MEMORIAL UNIVERSITY OF NEWFOUNDLAND

Faculty of Engineering and Applied Science

Engineering 5003 - Ship Structures

FINAL EXAMINATION

With Solutions

Date: Thursday. April 11, 2013 Professor: Dr. C. Daley
Time: 9:00 - 11:30 pm
Maximum Marks: 100

Instructions:
Please write/sketch clearly on the exam paper (use backs of pages if needed).
Answer all 8 questions.

This is a closed book exam. Some Formulae are given at the end of the question paper.

1. Definitions (10 marks)

Define the following terms:

i) simple beam theory
ii) hydrostatic state of stress
iii) net load curve
iv) superposition
v) virtual work

i) simple beam theory assumes a number of simplifications appropriate to prismatic beams: elastic, small deflection behaviour, with the assumption that plane sections remain plane. Shear strains are ignored, and all normal strains and stresses are in the axial direction.

ii) the hydrostatic state of stress is one where all normal stresses are equal and there are no shear stresses.

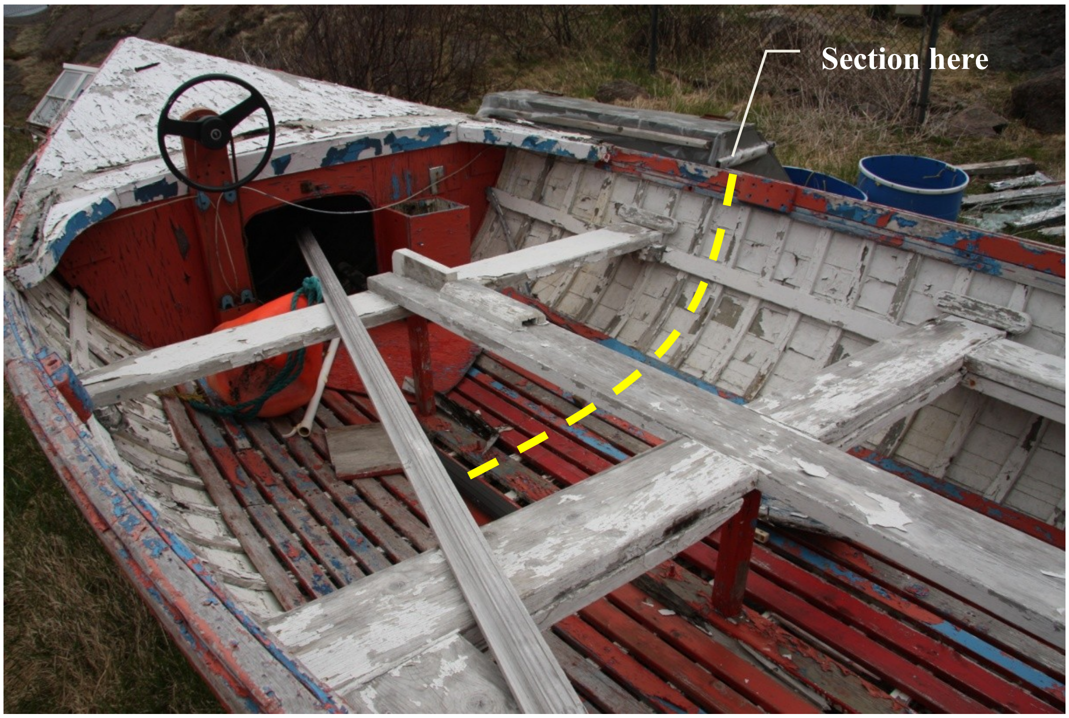
iii) net load curve is the difference between the weight curve along a hull and the buoyancy curve. The curve will have units of Force/length (i.e. kN/m or similar)

iv) superposition is the property of linear systems that permits us to add two separate solutions and get the result for both behaviours at once. This strategy is essential in most analyses.

