ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE
DEPARTMENT OF CIVIL ENGINEERING

Engineering Mechanics [CEN2201] Final Exam
Target Group: 2nd year regular students
Total Mark: 40%

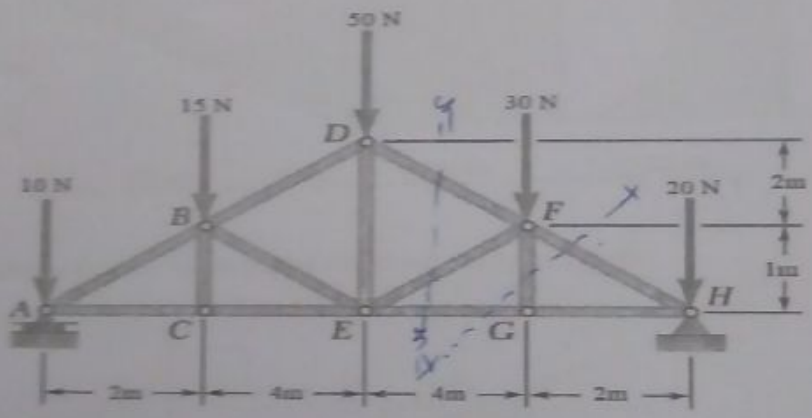
Date: May 21, 2021G.C
Time Allowed: 3Hrs

Note: - *The Exam is Closed Book*
-Procedure and Clarity has its own value
-Material Exchange is strictly forbidden

Q2 is for SoCEA students and
Q5 is for SoMCME students

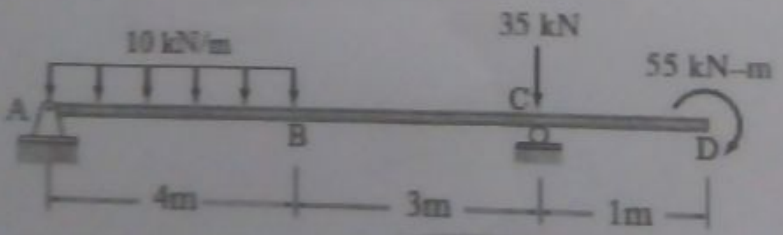
Q1. For the roof truss shown below:

a. Determine reaction forces at support A and H (2 pts.)
b. By using method of joint determine the force in members BE and BC (4 pts.)
c. By using method of section determine the force in members FE and FG (4 pts.)



Q2. For the beam and loading shown below:

a. Draw the shear force and bending moment diagrams (8pts.)
b. Determine the maximum magnitude of the bending moment and its location (X) From the left end (2pts)

