Name: **Student No.:**

Signature: ______________________________________

THE UNIVERSITY OF BRITISH COLUMBIA
DEPARTMENT OF CIVIL ENGINEERING

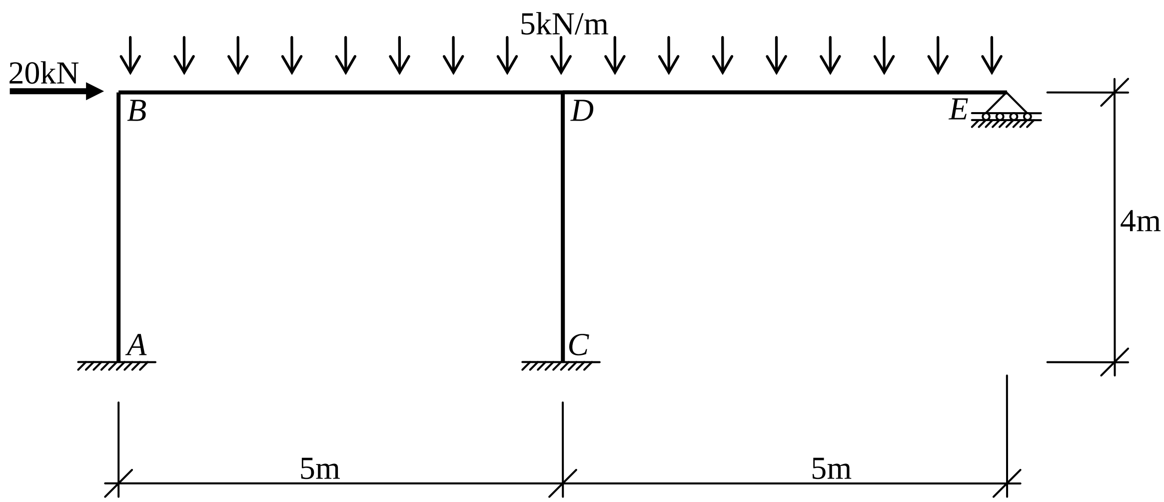
CIVL 332, Structural Analysis, 2007
Final Exam, December 10
Time: 3:30pm to 6:30pm
Location: OSBO A (Osborne Centre - Unit 1)

Practical information:

1. **This is a “closed book” examination. Calculators and writing utensils are allowed.**
2. **Present concise and tidy answers. Show how you obtain the answers.**
3. **The weight of the problems vary; allot your time accordingly!**
4. **It is preferred that you use the provided pages. Pages are left blank for your use.**
5. **Formula sheets are provided on the last two pages of the exam booklet. Please feel free to separate these pages from the booklet and keep them after the exam.**
6. **If you feel that something is unclear, please state your assumptions and work from there.**

Question	Weight	Mark
1	30	
2	20	
3	50	
Total	**100**	

Problem 1 [30 pts.]
Consider the structure below, which is subjected to a vertical uniformly distributed load and a horizontal point load. Use the stiffness method to solve this problem. Neglect axial deformations. *EI* is constant.



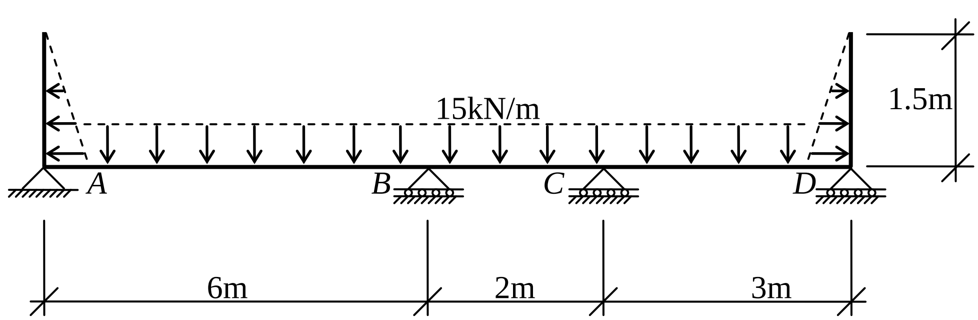
a) [13 pts.] Determine the degrees of freedom (DOFs). Number them as you wish. Then determine the stiffness matrix. Write the stiffness matrix in terms of *EI*. Use meters as length-unit.

b) [7 pts.] Determine the load vector. Use kN and meters as units. Make sure to be clear with signs.

Assume that you have solved the system of equations (by inverting the stiffness matrix). The results shows a horizontal (rightwards) displacement of B, D, and E equal to 86.7/*EI*. At B you get a clockwise rotation equal to 21.1/*EI*. At D you get a clockwise rotation equal to 12.2/*EI*. At E you get a counterclockwise rotation equal to 19.1/*EI*.

