The University of Sydney
Department of Civil Engineering

<u>CIVL2201 Structural Mechanics</u>

Semester 1, 2001

Time Allowed: 3 hours

<u>Instructions to Candidates</u>

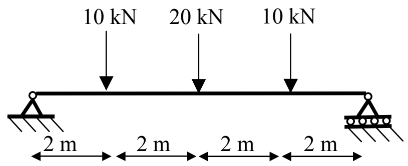
1) **This paper contains 3 parts: A, B, & C. Part A has 4 questions (Q 1 – Q 4, 35 %), Part B has 4 questions (Q 5 – Q 8, 50 %), and Part C has 2 questions (Q 9 - Q 10, 15 %).**
2) All questions may be attempted.
3) Suitable working, diagrams and explanations are required for each question.
4) Marks may be deducted for work that is not satisfactorily set out.
5) **Units are important and answers with incorrect units will not be awarded full marks.**
6) Programmable and non-programmable calculators may be used.
7) Read the questions carefully before answering.
8) **Annotated copies of the "Structural Mechanics Lecture Notes" may be taken into the exam, but no other written material is permitted.**
9) Students are reminded that satisfactory exam performance is an essential criterion in this course, and a mark of 65 % is required in Part A, and 50 % is required in Part B.

PART A – BASIC QUESTIONS
65 % is required in this section to achieve satisfactory examination performance

1) The diagram below shows a simply supported beam with three point loads.

    a) Draw the free body diagram of the beam clearly showing the support reactions. Calculate the value of the support reactions.

    b) Draw the bending moment diagram (BMD) and shear force diagram (SFD). Clearly indicate the values of bending moment and shear force at each load point and the supports. What are the values and locations of the maximum and minimum bending moment and shear force?



<u>Question 1 is worth 10 marks</u>

2) Briefly explain what is meant by the term *elastic behaviour* with particular reference to the content of this course. Diagram(s) and example(s) would greatly assist the answer. If possible, incorporate observations made during the laboratory session. An answer of approximately 100-150 words (about ½ page in the exam booklet assuming 7 – 8 words per line) plus diagrams is expected, but copying extracts from the lecture notes will receive no marks.

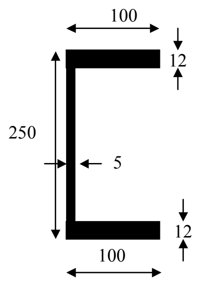
<u>Question 2 is worth 9 marks</u>

3) Consider the following channel section, the dimensions of which are shown in the diagram. The section is made from aluminium, which has a modulus of elasticity of $E_{aluminium}$ = 70000 MPa.

   a) Calculate the location of the centroid.

   b) Calculate the second moment of area of the section about the horizontal centroidal axis (I_x). Give the answer in both metric and non-metric units (assume 1 inch = 25.4 mm).

   c) If the aluminium beam is replaced by steel beam with the same dimensions (E_{steel} = 200000 MPa), will the answers to a) and b) above change? No calculations are expected – a yes/no answer with an explanation is required.



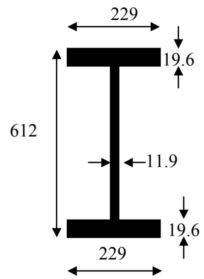
All dimensions are in mm

Question 3 is worth 9 marks

4) Consider the 610UB125 steel section which is shown below. The second moment of area about the major (horizontal) centroidal axis is $I_x = 986 \times 10^6$ mm^4. The steel has a yield stress of 300 MPa,.

   a) Calculate elastic section modulus for bending about the x – axis (Z_x).

   b) Calculate the bending moment (about the x - axis) that will cause first yield of the section.



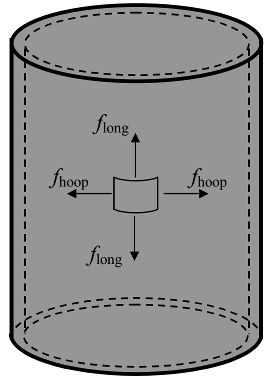
All dimensions are in mm

Question 4 is worth 7 marks

PART B – INTERMEDIATE QUESTIONS
50 % is required in this section to achieve satisfactory examination performance

5) Consider a closed cylindrical pressure vessel. The vessel has an outer diameter of 1 m and a thickness of 7.5 mm, and is subjected to an internal pressure of 15500 kPa.

Diameter = 1 m
Thickness = 7.5 mm



   a) Calculate the hoop stress and longitudinal stress experienced by a typical element within the vessel as shown in the attached diagram.

   b) Draw the Mohr's circle that represents the stresses calculated in a) above. (If you have not been able to answer part a), you may assume that f_{hoop} = 1050 MPa and f_{long} = 200 MPa. Note that these are *not* the correct answers to part a).)

   c) Assuming the pressure vessel is made from a material with yield stress f_y = 1000 MPa, determine whether the material has yielded according to both Tresca's and von Mises' yield criteria.

   d) The design engineer is concerned about the value of hoop stress in the pressure vessel, and wants to change the design of the vessel without changing the pressure. State one way in which the hoop stress could be halved without reducing the pressure in the vessel.