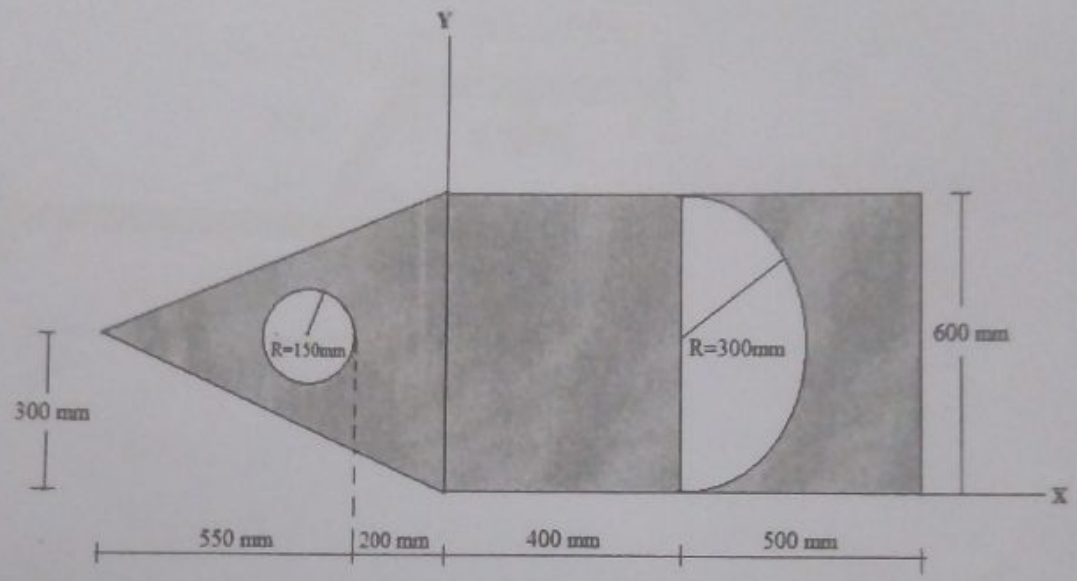


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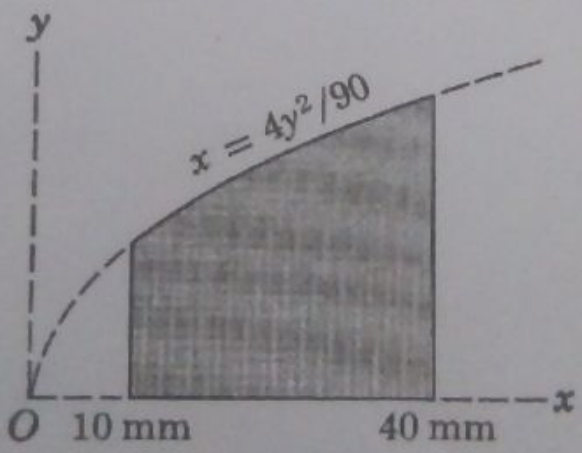
Q3. For the given composite body Shown below determine (15 pts.)

A. The centroid of the shaded area (7.5 pts.)

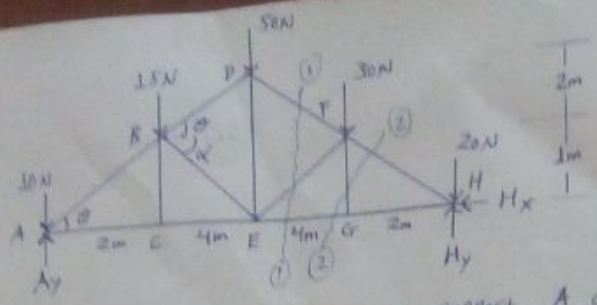
B. The moment of Inertia of the shaded area (7.5 pts.)



Q4. Calculate the Centroid of the shaded area about x and y axis (5 pts.)



1.



$\theta = \tan^{-1}(\frac{1}{2})$

$= \tan^{-1}(0.5)$

$= 26.56$

$\alpha = \tan^{-1}(\frac{1}{4})$

$= 14.04$

a. Determine the reaction forces at support A and H

$\Sigma M_H = 0, \quad -A_y(12) + 10(12) + 15(10) + 50(6) + 30(2) = 0$

$12A_y = 120 + 150 + 300 + 60$

$A_y = \frac{630}{12}$

$A_y = 52.5N$ (1)

$\Sigma F_y = 0, \quad A_y - 10 - 15 - 50 - 30 - 20 + H_y = 0$

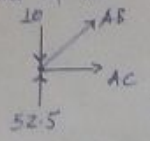
$H_y = 10 + 15 + 50 + 30 + 20 - 52.5$

$H_y = 125 - 52.5$

$H_y = 72.5N$ (1)

b. By using method of joint determine the force in members BE and BC

Joint A.



$\Sigma F_y = 0, \quad 52.5 - 10 + AB \sin 26.56 = 0$

$AB = \frac{-42.5}{\sin 26.56} = \frac{-42.5}{0.447} = -95.08N$ (1)

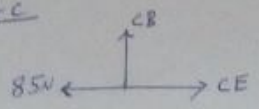
$\Sigma F_x = 0, \quad AC + AB \cos 26.56 = 0$

$AC - 95.08 \cos 26.56 = 0$

$AC = 95.08(0.894)$

$AC = 85N$ (1)

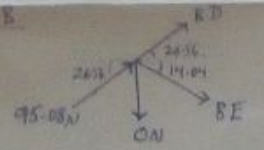
Joint C



$\Sigma F_x = 0, \quad CE - 85 = 0, \quad CE = 85N$

$\Sigma F_y = 0, \quad CB = 0$ (1)

