



ACBA 6007

Structural Calculations

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Question 1 Determine the force in each member of the truss shown.

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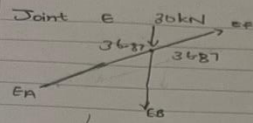
FBD

$30 \text{ kN} + 60 \text{ kN} + 30 \text{ kN}$
 $= 120 \text{ kN}$
 $\frac{120 \text{ kN}}{2}$
 $= 60 \text{ kN}$

Because the truss is symmetric in both loading & geometry, only the forces in half of the members need to be determined.

Joint A

$\theta = \tan^{-1}\left(\frac{3}{4}\right) = 36.87^\circ$
 $\sum F_y = 0 \Rightarrow AE \sin(36.87^\circ) + 60 = 0$
 $AE = -100 \text{ kN}$
 $\sum F_x = 0$
 $AB + AE \cos(36.87^\circ) = 0$
 $AB - 100 \cos(36.87^\circ) = 0$
 $AB = 80 \text{ kN}$

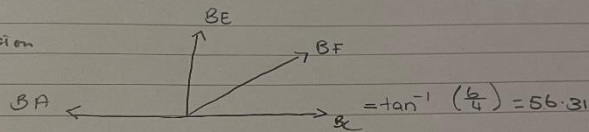


$$\begin{aligned}\sum F_x = 0 &\Rightarrow EF \cos(36.87) - EA \cos(36.87) = 0 \\ EF \cos(36.87) + 100 \cos(36.87) &= 0 \\ EF &= -100 \text{ kN}\end{aligned}$$

$$\begin{aligned}\sum F_y = 0 &\Rightarrow -EB - EA \sin(36.87) - 30 + EF \sin(36.87) = 0 \\ -EB + 100 \sin(36.87) - 30 - 100 \sin(36.87) &= 0 \\ EB &= -30 \text{ kN}\end{aligned}$$

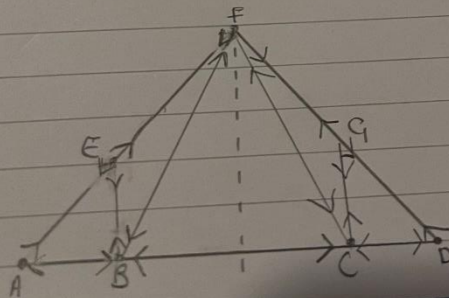
Joint B

$\rightarrow \leftarrow$ compression
 $\leftarrow \rightarrow$ Tension

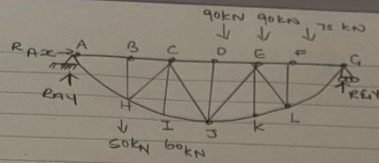


$$\begin{aligned}\sum F_y = 0 &\Rightarrow BE + BF \sin(56.31) = 0 \\ -30 + BF \sin(56.31) &= 0 \\ BF &= 36.06 \text{ kN}\end{aligned}$$

$$\begin{aligned}\sum F_x = 0 &\Rightarrow BC - BA + BF \cos(56.31) = 0 \\ BC - 80 + 36.06 \cos(56.31) &= 0 \\ BC &= 60 \text{ kN}\end{aligned}$$



Question 2



$$\sum F_y = 0 \Rightarrow R_{Ay} + R_{Gy} = 50 + 60 + 90 + 75$$

$$R_{Ay} + R_{Gy} = 365 \text{ kN}$$

$$\sum F_x = 0$$

$$R_{Ax} = 0$$

$$\sum M_A = 0 \Rightarrow (50 \times 6) + (60 \times 12) + (90 \times 18) + (90 \times 24) + (75 \times 30)$$

$$= 300 + 720 + 1620 + 2160 + 2250$$

$$= 7050$$

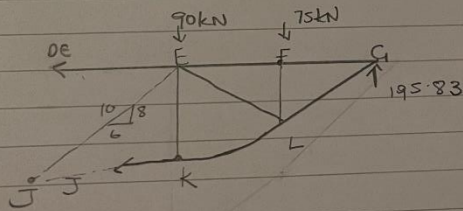
$$\frac{7050}{36}$$

$$R_{Gy} = 195.83$$

$$R_{Ay} = 365 \text{ kN} - R_{Gy}$$

$$= 365 \text{ kN} - 195.83$$

$$= 169.17 \text{ kN}$$



$$\Rightarrow \sum F_y = 0$$

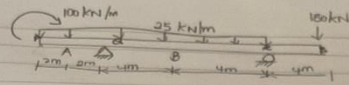
$$E_J \left(\frac{8}{10} \right) + J_K \left(\frac{1}{\sqrt{31}} \right) + 90 + 75 = 195.83$$

