MEMORIAL UNIVERSITY OF NEWFOUNDLAND

Faculty of Engineering and Applied Science

Engineering 5003 - Ship Structures

FINAL EXAMINATION

Date: Tuesday April 11, 2017 **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.

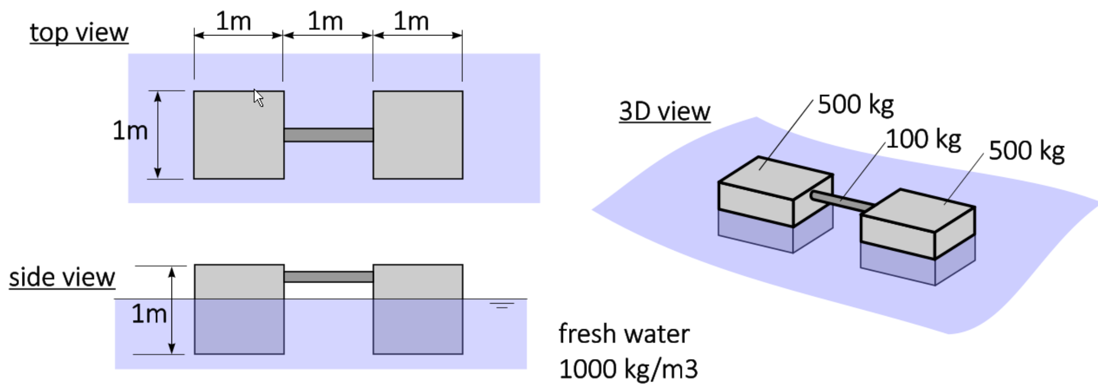
1. Basic concepts (12 marks)

Discuss the differences and connections between material behavior (theory of mechanics of materials) and structural behavior (theory of structures).

2. Hydrostatics (16 Marks)

There are two 1m-cubes rigid boxes that each weigh 500 kg. They are joined by a 1m long rigid bar (small diameter), connecting the two boxes. The joining bar is out of the water and weighs 100 kg. The construction is floating in fresh water (density 1000 kg/m3).

a) What is the draft that the cubes float at? (3)
b) What is the still water moment at the center? (5)
c) Sketch the shear force diagram. (5)
d) What is the moment where the bar connects to the box? (3)



3. Preliminary Calculations (14 Marks)

A vessel (oil tanker) has the following particulars:

Length: 220 m Beam: 40 m
Block Coefficient: 0.85 Displacement: 84337 tonnes
Water density: 1.025 tonnes/m3

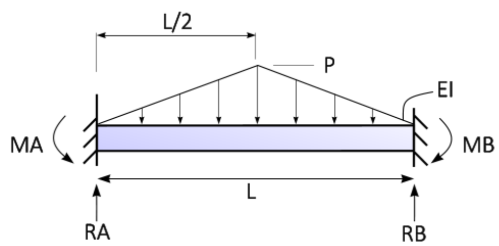
a) What is the vessel's draft? (3)
b) Using Prohaska's approach, sketch the weight distribution of the vessel. (6)
c) With the addition of Murray's method, determine an estimate of the still water bending moment at midships. (5)

4. Beam Responses (15 Marks)

A fixed-fixed beam is subject to a triangular load pattern as shown.

a) There is an attempt at a solution to the beam problem using Macaulay functions shown at the right below. There are errors on every line of the solution. Correct the Macaulay equations. (8)
b) How would you find MA and RA? Show as much of the solution as you can. (7)

Centered Triangular Load



$$\text{LOAD} = -2P/L \langle x-0 \rangle^{1} + 2P/L \langle x-L/2 \rangle^{1}$$

$$\text{SHEAR} = RA - P/L \langle x-0 \rangle^{2} + P/L \langle x-L/2 \rangle^{2}$$

$$\text{MOMENT} = MA + RA \langle x-0 \rangle^{1} - P/(3L) \langle x-0 \rangle^{3} + P/(3L) \langle x-L/2 \rangle^{3}$$

$$\text{SLOPE} = MA \langle x-0 \rangle^{1} + RA/2 \langle x-0 \rangle^{2} - P/(4L) \langle x-0 \rangle^{4} + P/(4L) \langle x-L/2 \rangle^{4}$$

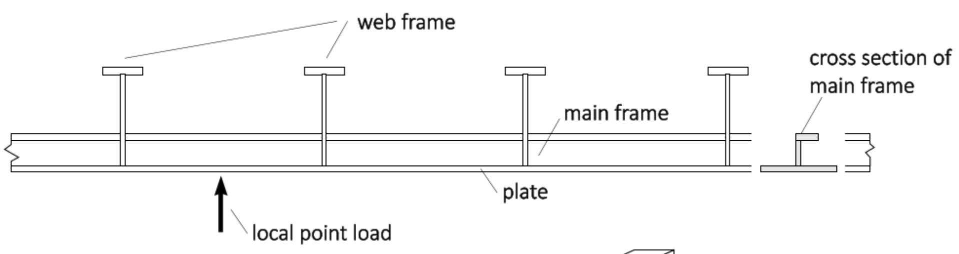
$$\text{DEFLECTION} = MA/2 \langle x-0 \rangle^{2} + RA/3 \langle x-0 \rangle^{3} - P/(5L) \langle x-0 \rangle^{5} + P/(5L) \langle x-L/2 \rangle^{5}$$