Joint B



$\Sigma F_x = 0 \quad 95.08\cos(26.56) + BD\cos 26.56 + BE\cos 14.04 = 0$

$0.894BD + 0.97BE = -85$

$\Sigma F_y = 0, \quad 0 + 95.08\sin(26.56) + BD\sin 26.56 - BE\sin 14.04 = 0$

$42.51 + 0.45BD - 0.24BE = 0$

$0.45BD - 0.24BE = -42.51$

$\frac{1}{0.97}(0.894BD + 0.97BE = -85)$

$\frac{1}{0.24}(0.45BD - 0.24BE = -42.51)$

$0.92BD + BE = -87.63$

$+ \quad 1.875BD - BE = -177.125$

$2.795BD = -264.755$

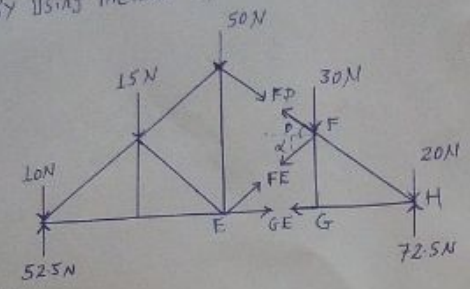
$BD = \frac{264.755}{2.795}, \quad BD = -94.72N$

$0.97BE = -85 - 0.894(-94.72)$

$BE = \frac{-85 + 84.8}{0.97} = \frac{-0.2}{0.97}$

$BE = 0.21N.$

C. By using method of section determine the force in members FE and FG



$\theta = \tan^{-1}(2/4) = 26.56°$

$\alpha = \tan^{-1}(1/4) = 14.04°$

Segment 2

$\sum M_E = 0, \quad -GE(1) - 20(2) + 72.5(2) = 0$

$GE = 145 - 40$

$GE = 105\,N$ (1)

$\sum F_x = 0, \quad -FD\cos 26.56 - FE\cos 14.04 - GE = 0$

$0.894\,FD + 0.97\,FE = -105$ ..... (1)

$\sum F_y = 0, \quad FD\sin 26.56 - FE\sin 14.04 - 30 - 20 + 72.5 = 0$

$0.447\,FD - 0.243\,FE = -22.5$ ..... (2)

$\frac{1}{0.894}[0.894\,FD + 0.97\,FE = -105]$

$-FD - 1.085\,FE = 117.45$ ..... (3)

$\frac{1}{0.447}[0.447\,FD - 0.243\,FE = -22.5]$

$FD - 0.544\,FE = -50.336$ ..... (4)

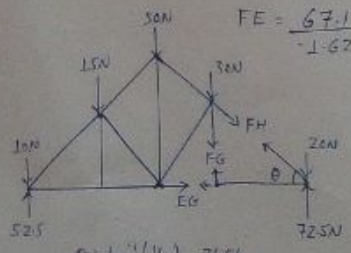
eqn (3) & (4)

$-FD - 1.085\,FE = 117.45$

$+\ FD - 0.544\,FE = -50.336$

$-1.629\,FE = 67.114$

$FE = \frac{67.114}{-1.629}, \quad FE = -41.2\,N$ (1)



$\theta = \tan^{-1}(1/2) = 26.56$

Segment 2

$\sum M_G = 0, \quad -20(2) + 72.5(2) + FH(\sin 26.56)(2) = 0$

$0.894\,FH = 40 - 145 = -105$ (1)

$FH = \frac{-105}{0.894}, \quad FH = -117.45\,N$

$\sum F_y = 0, \quad FG + FH\sin 26.56 - 20 + 72.5 = 0$

$FG - 117.45(0.447) - 20 + 72.5 = 0$

$FG = 52.5 + 20 - 72.5 + 52.5$

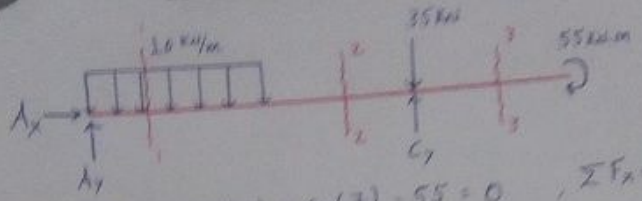
$FG = 0\,N$ (1)

$\therefore FE = 41.2\,N\ (C)$

$FG = 0\,N$

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2.



