# MEMORIAL UNIVERSITY OF NEWFOUNDLAND

Faculty of Engineering and Applied Science

Engineering 5003 - Ship Structures

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## FINAL EXAMINATION

## SOLNS

**Date: Thursday April 9, 2015** **Professor: Dr. C. Daley**
**Time: 1:00 - 3:30 pm**
**Maximum Marks: 100**

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

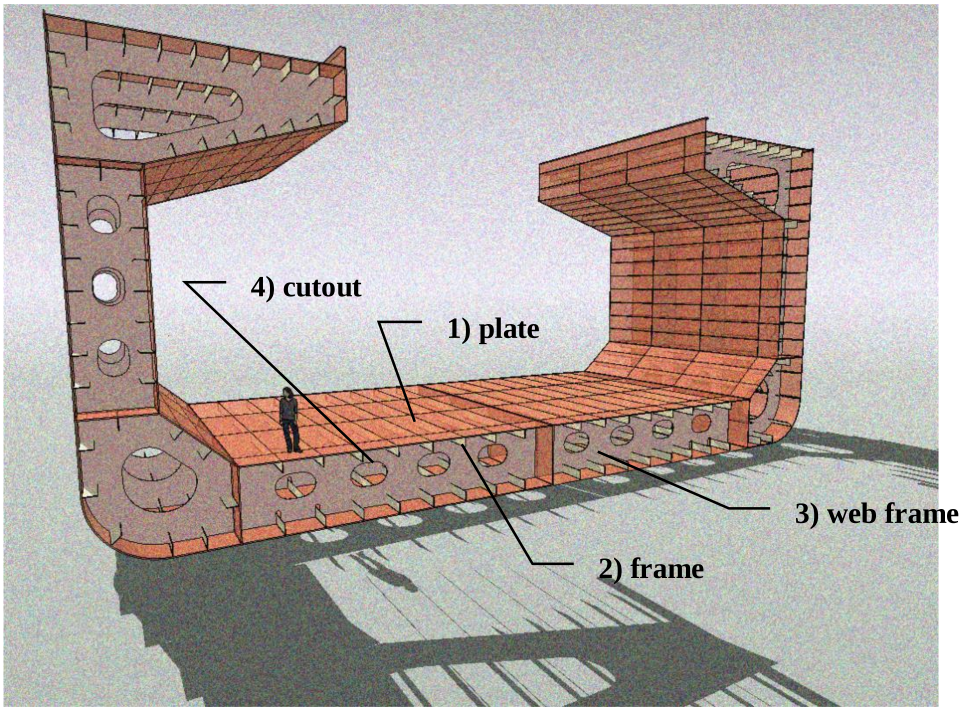
This is a closed book exam. Some Formulae are given at the end of the question paper.

## 1. <u>Design concepts</u> (12 marks)

The image below shows some components of a ship structure. In the inner bottom (where the person is standing) the plate is supported by frames and the frames are supported by deep web frames.

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

b) Why do the web frames have cutouts as shown, and how does this affect the structural design of the web frame?



a) the inner bottom plate would be subjects to stresses from <u>cargo loads</u>, <u>still water bending</u>, <u>wave bending</u>

b) the web frames cutouts <u>save weight</u> and <u>permit access for inspection</u>. The cutouts will <u>raise stresses</u>, especially shear. The cutouts would need to be stiffened and <u>add cost to construction</u> (more welds, more cuts).

## 2. Still Water Bending Stresses (18 Marks)

A recent news story in G-Captain read as follows;

> **Hanjin Heavy Industries Confirms 20,600 TEU Container Ship Orders**
>
> BY MIKE SCHULER ON APRIL 6, 2015
> Plans for the 20,600 TEU ships were first revealed by CMA CGM last month, but the details of the order had not yet been finalized.
> Hanjin says the ships will be built at the group's Subic Shipyard in the Philippines. Delivery is scheduled for the second half of 2017 and the vessels will be deployed on its main Asia-North Europe route. They will measure 400 meters long by 59 meters wide.

