces together.

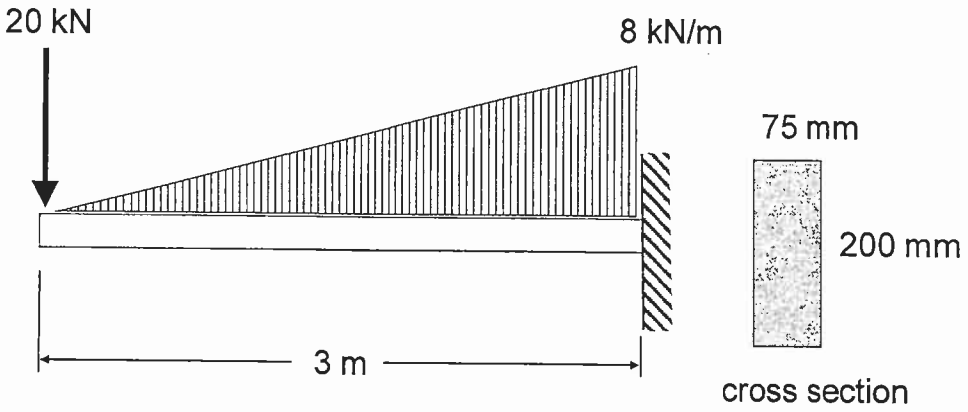


**Question 4:** A cantilevered beam (fixed at the base) supports a triangularly distributed load (with a maximum intensity of 8 kN/m) and concentrated load of 20 kN as shown. The beam is rectangular in cross-section with a 75 mm width and 200 mm depth. The beam is made from steel having an allowable normal stress of 240 MPa and elastic modulus of 200 GPa.

[18 marks] (a) determine the deflection and slope at the free end of the beam using the method of integration.

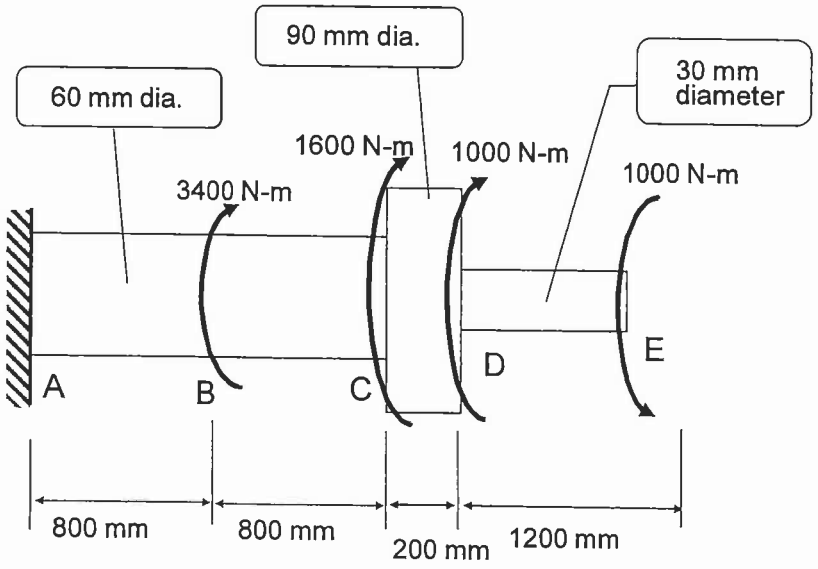
[2 marks] (b) recognizing that computation of deflection is a lengthy process using the method of integration, explain how you would compute the deflection of this beam in a design situation.



**Question 5:** A circular stepped shaft is subjected to four torques acting at B, C, D and E as shown. The entire shaft is made of steel with G = 80 GPa and a yield stress of 200 MPa. 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.

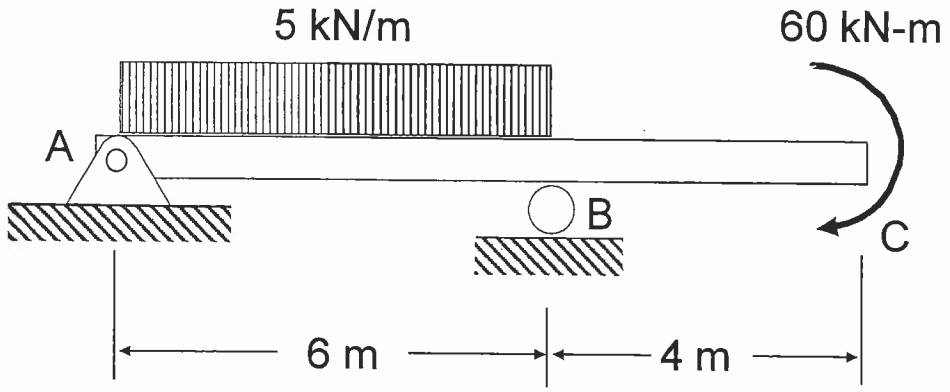
[8 marks] (b) find the angle of twist at the end of the shaft (point E) and give your answer in degrees.



