

Problems on Engineering Mechanics

(stable circle) Problem 1

From the figure, (Use Lami's theorem)

$$\sum F_x = 0$$

$$\Rightarrow R_D \cos 60^\circ - R_E \cos 30^\circ = 0$$

$$\Rightarrow \frac{R_D}{2} - \frac{\sqrt{3} R_E}{2} = 0$$

$$\Rightarrow R_D = \sqrt{3} R_E$$

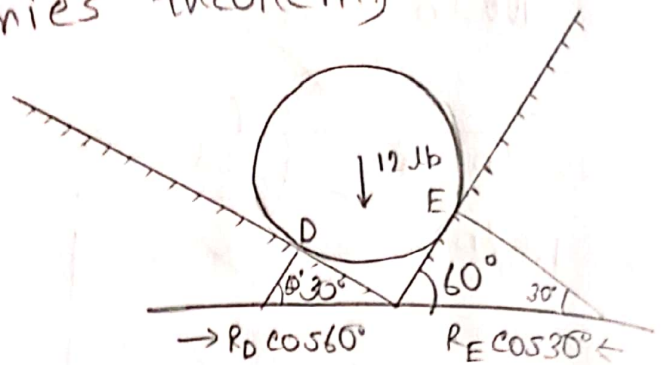
$$\sum F_y = 0$$

$$\Rightarrow R_D \sin 60^\circ + R_E \sin 30^\circ - 12 = 0$$

$$\Rightarrow \frac{\sqrt{3} R_D}{2} + \frac{R_E}{2} - 12 = 0 \Rightarrow 3R_E + R_E - 24 = 0$$

$$\Rightarrow R_E = 6 \text{ lb.}$$

$$\text{and } R_D = \sqrt{3} \times 6 = 10.39 \text{ lb.}$$



(s.c) Problem 2

$$\sum F_x = 0$$

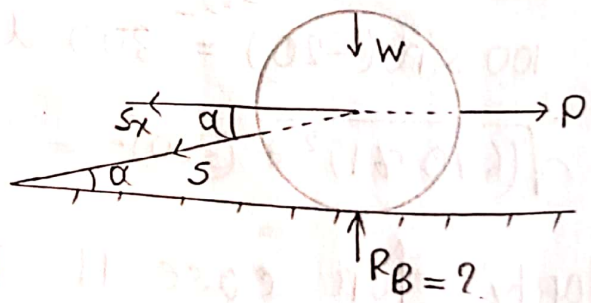
$$\Rightarrow P - S_x = 0$$

$$\Rightarrow P - S \cos \alpha = 0 \Rightarrow S = \frac{P}{\cos \alpha}$$

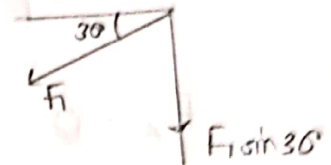
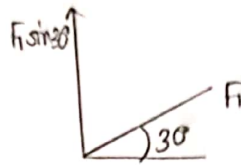
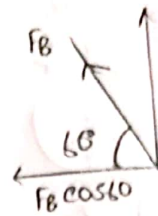
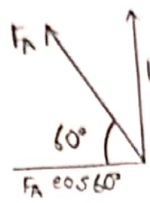
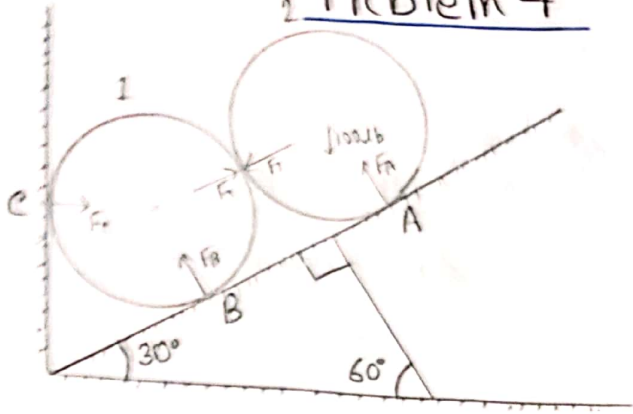
$$\text{And, } \sum F_y = 0$$

$$\Rightarrow -(W + S_x \sin \alpha) + R_B = 0$$

$$\Rightarrow R_B = \frac{P}{\cos \alpha} \cdot \sin \alpha + W = P \tan \alpha + W$$



2 Problem 4 (Double s.c)



(2)

(1)

For roller 2,

$$\sum F_x = 0 \Rightarrow F_1 \cos 30^\circ - F_A \cos 60^\circ = 0$$

$$\Rightarrow \frac{\sqrt{3} F_1}{2} - \frac{F_A}{2} = 0 \Rightarrow F_A = \sqrt{3} F_1$$

$$\sum F_y = 0 \Rightarrow F_1 \sin 30^\circ + F_A \sin 60^\circ - 100 = 0$$

$$\Rightarrow \frac{F_1}{2} + \frac{\sqrt{3} F_A}{2} = 100 \Rightarrow F_1 + 3F_1 = 200 \Rightarrow F_1 = 50$$

$$\therefore F_A = \sqrt{3} \times 50 = 86.6 \text{ lb.}$$

Again, at roller 1, $\sum Y = 0$

$$\Rightarrow F_b \sin 60^\circ - F_1 \sin 30^\circ - 100 = 0$$

$$\Rightarrow \frac{\sqrt{3} F_b}{2} - \frac{F_1}{2} = 100 \Rightarrow \sqrt{3} F_b = 200 + 50 \Rightarrow F_b = 144.3 \text{ lb.}$$

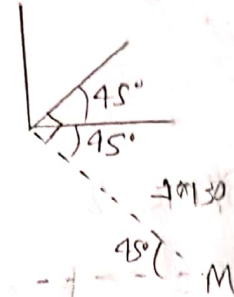
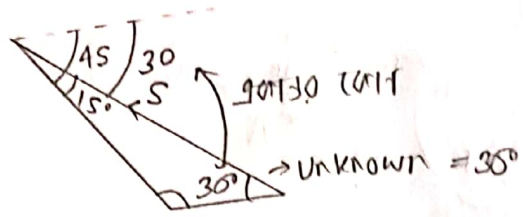
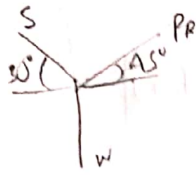
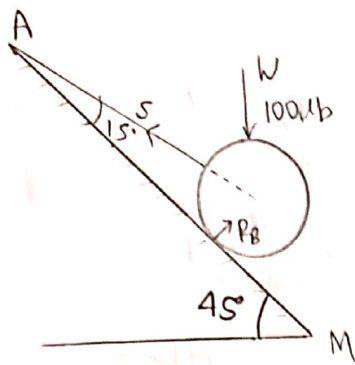
And, $\sum F_x = 0$

$$\Rightarrow F_c - F_1 \cos 30^\circ - F_b \cos 60^\circ = 0.$$

$$\Rightarrow F_c - \frac{\sqrt{3} F_1}{2} - \frac{F_b}{2} = 0 \Rightarrow 2F_c = \sqrt{3} \cdot 50 + 144.3$$

$$\Rightarrow F_c = 115.45 \text{ lb.}$$

Problem 5 (s.c) Lamy's theorem



$$\Sigma F_x = 0.$$

$$\Rightarrow R_B \cos 45^\circ - T \cos 30^\circ = 0. \quad (i)$$

$$\Rightarrow R_B = T \cdot \frac{\cos 30^\circ}{\cos 45^\circ}$$

$$\text{And, } \Sigma F_y = 0$$

$$\Rightarrow R_B \sin 45^\circ + T \sin 30^\circ - 1000 = 0. \quad (ii)$$

$$\Rightarrow T \cdot \frac{\cos 30^\circ}{\cos 45^\circ} \cdot \sin 45^\circ + T \sin 30^\circ - 1000 = 0$$

$$\Rightarrow T = 732.05 \text{ lb}$$

$$\therefore R_B = 732.05 \times \frac{\cos 30^\circ}{\cos 45^\circ} = 896.57 \text{ lb}$$

Problem 6 (Fishing Pole)

$$\Sigma X = 0$$

$$\Rightarrow R_A \cos 45^\circ - T \cos 15^\circ = 0 \quad (i)$$

$$\Rightarrow \frac{\sqrt{2} \cdot R_A}{2} - T \cdot 0.965 = 0$$

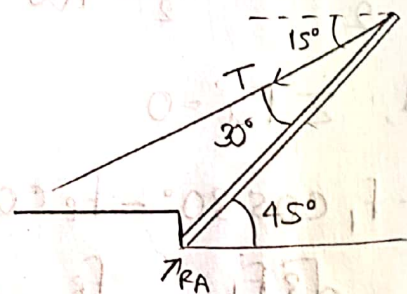
$$\Rightarrow R_A = 1.37 T$$

$$\Sigma Y = 0$$

$$\Rightarrow R_A \sin 45^\circ - T \sin 15^\circ - 20 = 0 \quad (ii)$$

$$\Rightarrow T = 14.14 \text{ lb}$$

$$\text{and, } R_A = 1.37 \times 14.14 = 19.37 \text{ lb}$$



Problem 8

$$\sin \theta = \frac{2}{4}$$

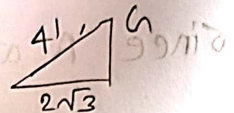
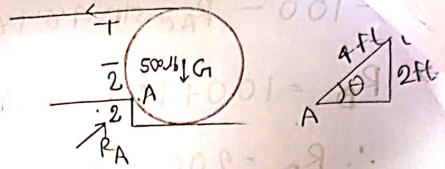
$$\Rightarrow \theta = \sin^{-1}\left(\frac{1}{2}\right) = 30^\circ$$

