98-Nav-A4, Ship Structure and Strength of Ships

3 hours duration

Notes

1) Attempt all questions. The exam is marked out of 100, with marks indicated [n] per question.

2) The exam is closed book. No notes or written material of any form is permitted. Casio or Sharp calculator models are allowed. Simple drawing equipment, such as a ruler or straightedge, pencil or pen, eraser are permitted. Some formulae are provided at the end of the exam.

3) Even in the case of numerical problems, written explanations of the solution are necessary, and should be neat, legible, clear and concise. Sketches, neatly labeled, should be used as appropriate to illustrate the method of solution. If there is any uncertainty, the candidate should explain the assumptions used in preparing the answer. The clarity of the answer will influence the grade.

Ql. General Aspects of Ship Structures

1a) [8] For each of the following structural aspects of a ship, list the types of loads and failure mechanisms that would be of concern and would tend to govern the design (no more than 3 types per item):

i: hull girder of oil tanker
ii: transverse frame in the bow of container ship
iii: bottom plating in a warship
iv: propeller shaft
v: fore deck
vi: hatch cover in a bulk carrier

1b) [8] Define the following terms:

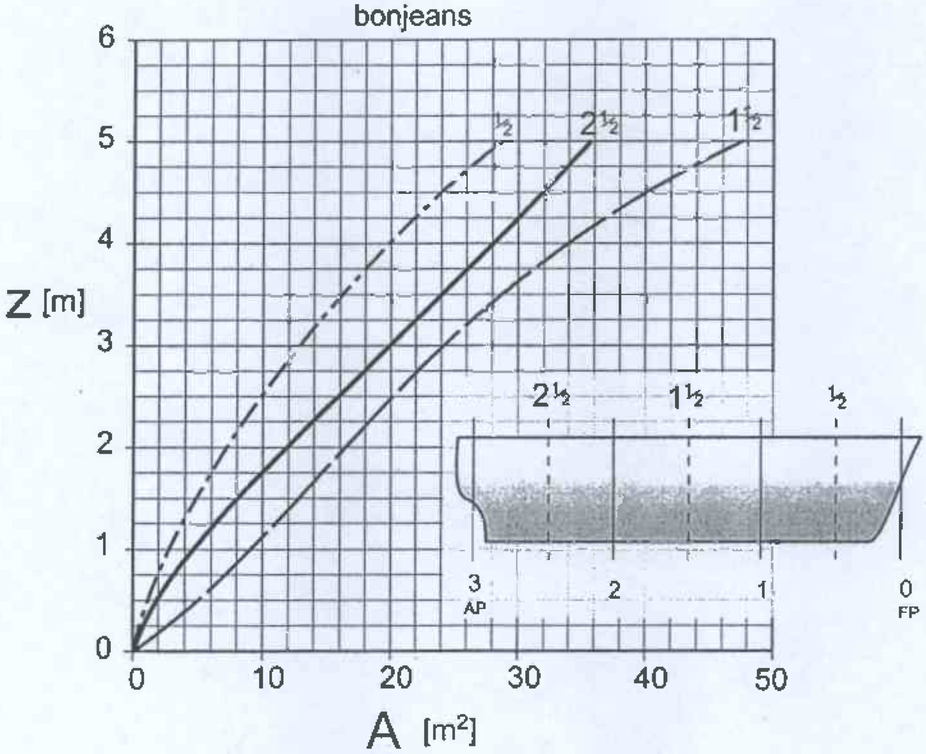
i: collision bulkhead
ii: long plate theory
iii: Grade A steel
iv: Double bottom girder
v: holland profile
vi: IACS

1c) [7] Describe and sketch various types of brackets found in ship structures.