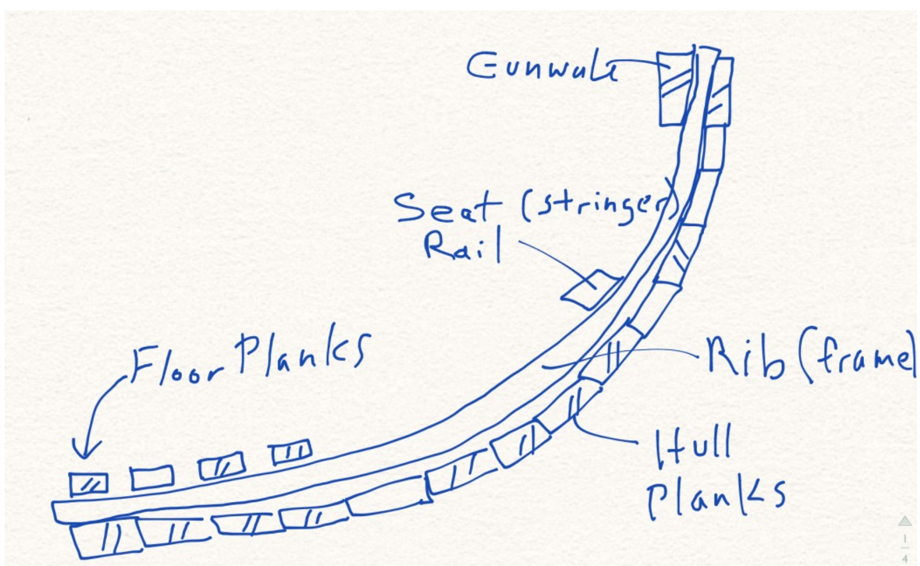
v) virtual work is the work done when a structural system is 'imagined' to move without any change in applied loads. The concept permits a energy-based solution of systems in equilibrium.

2. Sketching Structure (10 Marks)

The photo below is an old wooden boat. Draw a section through the boat (like a mid-ship section). You only need to draw the right (starboard) half. The intent is to show all the relevant structural parts at the section.