$$\sum F_y = 0$$

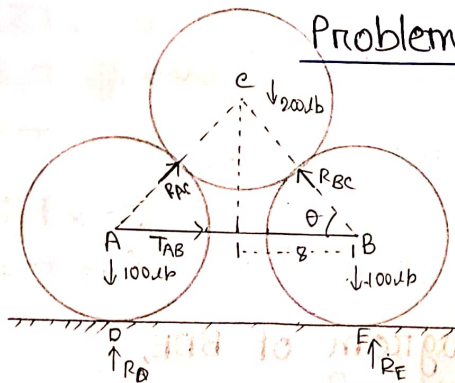
$$\Rightarrow R_A \sin 30^\circ - 500 = 0 \Rightarrow R_A = 1000 \text{ lb.}$$

$$\sum F_x = 0$$

$$\Rightarrow R_A \cos 30^\circ - T = 0 \Rightarrow T = 866.0254 \text{ lb.}$$



Problem 3 (Drum set)



$$\theta = \cos^{-1} \frac{8}{12}$$

$$= 48.18^\circ$$

consider body diagram for A, B, C

$$\sum F_x = 0$$

$$\Rightarrow R_{AC} \cos 48.18^\circ - R_{BC} \cos 48.18^\circ = 0$$

$$\Rightarrow R_{AC} = R_{BC}$$

$$\sum F_y = 0$$

$$\Rightarrow R_{AC} \sin 48.18^\circ + R_{BC} \sin 48.18^\circ - 200 = 0$$

$$\Rightarrow R_{AC} = \frac{200}{2 \sin 48.18^\circ} = 134.18$$

Again, consider body diagram of A

$$\sum F_x = 0$$

$$\Rightarrow T_{AB} - R_{AC} \cos 48.18^\circ = 0$$

$$\Rightarrow T_{AB} = 134.18 \times \cos 48.18^\circ = 89.47 \text{ lb}$$

$$\sin \theta = \frac{2}{4}$$

$$\Rightarrow \theta = \sin^{-1}\left(\frac{1}{2}\right) = 30^\circ$$

$$\Sigma F_y = 0$$

$$\Rightarrow R_A \sin 30^\circ - 500$$

$$\Sigma F_x = 0$$

$$\Rightarrow R_A \cos 30^\circ - T =$$

$$P_r \quad \text{Problem 8} \quad \Sigma F_x = 0$$

$$R_x - T = 0 \Rightarrow R_x = T, \quad \Sigma F_y = 0$$

$$R_y - 500 = 0, \quad R_y = 500$$

$$\Sigma M_A = 0.$$

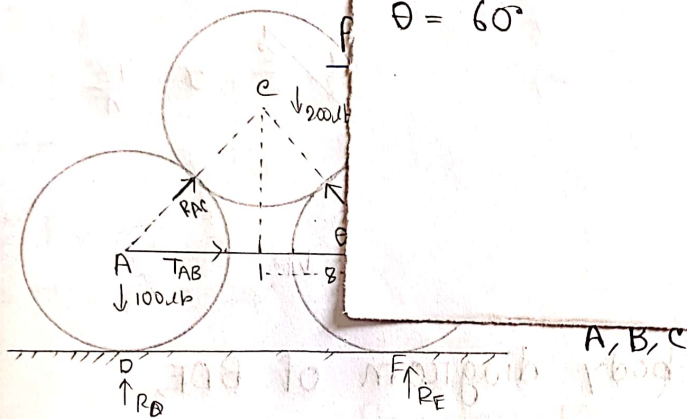
$$\Rightarrow -T \times 6 + 500 \cdot 2\sqrt{3} = 0$$

$$\Rightarrow T = 288.7 \text{ lb}$$

$$R = \sqrt{R_x^2 + R_y^2} = 577.35 \text{ lb}$$

$$\tan \theta = \frac{R_y \sin \alpha}{R_x + R_y \cos \alpha}$$

$$\theta = 60^\circ$$



$$\Sigma F_x = 0$$

$$\Rightarrow R_{AC} \cos 48.18^\circ - R_{BC} \cos 48.18^\circ = 0$$

$$\Rightarrow R_{AC} = R_{BC}$$

$$\Sigma F_y = 0$$

$$\Rightarrow R_{AC} \sin 48.18^\circ + R_{BC} \sin 48.18^\circ - 200 = 0$$

$$\Rightarrow R_{AC} = \frac{200}{2 \sin 48.18^\circ} = 134.18^\circ$$

Again, consider body diagram of A

$$\Sigma F_x = 0$$

$$\Rightarrow T_{AB} - R_{AC} \cos 48.18^\circ = 0$$

$$\Rightarrow T_{AB} = 134.18 \times \cos 48.18^\circ = 89.47 \text{ lb}$$

$$\sum F_y = 0$$

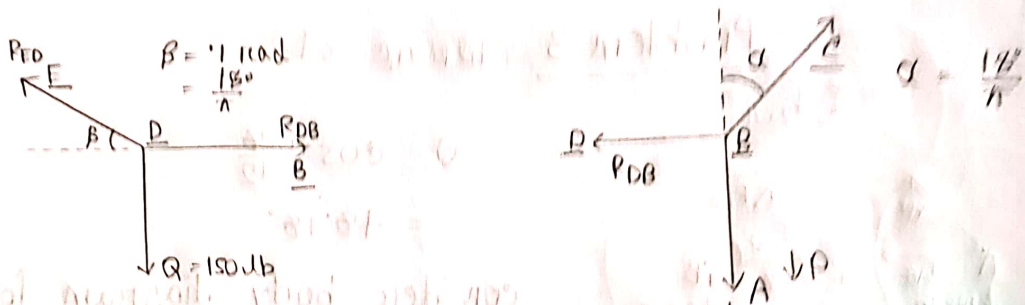
$$\Rightarrow 1 - 100 - R_{AE} \sin 48.18^\circ + R_D = 0.$$

$$\Rightarrow R_D = 100 + 134.18 \sin 48.18^\circ$$

$$\therefore R_D = 200 \text{ lb.}$$

since A and B identical $R_D = R_E = 200 \text{ lb.}$

Problem 9 (Rope tension formation)



consider the free body diagram of BDE,

$$\sum F_y = 0$$

$$\Rightarrow R_{ED} \sin \frac{18^\circ}{\pi} - Q = 0 \Rightarrow R_{ED} = 1150.25 \text{ lb.}$$

$$\sum F_x = 0.$$

$$\Rightarrow R_{DB} - R_{ED} \cos \frac{18^\circ}{\pi} = 0 \Rightarrow R_{DB} = 1195 \text{ lb.}$$

consider the free body diagram of DBE,

$$\sum F_x = 0 \Rightarrow R_{BE} \sin \frac{18^\circ}{\pi} - R_{DB} = 0. \quad [\sum F_x = 0]$$

$$\Rightarrow R_{BE} = 14974.95 \text{ lb.}$$

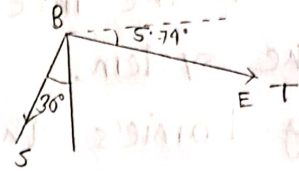
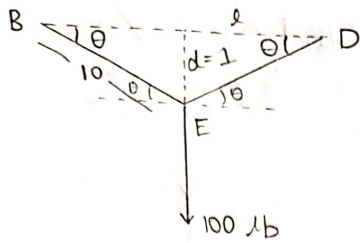
$$\sum F_y = 0$$

$$\Rightarrow R_{BE} \cos \frac{18^\circ}{\pi} - P = 0$$

$$\Rightarrow P = 14900 \text{ lb.} = \text{vertical pull at A.}$$

(ans)

Problem 11 (Rope Tension)



Consider the free body diagram of BED,

From, $\triangle BED$, $\theta = \sin^{-1}\left(\frac{1}{10}\right) = 5.74^\circ$

$$\sum F_y = 0$$

$$\Rightarrow T \sin 5.74^\circ + T \sin 5.74^\circ - 100 = 0$$

$$\Rightarrow T = 500 \text{ lb.}$$

$$\sum F_x = 0 \text{ [as } \angle FBA \neq \angle ABO, S \neq T \text{]}$$

$$\Rightarrow T \cos 5.74^\circ - S \sin 30^\circ = 0 \Rightarrow S = 999.99 \text{ lb.}$$

Problem 12 (Fishing Pole)

$$\sum M_A = 0.$$

$$\Rightarrow 5y' \times L - Q \times \frac{L}{2} \sin \theta = 0$$

$$\Rightarrow 5y' = 2 \cdot \frac{1}{2} \cdot \sin 60^\circ = 0.866$$

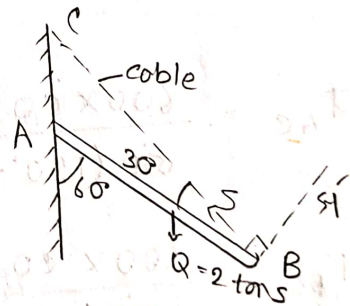
$$\Rightarrow S = \frac{0.866}{\sin 30^\circ} = 1.73 \text{ lb.}$$

Now,

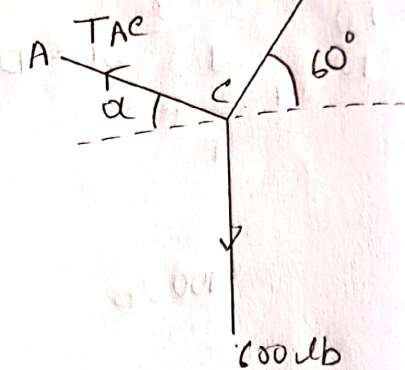
$$\sum F_x = 0 \Rightarrow A_x - S \sin 30^\circ = 0 \Rightarrow A_x = 0.867.$$

$$\sum F_y = 0 \Rightarrow A_y + S \cos 30^\circ - 2 = 0 \Rightarrow A_y = 0.5$$

$$\therefore \text{Reaction force at A, } R_A = \sqrt{A_x^2 + A_y^2} = 1.0008 \text{ lb.}$$