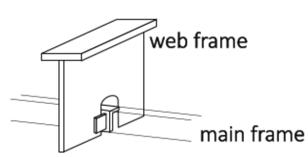
5. Moment Distribution Method (13 Marks)

a) What is a moment distribution factor? (3)
b) Describe the meaning of ‘carry over factor’ (3)

Now Consider a single longitudinal main frame in the bottom of a ship. Each main frame runs through many web frames (which are transverse to the axis of the ship). At each Web frame, there is just a small bracket joining the webs. The connevtion only transfers shear, not moment.

c) For a single point load applied to one frame as shown, how would you use the Moment distribution method to determine the bending moment in the frame that contains the point load. Sketch a simplified version of the problem for analysis. (7)

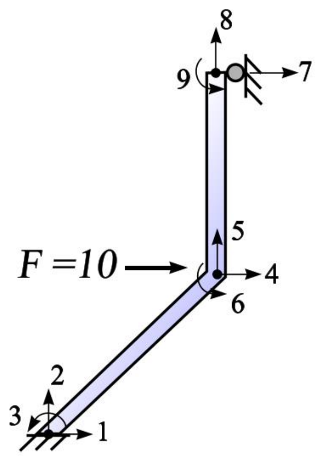




sketch of connection
between main frame
and web frame
a small bracket is welded
connecting the webs as shown

6. Matrix Structural Analysis (15 Marks)

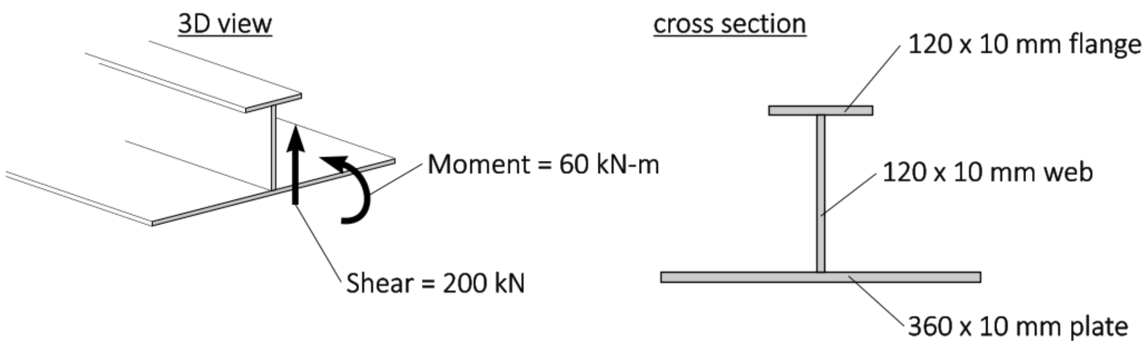
a) Describe how you would construct the stiffness matrix for this problem. (10)
b) Of all the load and deflections, which are known? (5)



7. Shear and Bending (15 Marks)

A frame is comprised of a flange, web and attached plating as shown. At a certain cross section ther is a moment of 60 kN-m and a shear of 200 kN.

a) what is the maximum bending stress at this cross section (6)
b) what is the maximum shear stress in the section. (7)
c) What is the shear force (in kN/m) that must be transferred from the flange to the web? (2)



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

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

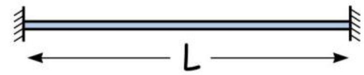
Shear flow: $q = \tau t, \quad q = Q\,m/I$