Q2. Hydrostatic Loads

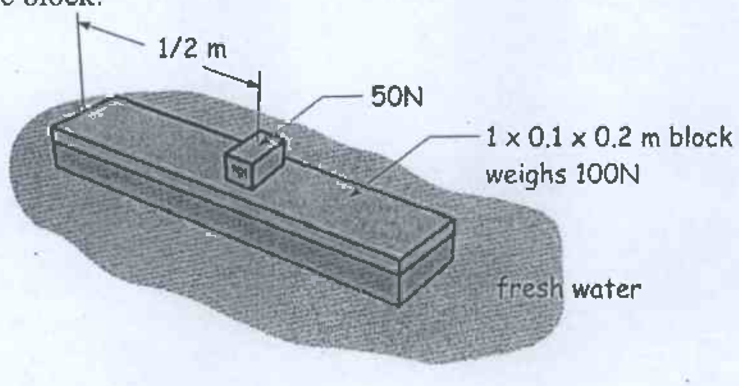
2 a) [10] The following diagram shows a simplified version of the bonjean curves for a vessel. There are 4 stations. The bonjean curves are given at the 3 half stations (assumed to apply to the whole region between stations). Lbp is 60m. The vessel is floating level (no trim), at a 4.5 m draft in fresh water (density = 1 t/m^3).

i. Where is the center of gravity of the vessel (distance from AP in m) ?
ii. What is the vessel displacement in tonnes at this draft?



2 b) [8] There is a 'rectangular' shaped block of wood, as shown in the image below. The block weighs 100 N and has uniform density. It is 1 m long and 0.20 m wide. It is 10 cm thick and is floating in fresh water. A 50N weight is placed on the center of the block.

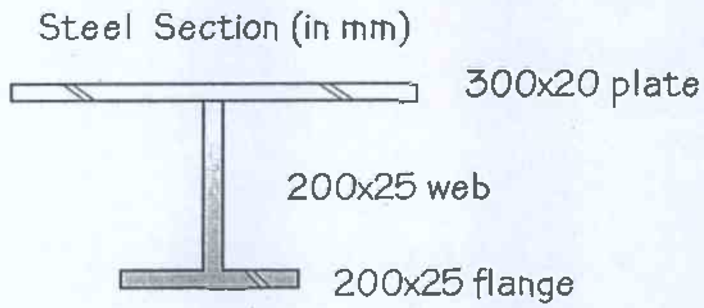
i. Draw the shear force and bending moment diagrams for the block along the long axis of the block.



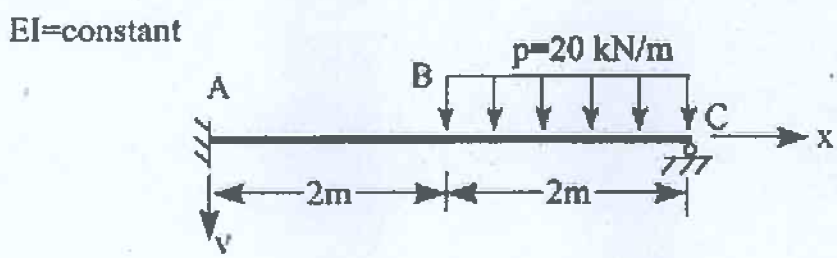
Q3. Structural Mechanics

3 a) [8] The figure below shows a cross section of a single transverse frame attached to shell plate. For this section:

i. locate the centroid
ii. find the moment of inertia
iii. find the section modulus



3 b) [10] Beam Bending. For the beam sketch below:



i. sketch by hand the shear, moment, slope and deflection diagrams (for this part no numbers are needed)
ii. assuming that $EI=1.0\ kN\text{-}m^2$ for the section, find the deflection at the middle of the beam (you can make use of the tables at the end of the exam).

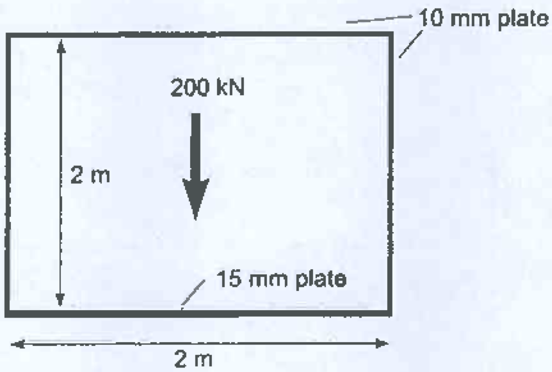
Q4. **Material Behaviour and Fatigue**

4 a) [12] Explain the following;
i. the von-Mises failure criteria
ii. the concept of von-Mises equivalent stress
iii. draw a Mohr's circle to represent a case of uniaxial stress
iv. draw a Mohr's circle to represent a case of pure shear. (in 2D)

4 b) [9] Describe the following terms related to Fatigue.
i. the S-N Curve
ii. Miner's Rule
iii. Connection details.