Consider the free body diagram of the system,



Using Lami's theorem,

$$\frac{T_{AC}}{\sin(90^\circ + 60^\circ)} = \frac{T_{BC}}{\sin(90^\circ + \alpha)} = \frac{600}{\sin(180^\circ - \alpha - 60^\circ)}$$

$$\Rightarrow \frac{T_{AC}}{\cos 60^\circ} = \frac{T_{BC}}{\cos \alpha} = \frac{600}{\sin(120^\circ - \alpha)}$$

$$\therefore T_{AC} = \frac{600 \times \cos 60^\circ}{\sin(120^\circ - \alpha)}, \text{ and,}$$

$$T_{BC} = \frac{600 \times \cos \alpha}{\sin(120^\circ - \alpha)}$$

a) T_{AC} will be minimum, when $\sin(120^\circ - \alpha) = 1$

$$\Rightarrow \sin(120^\circ - \alpha) = \sin 90^\circ$$

$$\Rightarrow \alpha = 30^\circ \quad (\text{Ans})$$

$$b) T_{AC} = \frac{600 \times \cos 60^\circ}{\sin(120^\circ - 30^\circ)} = 300 \text{ lb}$$

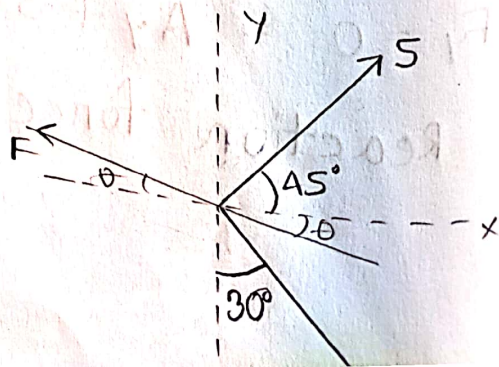
$$T_{BC} = \frac{600 \times \cos 30^\circ}{\sin(120^\circ - 30^\circ)} = 519.6 \text{ lb.} \quad (\text{Ans})$$

Problem 14 (Bow)

$$\Sigma F_y = 0$$

$$\Rightarrow F \sin \theta + 5 \sin 45^\circ - 5 \cos 30^\circ = 0$$

$$\Rightarrow F \sin \theta = 795 \quad (i)$$



$$\Sigma F_x = 0.$$

$$\Rightarrow F \cos 45^\circ + 5 \sin 30^\circ - F \cos \theta = 0.$$

$$\Rightarrow F \cos \theta = 6.04 \quad \text{(ii)}$$

From (i) \div (ii), we get,

$$\tan \theta = \frac{.795}{6.04} \Rightarrow \theta = 7.5^\circ \text{ (with x-axis). (Ans)}$$

From equation (i),

$$F = 6.09 \text{ lb. (Ans)}$$

Problem 17 (stable bar)

$$\Sigma M_A = 0$$

$$\Rightarrow (5 \times 8) - T_{PC} \times \sqrt{6^2 + 4^2} = 0.$$

$$\Rightarrow T_{PC} = 5.54 \text{ ton.}$$

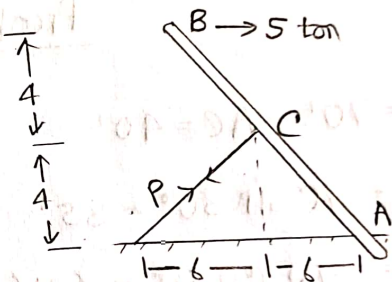
Now,

$$\Sigma F_x = 0 \Rightarrow A_x - T_{PC} \cos 56.3 + 5 = 0$$

$$\Rightarrow A_x = -1.923 \text{ ton.}$$

$$\Sigma F_y = 0 \Rightarrow T_{PC} \sin 56.3 - A_y = 0 \Rightarrow A_y = 5.54 \sin 56.3 = 4.61 \text{ ton}$$

$$\text{Reaction at A, } R_A = \sqrt{(A_x)^2 + (A_y)^2} = \sqrt{(4.62)^2 + (1.92)^2} = 5 \text{ tons.}$$



* Problem 18 (S.C) - (S.B)

$$\theta = \sin^{-1} \frac{r}{2r} = 30^\circ$$

$$AD = \sqrt{(2r)^2 - r^2} = \sqrt{3} \cdot r$$

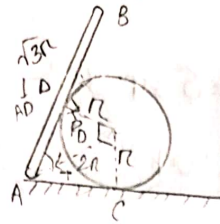
$$\sum M_A = 0 \Rightarrow R_D \times \sqrt{3}r - 1.5r \cos 60^\circ \times Q = 0$$

$$\Rightarrow R_D = \frac{\sqrt{3}}{4} Q$$

$$\sum F_x = 0$$

$$T \sin 60^\circ - R_D \cos 30^\circ = 0$$

$$\therefore T = R_D = 0.433 Q \quad (\text{Ans})$$



Problem 19 (crane)

$$BC = 70', AC = 40'$$

$$BM = 70 \sin 30^\circ = 35'$$

$$CM = 70 \cos 30^\circ = 60.62'$$

$$AM = (60.62' - 40') = 20.62'$$

$$\therefore \tan \alpha = \frac{AM}{BM} = \frac{20.62}{35}$$

$$\alpha = 30.50^\circ$$

$$\sum F_x = 0 \Rightarrow R_c \sin 30^\circ - T \cos 30.50^\circ = 0$$

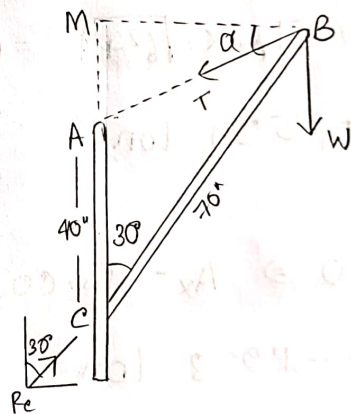
$$\Rightarrow R_c = 1.72 T$$

$$\sum F_y = 0 \Rightarrow R_c \cos 30^\circ - T \sin 30.50^\circ = W$$

$$\Rightarrow 1.72 T \cos 30^\circ - T \sin 30.50^\circ = 2$$

$$\Rightarrow T = 2.03 \text{ kg} \quad (\text{Ans})$$

$$\text{So, } R_c = 1.72 \times 2.03 = 3.5 \text{ kg} \quad (\text{Ans})$$



Problem 20

$$\frac{2.5}{l} = \cos \theta \Rightarrow l = \frac{2.5}{\cos \theta}$$

$$\sum F_y = 0$$

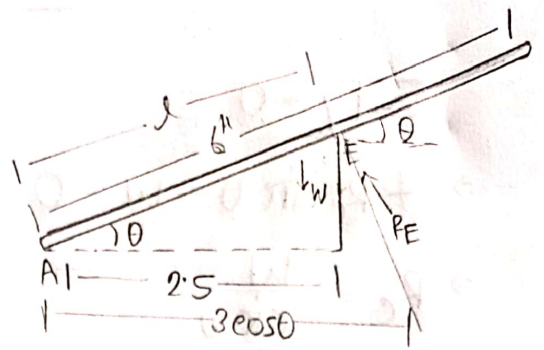
$$\Rightarrow R_E \cos \theta - W = 0$$

$$\Rightarrow R_E = \frac{W}{\cos \theta}$$

$$\sum M_A \Rightarrow W \cdot 3 \cos \theta - R_E \cdot l = 0 \Rightarrow W \cdot 3 \cos \theta - \frac{W}{\cos \theta} \cdot \frac{2.5}{\cos \theta} = 0$$

$$\Rightarrow 3 \cos^3 \theta - 2.5 = 0 \Rightarrow \cos \theta = \sqrt[3]{\frac{2.5}{3}} \Rightarrow \theta = \cos^{-1}(\text{Ans})$$

$$\Rightarrow \theta = 19.77^\circ \quad (\text{Ans})$$



Problem 21 (Centroid)

$$AE = l \cos(60 - \alpha)$$

$$AD = \frac{l}{2} \cos(60 - \alpha)$$

$$\sum M_A = 0$$

$$\Rightarrow W \times AD - 2W [l \cos \alpha - AE] = 0$$

$$\Rightarrow \frac{l}{2} \cos(60 - \alpha) - 2[l \cos \alpha - l \cos(60 - \alpha)]$$

$$\Rightarrow \cos(60 - \alpha) - 4 \cos \alpha + 4 \cos(60 - \alpha) = 0$$

$$\Rightarrow 5 [\cos 60 \cos \alpha + \sin 60 \cdot \sin \alpha] - 4 \cos \alpha = 0$$

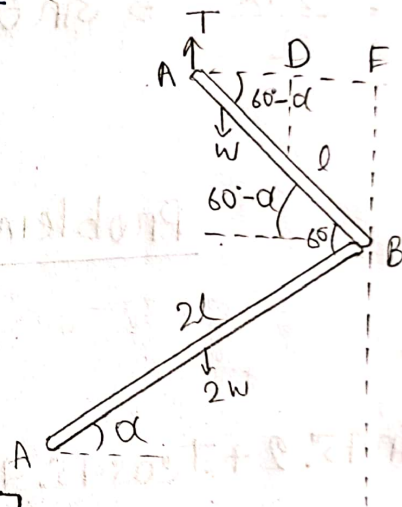
$$\Rightarrow 5 \left[\frac{1}{2} \cos \alpha + \frac{\sqrt{3}}{2} \sin \alpha \right] - 4 \cos \alpha = 0$$

$$\Rightarrow \frac{5\sqrt{3}}{2} \sin \alpha - \left(4 - \frac{5}{2}\right) \cos \alpha = 0$$

$$\Rightarrow \frac{5\sqrt{3}}{2} \sin \alpha = \frac{3}{2} \cos \alpha$$

$$\Rightarrow \tan \alpha = \frac{\sqrt{3}}{5}$$

(Ans)



