Student Number: ________________ Name: ______________________________

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE AND ENGINEERING
FINAL EXAMINATIONS, DECEMBER 2017

CIV102H1F – Structures and Materials-
An Introduction to Engineering Design

Examiner --- M.P.Collins

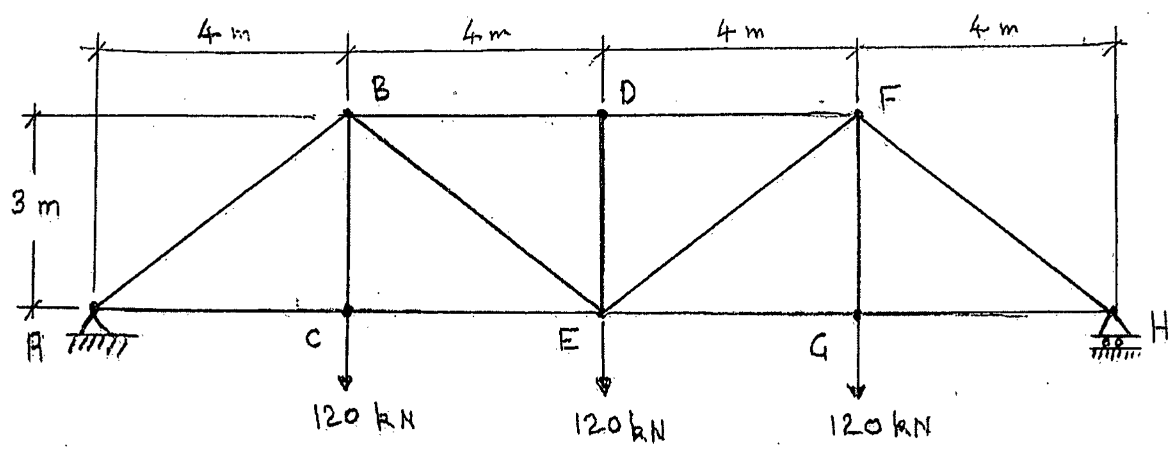
Permissible Aids: Notebook, calculator and set-square.

| | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| Total | |

1. The truss shown below is made from steel hollow structural sections with a yield stress of 350 MPa. The truss spans 16 m and supports the three 120 kN loads shown.

1(a) Calculate the axial force in each member of the truss due to the 120 kN loads. Neatly write your calculated forces above (or for vertical members to the left of) the appropriate members in the drawing. Use the convention +ve for tension and –ve for compression. (10 marks)

1(b) All members of the truss are HSS 127 x 127 x 6.4. Is the truss safe under the 120 kN loads? Yes or no? At what value of the three equal loads will the truss be on the boundary between safe and unsafe? (6 marks)

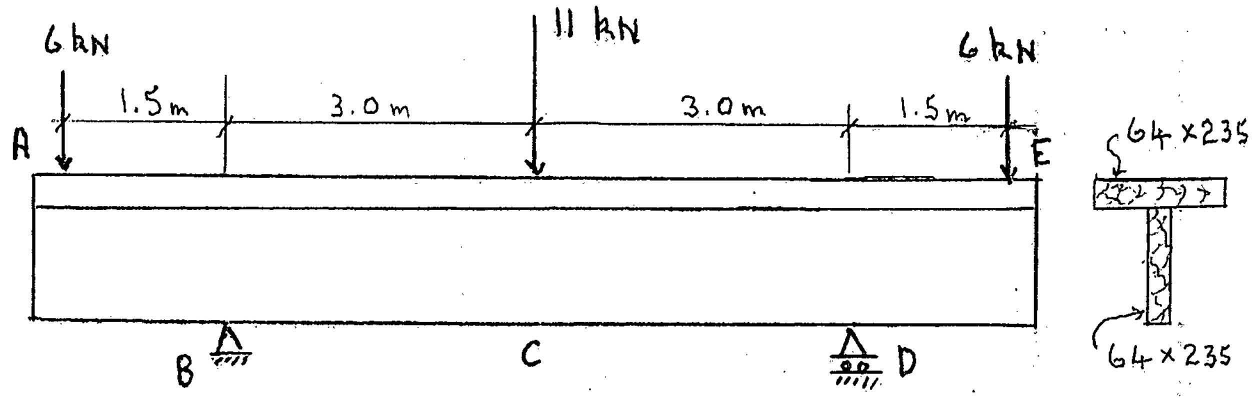


1(c). Use the method of virtual work to calculate the vertical deflection of joint **C** due to the application of the three 120 kN loads. Note that all members have an area of 2960 mm$^2$. Fill in the table below. Assume all members remain elastic and stable.
(14 marks)

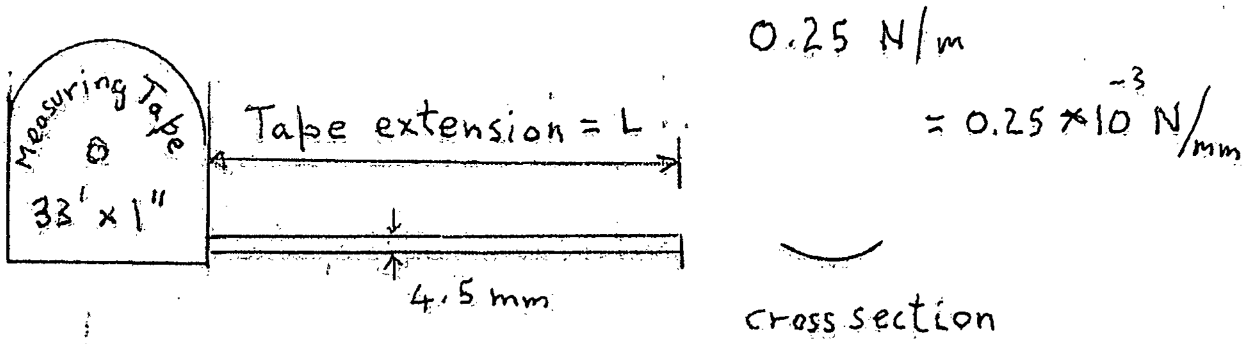
| Member | P<br>(kN) | ε<br>(mm/m) | L<br>(m) | Δ<br>(mm) | P*<br>(kN) | Work<br>(J) |
|---|---|---|---|---|---|---|
| BD<br>DF | | | | | | |
| AB<br>BE | | | | | | |
| EF<br>FH | | | | | | |
| BC<br>DE<br>FG | | | | | | |
| AC<br>CE | | | | | | |
| EG<br>GH | | | | | | |

2. The T-beam shown below has been fabricated by gluing together two 64 x 235 Hem-Fir No.1 grade sawn timber sections. The beam spans 6.0 m, has 1.5 m cantilever overhangs at each end and is subjected to the three point loads shown. These loads include allowances for the self-weight of the beam.

2(a) Draw the shear force and bending moment diagrams for the beam. Calculate and show important values. (6 marks)
2(b) Use Navier's equation to find the maximum flexural tensile stress and the maximum flexural compressive stress that occur in the beam. (7 marks)
2(c) Use Jourawski's equation to find the maximum shear stress in the beam. (4 marks)
2(d) Compare the calculated stresses in the beam with the safe stresses determined from page 190 of your notebook. Is the beam safe under these loads? (3 marks)
2(e) Determine the mid-span deflection of the beam caused by the three point loads. (10 marks)

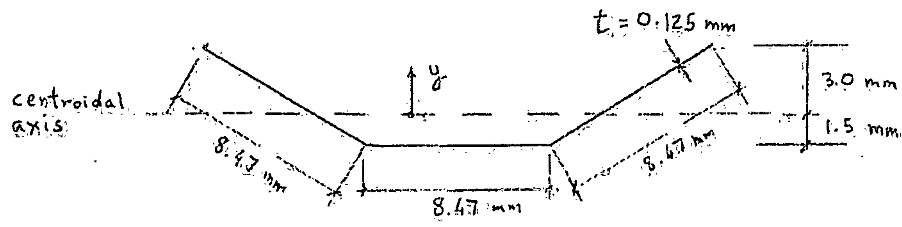


3. The cross-sectional shape of steel tape measures are designed so that the tape can be extended a convenient distance before the tape buckles under its own weight. The tape measure being discussed in this question has been made from a steel strip 10 m long, 25.4 mm wide and 0.125 mm thick. The 25.4 mm width has been curved into the arc of a circle so that the lowest fibre of steel is 4.5 mm below the uppermost fibres. The steel has a yield strength of 500 MPa, a Poissson's ratio, $\mu$, of 0.27 and E of 200 000 MPa. The steel tape weighs 0.25 Newtons per metre of length.




3(a) If the tape is extended one metre (L = 1000 mm) what will be the highest flexural compressive stress in the steel tape? The horizontal centroidal axis of the cross-section is located 1.50 mm above the lowest fibre of steel and the second moment of area, I, of this cross-section about this centroidal axis is 5.75 $mm^4$. (6 marks)

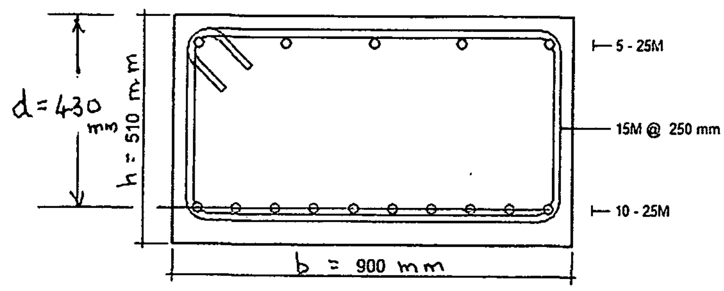
3(b) At what value of tape extension, L, will the flexural compressive stress reach the buckling stress of the steel tape? In evaluating buckling stress the actual cross-section of the steel tape can be "idealized" by the simpler cross-section shown below. (10 marks)

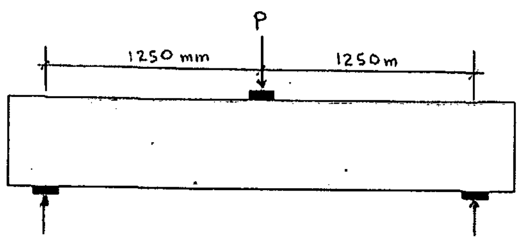



Idealized Cross Section

3(c) If the tape is turned upside down at what value of tape extension, L, will the flexural compressive stress reach the buckling stress of the steel tape? (8 marks)

4. The photo below, taken Nov.2, 2017, shows a reinforced concrete beam being loaded to failure under the Baldwin testing machine by a Point Load, P, applied at midspan as part of the MASc research project of Ms. Savannah Forest. The cross-sectional properties of this beam, shown below, are constant along the length of the beam.




The cylinder crushing strength of the concrete $f_c'$ was 40 MPa, the yield strength of the 25M longitudinal flexural reinforcement, $\sigma_y$, was 560 MPa while the yield strength of the 15M shear reinforcement was 475 MPa.

4(a) Use the procedure for "Design for moment" on page 162 of the notebook to determine the highest value of moment which can be **safely** resisted by the beam. Neglecting the self-weight of the beam what is the highest value of P which can be applied without exceeding the safe moment. (8 marks)

4(b) Use the procedure for "Design for shear" on page 162 of the notebook to determine the highest value of shear which can be **safely** resisted by the beam. Neglecting the self-weight of the beam what is the highest value of P which can be applied without exceeding the safe shear. (6 marks)

4(c) The simplified procedures for the moment and shear design of reinforced concrete incorporate safety factors by reducing the concrete contributions by a factor of 0.50, (corresponding to a factor of safety of 2.0) and by reducing the steel contributions by a factor of 0.60 (corresponding to a factor of safety of 1.67). Use your calculations from 4(a) and 4(b) and the above information on the factors of safety to predict what was the Baldwin Load which caused failure of the beam and did the beam fail in flexure or shear? (10 marks)