$$E_J \left(\frac{8}{10} \right) + J_K \left(\frac{1}{\sqrt{31}} \right) = 30.83$$

$$\Rightarrow \sum F_x = 0 \Rightarrow DG + E_2 \left(\frac{4}{10} \right) + JK \left(\frac{4}{\sqrt{31}} \right) = 0$$

$$\begin{aligned} \Rightarrow \sum M_J = 0 \\ (DE \times 8) &= (90 \times 6) + (75 \times 12) - (195.83 \times 18) \\ DG &= \frac{540 + 900 - (195.83 \times 18)}{8} \\ &= -260.62 \text{ kN (compressive)} \end{aligned}$$

Question 3a



$$\sum f_y = 0$$

$$-25 \times 12 + Q_y + R_y - 150 = 0$$

$$-300 + Q_y + R_y - 150 = 0$$

$$Q_y + R_y = 0 + 150 + 300$$

$$Q_y + R_y = 450 \text{ kN/m}$$

$$\sum M_R = 0 \Rightarrow$$

$$100 - 25 \times 12 \times \left(\frac{12}{2}\right) + Q_y \times 8 + 150 \times 4 = 0$$

$$100 - 1800 + 8Q_y + 600 = 0$$

$$8Q_y = 1800 - 600 - 100$$

$$Q_y = \frac{1100}{8}$$

$$Q_y = 137.5 \text{ kN}$$

$$R_y = 450 \text{ kN} - 137.5$$

$$R_y = 312.5 \text{ kN}$$

$$V_A = -25 \times 20$$

$$= -50 \text{ kN}$$

$$V_A = -100 + Q_y$$

$$= -100 + 137.5$$

$$= 37.5 \text{ kN}$$

$$V_D = -25 \times 4$$

$$= -100 \text{ kN}$$

Q to R

$$V_Q = 37.5 - 25x$$

$$= 37.5 - 25 \times 0$$

$$= 37.5 \text{ kN}$$

shear force @
Point B

$$V_B = 37.5 - 25 \times 4$$

$$= -62.5 \text{ kN}$$

$$V_R = 37.5 - 25 \times 8$$

$$= -162.5 \text{ kN}$$

At Q (support)

$$\begin{aligned} V_R &= 162.5 + R_y \\ &= -162.5 + 312.5 \\ &= 150 \text{ kN} \end{aligned}$$

At S (point load)

$$\begin{aligned} V_S &= 150 - 150 \\ &= 0 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_R &= 150 \text{ kN} \\ V_S &= 150 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_Q - R &= 0 \\ 37.5 - 25x &= 0 \end{aligned}$$

$$25x = 37.5$$

$$x = \frac{37.5}{25}$$

$$x = 1.5 \text{ m (from Q)}$$

$$x = 4 + 1.5 \text{ m (from P)}$$

Bending Moment

$$M_{P-Q} = 100 - 25 \times x \times \frac{x}{2}$$

$$= 100 - 12.5x^2$$

$$M_P = 100 - 12.5 \times 0^2$$

$$M_P = 100 \text{ kNm}$$

$$M_A = 100 - 12.5 \times 2^2$$

$$M_A = 50 \text{ kNm}$$

$$M_Q = 100 - 12.5 \times 4^2$$

$$= 100 \text{ kNm}$$

from Q to R

$$100 = 100(x-2) + 137.5(x-4) - 12.5(x-4)^2$$

$$M_Q = 100 - 100(4-2) + 137.5(4-4) - 12.5(4-4)^2$$

$$M_Q = 100 \text{ kN/m}$$

$$100 = 100(5.5-2) + 137.5(5.5-4) - 12.5(5.5-4)^2$$

$$= 71.875 \text{ kN/m}$$

$$M_B = 100 - 100(8-2) + 137.5(8-4) - 12.5(8-4)^2$$

$$M_B = 150 \text{ kN/m}$$

$$M_R = 100 - 100(12-2) + 137.5(12-4) - 12.5(12-4)^2$$

$$M_R = -600 \text{ kNm}$$

$$= 100 - 25 \times 12 \times \left(x - \frac{12}{2}\right) + 137.5(x-4) + 312.5(x-12)$$