Problem 22

$$\sum F_y = 0$$

$$\Rightarrow +R_c \sin \theta - W = 0$$

$$\Rightarrow R_c = \frac{W}{\sin \theta}$$

$$\sum M_A = 0.$$

$$\Rightarrow W \times \frac{1}{2} \sin \theta - R_c \times AC = 0.$$

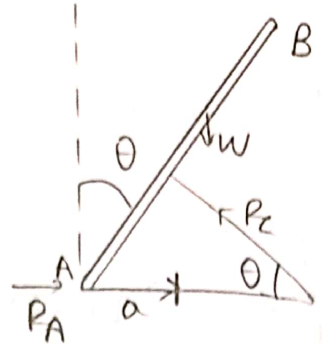
$$\Rightarrow \frac{WL}{2} \sin \theta = R_c \frac{a}{\sin \theta}$$

$$\Rightarrow \frac{WL}{2a} \sin^2 \theta = R_c = \frac{W}{\sin \theta}$$

$$\Rightarrow \frac{WL}{2a} \sin^3 \theta = W$$

$$\Rightarrow \sin^3 \theta = \frac{2a}{L} \Rightarrow \sin \theta = \sqrt[3]{\frac{2a}{L}} \Rightarrow \theta = \sin^{-1} \left(\sqrt[3]{\frac{2a}{L}} \right)$$

$$AC = \frac{a}{\sin \theta}$$



त्रिकोण त्रिभुज W से बना है जिसकी लंबाई 'L' है। तब से त्रिकोण बनाया जाये।

Problem 23

$$\sum M_A = 0$$

$$\Rightarrow 4P + T \sin 45^\circ \cdot 2 + T \cos 45^\circ \cdot 4 - T \cdot 6 = 0.$$

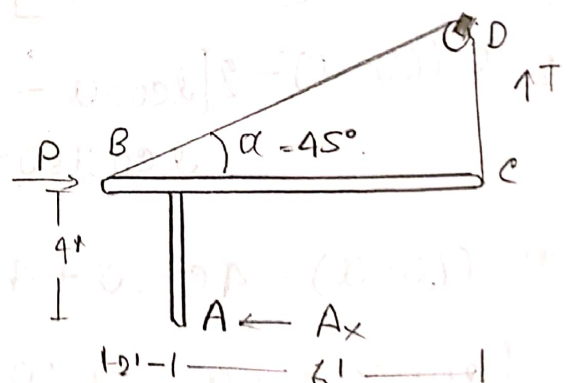
$$\Rightarrow 1.757T = 4P = 4 \times 200$$

$$\Rightarrow T = 455.22 \text{ lb (Ans)}$$

$$\sum F_x = 0$$

$$P + T \cos 45^\circ - A_x = 0.$$

$$\Rightarrow A_x = 521.9 \text{ lb}$$



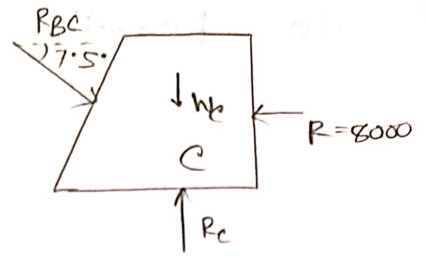
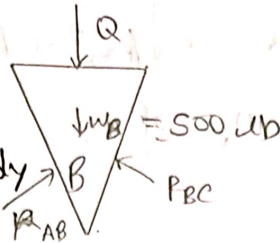
A_x और A_y के समतल में शून्य शक्ति है।

$$\sum F_y = 0.$$

$$\Rightarrow P + T \sin 45^\circ - A_y = 0$$

$$\Rightarrow A_y = 777.11 \text{ lb}$$

consider the free body diagram of body C,



$$\sum F_x = 0$$

$$\Rightarrow R_{BC} \cos 7.5 - R = 0$$

$$\Rightarrow R_{BC} = \frac{R}{\cos 7.5} = \frac{8000}{\cos 7.5} = 8069.031 \text{ lb.}$$

consider the free body diagram of body B,

$$\sum F_x = 0$$

$$\Rightarrow R_{AB} \cos 7.5 - R_{BC} \cos 7.5 = 0$$

$$\Rightarrow R_{AB} = R_{BC} = 8069 \text{ lb.}$$

$$\sum F_y = 0.$$

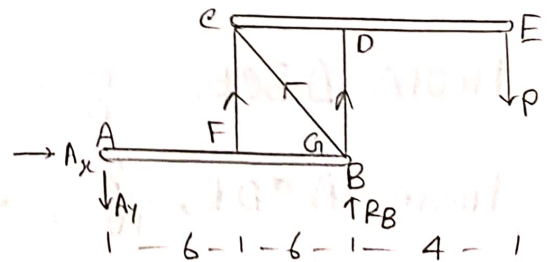
$$\Rightarrow R_{AB} \sin 7.5 + R_{BC} \sin 7.5 - W_B - Q = 0.$$

$$\Rightarrow Q = 2 R_{AB} \sin 7.5 - W_B$$

$$= 1606.432. \quad (\text{Ans})$$

Problem 24

consider the free body diagram of the frame,



$$\sum M_A = 0 \Rightarrow (P \times 16) - (R_B \times 12) = 0.$$

$$\Rightarrow R_B = \frac{4P}{3}.$$

$$\sum F_y = 0 \Rightarrow -P + R_B + A_y = 0 \Rightarrow A_y = P - R_B = P - \frac{4P}{3} = \frac{P}{3}$$

$$\sum F_x = 0 \Rightarrow A_x = 0.$$

$$\text{So, Reaction at } A = \sqrt{A_x^2 + A_y^2} = \sqrt{0^2 + \left(\frac{P}{3}\right)^2} \\ = \frac{P}{3}. \quad (\text{Ans}).$$

Problem 2.6

Consider the FBD,

$$\sum F_x = 0$$

$$\Rightarrow 5 \cos \alpha - 7 \cos \theta = 0.$$

$$\Rightarrow 7 \cos \theta = 5 \cos \alpha \quad \text{--- (i)}$$

$$\sum F_y = 0$$

$$\Rightarrow 5 \sin \alpha + 7 \sin \theta - 10 = 0.$$

$$\Rightarrow 7 \sin \theta = 10 - 5 \sin \alpha \quad \text{--- (ii)}$$

Squaring and adding eqn (i) and (ii),

$$7^2 (\sin^2 \theta + \cos^2 \theta) = 5^2 \cos^2 \alpha + (100 - 100 \sin \alpha + 25 \sin^2 \alpha)$$

$$\Rightarrow 25 \cos^2 \alpha + 25 \sin^2 \alpha - 100 \sin \alpha = 49 - 100$$

$$\Rightarrow 25 - 100 \sin \alpha = -51$$

$$\Rightarrow \sin \alpha = 0.76 \Rightarrow \alpha = 49.46^\circ \quad (\text{Ans})$$

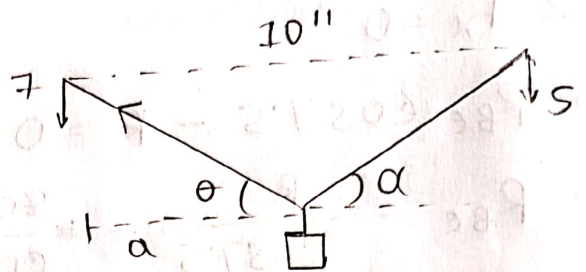
$$\text{From eqn (i), } \cos \theta = 62.34^\circ.$$

$$\text{From } \triangle BEF, \frac{h}{a} = \tan \theta \Rightarrow h = a \tan \theta = 1.91a.$$

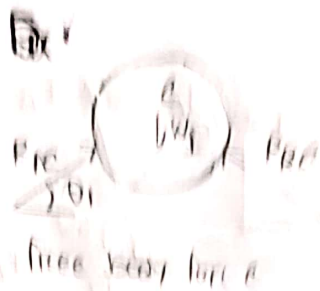
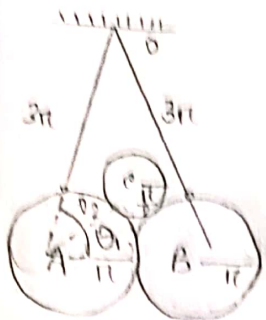
$$\text{From } \triangle CDE, \frac{h}{10-a} = \tan \alpha \Rightarrow h = (10-a) \tan \alpha \\ = (10-a) \times 1.17.$$

$$\text{So, } 1.91a = (10-a) \times 1.17.$$

$$\Rightarrow a = 3.8'' \quad (\text{Ans})$$



Problem 2/6



For B and C

$$\sum F_x = 0$$

$$\Rightarrow R_{AC} \cos 48^\circ \cdot 2 - R_{BC} \cos 48^\circ \cdot 2 = 0$$

$$\Rightarrow R_{AC} = R_{BC}$$

$$\sum F_y = 0$$

$$[R_{AB} = 0]$$

$$\Rightarrow R_{AC} \sin 48^\circ \cdot 2 + R_{BC} \sin 48^\circ \cdot 2 - W_1 = 0$$

$$\Rightarrow W_1 = 2 R_{AC} \sin 48^\circ \cdot 2 \Rightarrow R_{AC} = \frac{W_1}{2 \times \sin 48^\circ}$$

For free body diagram of A

$$\sum F_x = 0 \Rightarrow R_{AC} \cos 48^\circ \cdot 2 = T_{0A} \cos 75^\circ 5' = 0$$

$$\Rightarrow \frac{W_1 \times \cos 48^\circ \cdot 2}{2 \times \sin 48^\circ} = T_{0A} \cos 75^\circ 5' = 0$$

$$\Rightarrow T_{0A} = \frac{W_1 \times \cos 48^\circ \cdot 2}{2 \times \sin 48^\circ \times \cos 75^\circ 5'}$$