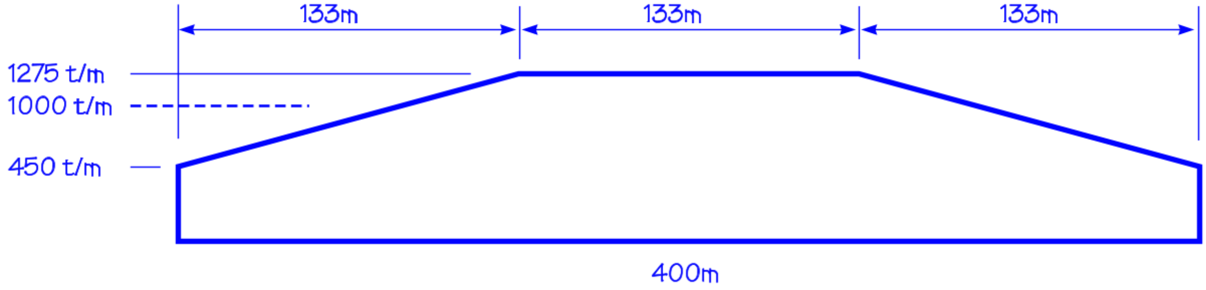
Imagine that you are going to design the above container ships.

a) Estimate the draft, and displacement (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: net load, shear and bending moment diagrams (approximate the values as well as you can). (5)

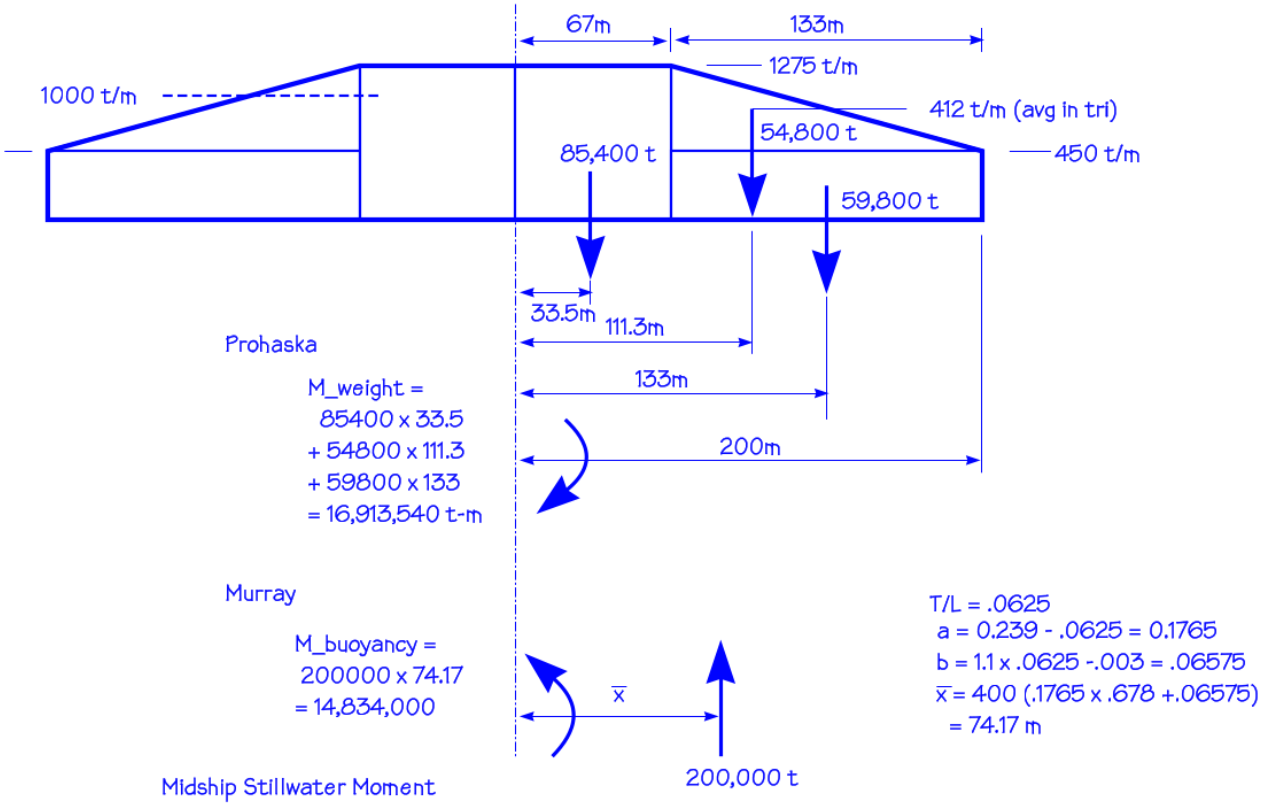
(a) T = 25m, CB=.678, $\Delta$ = 400,000 tonnes (selected to be close and also make weights easy to work out)