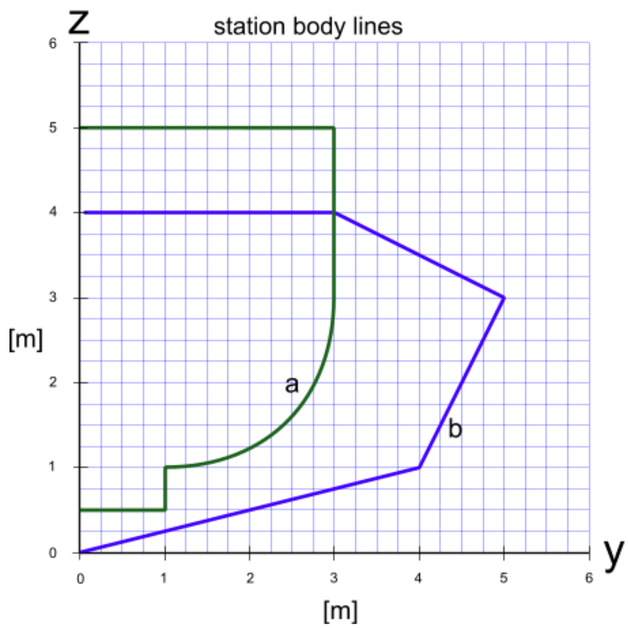


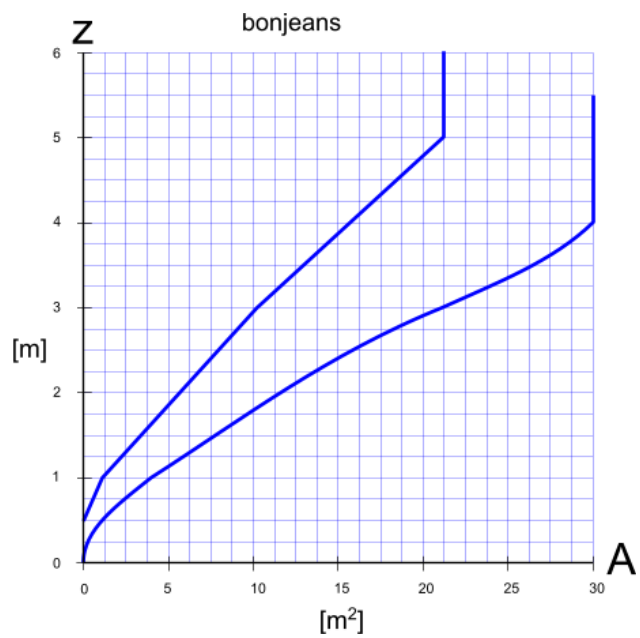
Sketch



3. Bonjean Curves (10 Marks)

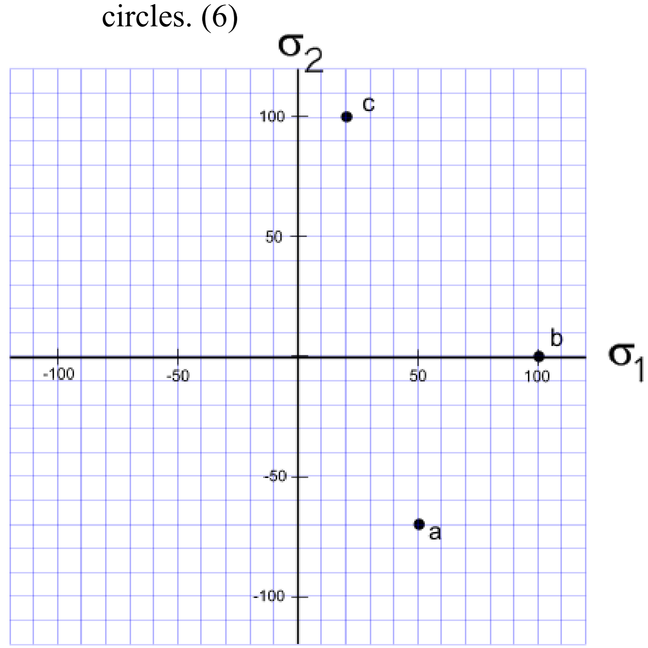
For the two body plans (a and b) shown below, draw the corresponding bonjean curves. (note:the body plan only shows half. The bonjean should be for the whole station)

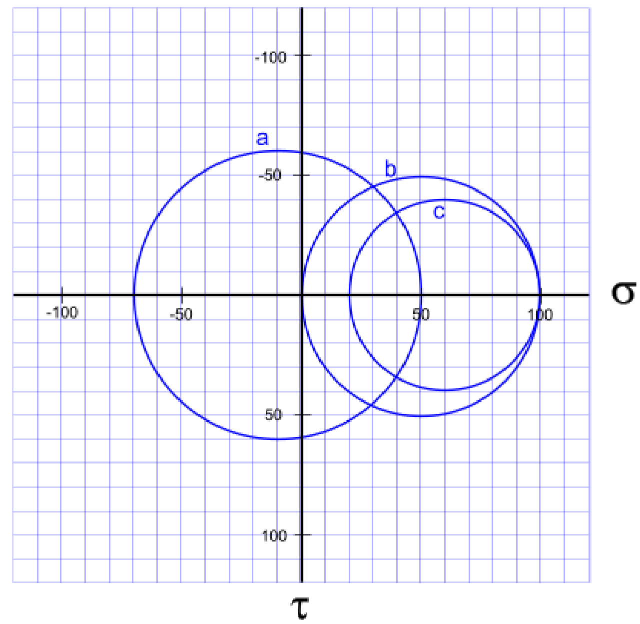




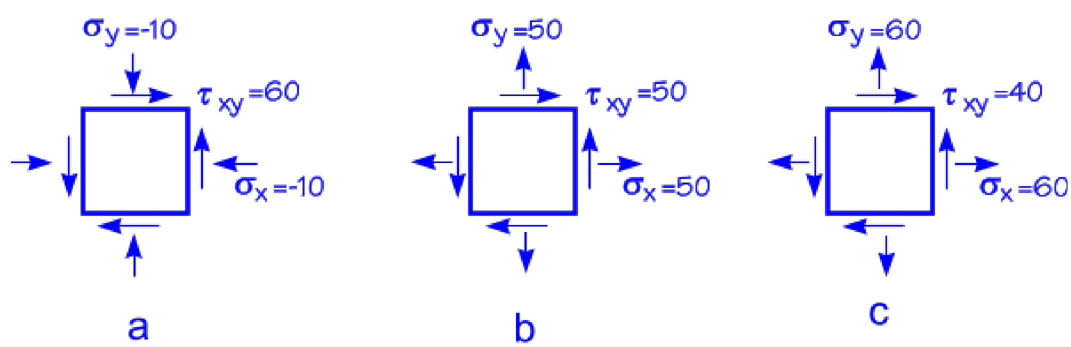
4. Stress and Strain (15 Marks)

a) For the three states of stress shown below at left (a,b,c) plot the corresponding Mohr's circles. (6)





b) For each case in a) above also show a sketch of the stresses on a unit square of material with the <u>maximum</u> shear stresses. (6)