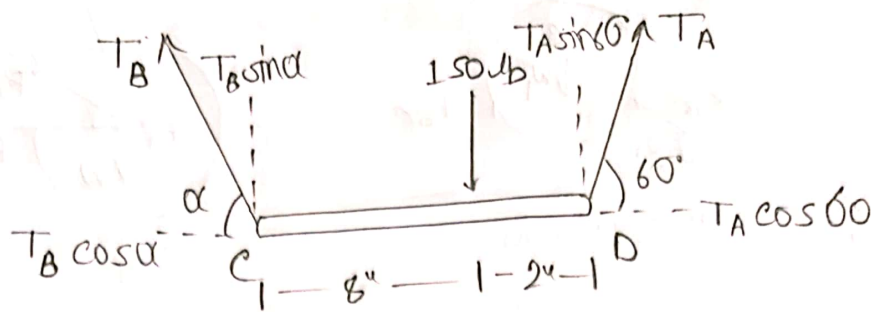
$$\sum F_y = 0$$

$$\Rightarrow -R_{AC} \sin 48^\circ \cdot 2 + T_{0A} \sin 75^\circ 5' - W = 0$$

$$\Rightarrow -\frac{W_1}{2 \times \sin 48^\circ} + \frac{W_1 \times \cos 48^\circ \cdot 2 \times \sin 75^\circ 5'}{2 \times \sin 48^\circ \cdot 2 \times \cos 75^\circ 5'} - W = 0$$

$$\Rightarrow -0.67 W_1 + 1.5799 W_1 - W = 0$$

Problem 2



From the free body diagram,

$$\sum M_c = 0 \Rightarrow F \times 8 - T_A \sin 60^\circ \times 10 = 0.$$

$$\Rightarrow T_A = 138.56 \text{ lb. So, } W_A = 138.56 \text{ lb.}$$

$$\sum F_y = 0.$$

$$\Rightarrow T_B \sin \alpha + T_A \sin 60^\circ - F = 0 \Rightarrow T_B \sin \alpha = 30 \text{ (i)}$$

$$\sum F_x = 0$$

$$\Rightarrow T_A \cos 60^\circ - T_B \cos \alpha = 0$$

$$\Rightarrow T_B \cos \alpha = 69.25 \text{ (ii)}$$

Squaring and adding equation (i) and (ii),

$$T_B^2 = 30^2 + (69.25)^2 = 5039.72.$$

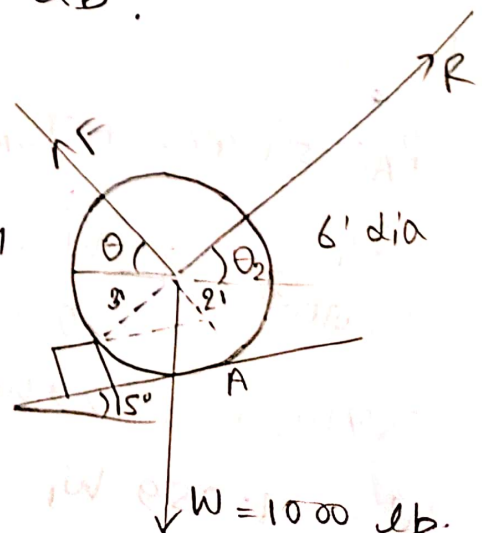
$$\Rightarrow T_B = 75.5 \text{ lb. So, } W_B = 75.5 \text{ lb.}$$

Problem 32

Consider the free body diagram of the wheel,

$$\theta_1 = \sin^{-1} \frac{2}{3} = 41.81^\circ$$

$$\theta_2 = 41.81^\circ + 15^\circ = 56.81^\circ$$



Using Lamies theorem, we get,

$$\frac{F}{\sin(90^\circ + 56.81^\circ)} \cdot \frac{R}{\sin(90^\circ + \theta)} = \frac{W}{\sin(180^\circ - \theta - \theta_2)}$$

$$\Rightarrow \frac{F}{\cos(56.81^\circ)} = \frac{R}{\cos \theta} = \frac{W}{\sin(\theta + 56.81^\circ)}$$

For the value of least force $F \sin(\theta + 56.81^\circ)$ will be maximum, if, $\sin(\theta + 56.81^\circ) = 1$

$$\theta = 33.19^\circ \quad (\text{Ans})$$

$$F = \frac{1000 \times \cos 56.81^\circ}{\sin(33.19^\circ + 56.81^\circ)} = 547.42 \text{ lb.} \quad (\text{Ans})$$

Problem 33

$$\Sigma F_x = 0$$

$$\Rightarrow A_x = 0$$

$$\Sigma F_y = 0 \Rightarrow A_y - 30 - 20 = 0.$$

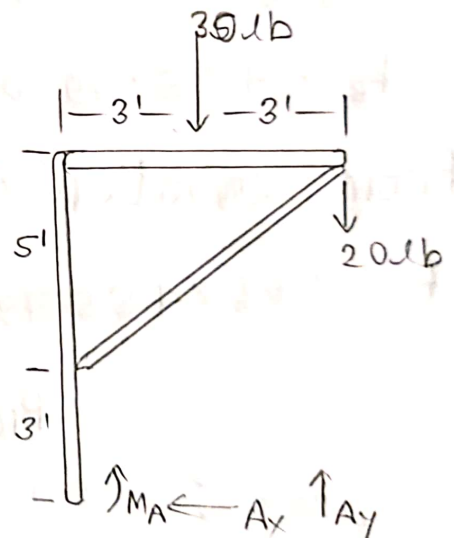
$$\Rightarrow A_y = 50.$$

$$\Sigma M_A = 0.$$

$$\Rightarrow -M_A + (30 \times 3) + (20 \times 6) = 0.$$

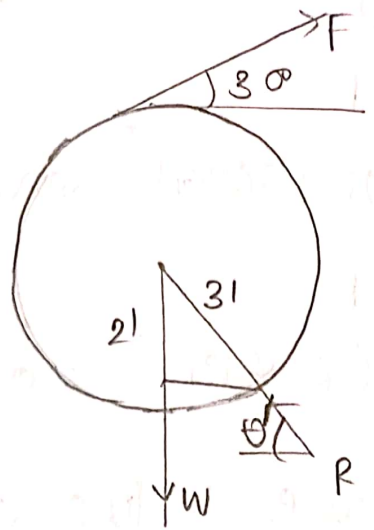
$$\Rightarrow M_A = 210 \text{ lb}\cdot\text{ft} \uparrow (\text{Ans})$$

$$\text{Reaction at A} = \sqrt{A_x^2 + A_y^2} = A_y = 50 \text{ lb} \quad (\text{Ans})$$



Problem 34

Consider the free body diagram of the wheel,



$$\sum F_x = 0$$

$$\Rightarrow F \cos 30^\circ - R_B \cos 41.81^\circ = 0.$$

$$\Rightarrow F = 0.86 R_B. \quad \text{--- (i)}$$

$$\theta = \sin^{-1} \frac{2}{3}$$

$$= 41.81^\circ$$

since the wheel is moving, $R_x = 0$ (Ans)

$$\sum F_y = 0.$$

$$\Rightarrow F \sin 30^\circ + R_B \sin 41.81^\circ - W = 0.$$

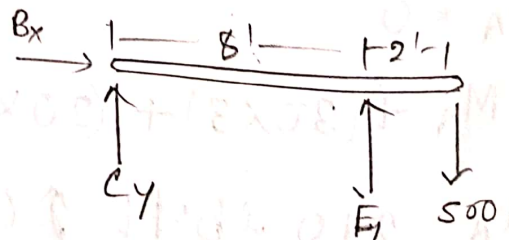
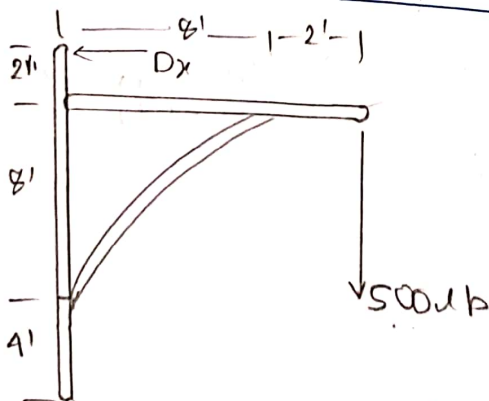
$$\Rightarrow 0.86 R_B \times \sin 30^\circ + R_B \sin 41.81^\circ = 500$$

$$\Rightarrow R_B = 455.79 \text{ lb} \quad \text{(Ans)}$$

From equation (i)

$$F = 0.86 \times 455.79 = 391.98 \text{ lb} \quad \text{(Ans)}$$

Problem 38



consider the free ^{body} diagram of the frame,

$$\sum M_A = 0 \Rightarrow 500 \times 10 - D_x \times 14 = 0$$

$$\Rightarrow D_x = 357.14 \text{ lb}$$

$$\sum F_x = 0 \Rightarrow A_x - D_x = 0 \Rightarrow A_x = D_x = 357.14 \text{ lb}$$

$$\sum F_y = 0 \Rightarrow A_y = 500 \text{ lb}$$

consider the free body diagram of CF

$$\sum M_c = 0 \Rightarrow 500 \times 10 - E_y \times 8 = 0$$

$$\Rightarrow E_y = 625 \text{ lb}$$

$$\sum F_y = 0 \Rightarrow C_y + E_y - 500 = 0$$

$$\Rightarrow C_y = \underline{500} - 625 = -125 \text{ lb} \therefore C_y = 125 \text{ lb} (\downarrow)$$

$$\sum F_x = 0$$

$$\Rightarrow C_x - E_x = 0 \Rightarrow C_x = E_x$$

consider the free body diagram of AD,

$$\sum M_B = 0$$

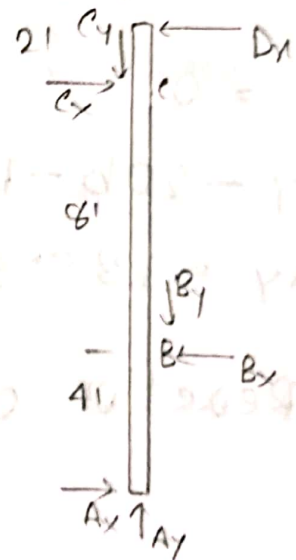
$$\Rightarrow -A_x \times 4 + C_x \times 8 - D_x \times 10 = 0$$

$$\Rightarrow -357.14 \times 4 + C_x \times 8 - 357.14 \times 10 = 0$$

$$\Rightarrow C_x = 625 \text{ lb}$$

$$\sum F_x = 0 \Rightarrow A_x + C_x - B_x - D_x = 0 \Rightarrow B_x = 625 \text{ lb}$$

$$\sum F_y = 0 \Rightarrow A_y - B_y + C_y = 0 \Rightarrow 500 - B_y + 125 = 0 \Rightarrow B_y = 625 \text{ lb}$$