**Question 6:** A simply supported beam supports a uniformly distributed load of 5 kN/m acting over the simple span and a concentrated moment of 60 kN-m applied at the end of the overhang. The beam is a wide flange cross-section using steel with an allowable normal stress of 260 MPa and allowable shear stress of 75 MPa. The elastic modulus of steel is 200 GPa.

[20 marks] 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.

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).

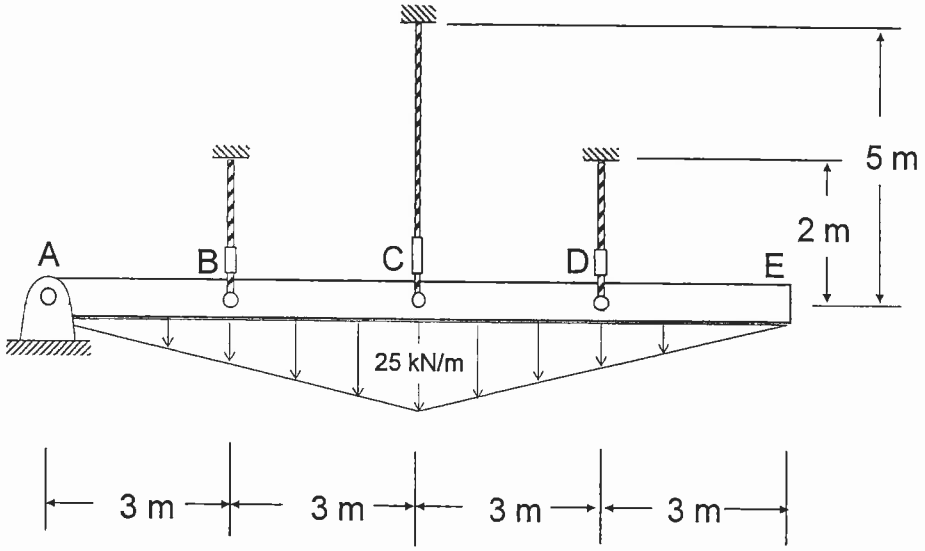
**No credit** will be given for a solution using the principle of superposition, when combinations of existing solutions are used to find an answer.

**Question 7:** A rigid bar is supported by a 19 mm diameter pin at A and three 12 mm diameter cables at points B, C and D. The cables at B and D have a length of 2 m while the cable at C has a length of 5 m. All three cables are made of high strength steel with an elastic modulus of 200 GPa and yield stress of 800 MPa. Given that the bar is loaded with a triangularly distributed load having a maximum intensity of 25 kN/m, do the following:

[12 marks] (a) find the forces developed in each cable

[4 marks] (b) determine the corresponding displacement at the end of the bar (point E)

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

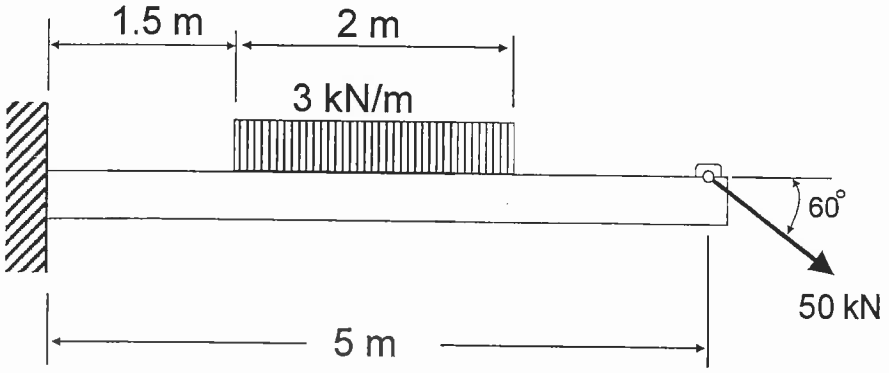


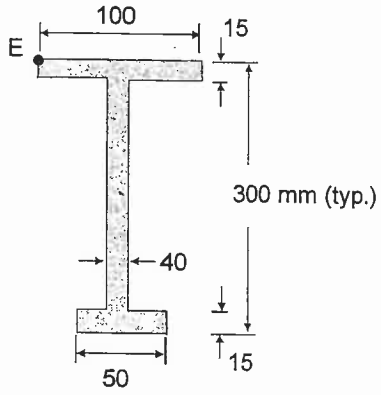
**Question 8:** A cantilevered beam (fixed at the base) is loaded with a uniformly distributed load over part of the span in addition to an inclined load at the end of the member as shown.

[20 marks] (a) Determine the distribution of normal stress at the base of the cantilever and sketch the distribution of stress over the cross-section of the member.

[6 marks] (b) Determine the maximum shear stress in the cross-section at the base of the cantilever.

[2 marks] (c) Determine the shear stress at point E on the cross section at the base of the cantilever.




beam cross-section
(all dimensions in mm)