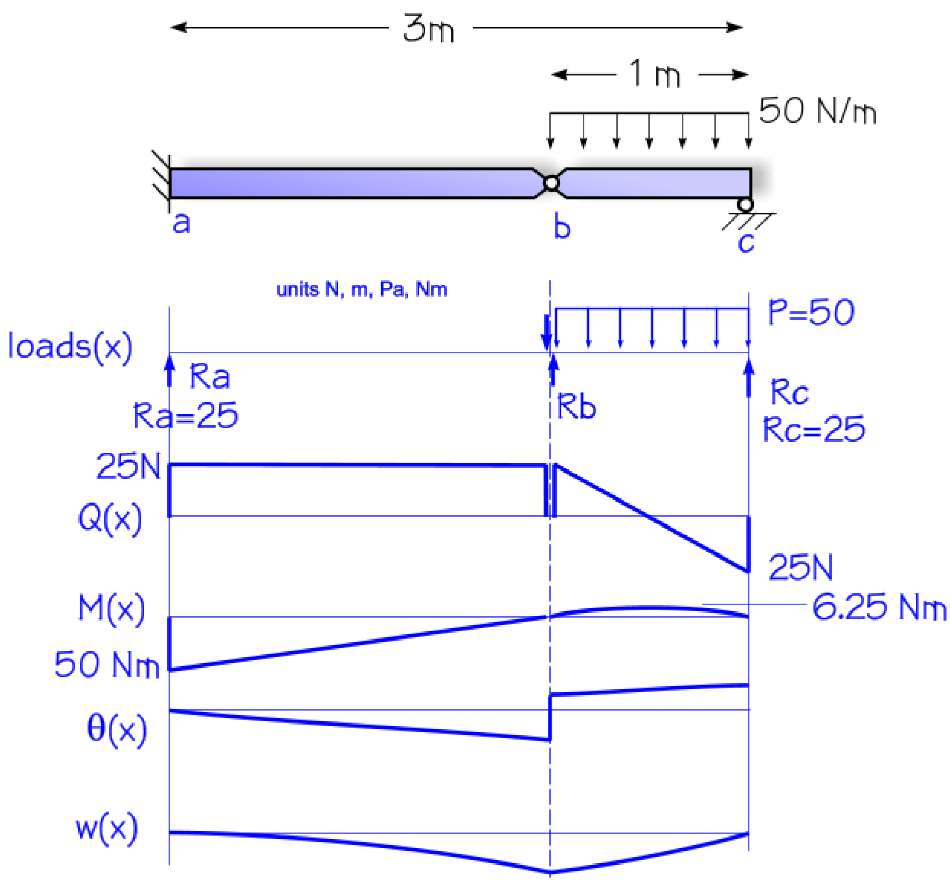


c) For each case in a) above, say what the von-mises equivalent stress is. (3)

The VM eqv stresses are a: 104.4, b: 100, c: 91.65

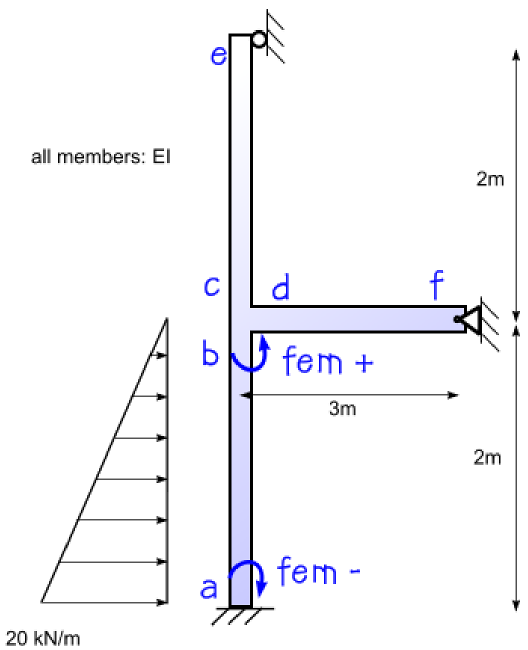
5. Beam Responses (10 Marks)

Draw the shear, moment , slope and deflection diagrams for this structure. There is a hinge a 1m from the right end. The hinge can hold shear but releases any moment. Put numerical values on shear and moment, but only show the shape of slope and deflection.



6. Moment Distribution Method (15 Marks)

Set up this problem as a moment distribution, and just solve the first cycle.