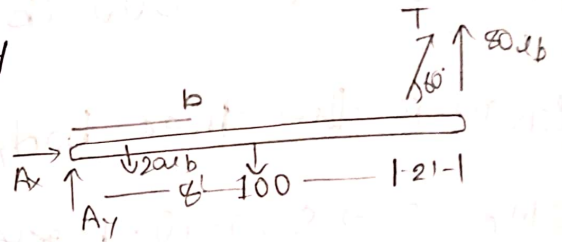


$$\therefore R_B = \sqrt{B_x^2 + B_y^2} = \sqrt{(625)^2 + (625)^2} = 883.88 \text{ lb}$$

$$R_C = \sqrt{C_x^2 + C_y^2} = \sqrt{(625)^2 + (125)^2} = 637.36 \text{ lb}$$

Problem 37

Consider the free body diagram of beam,



$$\Sigma F_x = 0$$

$$\Rightarrow T \cos 60^\circ - A_x = 0$$

$$\Rightarrow A_x = 40 \text{ lb}$$

$$\Sigma M_A = 0$$

$$\Rightarrow (20b) \times \frac{b}{2} + 100 \times 5 - 80 \times 8 \sin 60^\circ - 80 \times 10 = 0$$

$$\Rightarrow 10b^2 = 554.26$$

$$\Rightarrow b = 24 \text{ ft. (Ans)}$$

$$\Sigma F_y = 0$$

$$\Rightarrow A_y - 20b - 100 + 80 \sin 60^\circ + 80 = 0$$

$$\Rightarrow A_y = 135.57 \text{ lb}$$

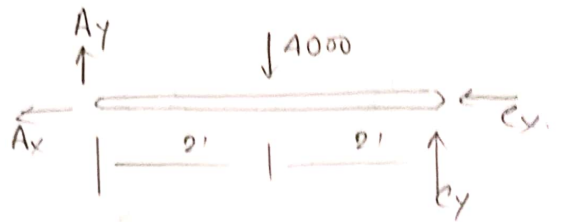
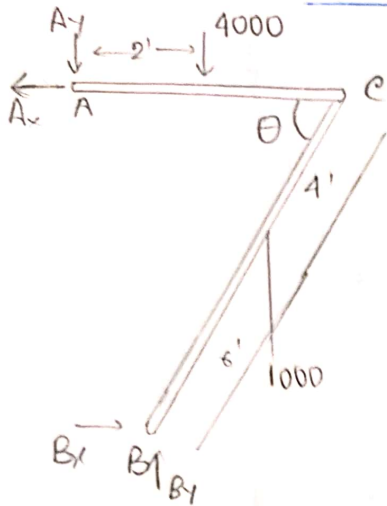
$$\therefore \text{Reaction at A, } R_A = \sqrt{A_x^2 + A_y^2}$$

$$= \sqrt{(40)^2 + (135.57)^2}$$

$$= 141.35 \text{ lb}$$

(Ans)

Problem 42



Consider the free body diagram of the frame.

$$\sum M_B = 0$$

$$\Rightarrow 1000 \times 6 \cos 66.42^\circ + 4 \times 2 \times 1000 - A_x \times 10 \sin 66.42^\circ = 0$$

$$\Rightarrow A_x = 1134.77 \text{ lb}$$

$$\sum F_x = 0 \Rightarrow A_x = B_x = 1134.77 \text{ lb}$$

$$\sum F_y = 0 \Rightarrow A_y + B_y - 4000 - 1000 = 0 \Rightarrow A_y + B_y = 5000 \quad \text{--- (i)}$$

Consider the free body diagram of frame member AC.

$$\sum M_e = 0$$

$$\Rightarrow A_y \times 4 - 4000 \times 2 \Rightarrow A_y = 2000 \text{ lb}$$

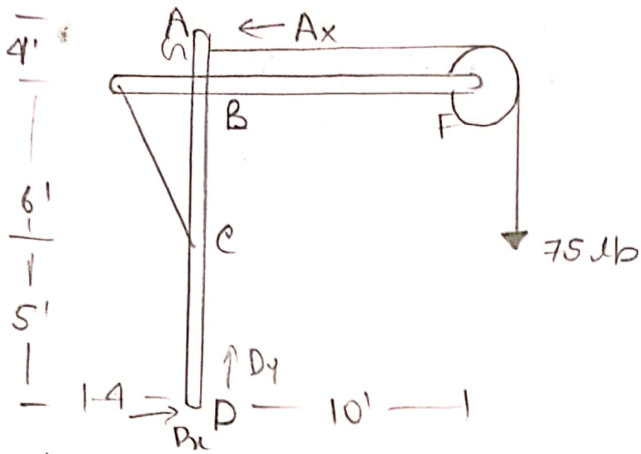
$$\text{from (i), } B_y = 3000 \text{ (Ans).}$$

$$\sum F_y = 0 \Rightarrow A_y + C_y - 4000 = 0 \Rightarrow C_y = 2000 \text{ lb}$$

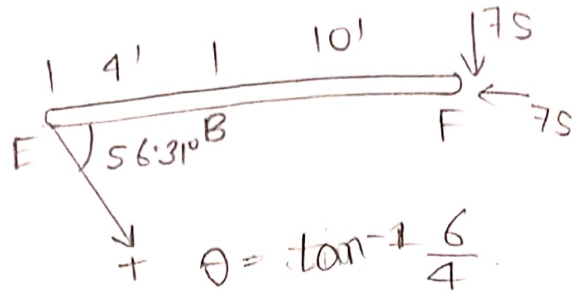
$$\sum F_x = 0 \Rightarrow -A_x - C_x = 0 \Rightarrow C_x = -1134.77$$

$$\therefore C_x = 1134.77 (\rightarrow) \text{ (Ans).}$$

Problem 46



free body of frame



free body of EF

Consider the free body diagram of the frame,

$$\sum M_B = 0$$

$$\Rightarrow 75 \times 12 - A_x \times 15 = 0 \Rightarrow A_x = 60 \text{ lb}$$

$$\sum F_x = 0 \Rightarrow D_x - A_x = 0 \Rightarrow D_x = A_x = 60 \text{ lb}$$

$$\sum F_y = 0 \Rightarrow D_y - 75 = 0 \Rightarrow D_y = 75 \text{ lb}$$

Consider the free body diagram of EF,

$$\sum M_B = 0$$

$$\Rightarrow 75 \times 10 - T \sin 56.31^\circ \times 4 = 0$$

$$\Rightarrow T = 225.35 \text{ lb}$$

$$\sum F_x = 0$$

$$\Rightarrow B_x + T \cos 56.31^\circ - 75 = 0 \Rightarrow B_x = 50 \text{ lb}$$

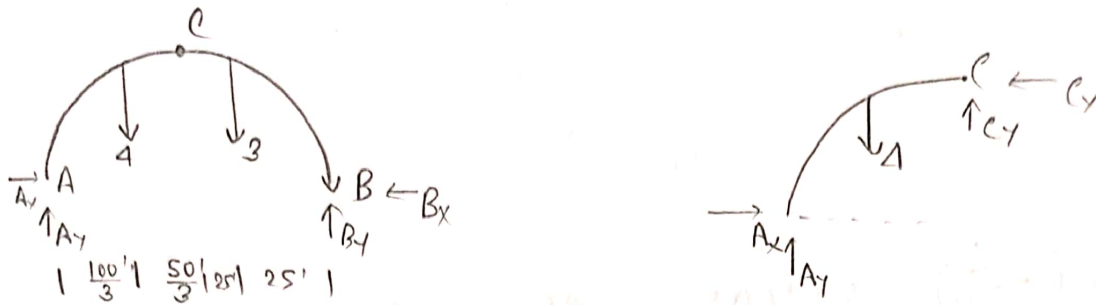
$$\sum F_y = 0$$

$$\Rightarrow B_y - T \sin 56.31^\circ - 75 = 0 \Rightarrow B_y = 262.5 \text{ lb}$$

Ans

Problem 50

Arch: It is a vertical curved structure that spans an elevated space.