$m = \int yt\,ds$

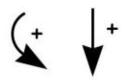
Torque: $Mx = 2qA$

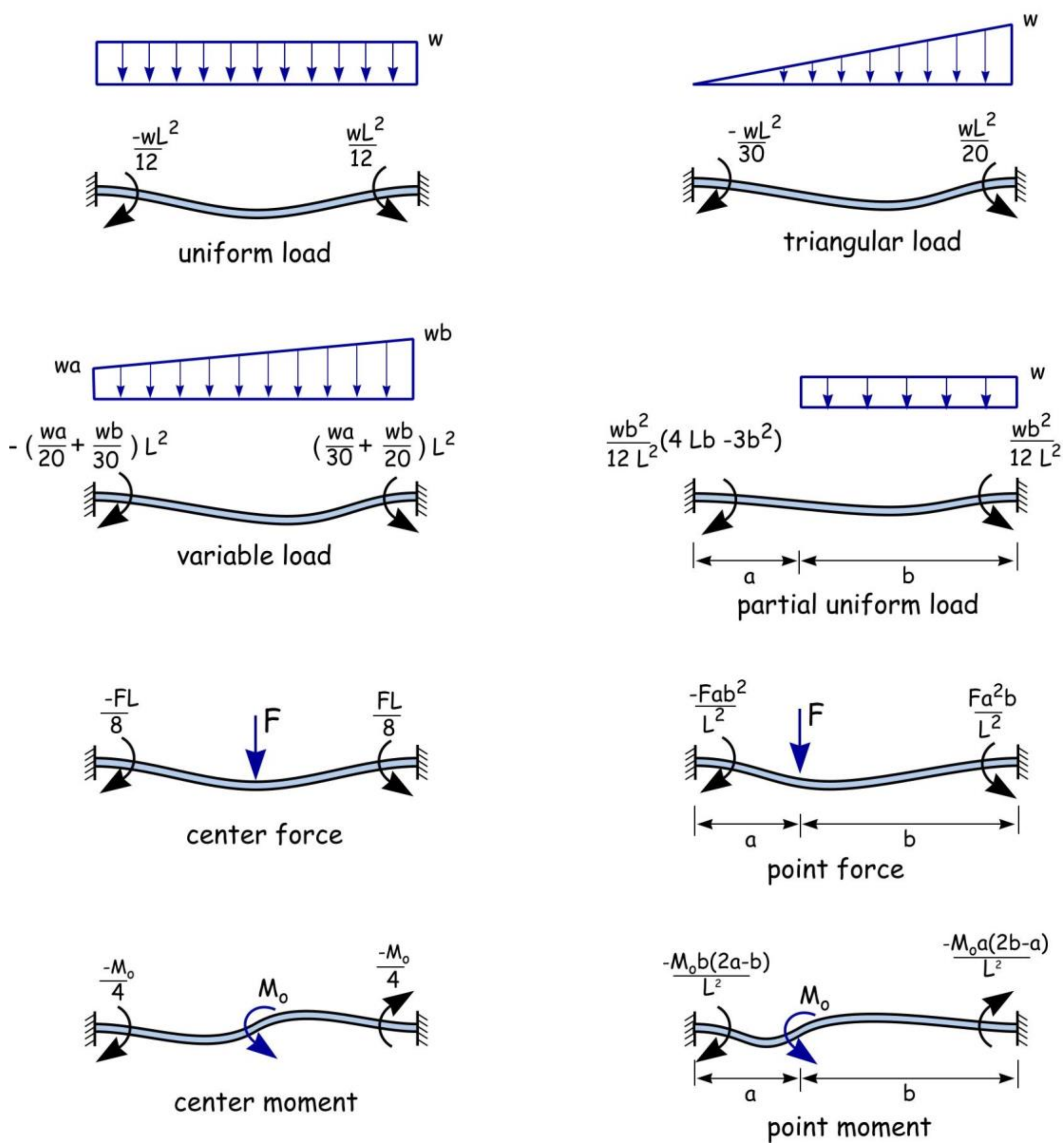
Fixed End Loads

fixed fixed beam, length L, constant EI:

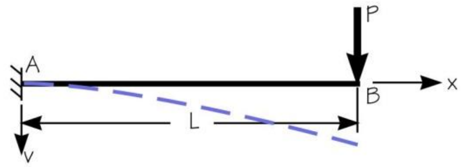
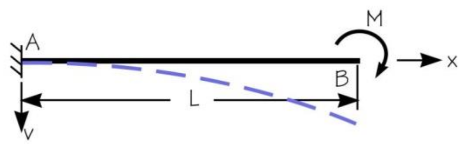
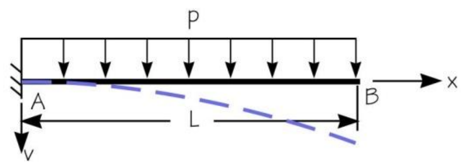
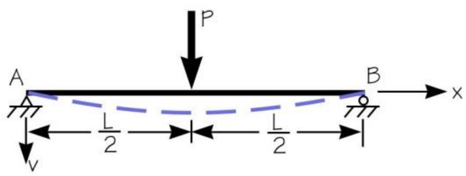
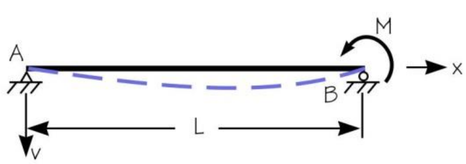
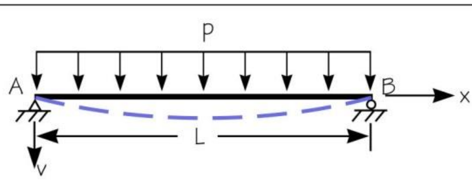
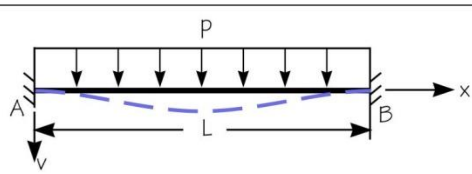
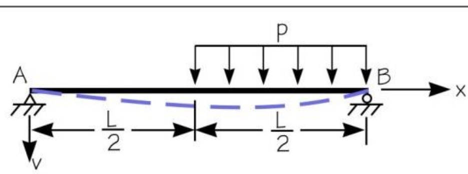


sign for moments and forces:





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	$\theta_A = \frac{-7\,pL^3}{384\,EI}$ $\theta_B = \frac{3\,pL^3}{128\,EI}$