$\Sigma M_A = 0$, $-10(4)(4/2) - 35(7) + C_y(7) - 55 = 0$, $\Sigma F_x = 0$, $A_x = 0$

$-80 - 245 - 55 + 7C_y = 0$

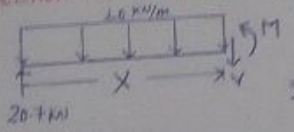
$C_y = \frac{380}{7} = 54.286$ KN (0.25)

$\Sigma F_y = 0$, $A_y - 10(4) - 35 + 54.286 = 0$

$A_y = 40 + 35 - 54.286$, $A_y = 20.714$ KN (0.25)

$\therefore A_y = 20.7$ KN, $C_y = 54.3$ KN

Section 1-1 ($0 < x \leq 4$) (0.5)



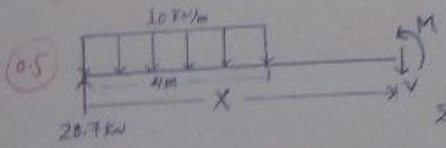
$\Sigma F_y = 0$, $20.7 - 10(x) - V = 0$

$V = 20.7 - 10x$ (0.5)

$\Sigma M = 0$, $M - 20.7(x) + 10(x)(x/2) = 0$

$M = 20.7x - 5x^2$ (0.5)

Section 2-2 ($4 \leq x \leq 7$) (0.5)



$\Sigma F_y = 0$, $20.7 - 10(4) - V = 0$

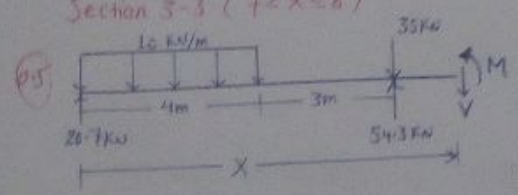
$V = -19.3$ KN (0.5)

$\Sigma M = 0$, $M - 20.7(x) + 10(4)(x-2) = 0$

$M - 20.7x + 40x - 80 = 0$

$M = -19.3x + 80$ (0.5)

Section 3-3 ($7 < x \leq 8$) (0.5)



$\Sigma F_y = 0$, $20.7 - 10(4) - 35 + 54.3 - V = 0$

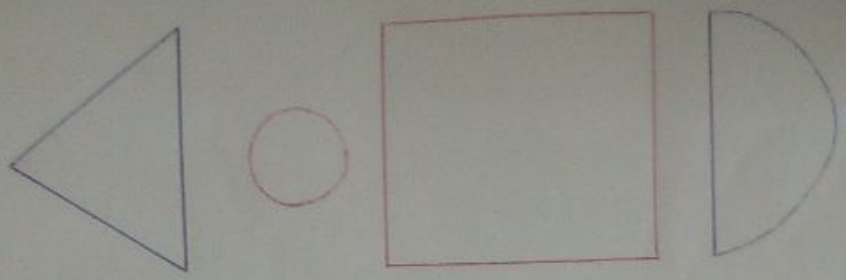
$V = 0$ (0.5)

$\Sigma M = 0$, $M - 20.7(x) + 40(x-2) - 54.3(x-7) + 35($

$M - 20.7x + 40x - 80 - 54.3x + 380.1 + 35x -$

$M = -55$ KN.m (0.5)

3.



a, Centroid of the Shaded area.

	Part	Area (mm^2)	$\bar{X}$ (mm)	$\bar{Y}$ (mm)	$A\bar{X}$ (mm^3)	$A\bar{Y}$ (mm^3)
1.5	Rectangle	540×10^3	450	300	243×10^6	162×10^6
1.5	Semi-circle	-141.372×10^3	527.324	300	-74.549×10^6	-42.412×10^6
1.5	Triangle	225×10^3	-250	300	-56.25×10^6	67.5×10^6
1.5	Circle	-70.686×10^3	-350	300	24.74×10^6	-21.206×10^6
	Total	552.942×10^3			136.941×10^6	165.882×10^6

$$\bar{X} = \frac{\Sigma A\bar{X}}{\Sigma A} = \frac{136.941 \times 10^6}{552.942 \times 10^3} = 247.66 \text{ mm} \quad 0.75$$

$$\bar{Y} = \frac{\Sigma A\bar{Y}}{\Sigma A} = \frac{165.882 \times 10^6}{552.942 \times 10^3} = 300 \text{mm} \quad 0.75$$

b. Moment of inertia of the Shaded area

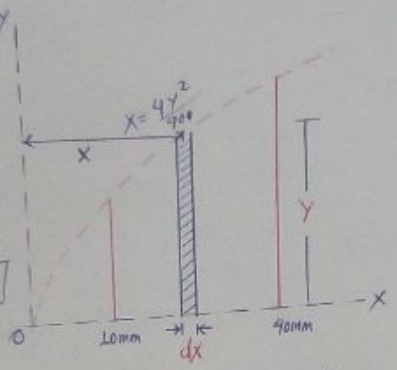
	Part	Area (mm^2)	dx (mm)	dy (mm)	Ad_x^2 (mm^4)	Ad_y^2 (mm^4)	$\bar{I}_x$ (mm^4)	$\bar{I}_y$ (mm^4)
1.5	Rectangle	540×10^3	300	450	48.6×10^9	109.35×10^9	16.2×10^9	36.45×10^9
1.5	Semi-circle	-141.372×10^3	300	527.324	-12.723×10^9	-39.311×10^9	-3.18×10^9	-0.891×10^9
1.5	Triangle	225×10^3	300	-250	20.25×10^9	14.062×10^9	4.5×10^9	7.031×10^9
1.5	Circle	-70.686×10^3	300	-350	-6.362×10^9	-8.659×10^9	-0.398×10^9	-0.398×10^9
	Total	552.942×10^3			49.765×10^9	75.442×10^9	17.122×10^9	42.192×10^9

$$I_x = \Sigma \bar{I}_x + \Sigma Ad_x^2 = 17.122 + 49.765 = 66.887 \text{ mm}^4 \times 10^9 \quad 0.75$$

$$I_y = \Sigma \bar{I}_y + \Sigma Ad_y^2 = 42.192 + 75.442 = 117.634 \times 10^9 \text{ mm}^4 \quad 0.75$$

$$\therefore I_x = 66.887 \times 10^9 \text{ mm}^4 \quad \& \quad I_y = 117.634 \times 10^9 \text{ mm}^4$$

4



$dA = Y\,dX$

$X = \frac{4Y^2}{90}$, $Y^2 = \frac{90X}{4}$

$Y = \sqrt{\frac{90X}{4}}$

$A = \int dA$

$= \int Y\,dX$

$= \int \left(\frac{90X}{4}\right)^{1/2} dX$

$= \sqrt{225} \int X^{1/2}\,dX$

$= \sqrt{225} \left[\frac{2}{3}X^{3/2}\right]_{10}^{40}$

$= \frac{2\sqrt{225}}{3}\left[221.359\right]$

$= 700\ mm^2$ (1)

$\bar{X} = \frac{\int \bar{x}\,dA}{\int dA} = \frac{\int X \cdot Y \cdot dX}{\int Y \cdot dX} = \frac{\int X \cdot \left(\frac{90X}{4}\right)^{1/2} dX}{\int \left(\frac{90X}{4}\right)^{1/2} dX} = \frac{\left(\frac{90}{4}\right)^{1/2} \int X^{3/2}\,dX}{\left(\frac{90}{4}\right)^{1/2} \int X^{1/2}\,dX}$

$= \frac{\frac{2}{5}X^{5/2}\Big|_{10}^{40}}{\frac{2}{3}X^{3/2}\Big|_{10}^{40}} = \frac{2}{5}\cdot\frac{3}{2}\left[\frac{40^{5/2} - 10^{5/2}}{40^{3/2} - 10^{3/2}}\right]$

$= \frac{3}{5}\left[\frac{10,119.288 - 316.228}{252.982 - 31.628}\right] = \frac{3}{5}\left[\frac{9,803.06}{221.359}\right] = \frac{3}{5}(44.286)$

$\bar{X} = 26.572\ mm$ (2)

$\bar{Y} = \frac{\int \bar{y}\,dA}{\int dA} = \frac{\int \frac{Y}{2} \cdot Y \cdot dX}{\int Y \cdot dX} = \frac{\frac{1}{2}\int Y^2\,dX}{\int Y \cdot dX} = \frac{\frac{1}{2}\int \frac{90X}{4}\,dX}{\int \left(\frac{90X}{4}\right)^{1/2} dX} = \frac{\frac{90}{8}\int X \cdot dX}{\sqrt{90/4}\int X^{1/2}\,dX}$

$= \frac{\frac{90}{8}\left[\frac{X^2}{2}\Big|_{10}^{40}\right]}{\sqrt{90/4}\left[\frac{2}{3}X^{3/2}\Big|_{10}^{40}\right]} = \frac{\frac{90}{16}\left[40^2 - 10^2\right]}{\frac{2}{3}\sqrt{225}\left[40^{1.5} - 10^{1.5}\right]} = \frac{\frac{90}{16}\left[1600 - 100\right]}{\frac{2}{3}\sqrt{225}\left[252.982 - 31.623\right]}$

$= \frac{8,437.5}{3.162(221.359)} = 12.055$

$\bar{Y} = 12.055\ mm$ (2)