CIV102F Assignment # 4 – October 4-6, 2022

Due October 11-13, (before assigned tutorial), 2022

General Instructions

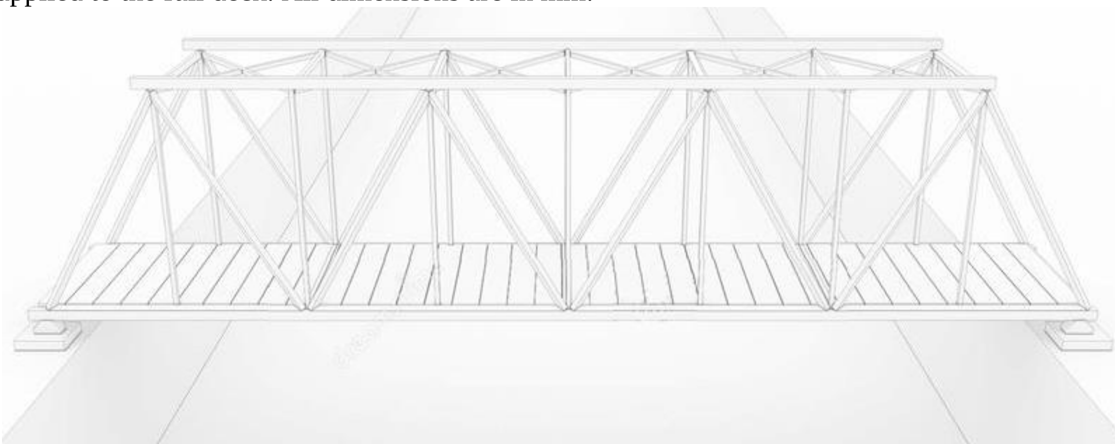
- There are five questions on this assignment. All questions must be attempted; however, only one question will be graded.
- Submissions which are incomplete and do not contain a serious attempt to solve each question will receive a grade of 0.
- Intermediate steps must be provided to explain how you arrived at your final answer. Receiving full marks requires both the correct process and answer.
- All final answers must be reported using slide-rule precision (ie, four significant figures if the first digit is a "1", three otherwise), and engineering notation for very large or very small quantities.
- Submissions must be prepared neatly and be formatted using the requirements discussed in the course syllabus. Marks will be deducted for poor presentation of work.

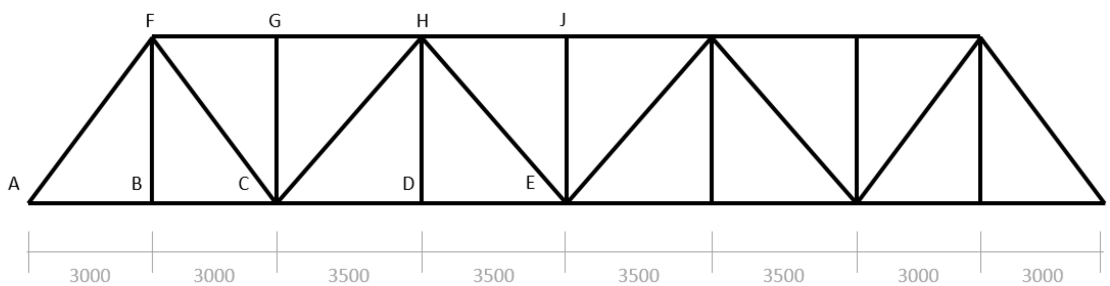
Assignment-Specific Instructions

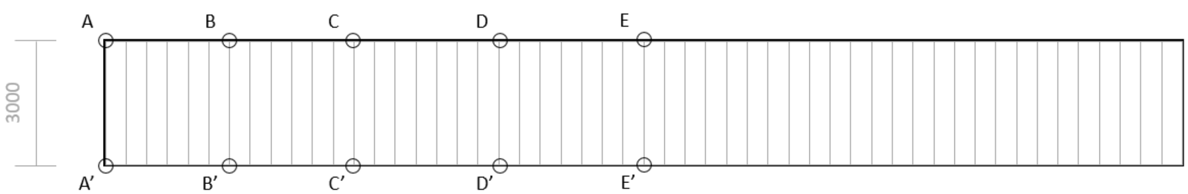
- Final answers **must** be provided in a neat sketch of each structure with the member forces written in. Tension members should be indicated as (+) and compression members should be indicated as (-)