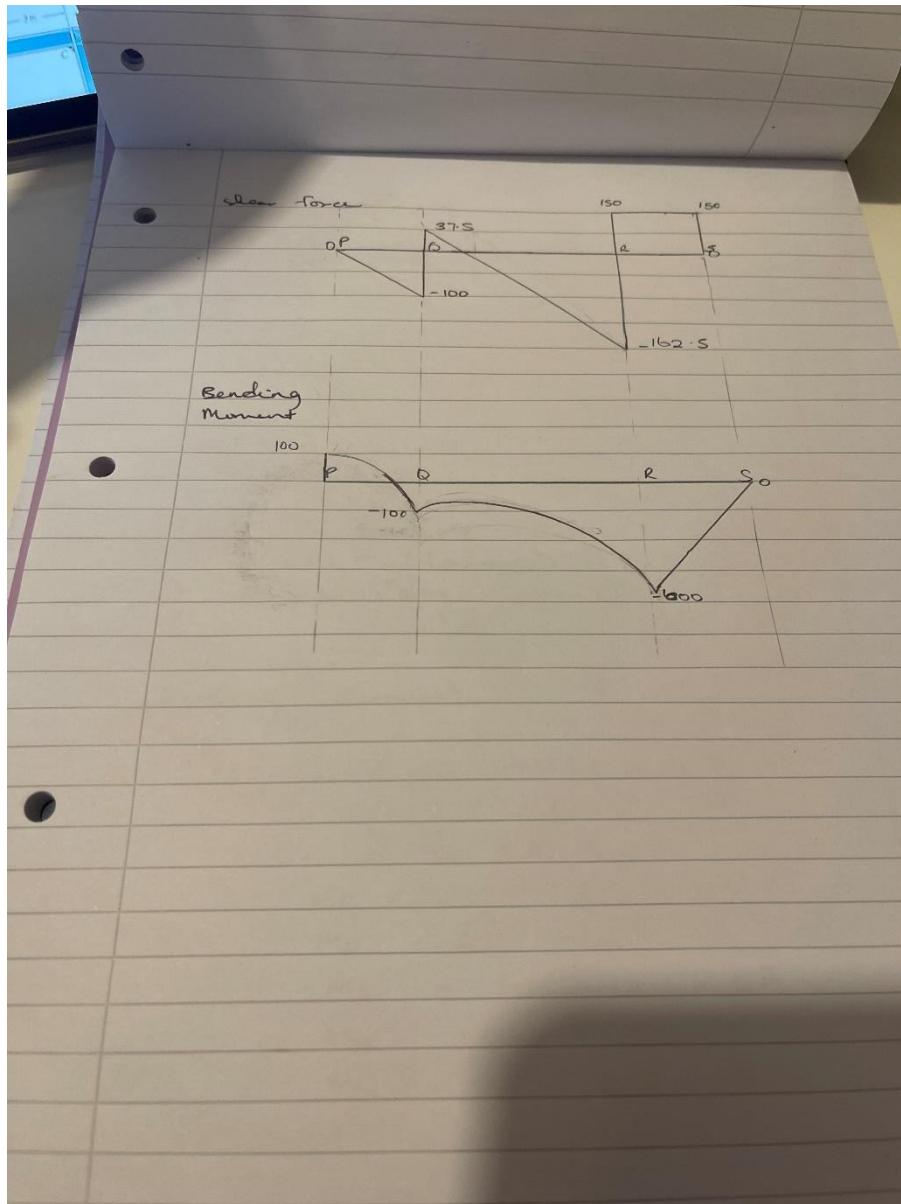
$$= 100 - 300(x-6) + 137.5(x-4) + 312.5(x-12)$$

$$M_R = 100 - 300 \times (12-6) + 137.5(12-4) + 312.5(12-12)$$

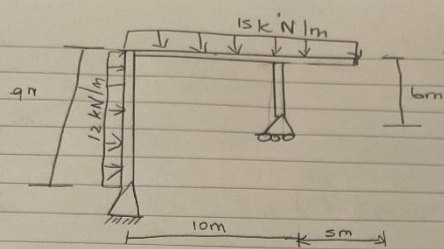
$$M_R = -600 \text{ kNm}$$

$$M_S = 100 - 300(16-6) + 137.5(16-4) + 312.5(16-12)$$

$$M_S = 0 \text{ kN}$$



Question 3b.



$$\sum M_A = 0 \Rightarrow -B_y \times 10 + 12 \times 9 \times \frac{9}{2} + 15 \times (10+5) \times \frac{10+5}{2} = 0$$

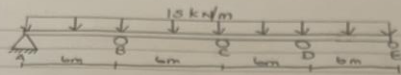
$$B_y \times 10 = 217.35 \text{ kN}$$

$$\sum F_y = 0 \Rightarrow A_y + B_y - 15 \times (10+5) = 0$$

$$A_y + 217.35 - 15 \times 15 = 0$$

$$A_y = 7.65 \text{ kN}$$

Question 4a.



$$\begin{aligned}
 DF_{BA} &= \left(\frac{3}{4}\right)\left(\frac{1}{6}\right) = 0.43 & DF_{CB} &= \left(\frac{1}{6}\right) = 0.5 \\
 DF_{BC} &= \left(\frac{1}{6}\right) = 0.57 & DF_{CD} &= \left(\frac{1}{6}\right) = 0.5 \\
 DF_{DC} &= \left(\frac{1}{6}\right) = 0.57 & DF_{DE} &= \left(\frac{3}{4}\right)\left(\frac{1}{6}\right) = 0.43
 \end{aligned}$$

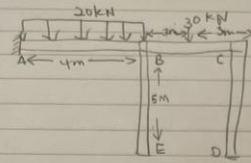
$$\begin{aligned}
 FEM &= \frac{(15)(6)^2}{12} \\
 &= 45 \text{ kN}
 \end{aligned}$$

$$\begin{aligned}
 FEM_{BA} &= \frac{-(15)(6)^2}{12} \\
 &= -45 \text{ kN}
 \end{aligned}$$

$$\begin{aligned}
 FEM_{AB} &= FEM_{BC} = FEM_{CD} = FEM_{DE} \\
 FEM_{BA} &= FEM_{CB} = FEM_{DC} = FEM_{ED}
 \end{aligned}
 \quad \left. \begin{array}{l} \text{the beam \à loading is} \\ \text{symmetrical.} \end{array} \right\}$$

Member	AB	BA	BC	CB	CD	DC	DE	ED
D.F		0.43	0.57	0.5	0.5	0.57	0.43	
F.E.M	-45	45	-45	45	-45	45	-45	45
Bal	45	22.5					-22.5	-45
Distribution		-9.7	-12.8	0	0	12.8	9.7	
C.O	0		0	-6.4	6.4	0		0
F.M	0	57.8	-57.8	38.6	-38.6	57.8	-57.8	0

Question 4b.



$$M_{AB} = -\frac{(WL^2)}{12}$$

$$= -\frac{20 \times 4^2}{12}$$

$$= -26.6$$

$$M_{BA} = \frac{(WL^2)}{12}$$

$$= \frac{20 \times 4^2}{12}$$

$$= 26.6$$

$$M_{BC} = -\frac{(WL)}{8}$$

$$= -22.5$$

$$M_{CB} = \frac{(WL)}{8}$$

$$= 22.5$$

Distribution factor

$$D_{BA} = \frac{(4EI)}{\frac{4EI}{4} + \frac{(4EI)}{6} + \frac{(4EI)}{5}}$$

$$= 0.4$$

$$D_{BE} = \frac{\left(\frac{4EI}{5}\right)}{2.46EI}$$

$$= 0.33$$

$$D_{BC} = \frac{\left(\frac{3EI}{6}\right)}{2.46EI}$$

$$= 0.20$$

$$CB = \frac{(3EI)}{6} + \frac{(4EI)}{5}$$

$$= 0.83$$

$$CD = \frac{(4EI)}{5}$$

$$= 0.62$$

	A		B		E	C		D
member	AB	BA	BC	BE	EB	CB	CD	DC
DF		0.4	0.2	0.33		0.83	0.62	
F-EM	-26.6	26.6	-22.5	0		22.5	0	0
bal		-1.64	-4.1	-1.35		-18.67	-13.95	
C.O	-0.82		-9.13		0.67	-18.67	-13.95	-6.97
	-27.42	24.96	-33.73	-1.35	0.67	-18.67	-13.95	-6.97

$$M_{BA} = 24.96$$

$$M_{BC} = -33.73$$

$$M_{BE} = -1.35$$

$$M_{CB} = -18.67$$

$$M_{CD} = -13.95$$