Consider the free body diagram of structure

$$\sum M_A = 0 \Rightarrow 4 \times \frac{100}{3} + 3 \times 75 - B_y \times 100 = 0.$$

$$\Rightarrow B_y = 3.58 \text{ tons.}$$

$$\sum F_x = 0 \Rightarrow A_x - B_x = 0 \Rightarrow A_x = B_x \quad \text{(i)}$$

$$\sum F_y = 0 \Rightarrow A_y + B_y - 3 - 4 \Rightarrow A_y = 3.42 \text{ tons.}$$

$$\text{Reaction at A} = \sqrt{A_x^2 + A_y^2} = 4.01 \text{ tons (ans)}$$

consider the free body of Ac,

$$\sum M_c = 0$$

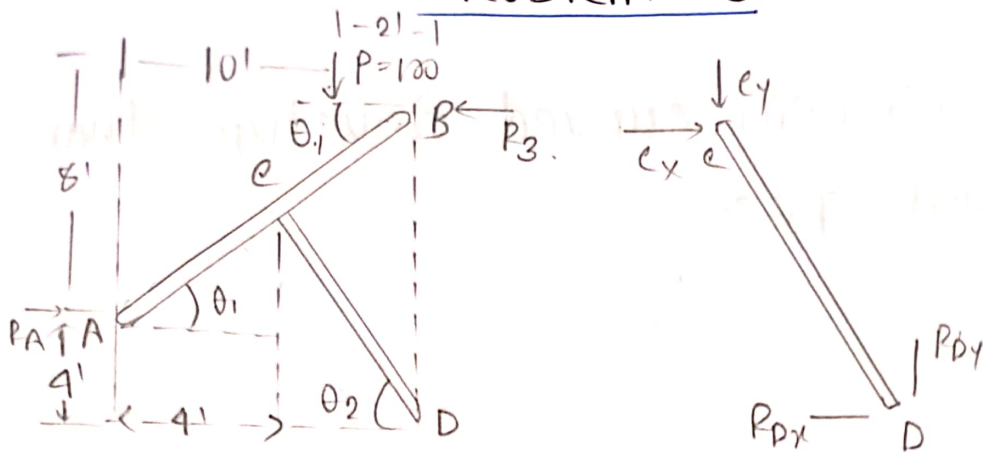
$$\Rightarrow A_y \times 50 - A_x \times 50 - 4 \times \frac{50}{3} = 0$$

$$\Rightarrow A_x = 2.087 \text{ tons.}$$

From equation (i), $A_x = B_x = 2.087 \text{ tons.}$

$$\text{Reaction at B} = \sqrt{B_x^2 + B_y^2} = 4.14 \text{ tons (Ans)}$$

Problem 33



$$\theta_1 = \tan^{-1} \left(-\frac{6}{12} \right) = 33'69''$$

$$\theta_2 = \tan^{-1} \left(\frac{6.67}{8} \right) = 39'82''$$

$$CE = 4 \times \tan 33'69'' = 2.67$$

consider the free body diagram of the frame

$$\sum M_c = 0 \quad [Pin \text{ at } c]$$

$$\Rightarrow \cancel{R_A} \times 100 \times 6 - R_A \times 2.67 - R_B \times 5.33 = 0$$

$$\Rightarrow 2.67 R_A - 1.533 R_B = 600 \quad \text{--- (i)}$$

$$\sum M_D = 0 \quad [Base]$$

$$\Rightarrow R_A \times 4 - 100 \times 2 - R_B \times 12 = 0$$

$$\Rightarrow 4R_A - 12R_B = 200 \Rightarrow R_A - 3R_B = 50 \quad \text{--- (ii)}$$

From equation (i) and (ii),

$$R_A = 154.9 \text{ lb} \text{ and } R_B = 34.97 \text{ lb} \quad \text{(Ans)}$$

$$\sum F_y = 0 \Rightarrow R_{Dy} - 100 = 0 \Rightarrow R_{Dy} = 100 \text{ lb}$$

$$\sum F_x = 0 \Rightarrow R_A - R_B - R_{Dx} = 0 \Rightarrow R_{Dx} = 119.93 \text{ lb}$$

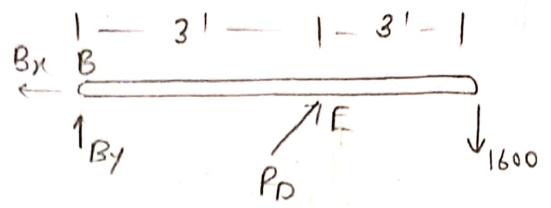
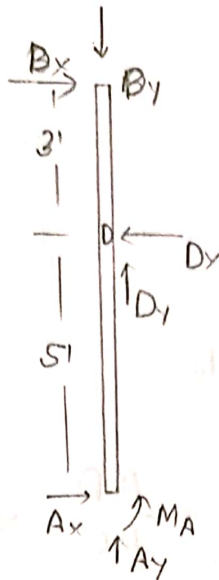
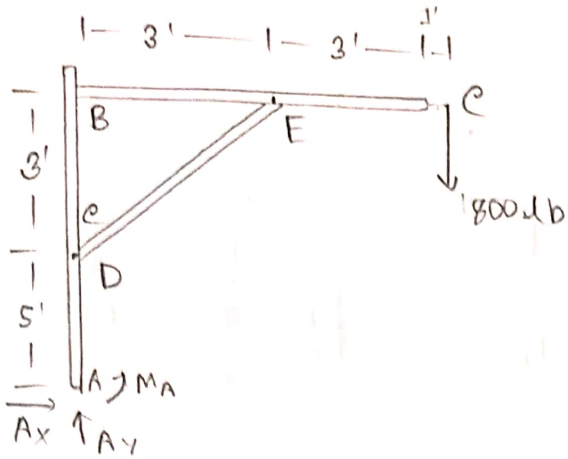
consider the free body diagram of cD.

$$\sum F_x = 0 \Rightarrow C_x - R_{Dx} = 0 \Rightarrow C_x = R_{Dx} = 119.93 \text{ lb}$$

$$\sum F_y = 0 \Rightarrow R_{Dy} - C_y = 0 \Rightarrow C_y = R_{Dy} = 100 \text{ lb}$$

(Ans)

Problem 54



Consider the free body diagram of the frame.

$$\sum F_x = 0 \Rightarrow A_x = 0$$

$$\sum F_y = 0 \Rightarrow A_y = 1600 \text{ lb.}$$

$$\sum M_A = 0 \Rightarrow -M_A + 1600 \times 7 = 0 \Rightarrow M_A = 11200 \text{ lb}\cdot\text{ft.}$$

Reaction at A, $R_A = \sqrt{A_x^2 + A_y^2} = 1600 \text{ lb.}$

Consider the free the body diagram of AB,

$$\sum M_B = 0 \Rightarrow A_x \times 8 - D_x \times 3 + M_A = 0.$$

$$\Rightarrow D_x = \frac{M_A}{3} = 3200 \text{ lb.} / 3733 \text{ lb.}$$

$$\sum F_y = 0 \Rightarrow A_y + D_y - B_y = 0.$$

$$\Rightarrow B_y - D_y = 1600 \text{ lb.} \quad \text{--- (i)}$$

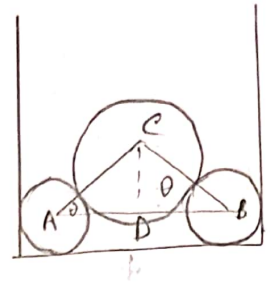
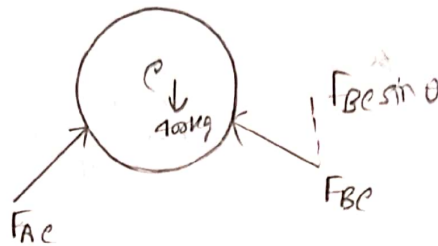
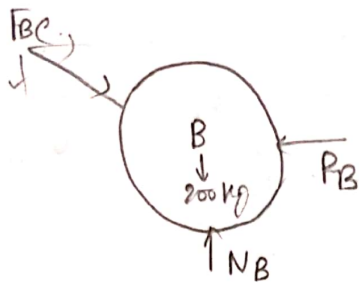
consider the free body diagram BC,

$$\sum M_E = 0. \Rightarrow 1600 \times 3 + B_y \times 3 = 0.$$

$$\Rightarrow B_y = -1600$$

From eq (i). $D_y = 3200 \downarrow$ (Ans).

Problem 68



$$\text{From } \triangle ABC, \cos \theta = \frac{AD}{AC} \Rightarrow \theta = \cos^{-1} \frac{35}{45} = 38.94^\circ$$

consider the free body diagram of C,

$$\sum F_x = 0 \Rightarrow F_{AC} \cos 38.94^\circ - F_{BC} \cos 38.94^\circ = 0.$$

$$\Rightarrow F_{AC} = F_{BC} \quad \text{--- (i)}$$

$$\sum F_y = 0 \Rightarrow F_{AC} \sin 38.94^\circ + F_{BC} \sin 38.94^\circ - 400 = 0.$$

$$\Rightarrow 2F_{AC} \sin 38.94^\circ = 400 \Rightarrow F_{AC} = 318.21 \text{ kg}$$

$$\therefore F_{AC} = F_{BC} = 318.21 \text{ kg}$$

consider the free body diagram of B,

$$\sum F_x = 0 \Rightarrow F_{BC} \cos 38.94^\circ - P_B = 0 \Rightarrow P_B = 247.51 \text{ kg}$$

$$\sum F_y = 0 \Rightarrow N_B - 200 - F_{BC} \sin 38.94^\circ = 0.$$

$$\Rightarrow N_B = 400 \text{ kg}$$

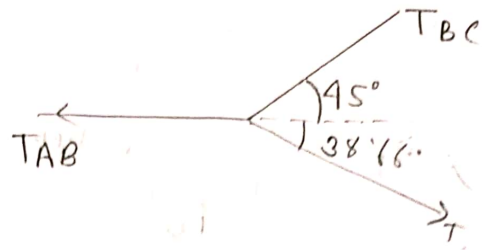
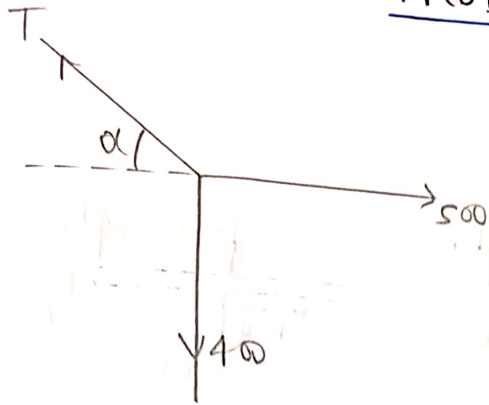
since the cylinders A and B are identical,

$$P_A = P_B = 247.51 \text{ kg}$$

$$N_A = N_B = 400 \text{ kg}$$

(Ans)

