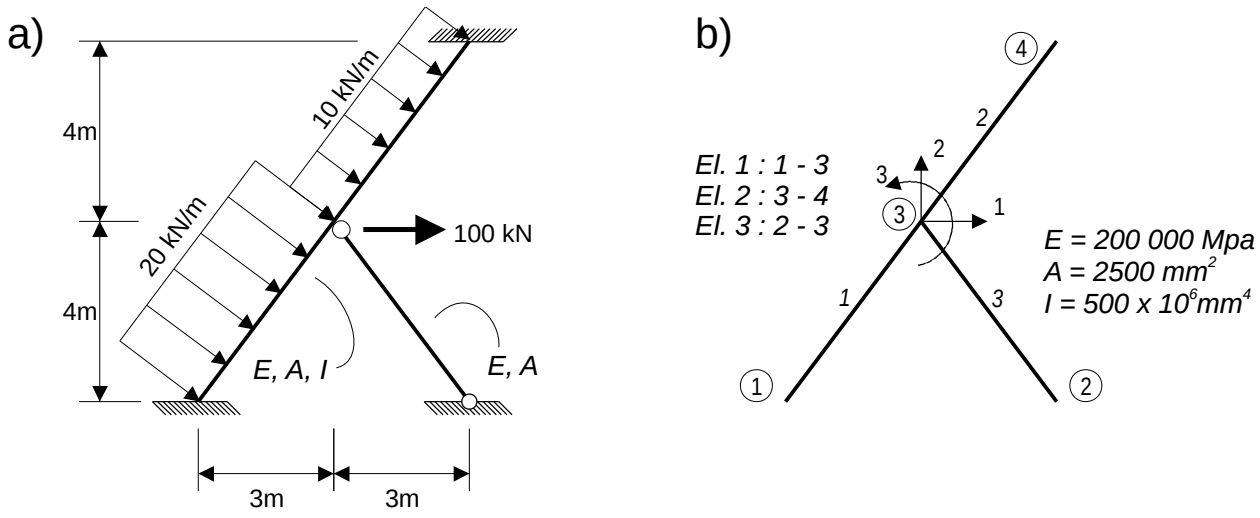
ORDRE DES INGÉNIEURS DU QUÉBEC
NOVEMBER 2011 SESSION

Open book examination
Calculators: only authorized models
Duration: 3 hours

98-Civ-B1
Advanced structural analysis

Note: The following structures all have linear elastic behavior.

Question 1 (25 points):
Consider the structure illustrated below. Use the matrix displacement method ([**K**][**U**] = [**P**]). The load case is illustrated in Fig **(a)**. Node, element, and degree-of-freedom numbers are illustrated in Fig **(b)**. **Member #3 is a truss elements.**



The element stiffness matrix for element 3 $[\mathbf{K_3}]_{6x6}$, in **global** coordinates, is ([**kN**/**m**]):

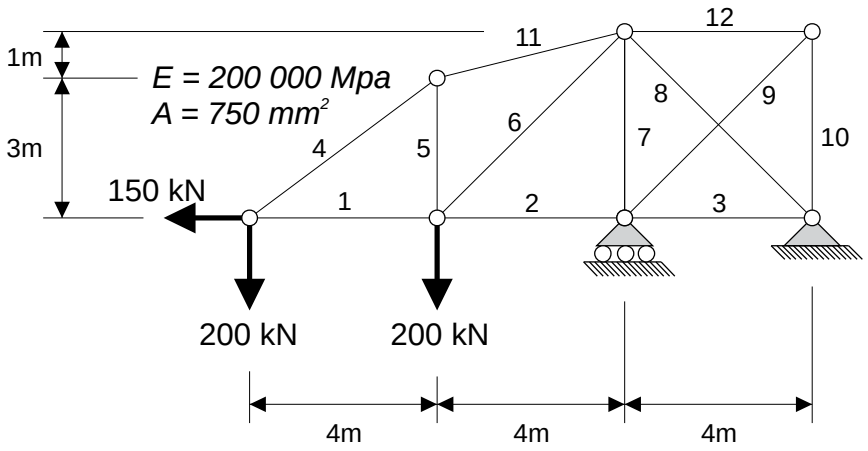
$$K1 = \begin{bmatrix} 42144 & 43392 & -19200 & -42144 & -43392 & -19200 \\ 43392 & 67456 & 14400 & -43392 & -67456 & 14400 \\ -19200 & 14400 & 80000 & 19200 & -14400 & 40000 \\ -42144 & -43392 & 19200 & 42144 & 43392 & 19200 \\ -43392 & -67456 & -14400 & 43392 & 67456 & -14400 \\ -19200 & 14400 & 40000 & 19200 & -14400 & 80000 \end{bmatrix}$$

Write the element stiffness matrices $[\mathbf{K_2}]_{6x6}$ and $[\mathbf{K_3}]_{6x6}$ in **global** coordinates. Then, assemble the global stiffness matrix $[\mathbf{K}]_{3x3}$. Use [**kN**] and [**m**] units.

Question 2 (30 points) :
Consider the structure illustrated above (Question 1). Use [**kN**] and [**m**] units.

- Assemble the nodal force vector $\mathbf{[P]}_{3x1}$.
- Calculate and plot the displacements $\mathbf{[U]}_{3x1}$.
- Calculate the internal member forces for each member. Illustrate the axial force diagram, the shear diagram and the bending moment diagram for the structure.
- Calculate the axial forces in members 3 and 4.

Question 3 (30 points) :
Calculate the axial forces in each bar of the truss illustrated on the right. Indicate the forces in each bar on a sketch of the truss. **The bars are numbered from 1 to 12**.
Hint : You may use the consistent displacement method.



Question 4 (15 points) :

Figures (a) and (b) each show two structures. For each case (a and b), indicate which structure will have the **highest** natural frequency (1st mode). Briefly explain why.