MEMORIAL UNIVERSITY OF NEWFOUNDLAND

Faculty of Engineering and Applied Science

Engineering 5003 - Ship Structures

FINAL EXAMINATION

SOLNs

Date: Wednesday April 13, 2016 **Professor: Dr. C. Daley**
Time: 9:00 - 11:30 pm
Maximum Marks: 100

Instructions:
Please write/sketch clearly in the white answer book.
Answer all 7 questions.

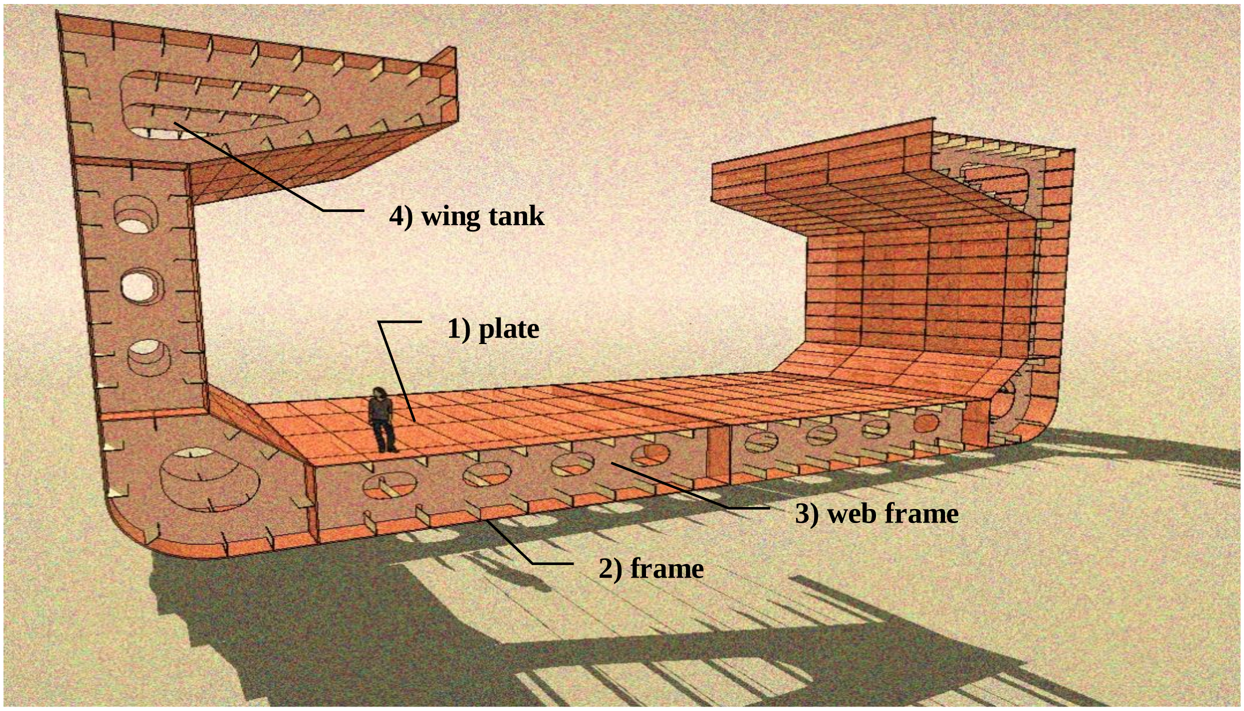
This is a closed book exam. Some Formulae are given at the end of the question paper.

1. Design concepts (12 marks)

The image below shows some components of a ship structure, near the midbody.

a) When the ship is at sea on a voyage what sort of loads would cause stresses in the plate below the wing tank?

b) at the intersection of the bottom frames and bottom the web frames and the plating – what would the key stresses be caused by?



a) – hull girder bending, local stresses if there is weight of ballast water in wing tank, shear due to global vertical shear flow and global torsion

b) Hull girder bending (in x) frame bending due to external pressure (in x), and web frame bending due to external pressure (in y). In the corner there would be no plate bending.

2. Still Water Bending Stresses (18 Marks)

Imagine that you are designing a ship of Length 260m, Beam of 47m and Draft of 15.6m in seawater. The Displacement is 127,000 t.

Imagine that you are going to design the above container ships.

a) What is the Block Coefficient (3)
b) Estimate the weight distribution according to Prohaska (5)
c) Use the above together with Murray's method to get the still water bending moment at midships. (5)
d) Roughly Sketch the following: buoyancy curve, weight curve, net load, shear and bending moment diagrams (approximate the values as well as you can). (5)
e)

a) $260 \times 47 \times 15.6 \times 1.025 \times C_B = 127{,}000$

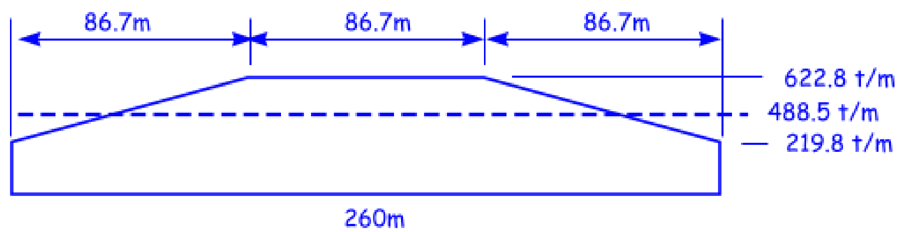
$C_B = 0.65$

$\overline{W} = 127{,}000/260 = 488.5$ t/m

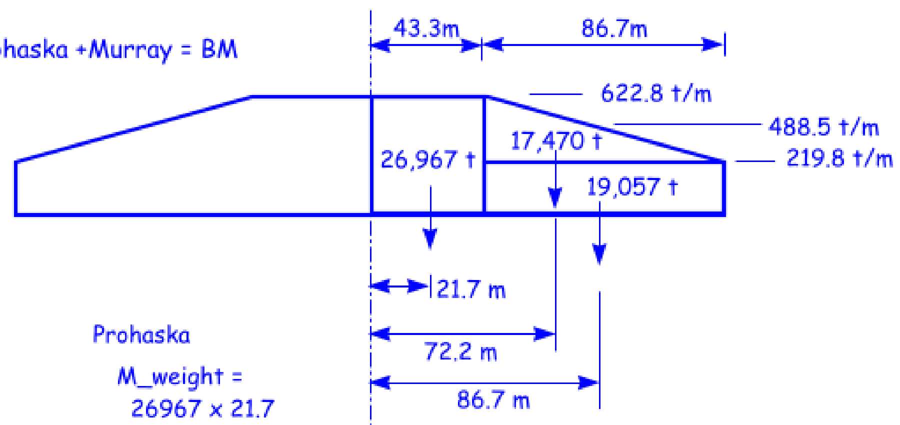
$a/\overline{W} = .45 \Rightarrow a = 219.8$ t/m

$b/\overline{W} = 1.275 \Rightarrow b = 622.8$ t/m

b) Prohaska



c) Prohaska +Murray = BM

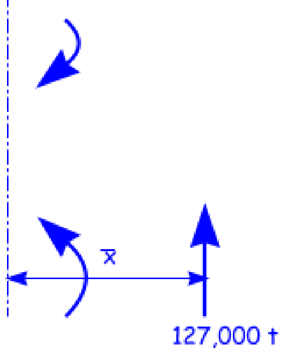


Prohaska

M_weight =
26967 x 21.7
+ 17470 x 72.2
+ 19057 x 86.7
= 3,498,730 t-m (hog)

Murray

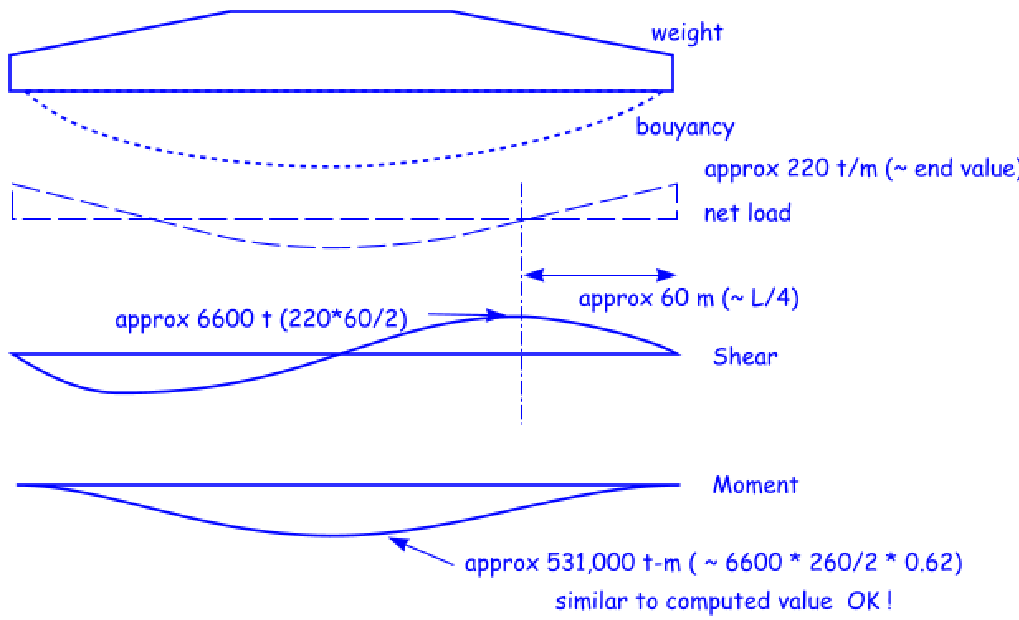
M_buoyancy =
127000 /2x 46.63
= 2,961,068 t-m (sag)



T/L = 15.6/260 = 0.06
a = 0.179
b = .063
$\overline{x}$ = 260 (.179 x .65 +.063)
= 46.63 m

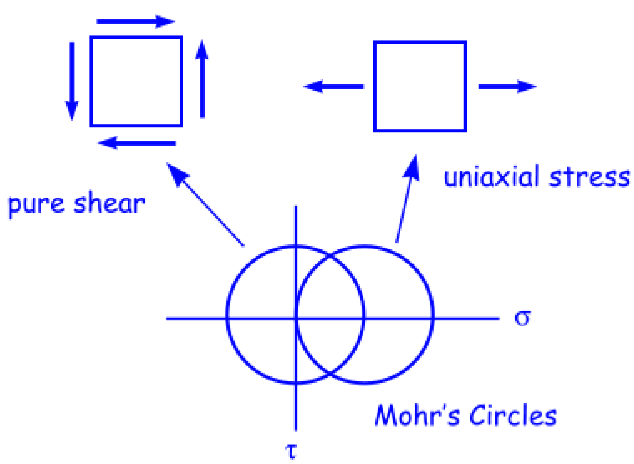
Midship Stillwater Moment
= 537,661 t-m (hog)

d) Response curves (with estimates)



3. Material Behaviour (13 Marks)

a) for a state of pure shear draw a Mohr's circle. (3)
b) on the same plot, draw a mohr's circle for a state of uniaxial stress (3)

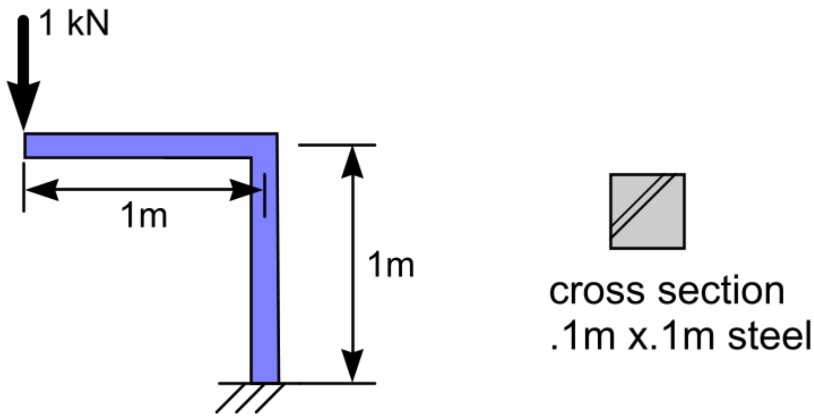


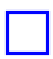
c) discuss the importance of Hooke's law. (7)

Hooke's law says that stress-strain and force-deflection are linear. This simple relationship permits the easy analysis of almost all structural systems due to the validity of superposition.

4. Beam Responses (12 Marks)

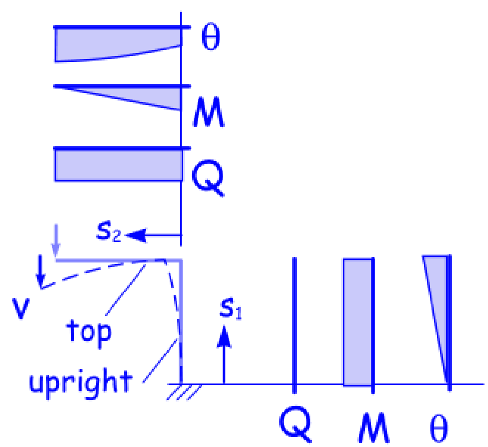
An L stand is sketched below. A vertical load of 1kN is applied to the tip. Using direct integration solve the problem. Plot all responses (Q, M, θ, v) in terms of the path coordinate 's' (ie along the bar starting from the base – ie straighten the plots out), with key values indicated.
How far does the tip move (vertically and laterally)?



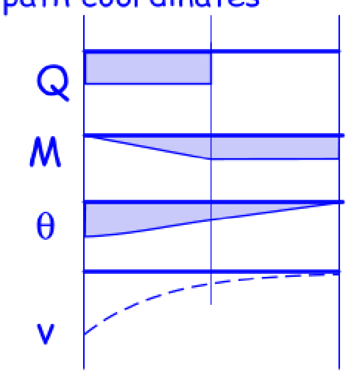


$EI = 2x10^{11} \times .1^4/12 = 1,666,666$ N m^2
$EI = 1,667$ kN m^2

solution sketch
drawn in beam coordinates



drawn in path coordinates



This loading causes constant shear of 1kN in top and 0 in upright
The moment in the top increases from 0 to 1 linearly.
The moment in the upright is constant of 1.

solution by direct integration

$Q(s_1) = 0 \qquad Q(s_2) = 1$ kN

$M(s_1) = 1$ kNm $\qquad M(s_2) = (1-s_2)$ kNm

$$\theta(s_1) = 0 + \frac{1}{EI}\int M(s_1) = \frac{s_1}{EI} \text{ rad}$$

$$\theta(\text{corner}) = \frac{1}{1667} \text{ rad}$$

$$\theta(s_2) = \frac{1}{EI} + \int M(s_2) = \frac{1}{EI} + \frac{1}{EI}\left(s_2 - \frac{s_2^2}{2}\right)$$

$$\theta(\text{tip}) = \frac{1.5}{1667} \text{ rad}$$

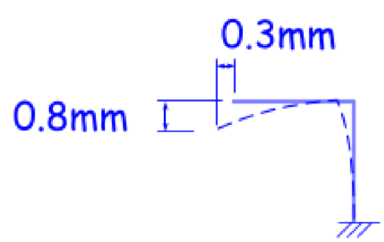
lateral deflection $\quad v(s_1) = 0 + \int \theta(s_1) = \frac{s_1^2}{2EI}$ m

$v(\text{corner}) = .0003$ m

vertical deflection $\quad v(s_2) = 0 + \int \theta(s_2) = \frac{s_2}{EI} + \frac{1}{EI}\left(\frac{s_2^2}{2} - \frac{s_2^3}{6}\right)$

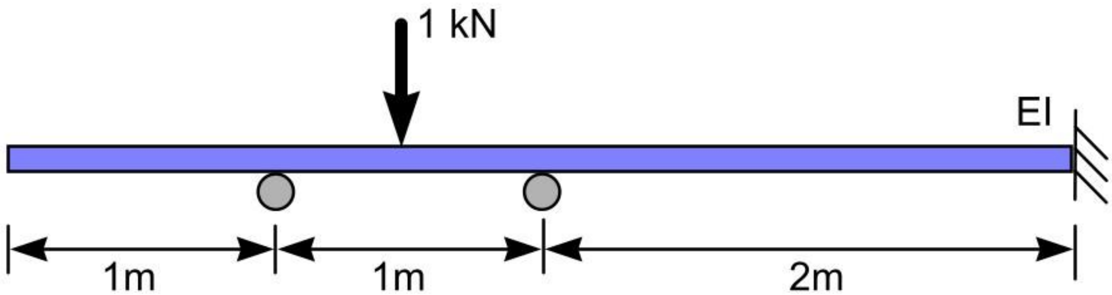
$v(\text{corner}) = .0008$ m

deflections:

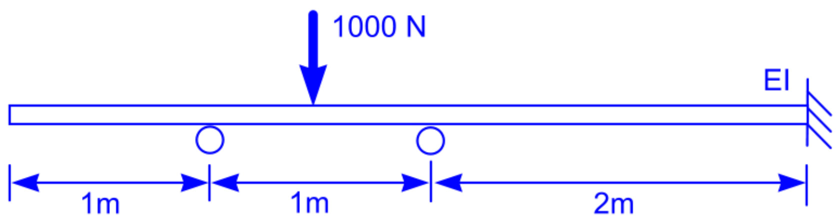


5. Moment Distribution Method (15 Marks)

Solve the problem shown below using the moment distribution method.



- ignore free cantilever at left.
  - FEM are FL/8 from table
  - Distribution factors are 1/3 and 2.3 at middle support



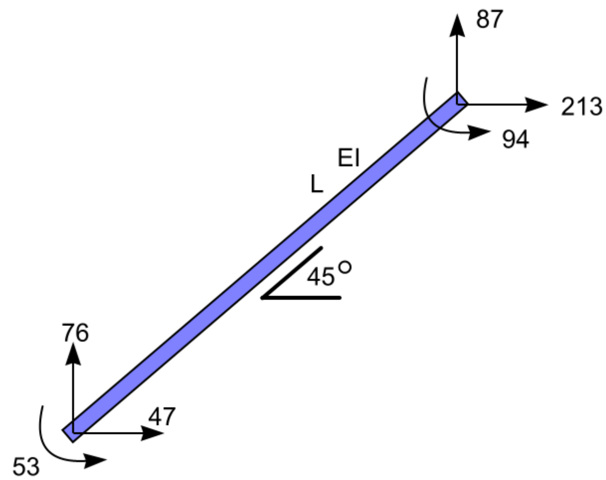
$$\frac{1/2}{1/1 + 1/2} = 1/3$$

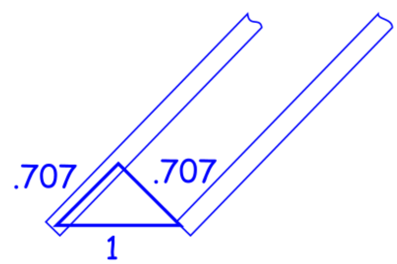
MDF	1	.667	.333		0
FEM	-125	125	0		0
Corr.	+125	-83.3	-41.7		0
CO	-41.7	62.5	0		-20.8
New EM	-41.7	104.2	-41.7		-20.8
Corr.	41.7	-41.7	-20.8		0
CO	-20.8	20.8	0		-10.4
New EM	-20.8	-83.3	-62.5		-31.2

a few more cycles needed

6. Matrix Structural Analysis (15 Marks)

A single beam is shown in its global position. The global degrees of freedom are indicated. What is $k_{47,47}$ (one of the member stiffness terms in global coordinates) ?
If you can't derive it, explain how you would.





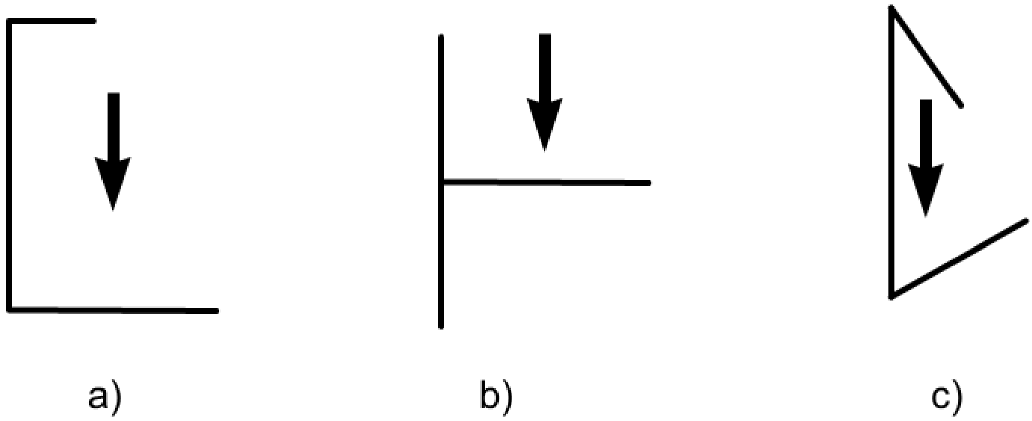
moving dof 47 global by 1 is equivalent to moving dof 1 local by .707 and local 2 by .707
force in 1 local will be .707 AE/L (along beam), which creates $.707^2 AE/L$ in 47
force in 2 local will be .707 $12EI/L^3$ (across beam), which creates $.707^2\ EI/L^3$ in 47

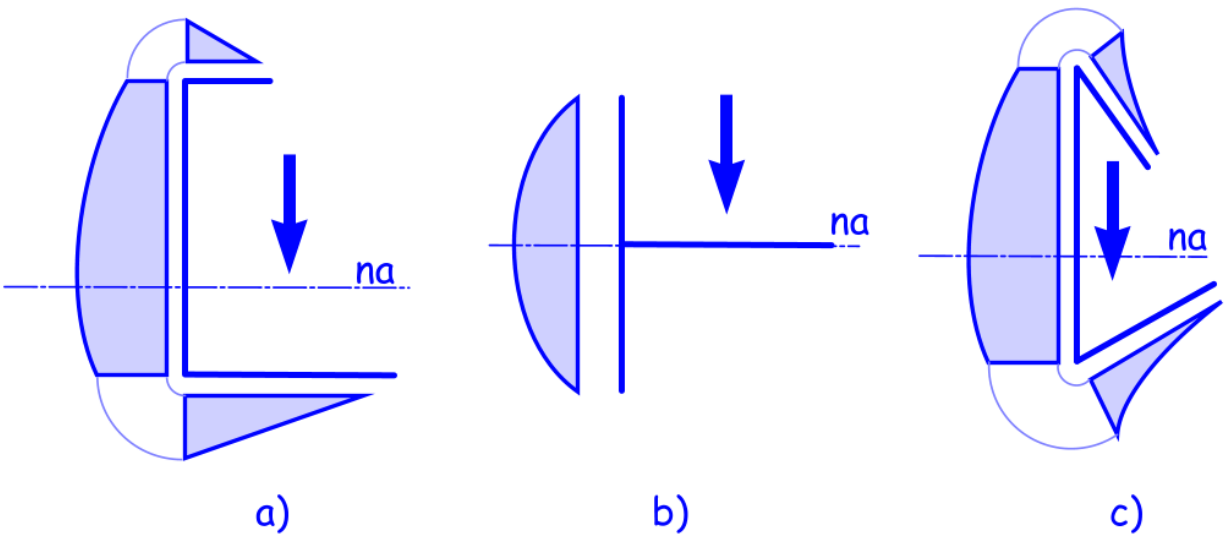
$$\underset{\text{global}}{k_{47,47}} = .707^2 \underset{\text{local}}{k_{11}} + .707^2 \underset{\text{local}}{k_{22}}$$

$$= 0.5\ AE/L + 6EI/L^3$$

7. Shear Flow (15 Marks)

a) Sketch the shear flow patterns for the three cases shown below (no numbers needed) (6).





Formulae Sheet

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

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

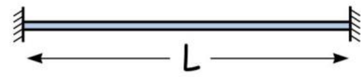
Shear flow: $q = \tau t, \quad q = Q\,m/I$

$m = \int yt\,ds$

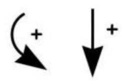
Torque: $Mx = 2qA$

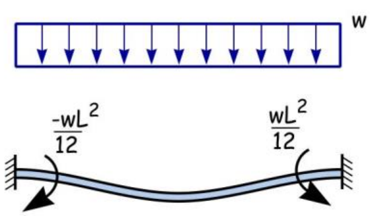
Fixed End Loads

fixed fixed beam, length L, constant EI:

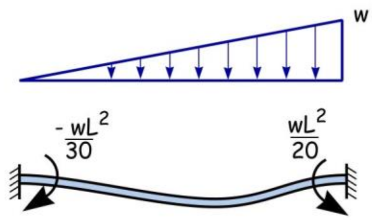


sign for moments and forces:

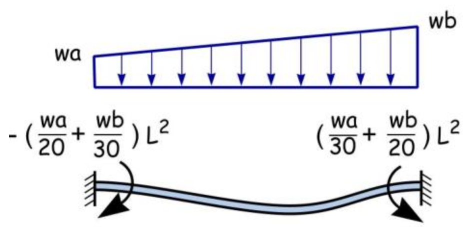




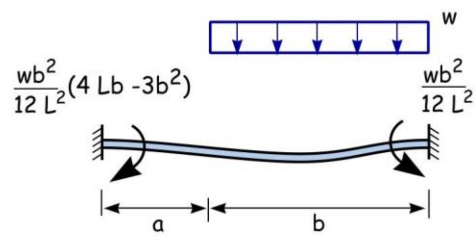
uniform load



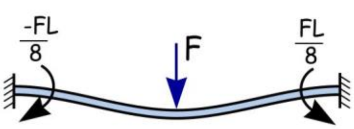
triangular load



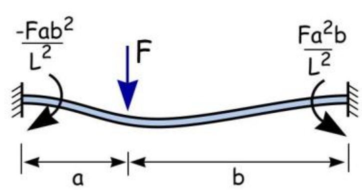
variable load



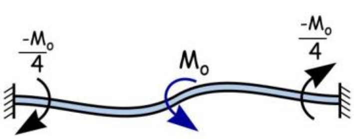
partial uniform load



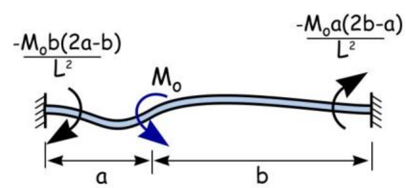
center force



point force

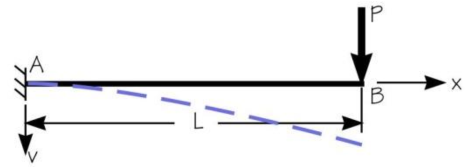
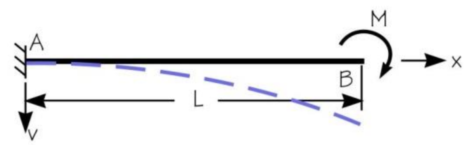
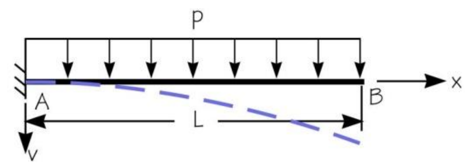
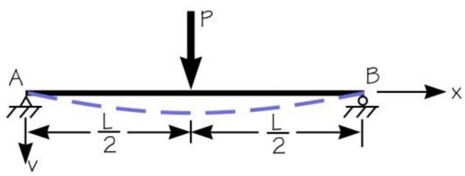
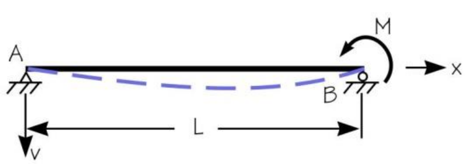
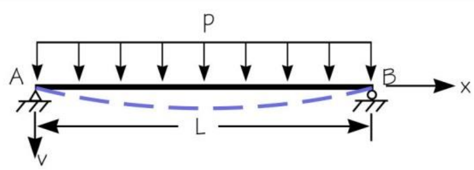
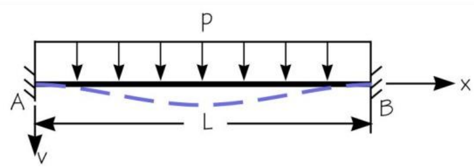
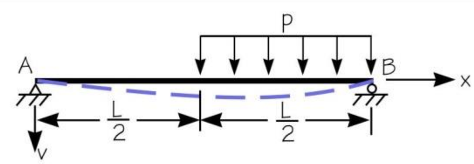


center moment



point moment

Deflection and Slopes of Beams

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