α: @ b $\frac{EI/2}{EI/2+EI/2+EI/3} = 3/8$

@ c $\frac{EI/2}{EI/2+EI/2+EI/3} = 3/8$

@ d $\frac{EI/3}{EI/2+EI/2+EI/3} = 1/4$

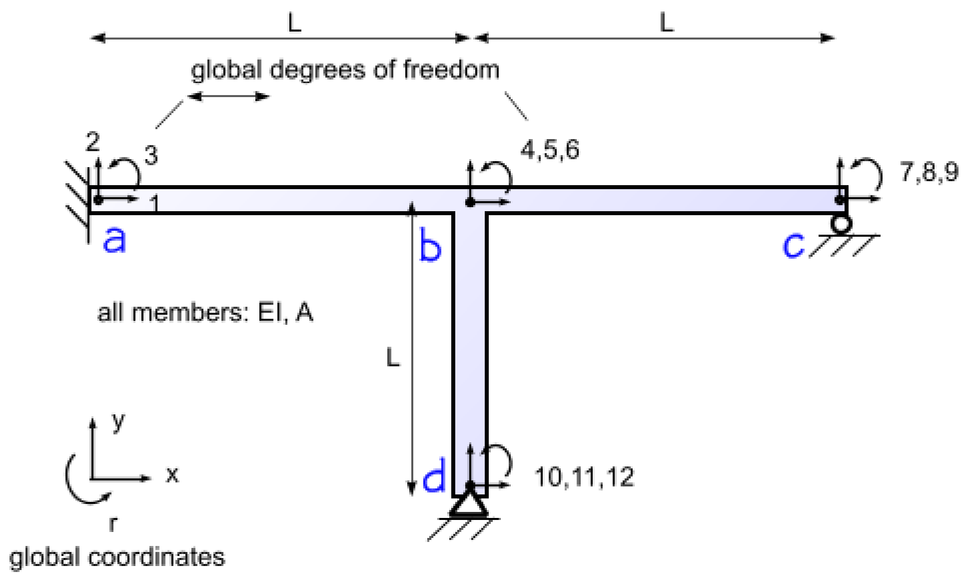
fem (+ ↺) @ a fem = $-20\ 2^2/20 = -4$

fem = $+20\ 2^2/30 = +2.67$

	a	b	c	d	e	f
α	0	3/8	3/8	1/4	1	1
fem	-4	2.67	0	0	0	0
corr (tot)	0		-2.67		0	
corr (indiv)	0	-1	-1	-.67	0	0
co	-.5	0	0	0	-.5	-.33
em	-4.5	1.67	-1	-.67	-.5	-.33

7. Matrix Structural Analysis (15 Marks)

Consider how this frame would be solved using matrix structural analysis. Give the equations for $k_{4,4}$ and $k_{10,10}$ terms from the global stiffness matrix. The global degree of freedom numbering is given.



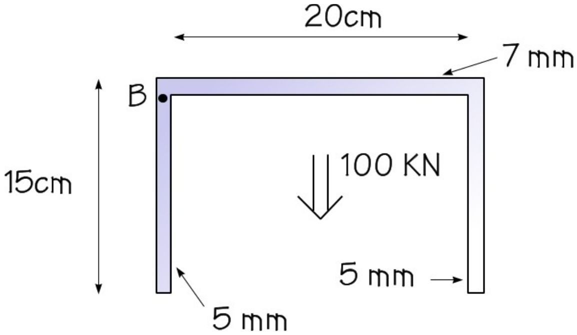
D of F 4 is the x movement at node 'b'. $k_{4,4}$ is the sum of the axial terms from beam a-b and b-c plus the shear term from beam b-d. $k_{10,10}$ is the shear term from beam b-d.