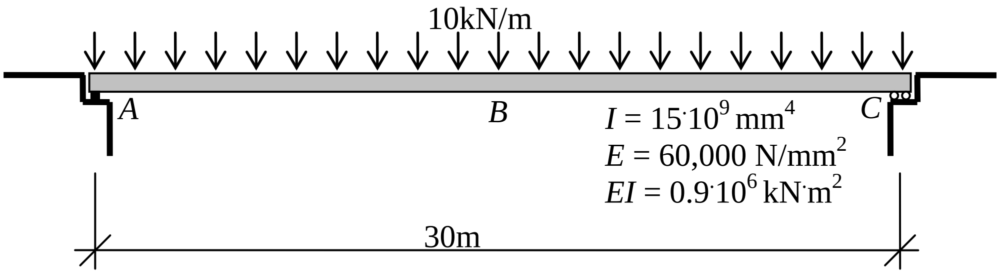
c) [10 pts.] Determine the bending moment diagram. Identify values at least at A, B, C, D, and E. (This may be somewhat time-consuming, so you may want to save this for last. At least show the methodology you would use.)

Problem 2 [20 pts.]
Consider the structure below, subjected to water pressure. *EI* is constant. Determine the bending moment diagram for this structure by whichever method you prefer.



Problem 3 [50 pts.]

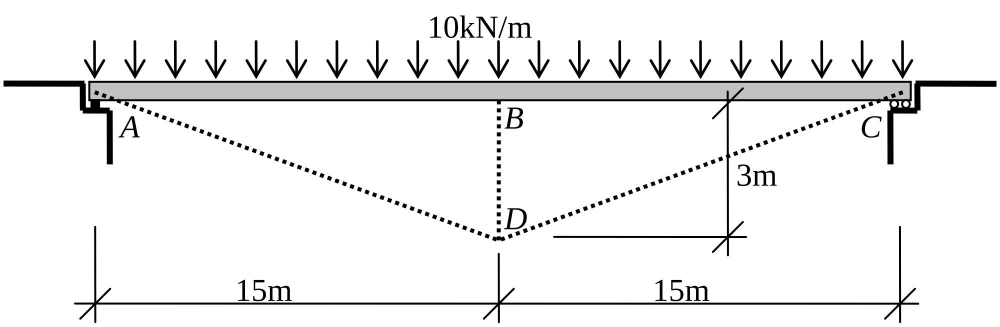
Consider the 30 meter long bridge in the figure below. The support conditions make it a "simply supported beam." The midpoint is denoted as *B*.



a) [2 pts.] Draw the bending moment diagram for the beam. Identify the maximum bending moment value (at mid-span).

b) [5 pts.] Use the moment area method to determine the maximum deflection (at mid-span).

As the chief engineer, you deem the maximum moment and deflection from above to be unacceptable. To solve the problem, you propose the following design, involving three truss members (shown with dotted lines):



Truss members: $A = 40 \cdot 10^3$ mm^2
$E = 200{,}000$ N/mm^2
$EA = 8 \cdot 10^6$ kN

Beam member: $I = 15 \cdot 10^9$ mm^4
$E = 60{,}000$ N/mm^2
$EI = 0.9 \cdot 10^6$ kN$\cdot$m^2

c) [2 pts.] Determine the degree of static indeterminacy for this modified structure.

d) [12 pts.] Use the flexibility method to determine the bending moment diagram for the beam. Neglect axial deformations in the beam member (member *AC*).

e) [7 pts.] Determine the shear force diagram associated with your bending moment diagram from d). Use the answer to compute the location and value of the maximum bending moment in span *BC*.

f) [7 pts.] Determine the deflection at *B* with whichever method you prefer.

g) [8 pts.] You are now happy with the values of the moments and deflections in the bridge. However, you decide to shorten members AD and DC (assume equal shortening of both members) to eliminate the deflection computed in Problem e). Determine the value of this shortening.

h) [7 pts.] Determine the bending moment diagram for the beam after the shortening of the members, *without* any external loads acting.

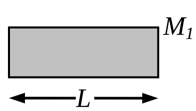
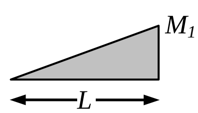
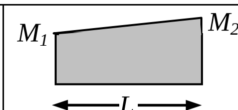
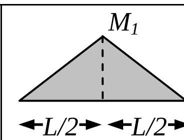
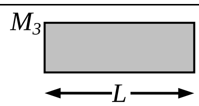
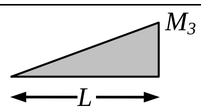
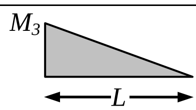
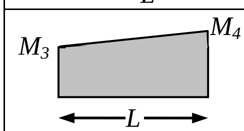
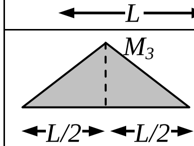
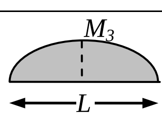
FORMULA SHEET (2 pages)

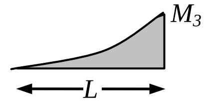
Degree of static indeterminacy: $DSI = (f m + r) - (e j + h)$