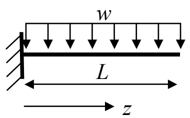
Question 5 is worth 13 marks

6) Consider the cantilever with a uniformly distributed load, magnitude w, shown below.

   a) Draw the bending moment diagram (BMD) and shear force diagram (SFD). Clearly indicate the values of bending moment and shear force at the support, midspan, and the free end.

   b) Determine a general expression for the vertical deflection at any distance z from the support, in terms of the load w, the total length L, the elastic modulus of the material E and the second moment of area of the beam (I).

   c) What is the maximum deflection of the beam?



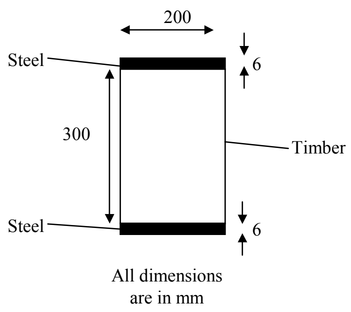
Question 6 is worth 12 marks

7) A builder strengthens a 200 mm × 300 mm timber beam by connecting 6 mm steel plates to the top and bottom of the beam as shown below. The beam can then be assumed to act compositely. The beam is subjected to a positive bending moment about the horizontal axis of 35 kNm. It can be assumed that E_{timber} = 12500 MPa and E_{steel} = 200000 MPa.

a) Draw the strain distribution across the section (values required).

b) Draw the stress distribution across the section (values required).

c) How would the answers to a) and b) above change if a moment of –35 kNm (ie a negative moment) was applied? No calculations are expected – a brief answer with an explanation is required.



Question 7 is worth 13 marks

8) An innovation in structural engineering is the Concrete Filled Double Skinned Tube (CFDST). A CFDST consists of a hollow section placed inside another larger hollow section, and the space in between filled with concrete. The inside of the inner tube is not filled. Once filled, the CFDST acts compositely. It can be assumed that $E_{concrete}$ = 40 GPa and E_{steel} = 200000 MPa and that both materials behave elastically.

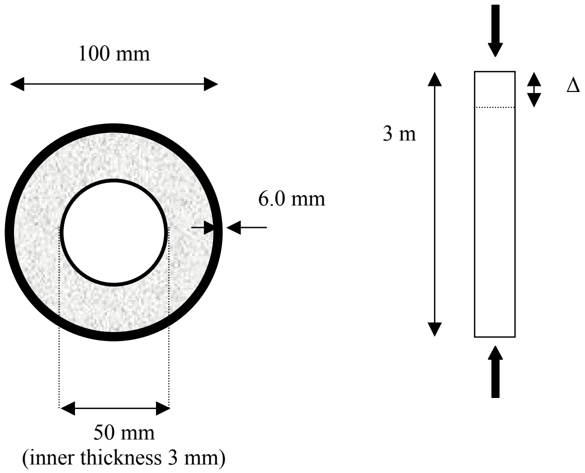
Consider the CFDST shown below. The outer tube has outer diameter 100 mm and thickness 6 mm, and the inner tube has outer diameter 50 mm and thickness 3 mm. The member is used as a column, 3 m in length, and is subjected to an axial compression. The design engineer wants to ensure that the strain in the concrete does not exceed $\varepsilon_{concrete, max}$ = 0.0022.

a) What is the strain in the steel when the concrete reaches $\varepsilon_{concrete, max}$?

b) Calculate the stresses in the steel and the concrete when the concrete reaches $\varepsilon_{concrete, max}$.

c) What is the maximum axial load the column can carry while ensuring the concrete strain does not exceed its maximum allowable value, $\varepsilon_{concrete, max}$?

d) What is the axial shortening (Δ) of the column due to this compressive load?



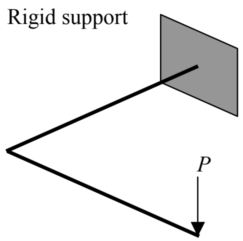
<u>Typical column cross-section</u>

Question8 is worth 12 marks

PART C – ADVANCED QUESTIONS

The questions in this section are designed for students who seek to obtain a mark of Distinction or higher. They are more difficult and will be marked using different criteria. The majority of marks will be awarded to completed questions, and only minor marks will be awarded to partially answered questions – ie it is better to complete one question fully, than half complete 2 questions.

9) The L-shaped structure is made up of two components, each of length *L*. Both beams lie in a horizontal plane and each segment is perpendicular to the adjacent segment. There is a vertical load *P* at the end of the beam. The support is completely fixed, preventing deflection in every direction, and rotation about any axis. Draw the bending moment and twisting moment diagrams for the structure.



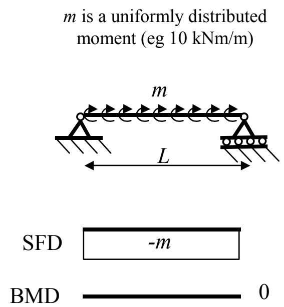
Question 9 is worth 8 marks

10) Consider the beam that was given in Q1)h) of Tutorial 2 and given below. The shear force diagram and bending moment diagram are also shown.

a) Draw the free body diagram of the beam and determine the reactions.

b) By making an arbitrary cut at any cross-section in the beam, and releasing the internal actions, verify that the SFD and BMD given are correct.

c) The moment and shear force do not satisfy the theory developed in Section 3.5 of the lecture notes: that $V = dM/dz$. How can this be accounted for? If possible, derive an alternate differential equation that will explain this behaviour. [*Hint*: consider any assumptions made in the Lecture Notes – are they applicable in this case?].



Question 10 is worth 7 marks

This is the end of the examination paper.