5. **Shear in Ships**

5 a) [12] For the section of a simple steel hull shown below, with a vertical shear force of 200kN;
i. find the moment of inertia and section modulus and location of the neutral axis.
ii. Solve the shear flow and plot it
iii. calculate and show the shear stress value the deck edge.



5b) [6] For the cross section shown above,
i. sketch the pattern of shear flow that would arise for a pure torsion applied to the section.

Some Useful Formulae

Weight of a Vessel:

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

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 for a rectangle

Ina = 1/12 a d^2

Family of Differential Equations Beam Bending

$v =$ deflection [m]

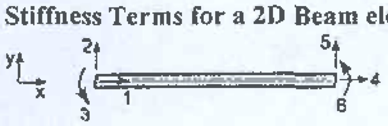
$v' = \theta =$ slope [rad]

$v'EI = M =$ bending moment [N-m]

$v''EI = Q =$ shear force [N]

$v'''EI = P =$ line load [N/m]

Stiffness Terms for a 2D Beam element



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

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

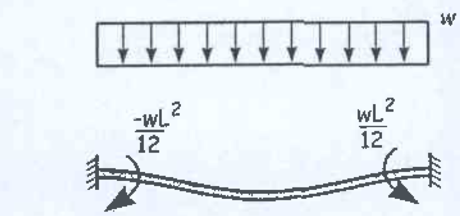
$m = \int yt\,ds$

Torque: $Mx = 2qA$

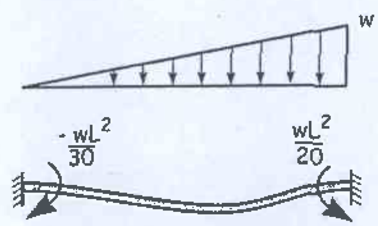
Fixed End Loads

fixed fixed beam, length L, constant EI:

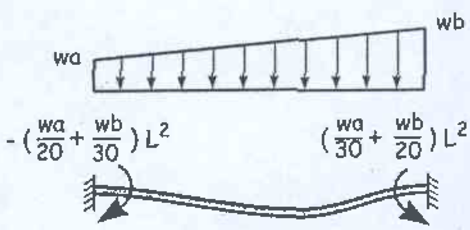
sign for moments and forces:



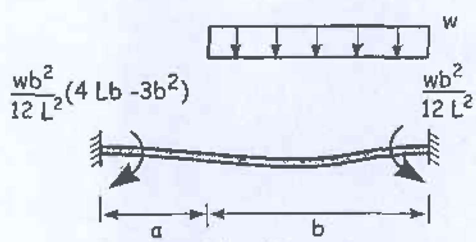
uniform load



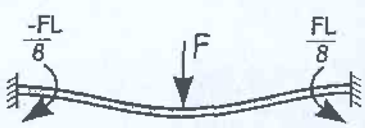
triangular load



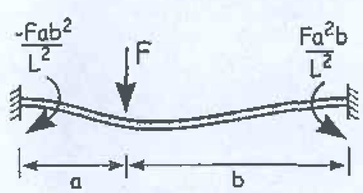
variable load



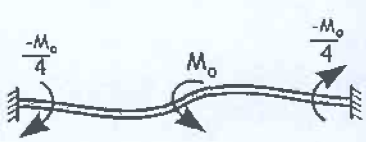
partial uniform load



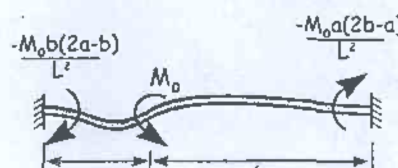
center force



point force



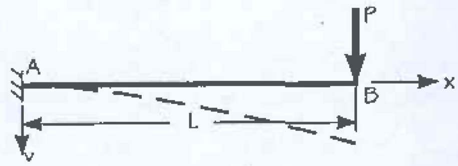
center moment



point moment

Deflection and Slopes of Beams

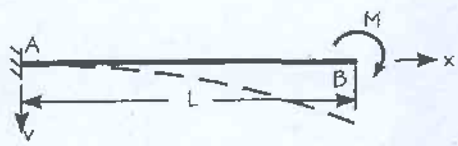
Loading — **Deflection** — **Slope**



$v = \frac{Px^2}{6EI}(3L - x)$

$v_{max} = v_B = \frac{PL^3}{3EI}$

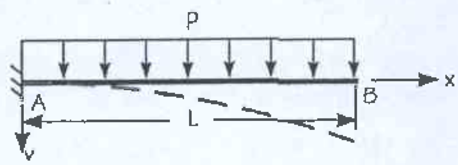
$\theta_B = \frac{PL^2}{2EI}$



$v = \frac{Mx^2}{2EI}$

$v_{max} = v_B = \frac{ML^2}{2EI}$

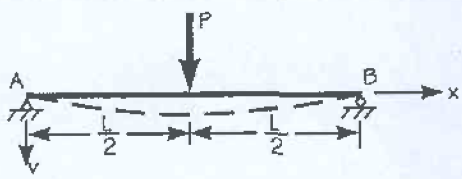
$\theta_B = \frac{ML}{EI}$



$v = \frac{px^2}{24EI}(6L^2 - 4Lx + x^2)$

$v_{max} = v_B = \frac{pL^4}{8EI}$

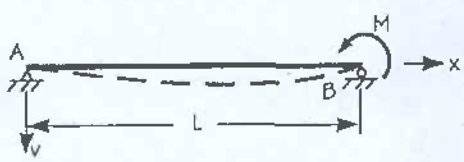
$\theta_B = \frac{pL^3}{6EI}$



$v = \frac{Px^2}{48EI}(3L^2 - 4x^2)$

$v_{max} = \frac{PL^3}{48EI}$ @ $x = L/2$

$\theta_A = -\theta_B = \frac{PL^2}{16EI}$

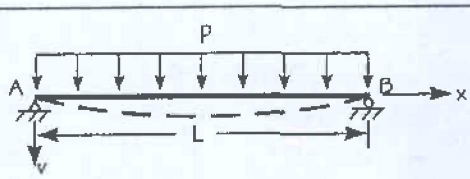


$v = \frac{Mx}{6EI\,L}(L^2 - x^2)$

$v_{max} = \frac{ML^2}{9\sqrt{3}\,EI}$ @ $x = L/\sqrt{3}$

$\theta_A = \frac{ML}{6EI}$

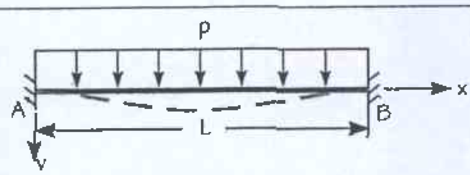
$\theta_B = -\frac{ML}{3EI}$



$v = \frac{px}{24EI}(L^3 - 2Lx^2 + x^3)$

$v_{max} = \frac{5\,pL^4}{384\,EI}$ @ $x = L/2$

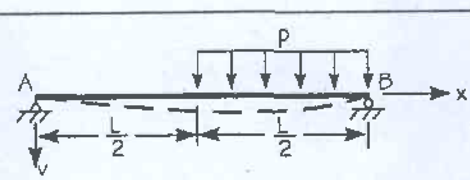
$\theta_A = -\theta_B = \frac{pL^3}{24EI}$



$v = \frac{px^2}{24EI}(L - x)^2$

$v_{max} = \frac{pL^4}{384\,EI}$ @ $x = L/2$

$\theta_A = \theta_B = 0$



$v_{cent} = \frac{3\,pL^4}{256\,EI}$ @ $x = L/2$

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

$\theta_B = \frac{3\,pL^3}{128\,EI}$