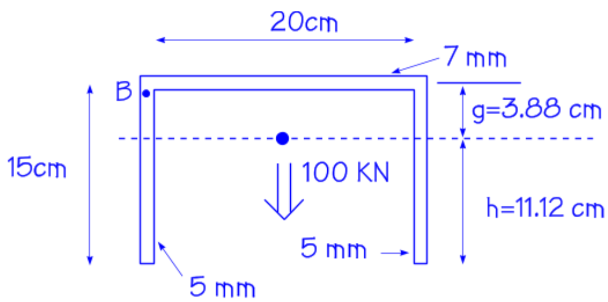
$$k_{4,4} = AE/L + AE/L + 12EI/L^3$$

$$k_{10,10} = 12EI/L^3$$

8. Shear (15 Marks)

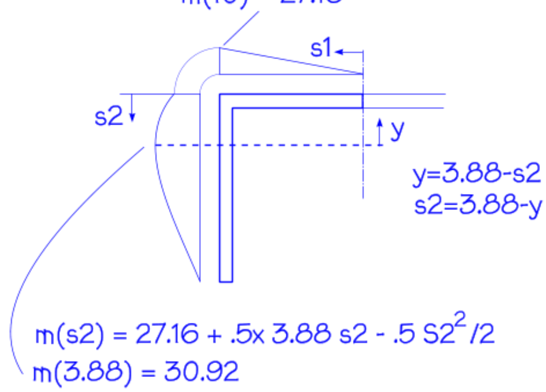
a) What is the shear stress at B?
b) Where is the shear center for this member?





$m(s1) = y\ t\ s1 = 2.716$

$m(10) = 27.16$



$A = 20 \times .7 + 2 \times 15 \times .5 = 29\ cm^2$

$$g = \frac{2 \times 15 \times .5 \times 7.5}{A} = 3.88\ cm$$

$I = 2/3 \times 15 \times .5 \times 15^2 - A\ g^2$

$I = 689\ cm^4$

$m(s2) = 27.16 + .5 \times 3.88\ s2 - .5\ S2^2/2$

$m(3.88) = 30.92$

$m(15) = 0$

$$q(@s1{=}10) = \frac{Q\ m}{I} = \frac{100 \times 27.16}{689} = 3.942\ kN/cm$$

$\tau(@s1{=}10) = 3.942/.5 = 7.88\ kN/cm^2$

$= 78.8\ MPa$

Formulae

Weight of a Vessel:

$W = \Delta = C_B \cdot L \cdot B \cdot T \cdot \gamma$

Prohaska for parallel middle body : $\overline{W} = \frac{W_{hull}}{L}$ the values of a and b are ;

	$\frac{a}{\overline{W}}$	$\frac{b}{\overline{W}}$
Tankers (C_B = .85)	.75	1.125
Full Cargo Ships (C_B = .8)	.55	1.225
Fine Cargo Ships (C_B=.65)	.45	1.275
Large Passenger Ships (C_B=.55)	.30	1.35

$$\Delta lcg = \frac{x}{\overline{W}} L \frac{7}{54}$$

Murray's Method

$$BM_B = \frac{1}{2}\left(\Delta_a g_a + \Delta_f g_f\right) = \frac{1}{2}\Delta \cdot \bar{x}$$

$$\bar{x} = L(a \cdot C_B + b)$$

Where

T/L	a	b
.03	.209	.03
.04	.199	.041
.05	.189	.052
.06	.179	.063

This table for a and b can be represented adequately by the equation;

$a = .239 - T/L$

b = 1.1 T/L -.003

Trochoidal Wave Profile

$x = R\theta - r \sin \theta$

$z = r(1 - \cos \theta)$

θ = rolling angle

2D Hooke's Law

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = \frac{E}{1-\nu^2} \begin{bmatrix} 1 & \nu & 0 \\ \nu & 1 & 0 \\ 0 & 0 & \frac{1-\nu}{2} \end{bmatrix} \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix}$$

von Mises

yield envelope: $\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2 = \sigma_{yield}^2$

equivalent stress: $\sigma_{eqv} = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2}$

Section Modulus Calculations

Ina = 1/12 a d^2

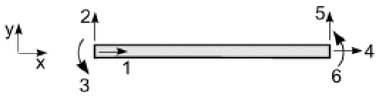
= 1/12 t b^3 $\cos^2\theta$

Family of Differential Equations Beam Bending

v = deflection [m]

$v' = \theta =$ slope [rad]
$v''EI = M =$ bending moment [N-m]
$v'''EI = Q =$ shear force [N]
$v''''EI = P =$ line load [N/m]

Stiffness Terms



2D beam = 6 degrees of freedom

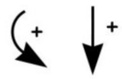
$$K = \begin{bmatrix} \frac{AE}{L} & 0 & 0 & \frac{-AE}{L} & 0 & 0 \\ 0 & \frac{12EI}{L^3} & \frac{6EI}{L^2} & 0 & \frac{-12EI}{L^3} & \frac{6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & \frac{4EI}{L} & 0 & \frac{-6EI}{L^2} & \frac{2EI}{L} \\ \frac{-AE}{L} & 0 & 0 & \frac{AE}{L} & 0 & 0 \\ 0 & \frac{-12EI}{L^3} & \frac{-6EI}{L^2} & 0 & \frac{12EI}{L^3} & \frac{-6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & \frac{2EI}{L} & 0 & \frac{-6EI}{L^2} & \frac{4EI}{L} \end{bmatrix}$$

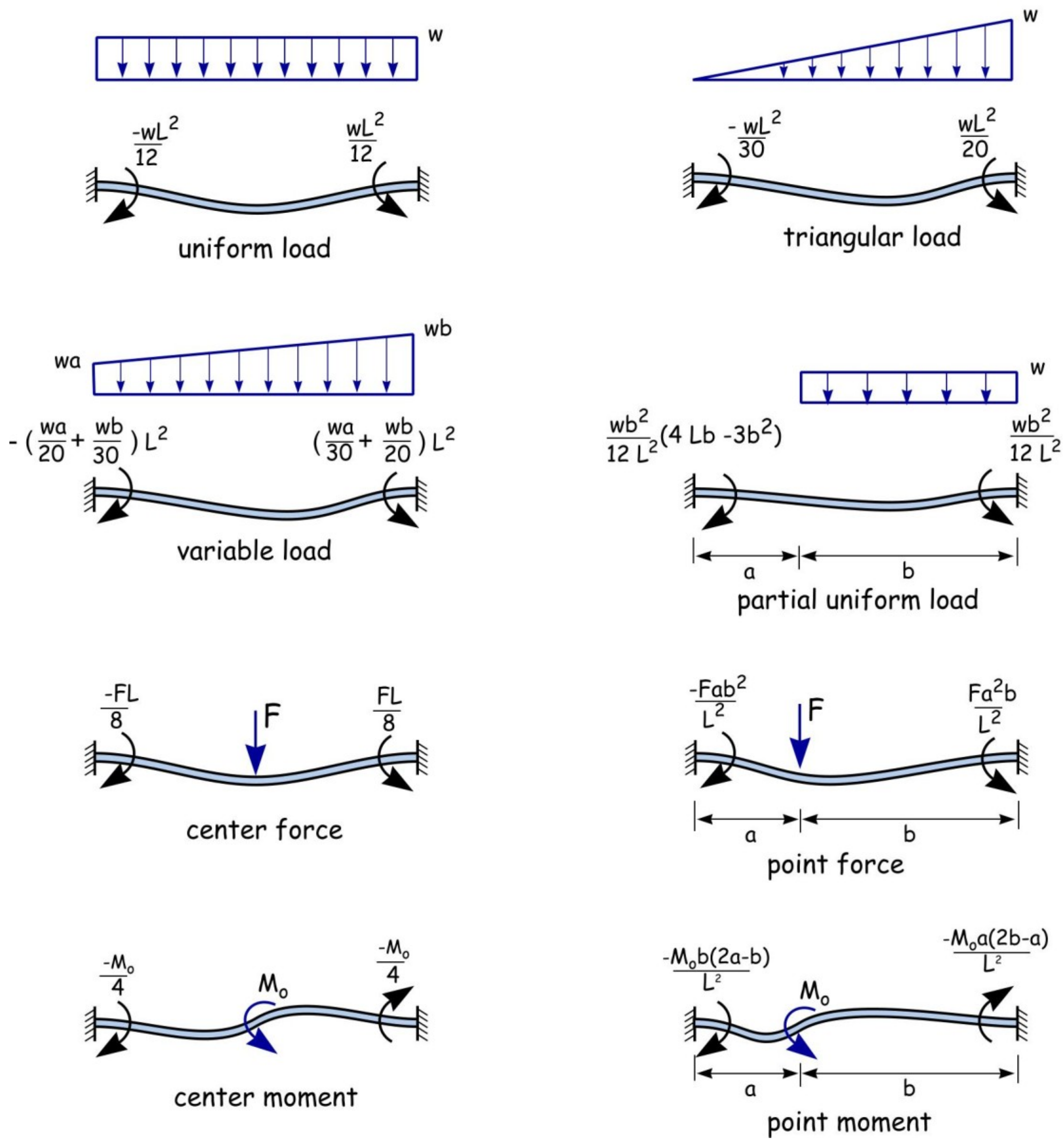
Shear flow: $q = \tau t$, $q = Q m / I$
$m = \int yt\, ds$

Torque: $M_x = 2qA$

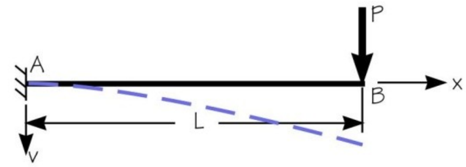
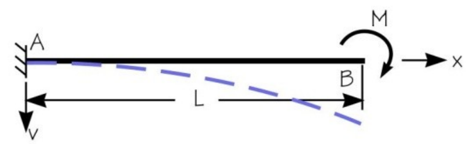
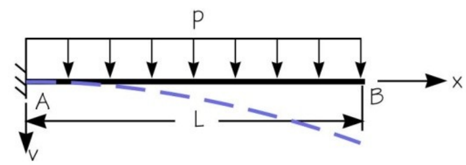
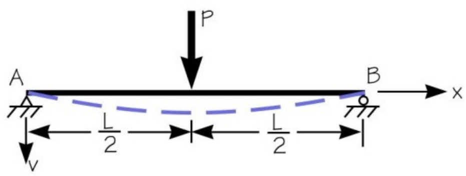
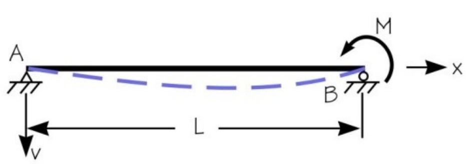
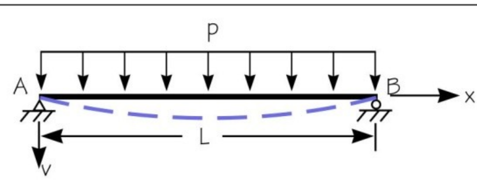
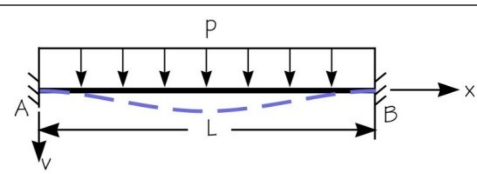
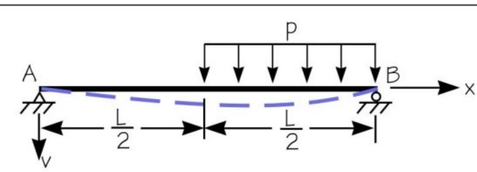
Fixed End Loads

fixed fixed beam, length L, constant EI: 

sign for moments and forces: 



Deflection and Slopes of Beams

Loading	Deflection	Slope
	$v = \frac{Px^2}{6EI}(3L - x)$ $v_{max} = v_B = \frac{PL^3}{3EI}$	$\theta_B = \frac{PL^2}{2EI}$
	$v = \frac{Mx^2}{2EI}$ $v_{max} = v_B = \frac{ML^2}{2EI}$	$\theta_B = \frac{ML}{EI}$
	$v = \frac{px^2}{24EI}(6L^2 - 4Lx + x^2)$ $v_{max} = v_B = \frac{pL^4}{8EI}$	$\theta_B = \frac{pL^3}{6EI}$
	$v = \frac{Px^2}{48EI}(3L^2 - 4x^2)$ $v_{max} = \frac{PL^3}{48EI}$ @ $x=L/2$	$\theta_A = -\theta_B = \frac{PL^2}{16EI}$
	$v = \frac{Mx}{6EI\,L}(L^2 - x^2)$ $v_{max} = \frac{ML^2}{9\sqrt{3}\,EI}$ @ $x=L/\sqrt{3}$	$\theta_A = \frac{ML}{6EI}$ $\theta_B = -\frac{ML}{3EI}$
	$v = \frac{px}{24EI}(L^3 - 2Lx^2 + x^3)$ $v_{max} = \frac{5\,pL^4}{384\,EI}$ @ $x=L/2$	$\theta_A = -\theta_B = \frac{pL^3}{24EI}$
	$v = \frac{px^2}{24EI}(L - x)^2$ $v_{max} = \frac{pL^4}{384\,EI}$ @ $x=L/2$	$\theta_A = \theta_B = 0$
	$v_{cent} = \frac{3\,pL^4}{256\,EI}$ @ $x=L/2$	$\theta_A = \frac{-7\,pL^3}{384\,EI}$ $\theta_B = \frac{3\,pL^3}{128\,EI}$