Truss Analysis: Applied Joint Loads

1. The figure below shows a truss bridge from a 3D view, an elevation view (side view), and a plan view (floor/ceiling view). Calculate the applied joint loads at joints A to E if the bridge was carrying a uniformly distributed load of w = 9.2 kPa [kN/m^2] applied to the full deck. All dimensions are in mm.

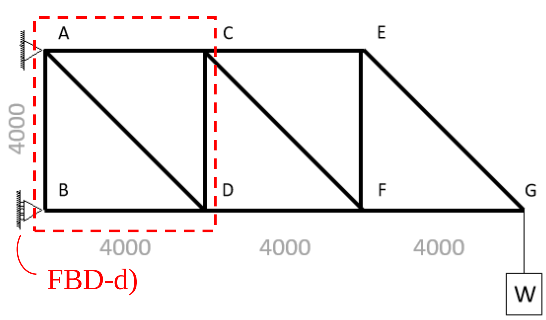






Truss Analysis: Method of Joints and Method of Sections

2. The truss structure shown below is holding a weight W = 141.4 kN. Perform the following consecutive tasks:



a) Draw a free body diagram (FBD) of the entire structure where the only forces acting on the free body are:

- the force of the weight W
- the reactions forces of the pin support at joint A
- the reaction force of the roller support at joint B

Then, solve for the reaction forces using ΣFx=0, ΣFy=0, ΣM=0

b) Draw a FBD of joint B where the only forces acting are:

- The reaction force of the roller at joint B
- The unknown member forces in members AB and BD

Then, solve for the forces in AB and BD using ΣFx=0, ΣFy=0

c) Draw a FBD of joint A and solve for the forces in member AD and AC similarly to part b)

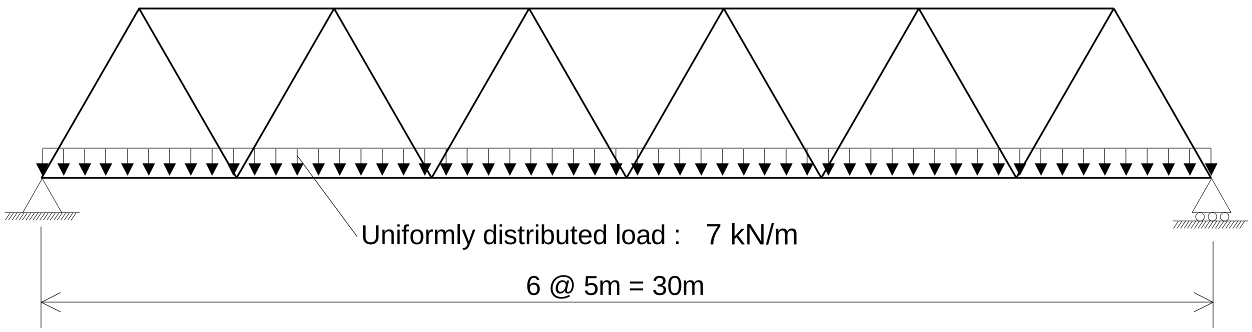
d) Draw the FBD (FBD-d shown in diagram) where the only forces acting on the free body are:

- The reaction forces at joints A and B
- The unknown member forces in member CE, CF, and DF

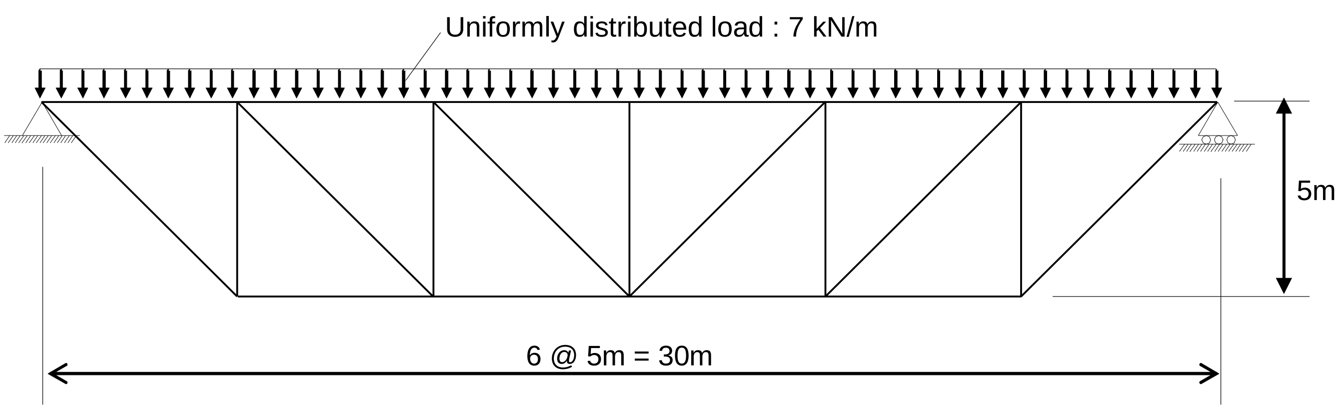
Then, solve for the forces in member CE, CF, and DF using ΣFx=0, ΣFy=0, ΣM=0

Truss Analysis

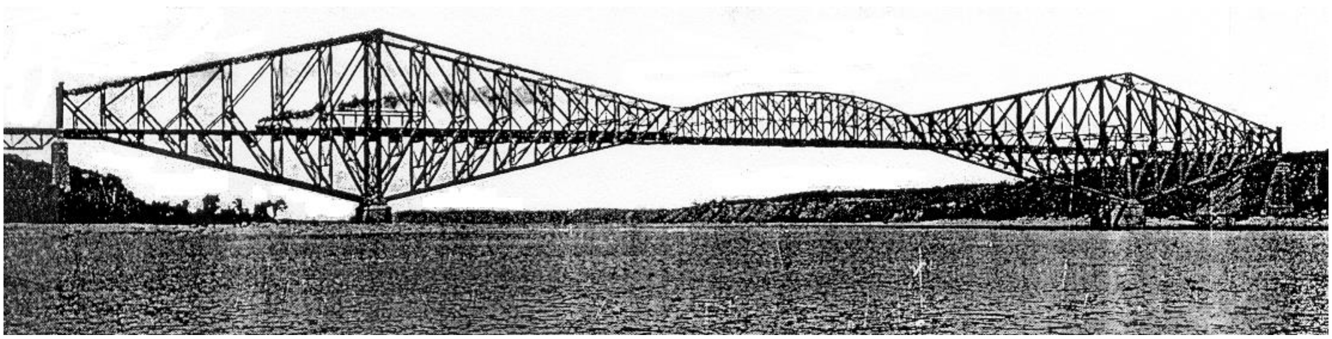
3. Calculate the applied joint loads acting on all bottom joints from the uniformly distributed load and solve for the forces in all members of the Warren truss below. All members have the same length. Truss must be solved using method of joints or method of sections. Sample calculations are only required for the first two joints or sections. Present your final member forces on a truss diagram. Denote tension forces with (+) and compression with (−).



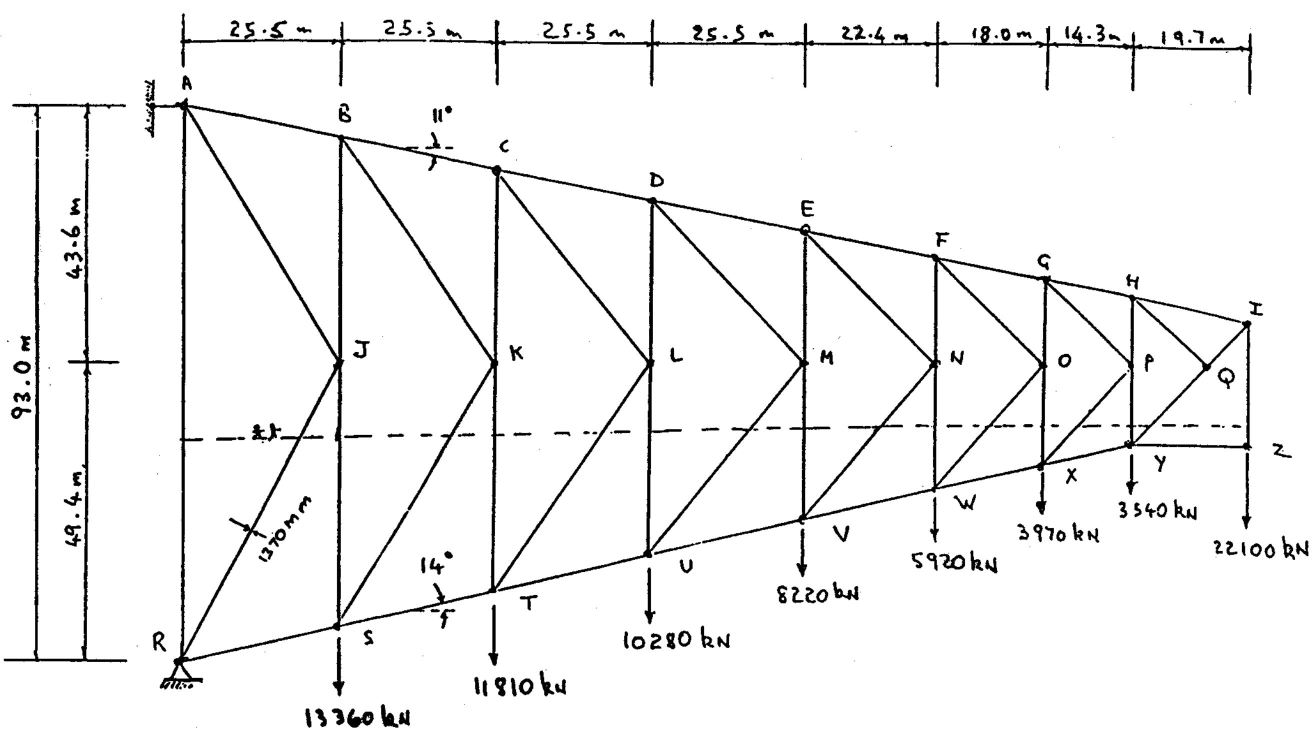
4 (OPTIONAL). Calculate the joint loads and solve for the forces in the members of the inverted Pratt truss shown below. Write the calculated member forces on a diagram you draw for your submission. Use (+) for tension and (-) for compression.



5. (Previous Final Exam) On October 17, 1917 the first train passed over what was described by the Engineering News Record of the day as the “greatest of bridges,” the Quebec Bridge over the St. Lawrence. After the failure of the original bridge during construction in 1907, a three-man Royal Commission, including Prof. John Galbraith of the University of Toronto, investigated the disaster. In 1911 a new design was approved and construction re-started in 1913. The bridge has a total length of 987 m with the main span being 549 m. This main span consists of two cantilever “arms” extending out 176.5 m from the two piers joined by a suspended span 196 m long. See photograph.



As well as being the longest span bridge in the world, the bridge was notable for being the first to use the K system of web members. This system, now widely used for steel structures, was invented by Phelps Johnson and Herrick Duggan, the designers of the new bridge. The figure below shows one of the two trusses of one of the cantilever arms with its K system of web members. The loads due to the self-weight of the structure and a long, heavily loaded train passing over the bridge are also shown. The 22,100 kN load at joint Z comes from the suspended span. As can be seen, there are 26 joints in the truss, 49 members, and 3 unknown reaction forces (2 at R, and 1 horizontal force at A). Hence, the forces in the members can be found by solving 52 equations in 52 unknowns. As a result of this procedure it has been found that member AR is subjected to a compression force of 36100 kN.



(a) By examining the equilibrium of the entire truss shown above find the 3 reaction forces.
(b) By examining the equilibrium of joint A determine the forces in members AB and AJ
(c) By examining the equilibrium of joint R determine the forces in members RS and RJ.
(d) Find the forces in members IZ, ZY, IH, IQ, QY, QH, HP and HG.

Moment of Inertia

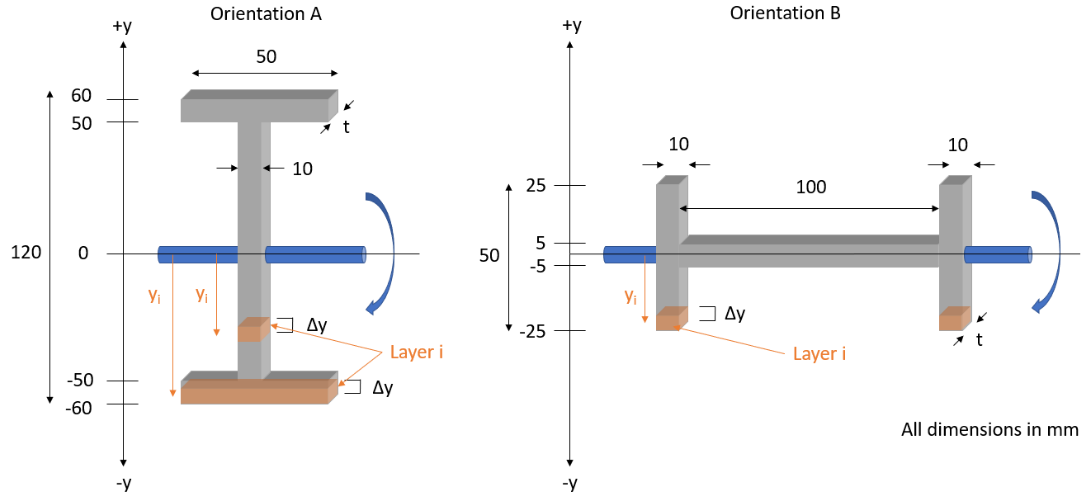
6. The "I" shaped object shown below is oriented in two different ways about different axis of rotation. In lecture, we solved for the mass moment of inertia, I_m, of a rectangular object by discretizing the object into layers and using the summation:

$$I_m = \sum_{i=1}^{n} I_{mi} = \sum_{i=1}^{n} {y_i}^2 \Delta m_i = \sum_{i=1}^{n} {y_i}^2 \rho t b_i \Delta y = \rho t \sum_{i=1}^{n} {y_i}^2 b_i \Delta y$$

$where$:

$I_{mi} = Incremental\ mass\ moment\ of\ inertia\ of\ layer\ i$
$y_i = Distance\ between\ the\ axis\ of\ rotation\ and\ the\ center\ of\ layer\ i$
$\Delta m_i = Incremental\ mass\ of\ layer\ i$
$\rho = Density\ of\ the\ material$
$t = Out\ of\ plane\ depth$
$b_i = Width\ of\ layer\ i$
$\Delta_y = Incremental\ thickness\ of\ layer\ i$

a) Using the same method, calculate the mass moment of inertia, I_m, of the "I" shaped object in orientation A (I_{mA}) and orientation B (I_{mB}). Set $\Delta y = 5$ mm (therefore, in orientation A, there will be 120mm/5mm = 24 layers to sum over and in orientation B, there will be 50mm/5mm = 10 layers) and set $\rho = 1$ kg/mm^3 and $t = 1$ mm. Excel can be used.



b) If the object is set into rotation with the same angular acceleration, α, in both orientations, calculate how much more moment is required to rotate the object in orientation A vs orientation B as a ratio.

c) Calculate the *area* moment of inertia, I, of orientation A ($I = I_m / \rho t$). Provide your answer in mm^4.

d) Imagine if a large number of the "I" shaped objects were glued together back-to-back to form a beam in both orientations as seen in the figure below. **Without doing any calculations**, which orientation do you think will be harder to bend (in order words, provide stronger resistance against bending)?