(b) est a = .45, b = 1.275

Therefor the weight distribution is;



c)



Prohaska

M_weight =
85400 x 33.5
+ 54800 x 111.3
+ 59800 x 133
= 16,913,540 t-m

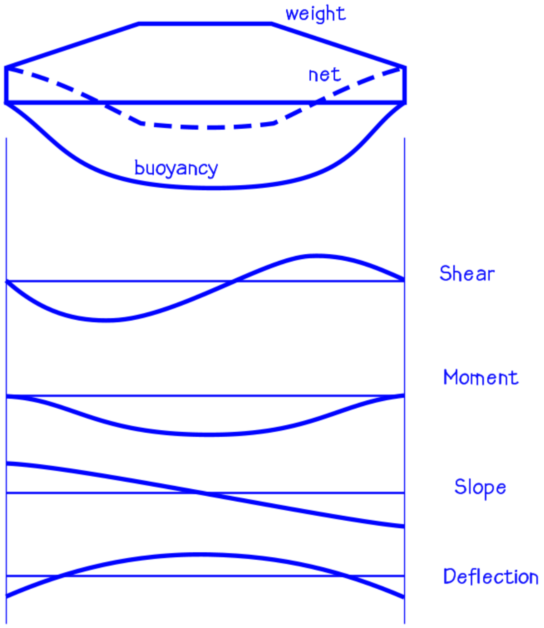
Murray

M_buoyancy =
200000 x 74.17
= 14,834,000

T/L = .0625
a = 0.239 - .0625 = 0.1765
b = 1.1 x .0625 -.003 = .06575
$\bar{x}$ = 400 (.1765 x .678 +.06575)
= 74.17 m

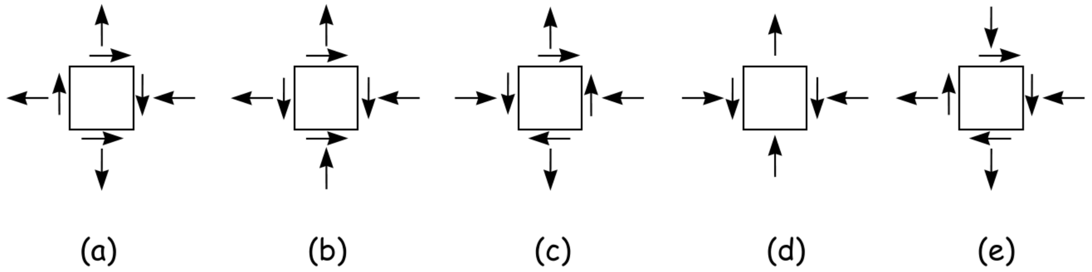
Midship Stillwater Moment
= 2,079,540 t-m (hog)

e) Sketch of net load, shear, moment, slope and deflection



## 3. State of Stress (13 Marks)

a) For the 5 sketches below, explain whether the 'body' (a unit cube) is in equilibrium or not and if not why not. Also say whether this sketch constitutes a 'state of stress' or not. (6)



all vectors indicate a unit force (normal or shear) acting on a unit cube.

(a) in horizontal and vertical equilibrium but not in moment equilibrium - not a state of stress

(b) in equilibrium - not a state of stress

(c) in equilibrium - this is a state of stress

(d) in equilibrium - not a state of stress

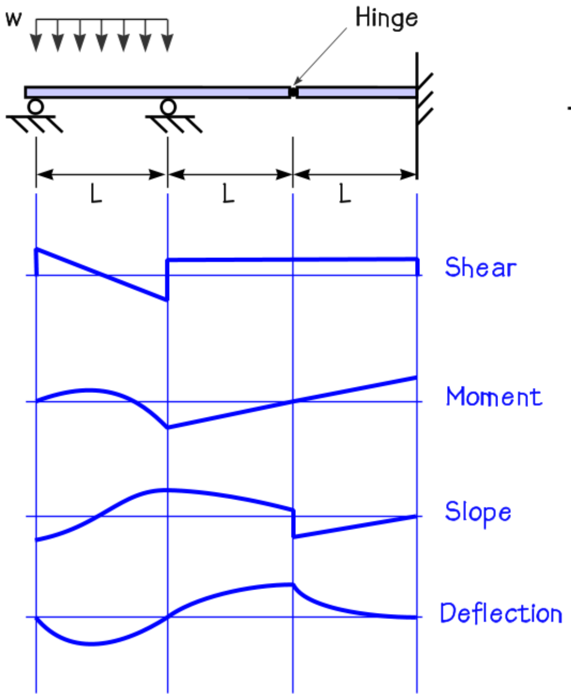
(e) not in any equilibrium (h, v or rotation) and not a state a stress