The slope-deflection equation: $M_{NF} = \frac{2EI}{L}\left(2\theta_N + \theta_F - 3\psi_{NF}\right) + FEM_{NF}$

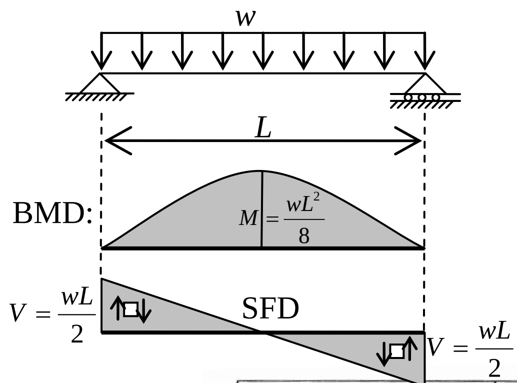
The principle of virtual work: $Q \cdot \delta_p = \int_0^L \frac{M_Q \cdot M_P}{EI}dx + \sum \frac{F_Q \cdot F_P \cdot L}{EA}$

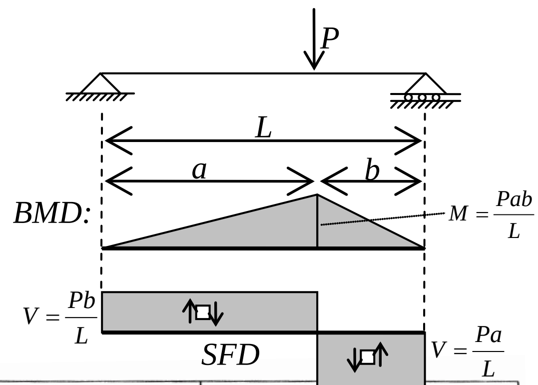
Formulas for the integral $\int_0^L \frac{M_Q \cdot M_P}{EI}dx$

M_Q \ M_P				
	$\frac{1}{EI}M_1M_3L$	$\frac{1}{2EI}M_1M_3L$	$\frac{1}{2EI}(M_1+M_2)M_3L$	$\frac{1}{2EI}M_1M_3L$
	$\frac{1}{2EI}M_1M_3L$	$\frac{1}{3EI}M_1M_3L$	$\frac{1}{6EI}(M_1+2M_2)M_3L$	$\frac{1}{4EI}M_1M_3L$
	$\frac{1}{2EI}M_1M_3L$	$\frac{1}{6EI}M_1M_3L$	$\frac{1}{6EI}(2M_1+M_2)M_3L$	$\frac{1}{4EI}M_1M_3L$
	$\frac{1}{2EI}M_1(M_3+M_4)L$	$\frac{1}{6EI}M_1(M_3+2M_4)L$	$\frac{1}{6EI}M_1(2M_3+M_4)L + \frac{1}{6EI}M_2(M_3+2M_4)L$	$\frac{1}{4EI}M_1M_3L + \frac{1}{4EI}M_1M_4L$
	$\frac{1}{2EI}M_1M_3L$	$\frac{1}{4EI}M_1M_3L$	$\frac{1}{4EI}M_1M_3L + \frac{1}{4EI}M_2M_3L$	$\frac{1}{3EI}M_1M_3L$
	$\frac{2}{3EI}M_1M_3L$	$\frac{1}{3EI}M_1M_3L$	$\frac{1}{3EI}(M_1+M_2)M_3L$	$\frac{5}{12EI}M_1M_3L$

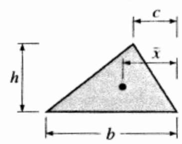
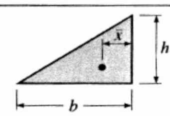
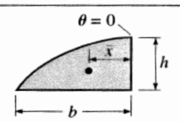
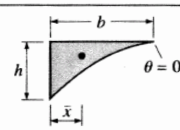
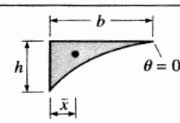
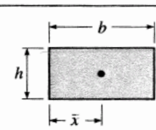
	$\frac{1}{3EI}M_1M_3L$	$\frac{1}{4EI}M_1M_3L$	$\frac{1}{12EI}(M_1+3M_2)M_3L$	$\frac{7}{48EI}M_1M_3L$

Simply supported beam cases:





Area properties:

Shape	Figure	Area	Centroidal Distance $\bar{x}$
(a) Triangle		$\frac{bh}{2}$	$\frac{b+c}{3}$
(b) Right triangle		$\frac{bh}{2}$	$\frac{b}{3}$
(c) Parabola		$\frac{2bh}{3}$	$\frac{3b}{8}$
(d) Parabola		$\frac{bh}{3}$	$\frac{b}{4}$
(e) Third-degree parabola		$\frac{bh}{4}$	$0.2b$
(f) Rectangle		bh	$\frac{b}{2}$

Fixed-end moments: