Section A

Q1 Write the assumptions made in the analysis of truss.

Sol. i) All members have negligible weight
ii) All members have uniform cross-section
iii) All members have only axial force.

Q2 Explain E, G and K.

Sol. Modulus of elasticity (E).

Normal stress (σ) is directly proportional to normal strain (ε), and the ratio is known as modulus of elasticity.

Modulus of rigidity (G).

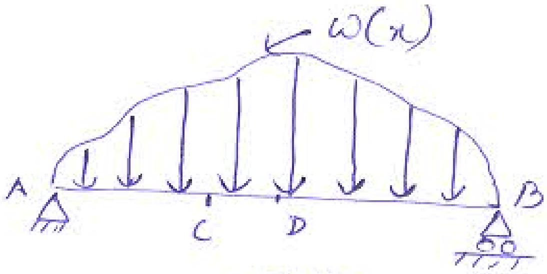
The ratio of shear stress to shear strain is known as modulus of rigidity

Bulk modulus (K).

The ratio of volumetric stress to volumetric strain is a constant known as bulk modulus.

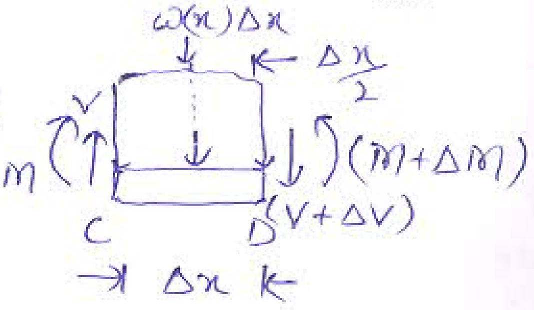
Q3 Write the relationship between load, shear force and bending moment.

Sol. Consider a section AB CD for which CD is used for analysis.



Relation b/w load & shear force

$$\frac{dV}{dx} = -\omega(x)$$



Relation b/w shear force & bending M.

$$\frac{dM}{dx} = V$$

Q4 State the parallel-axis theorem and perpendicular axis theorem for moment of inertias of areas.

Sol. i) Perpendicular axes theorem.

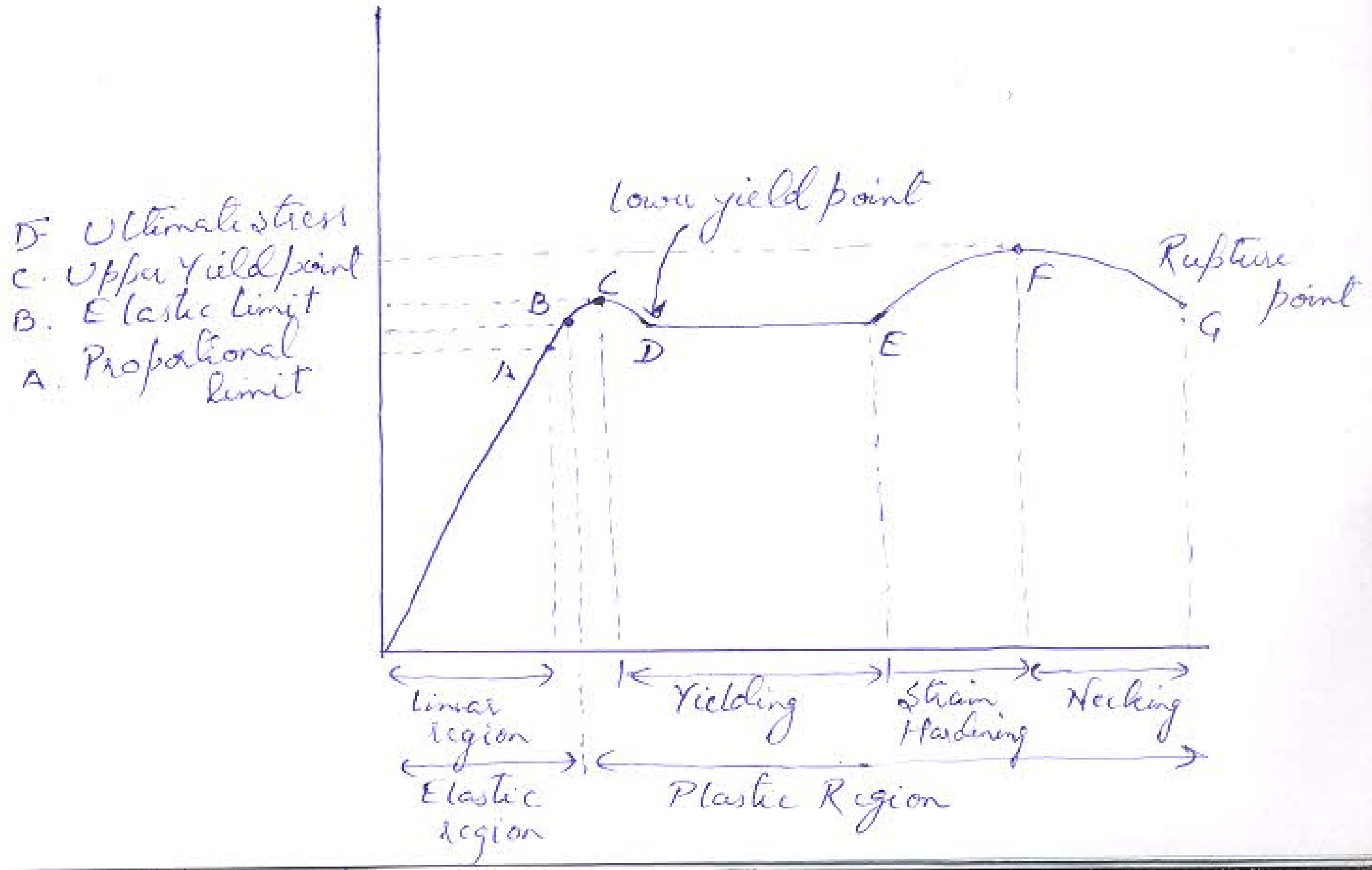
Moment of inertia of an area about an axis perpendicular to its plane at any point is equal to the sum of moments of inertia about any two mutually perpendicular axes through the same point in the plane of the area.

ii) Parallel axes theorem.

Moment of inertia of any area about an axis in its plane is the sum of moment of inertia about a parallel axis passing through the centroid of the area and the product of area and square of the distance between two parallel axes.

Q5 Draw stress-strain diagram for mild steel.

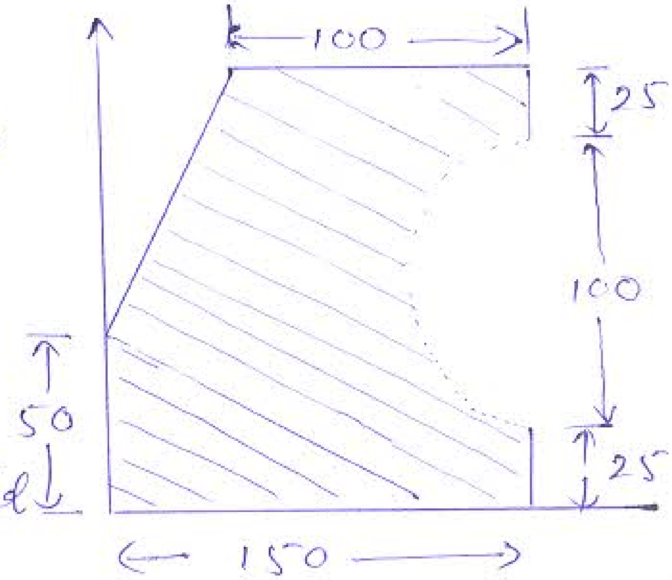
Sol.



Section B

Q6 Determine the centroid of the shaded plane area shown.

Sol. The shaded area can be obtained by subtracting the semicircle & triangle from the given square



The calculations are tabulated as follows.

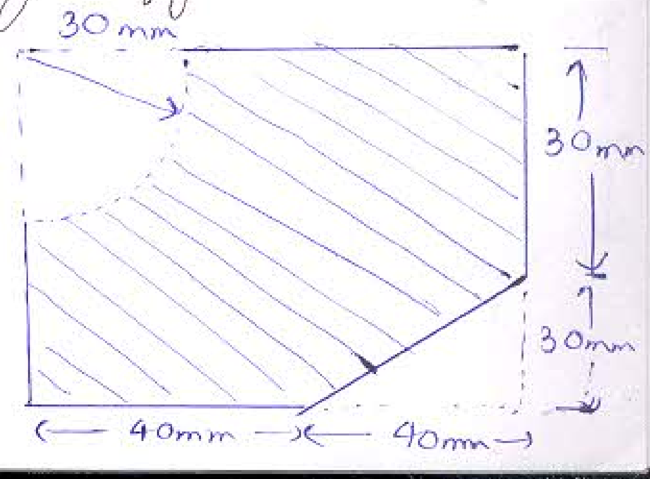
Part No	Area	x	y
1	Square $150\times150 = 22500$	75	75
2	Triangle $-\frac{1}{2}\times 50\times100 = -2500$	$50/3$	$150-\frac{100}{3}$
3	Semicircle $-\frac{\pi}{8}\times 100^2 = -3927$	$150-\frac{4\times50}{3\pi}$	$50+25$

$$\bar{X} = \frac{\Sigma Ax}{\Sigma A} = \frac{8459003.94}{16073} = 70.93 \text{ units}$$

$$\bar{Y} = \frac{\Sigma Ay}{\Sigma A} = \frac{1101308.33}{16073} = 68.52 \text{ units}$$

Q7 Find the moment of inertia of given figure about horizontal centroidal axis.

Sol. The shaded area can be obtained by subtracting the area of a quarter circle and triangle from a rectangle given.



For rectangle

$A_1 = (40+40)\times(30+30)$

$y_1 = 30$

For quarter circle

$A_2 = -\frac{\pi \times 30^2}{4}$

$y_2 = 60 - \frac{4\times 30}{3\pi}$

For triangle

$A_3 = -\frac{1}{2}\times 40\times 30$

$y_3 = \frac{30}{3}$

$\bar{Y} = \frac{A_1y_1 - A_2Y_2 - A_3Y_3}{A_1 - A_2 - A_3}$

$= \frac{104588.5}{3493.14}$

$= 29.94\ mm$

$$I_{xx} = \Sigma\left[I_x + A(y-\bar{Y})^2\right]$$

$$= \left[\frac{80\times 60^3}{12} + 80\times 60\times(30-29.94)^2\right]$$

$$-\left[0.055\times 30^4 + \frac{\pi\times 30^2}{4}\times(17.33)^2\right]$$

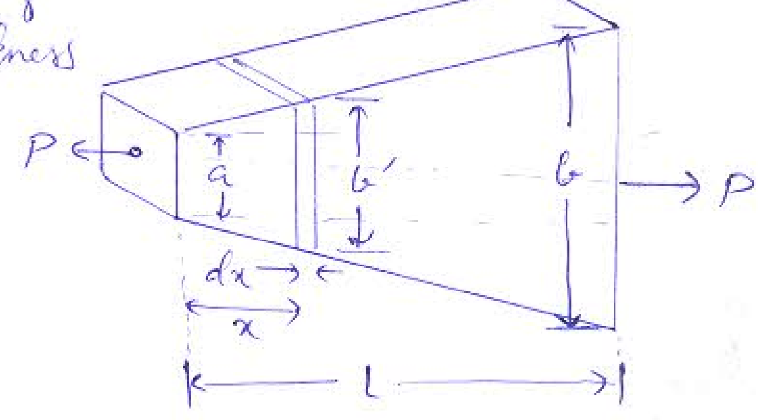
$$-\left[\frac{40\times 30^3}{36} + \frac{1}{2}\times 40\times 30\times\left(\frac{30}{3} - 29.94\right)^2\right]$$

$$= 914{,}885.85\ mm^4$$

Q8 Derive the expression for elongation of rectangular tapered bar subjected to longitudinal load.

Sol. Tapered bars with rectangular cross-section

Consider a tapered bar of length L, constant thickness t and width varying linearly from a to b (b > a) as shown.



As width varies linearly.

$$\frac{b-a}{L} = \frac{b'-a}{x}$$

$$b' = a + \left(\frac{b-a}{L}\right)x$$

Area of strip $= b't$

$$= \left[a + \left(\frac{b-a}{L}\right)x\right]t$$

Elongation of differential element $= \frac{PL}{AE}$

$$= \frac{P\,dx}{\left[a + \left(\frac{b-a}{L}\right)x\right]tE}$$

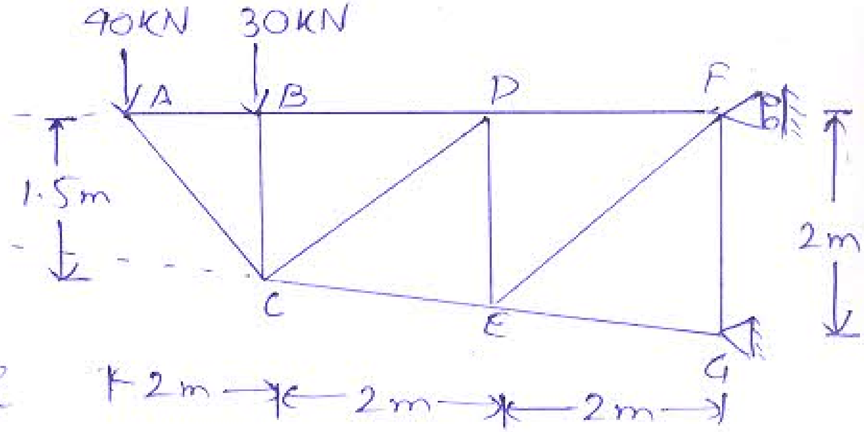
Total elongation δL of the bar,

$$\delta L = \int_0^L \frac{P\,dx}{\left[a + \left(\frac{b-a}{L}\right)x\right]tE} = \frac{P}{tE}\left[\frac{\ln\left\{a + \left(\frac{b-a}{L}\right)x\right\}}{\left(\frac{b-a}{L}\right)}\right]_0^L$$

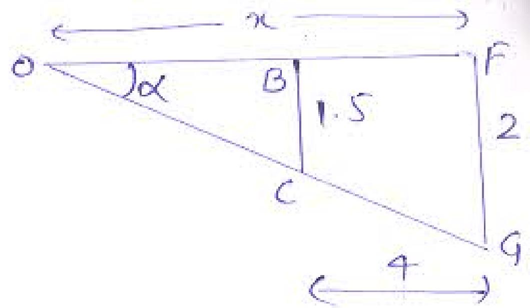
$$= \frac{PL}{t(b-a)E}(\ln b - \ln a) = \frac{PL}{t(b-a)E}\ln\left(\frac{b}{a}\right)$$

Q9 For the truss shown in figure, calculate the forces in members BD, CD and CE by the method of section.

Sol



Let extensions of FA and GC meet at a point O. Now from similar triangle we can have,



$$\frac{OF}{FG} = \frac{OB}{BC}$$

$$\frac{x}{2} = \frac{x-4}{1.5}$$

$$x = 16$$

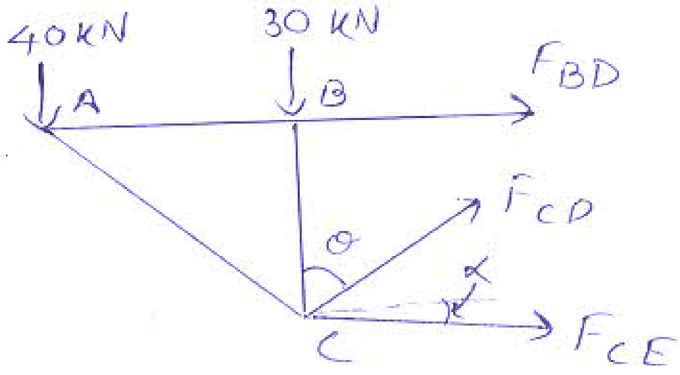
Also

$$\tan\alpha = \frac{FG}{OF}$$

$$= \frac{2}{16}$$

$$\alpha = 7.125^{\circ}$$

Taking a section through the members whose value is to be determined we have.



$$\Sigma M_C = 0$$

$$+40 \times 2 - F_{BD} \times 1.5 = 0$$

$$F_{BD} = 53.33\,N$$

$$\Sigma F_y = 0$$

$$\left(\tan\theta = \frac{2}{1.5} \quad \theta = 53.13 \right)$$

$$-40 - 30 + F_{CD}\cos\theta - F_{CE}\sin\alpha = 0$$

$$F_{CD}\cos\theta - F_{CE}\sin\alpha = 70 \qquad \text{—— (1)}$$

Also, $\Sigma F_x = 0$

$$+F_{BD} + F_{CD}\sin\theta + F_{CE}\cos\alpha = 0$$

$$F_{CD}\sin\theta + F_{CE}\cos\alpha = -53.33 \qquad \text{—— (2)}$$

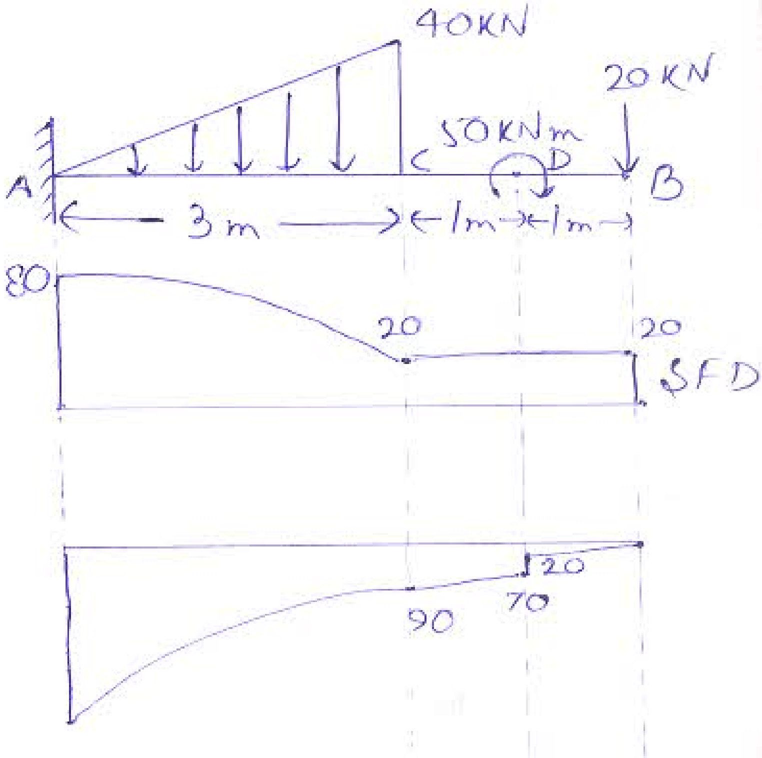
From equations (1) & (2), we have,

$$F_{CD} = 24\,N$$

$$F_{CE} = -73.09\,N$$

Q10 Draw the shear force and bending moment diagram of the beam shown in figure with calculations.

Sol. Let R_A and M_A be the vertical component of reaction and reaction moment respectively at A.



$\Sigma F_y = 0$

$R_A - \frac{1}{2} \times 3 \times 40 - 20 = 0$

$\therefore R_A = 80$

$\Sigma M_A = 0$

$M_A - \left(\frac{1}{2} \times 3 \times 40\right) \times \left(\frac{2}{3} \times 3\right)$

$- 50 - 20 \times 5 = 0$

$M_A = +270$

Shear force values.

$V_A = 80$

$V_C = +80 - \frac{1}{2} \times 3 \times 40 = 20$

$V_D = 0$

Bending moment values

$M_A = -270$

$M_C = -270 + 80 \times 3 - 60 \times 1$

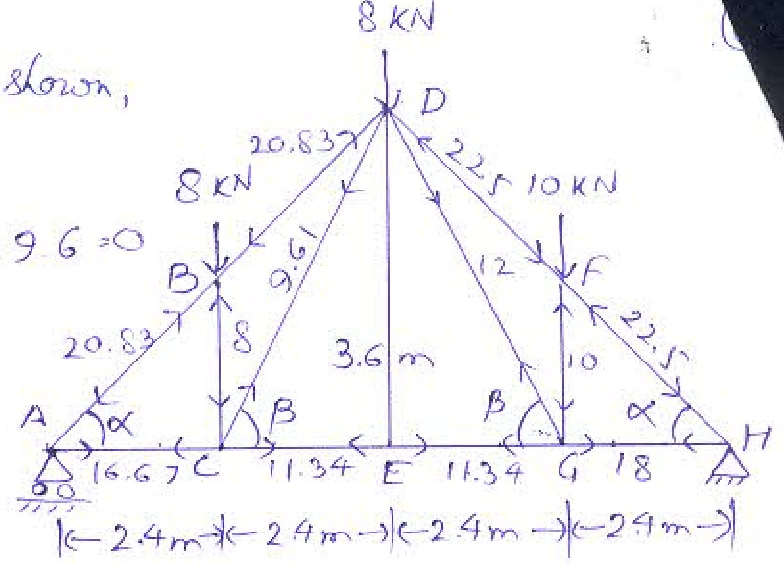
$M_D = -270 + 80 \times 4 - 60 \times 2 + 50$

$M_B = -270 + 80 \times 5 - 60 \times 3$
$+ 50$

Section C

Q11 Find the axial forces in all the members of the truss shown in figure.

Sol. From FBD of the truss shown,



$\Sigma M_A = 0$

$-8\times2.4 - 8\times4.8 - 10\times7.2 + R_H\times9.6 = 0$

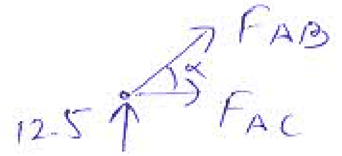
$R_H = 13.5$

$\Sigma F_y = 0$

$R_A - 8 - 8 - 10 + R_H = 0$

$R_A = 12.5$

From FBD of A,



ΣF_y

$12.5 + F_{AB}\sin\alpha = 0$

$F_{AB} = \dfrac{-12.5}{\sin\alpha}$

$= -20.83$ KN

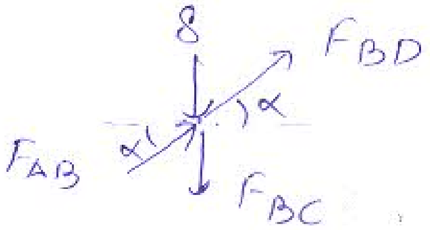
$\tan\alpha = \dfrac{3.6}{4.8} = 36.87$

ΣF_x

$F_{AB}\cos\alpha + F_{AC} = 0$

$F_{AC} = 16.67$ KN

From FBD of B,



ΣF_y

$-8 + F_{AB}\sin\alpha - F_{BC} + F_{BD}\sin\alpha = 0$

$F_{BD}\sin\alpha - F_{BC} = -4.498$

ΣF_x

$+F_{BD}\cos\alpha + F_{AB}\cos\alpha = 0$

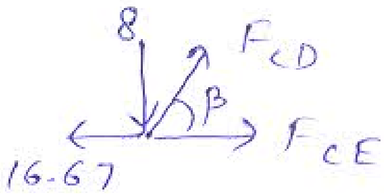
$F_{BD} = -20.83$ KN

In triangle CDE,

$\tan\beta = \dfrac{DE}{CE} = \dfrac{3.6}{2.4}$

$\beta = 56.31$

From FBD of C



$\Sigma F_y = 0$

$-8 + F_{CD} \sin\beta = 0$

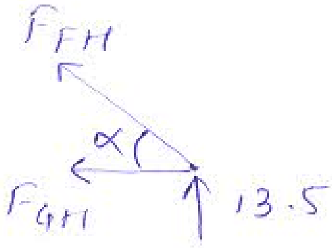
$F_{CD} = 9.61$ KN

$\Sigma F_x = 0$

$-16.67 + F_{CE} + F_{CD} \cos\beta = 0$

$F_{CE} = 11.34$ KN

From FBD of H



$\Sigma F_y = 0$

$13.5 + F_{FH} \sin\alpha = 0$

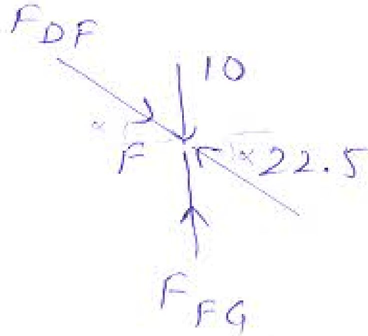
$F_{FH} = -22.5$ KN

ΣF_x

$-F_{FH} \cos\alpha - F_{GH} = 0$

$F_{GH} = 18$ KN

From FBD of F



$\Sigma F_x = 0$

$F_{DF} \cos\alpha = 22.5 \cos\alpha$

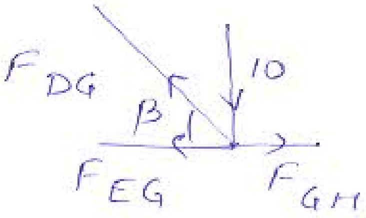
$F_{DF} = 22.5$

$\Sigma F_y = 0$

$-F_{DF} \sin\alpha - 10 + 22.5 \sin\alpha + F_{FG} = 0$

$F_{FG} = 10$

From FBD of G



ΣF_y

$F_{DG} \sin\beta - 10 = 0$

$F_{DG} = 12.$ KN

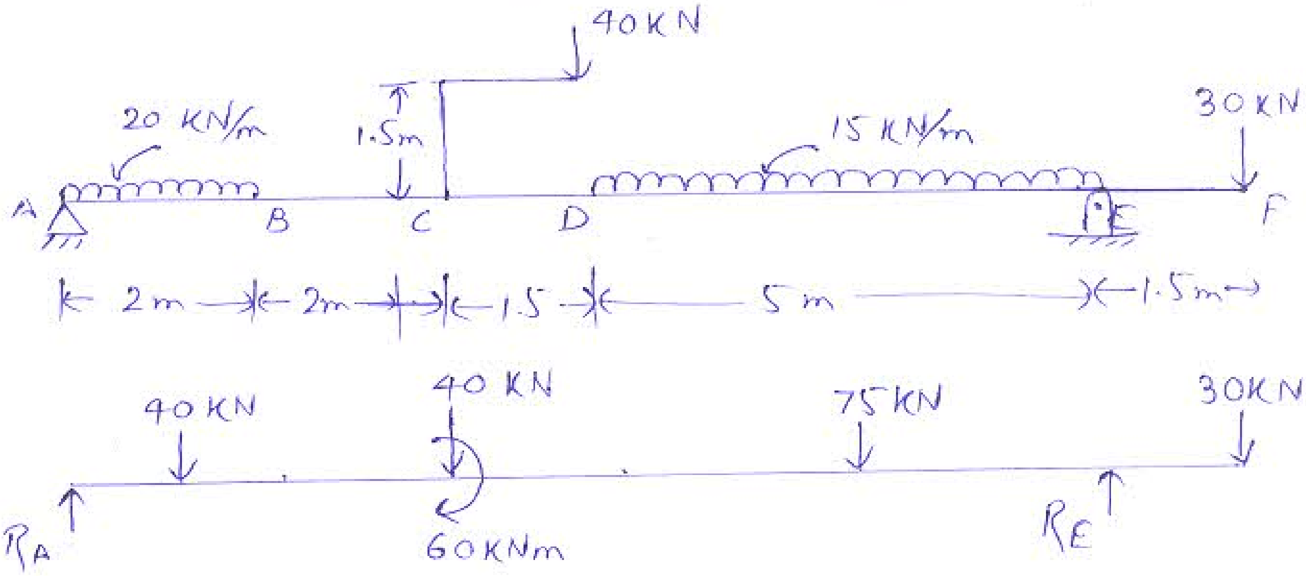
ΣF_x

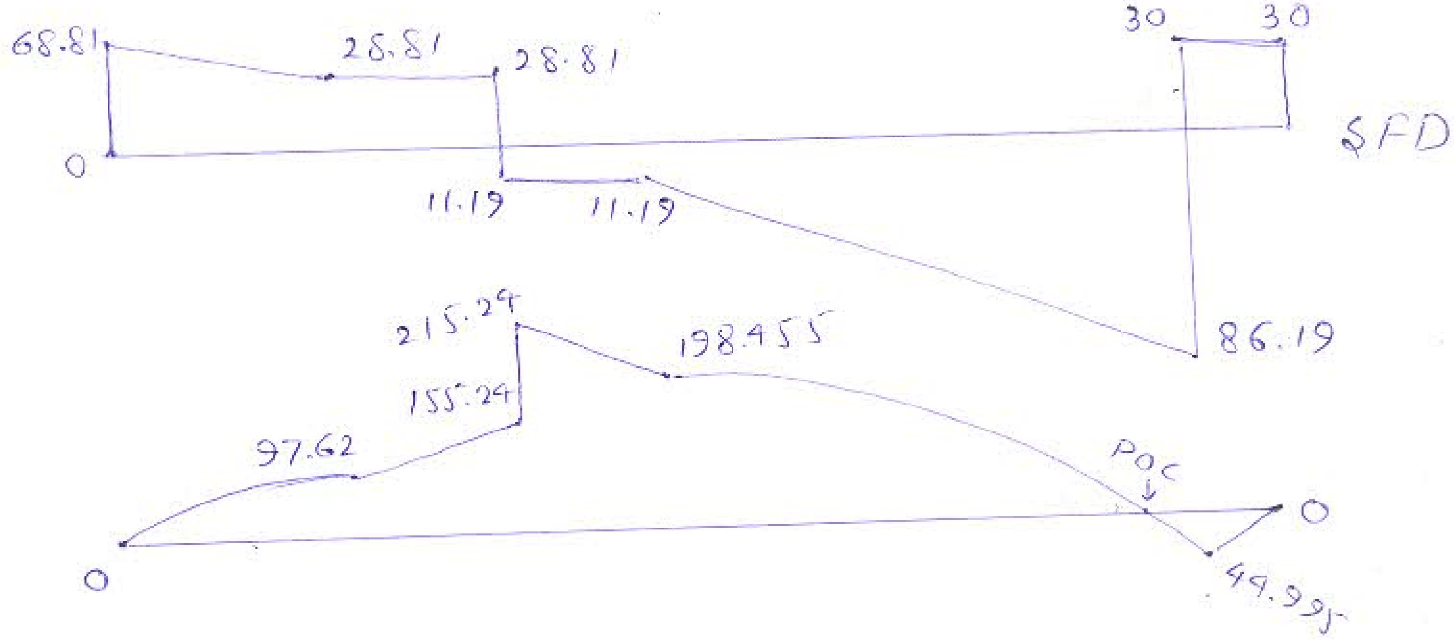
$-F_{DG} \cos\beta - F_{EG} + F_{GH} = 0$

$F_{EC} = 11.34$ KN

Q12 Draw the shear force and bending moment diagram of the beam shown in figure with calculations. Also find the point of contraflexure if any

Sol.





Let R_A and R_E be the vertical reactions at A & E. We have

$\Sigma M_A = 0$

$-40 \times 1 - 40 \times 4 - 60 - 75 \times 8 + R_E \times 10.5 - 30 \times 12 = 0$

$R_E = 116.19$ KN

$\Sigma F_y = 0$

$R_A + R_E = 40 + 40 + 75 + 30$

$R_A = 68.81 \text{ kN}$

Shear Force Values

$V_A^L = 0$

$\quad R = 68.81$

$V_B = +68.81 - 40 = 28.81$

$V_C^L = 28.81$

$\quad R = -11.19$

$V_D = -11.19$

$V_E^L = -11.19 - 75 = -86.19$

$\quad R = 30$

$V_F = 0$

Bending Moment Values

$M_A = 0$

$M_B = 68.81 \times 2 - 40 \times 1 = 97.62$

$M_C^L = 68.81 \times 4 - 40 \times 3 = 155.24$

$\quad R = 155.24 + 60 = 215.24$

$M_D = 68.81 \times 5.5 - 40 \times 4.5 - 40 \times 1.5 + 60 = 198.455$

$M_E = 68.81 \times 10.5 - 40 \times 9.5 - 40 \times 6.5 + 60 - 75 \times 2.5$

$= -44.995$

$M_F = 68.81 \times 12 - 40 \times 11 - 40 \times 8 + 60 - 75 \times 4$

$+ 116.19 \times 1.5 = 0$

Point of Contraflexure.

There is a point of contraflexure between D and E. Let it be at a distance x, from A. The bending moment at this point is zero.

$$+68.81 \times x - 40 \times (x-1) - 40 \times (x-4) + 60 - 75 \times (x-8) = 0$$

$$68.81x - 40x + 40 - 40x + 160 + 60 - 75x + 600 = 0$$

$$x = 9.98 \text{ m.}$$

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