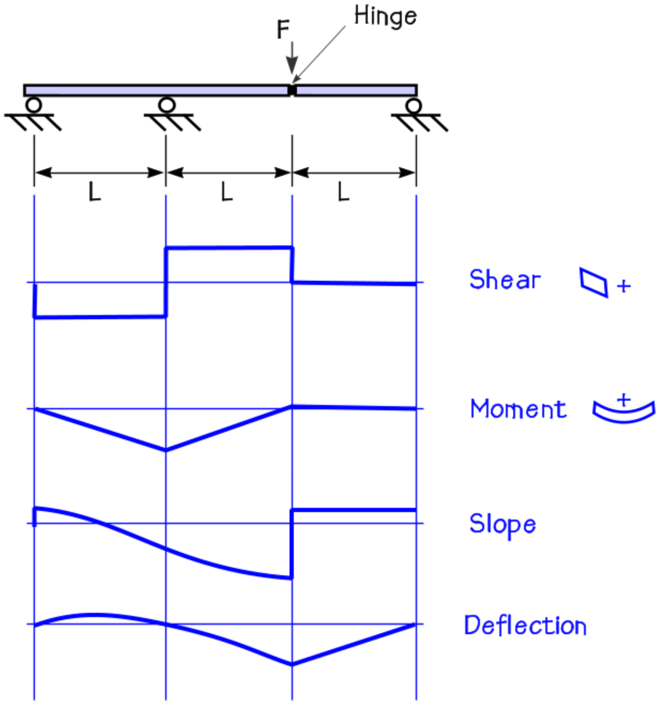
b) discuss the importance of Hooke's law. (7)

Hooke's law describes a linear relationship between stress and strain, which can also be seen as a linear relationship between load and deflection, for any load and any simple body, 'free body' or structure. This linearity permits use of principle of superposition and thus enables all structural analysis. All analysis methods rely on this concept.

## 4. Beam Responses (12 Marks)

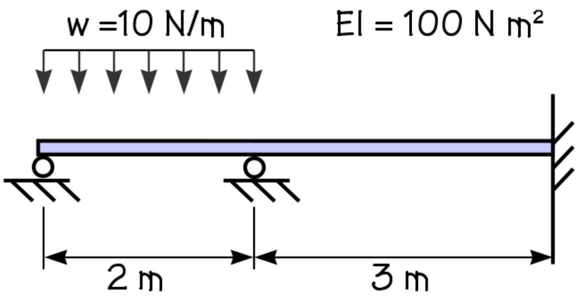
Sketch the shear, bending, slope and deflection patterns for the two cases shown below. No numerical values are required. (6 marks each problem)





## 5. Moment Distribution Method (15 Marks)

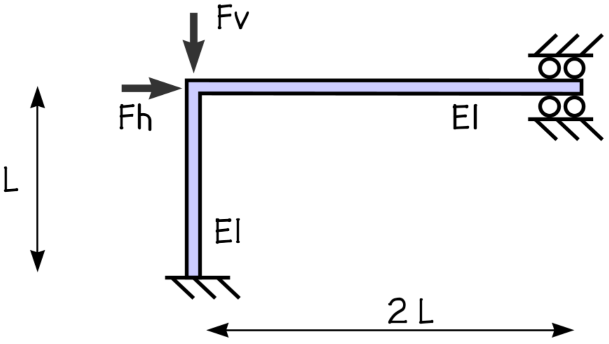
Solve the problem shown below using the moment distribution method.

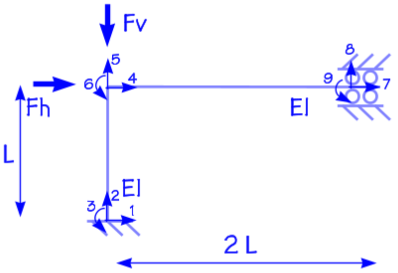


| | | | | | |
|---|---|---|---|---|---|
| MDF | 1 | .6 | .4 | | 0 |
| FEM | -3.33 | 3.33 | 0 | | 0 |
| Corr. | 3.33 | -2. | -1.33 | | 0 |
| CO | -1 | 1.67 | 0 | | -.67 |
| New EM | -1 | 3. | -1.33 | | -.67 |
| Corr. | +1 | -1. | -.67 | | 0 |
| CO | -.5 | +.5 | 0 | | -.33 |
| New EM | -.5 | 2.5 | -2. | | -1. |
| Corr. | +.5 | -.3 | -.2 | | 0 |
| CO | -.15 | +.25 | 0 | | -.1 |
| New EM | -.15 | 2.45 | -2.2 | | -1.1 |

## 6. Matrix Structural Analysis (15 Marks)

Write the matrix equation that describes the structure shown below. Give the terms in the Global stiffness matrix, and indicate which terms in the loads and response which are known and unknown. You will need to define a numbering system to describe the degrees of freedom for the structure in global terms.





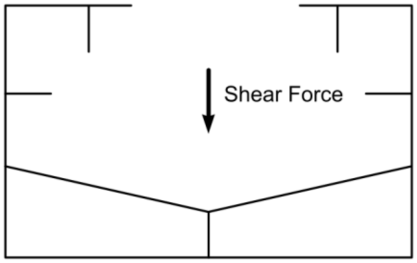
Structure

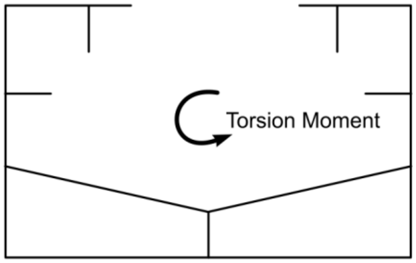
$$\begin{array}{r}\text{unknown}\left\{\begin{array}{c}R1\\R2\\R3\end{array}\right.\\\text{known}\left\{\begin{array}{c}Fh\\Fv\\0\\0\end{array}\right.\\\text{unknown}\left\{\begin{array}{c}R8\\R9\end{array}\right.\end{array}
=
\begin{array}{c|ccccccccc|}
 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9\\
1 & \frac{12EI}{L^3} & 0 & \frac{6EI}{L^2} & \frac{-12EI}{L^3} & 0 & \frac{6EI}{L^2} & 0 & 0 & 0\\
2 & 0 & \frac{AE}{L} & 0 & 0 & \frac{-AE}{L} & 0 & 0 & 0 & 0\\
3 & \frac{6EI}{L^2} & 0 & \frac{4EI}{L} & \frac{-6EI}{L^2} & 0 & \frac{2EI}{L} & 0 & 0 & 0\\
4 & \frac{-12EI}{L^3} & 0 & \frac{-6EI}{L^2} & \frac{AE}{2L}+\frac{12EI}{L^3} & 0 & \frac{-6EI}{L^2} & \frac{-AE}{2L} & 0 & 0\\
5 & 0 & \frac{-AE}{L} & 0 & 0 & \frac{12EI}{8L^3}+\frac{AE}{L} & \frac{6EI}{4L^2} & 0 & \frac{-12EI}{8L^3} & \frac{6EI}{4L^2}\\
6 & \frac{6EI}{L^2} & 0 & \frac{2EI}{L} & \frac{-6EI}{L^2} & \frac{6EI}{4L^2} & \frac{6EI}{L} & 0 & \frac{-6EI}{4L^2} & \frac{2EI}{2L}\\
7 & 0 & 0 & 0 & \frac{-AE}{2L} & 0 & 0 & \frac{AE}{L} & 0 & 0\\
8 & 0 & 0 & 0 & 0 & \frac{-12EI}{8L^3} & \frac{-6EI}{4L^2} & 0 & \frac{12EI}{8L^3} & \frac{-6EI}{4L^2}\\
9 & 0 & 0 & 0 & 0 & \frac{6EI}{4L^2} & \frac{2EI}{2L} & 0 & \frac{-6EI}{4L^2} & \frac{4EI}{2L}
\end{array}
\begin{array}{l}\left.\begin{array}{c}0\\0\\0\end{array}\right\}\text{known}\\\left.\begin{array}{c}d4\\d5\\d6\\d7\end{array}\right\}\text{unknown}\\\left.\begin{array}{c}0\\0\end{array}\right\}\text{known}\end{array}$$

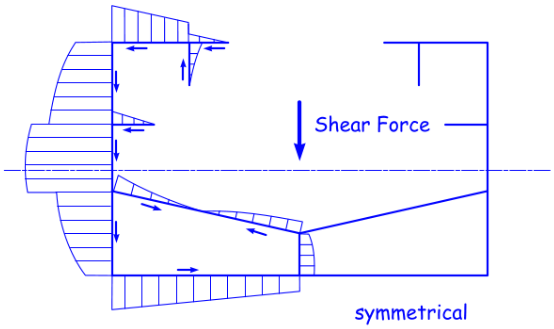
5 unknown forces and 4 unknown movements for totoal of 9 unknowns.

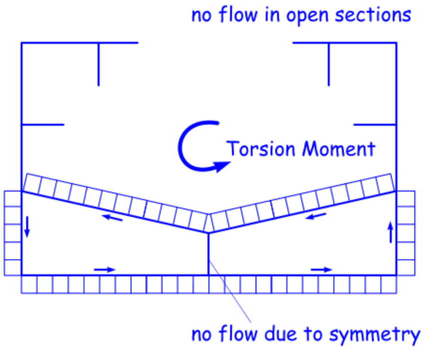
## 7. Shear Flow (15 Marks)

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

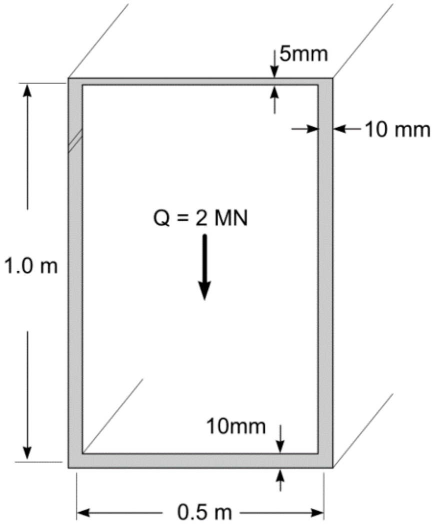


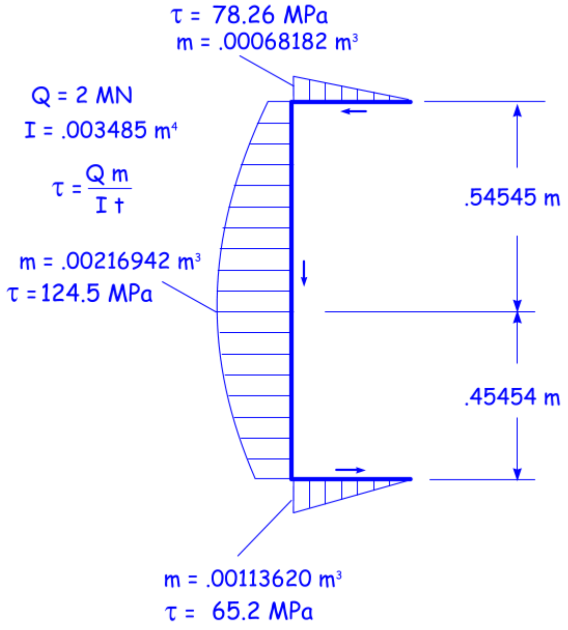






b) A cross section of a box girder is shown below. A vertical shear force of 2 MN is applied. Solve the shear flow, plot it and then also show the shear stress values (9).





# 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]

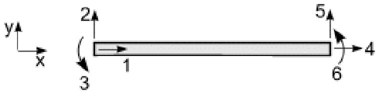
$v' = \theta =$ slope [rad]

$v''EI = M =$ 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

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

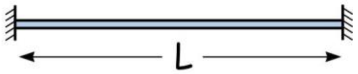
Shear flow: $q = \tau t, \quad q = Q\,m/I$

$m = \int yt\,ds$

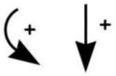
Torque: $Mx = 2qA$

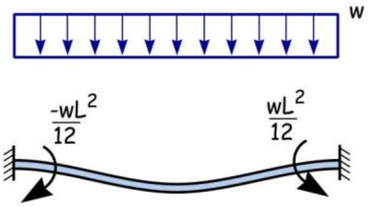
# Fixed End Loads

fixed fixed beam, length L, constant EI:

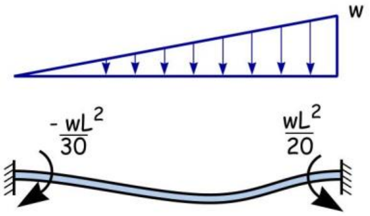


sign for moments and forces:

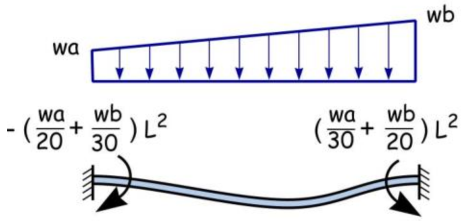




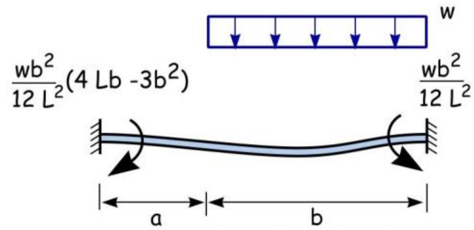
uniform load



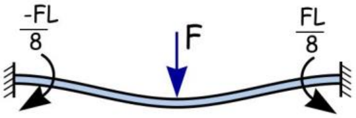
triangular load



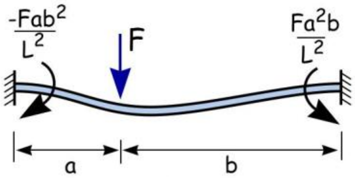
variable load



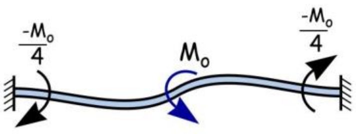
partial uniform load



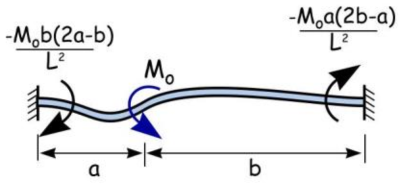
center force



point force

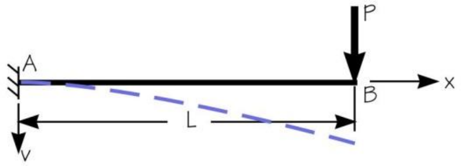
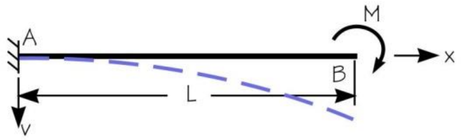
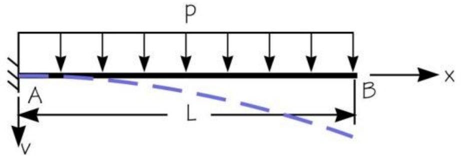
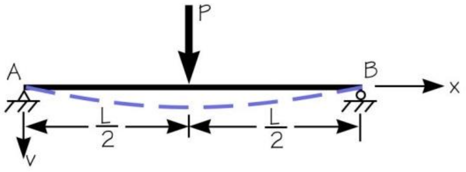
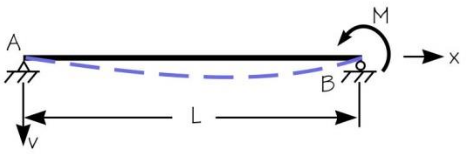
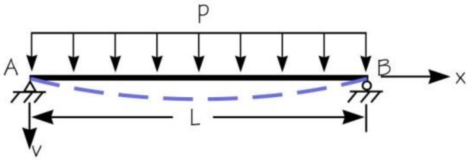
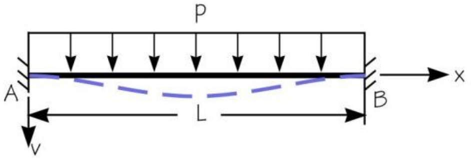
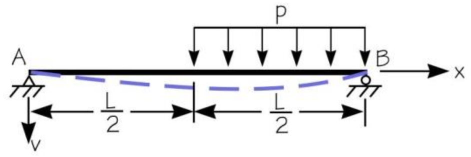


center moment



point moment

## Deflection and Slopes of Beams

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