Problem 69



consider the free body diagram of BDE,

$$\Sigma F_x = 0$$

$$\Rightarrow 500 - T \cos \alpha = 0.$$

$$\Rightarrow T \cos \alpha = 500 \quad \text{(i)}$$

$$\Sigma F_y = 0. \Rightarrow T \sin \alpha - 400 = 0.$$

$$\Rightarrow T \sin \alpha = 400 \quad \text{(ii)}$$

$$(i)^2 + (ii)^2 \Rightarrow T^2 (\cos^2 \alpha + \sin^2 \alpha) = 500^2 + 400^2.$$

$$\Rightarrow T = 640.31 \text{ lb.}$$

dividing equation (ii) by (i),

$$\tan \alpha = \frac{400}{500} \Rightarrow \alpha = 38.66^\circ.$$

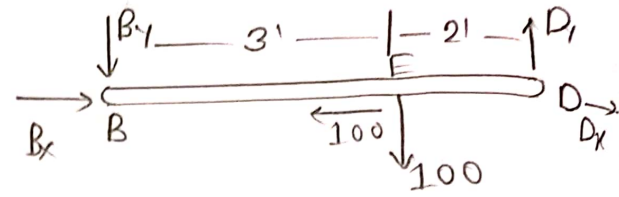
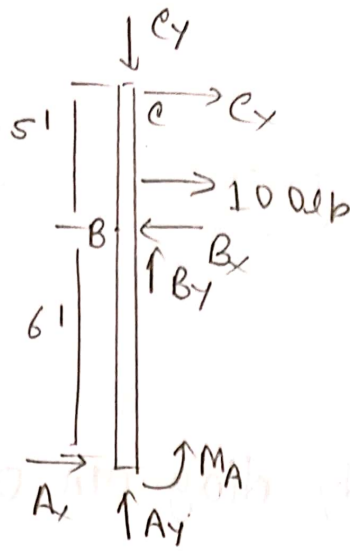
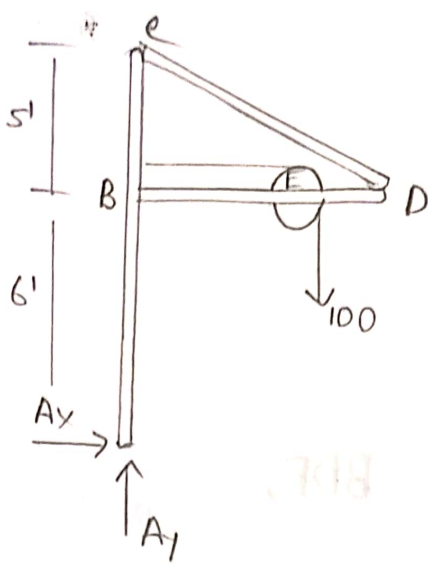
From equation (i), $T = \frac{500}{\cos 38.66^\circ} = 640.31 \text{ kg}$

consider the free body diagram of DBE,

$$\Sigma F_y = 0.$$

$$\Rightarrow T_{BC} \sin 45^\circ - T \sin 38.66^\circ = 0.$$

$$\Rightarrow T_{BC} = \frac{640.31 \sin 38.66^\circ}{\sin 45^\circ} = 565.69 \text{ lb} \quad \text{(Ans)}$$



Consider the free body diagram of the frame,

$$\sum F_x = 0 \Rightarrow A_x = 0$$

$$\sum F_y = 0 \Rightarrow A_y - 100 = 0$$

$$\sum M_A = 0 \Rightarrow -M_A + 100 \times 4 = 0 \Rightarrow M_A = 400 \text{ lb.}$$

Consider the free body diagram of AC,

$$\sum M_B = 0 \Rightarrow C_x \times 5 - A_x \times 6 - M_A + 100 \times 1 = 0.$$

$$\Rightarrow C_x = 60 \text{ lb} \quad (\text{Ans})$$

$$\sum F_x = 0 \Rightarrow C_x - B_x + A_x = 0 \Rightarrow C_x = B_x = 60 \text{ lb.}$$

$$\sum F_y = 0 \Rightarrow A_y + B_y - C_y = 0 \Rightarrow C_y = A_y + B_y = 100 + B_y \quad \text{---(i)}$$

Consider the free body diagram of BD,

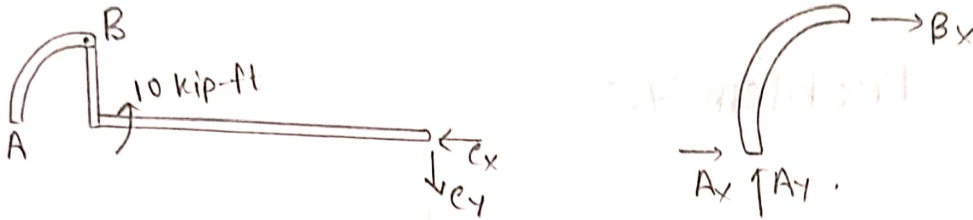
$$\sum M_D = 0 \Rightarrow -B_y \times 5 - 2 \times 100 = 0.$$

$$\Rightarrow B_y = -40 \therefore B_y = 40 \uparrow \quad (\text{Ans})$$

$$\text{From (i)} \Rightarrow C_y = 100 - 40 = 60 \text{ lb} \quad (\text{Ans})$$

Problem 73

kip is a US customary unit of force. It equals 1000 pounds-force. Its symbols kip, or less frequently klb.



Consider the free body diagram of the frame.

$$\sum M_A = 0 \Rightarrow -C_y \times 6 - 10 = 0 \Rightarrow C_y = -1.67 \text{ kip.}$$

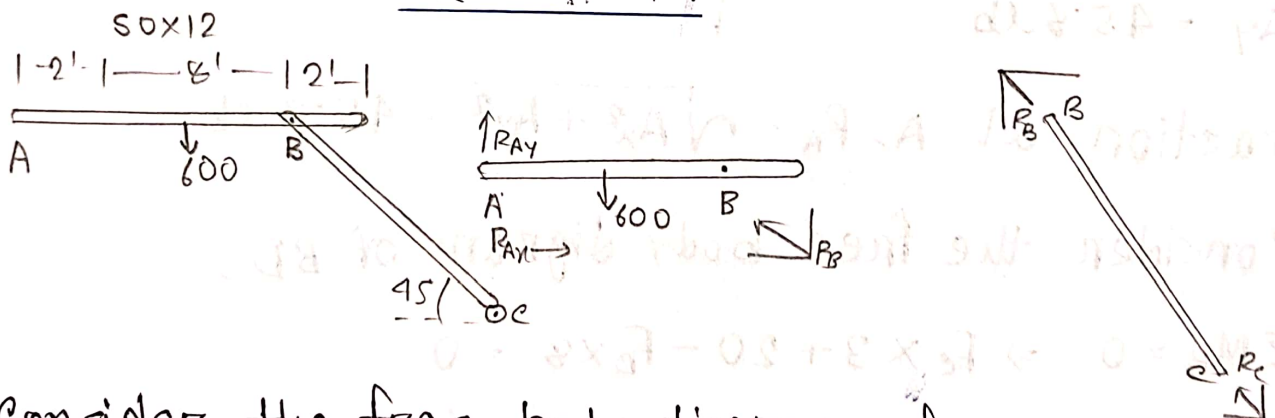
$$\sum F_x = 0 \Rightarrow A_x - C_x = 0 \Rightarrow A_x = C_x.$$

$$\sum F_y = 0 \Rightarrow A_y + C_y = 0 \Rightarrow A_y = -C_y = 1.67 \text{ kip.}$$

Consider the free body diagram of the frame.

$$\sum M_B = 0 \Rightarrow A_y \times 2 - A_x \times 2 \Rightarrow A_x = 1.67 \text{ kip.}$$

Problem 74



Consider the free body diagram of AB.

$$\sum M_A = 0 \Rightarrow 600 \times 4 - R_B \sin 45^\circ \times 8 = 0.$$

$$\Rightarrow R_B = 424.26 \text{ lb.}$$

$$\sum F_x = 0 \Rightarrow R_{Ax} - R_B \cos 45^\circ \Rightarrow R_{Ax} = 300$$

$$\sum F_y = 0 \Rightarrow R_{Ay} + R_B \sin 45^\circ - 600 = 0 \Rightarrow R_{Ay} = 300 \text{ lb.}$$

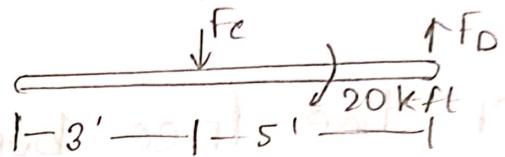
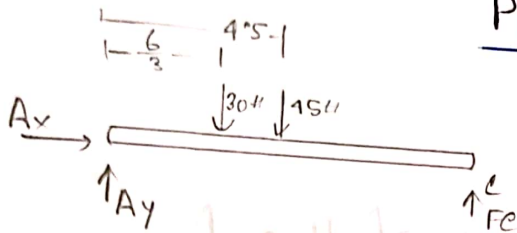
$$\therefore R_{A_{total}} = \sqrt{300^2 + 300^2} = 424.26 \text{ lb.}$$

consider the free body diagram of BC

$$\sum F_x = 0 \Rightarrow R_B \cos 45^\circ - R_C \cos 45^\circ = 0$$

$$\Rightarrow R_B = R_C = 424.26 \text{ lb (Ans).}$$

Problem 75



consider the free body diagram of AC

$$\sum M_A = 0.$$

$$\Rightarrow \frac{6}{3} \times \left(\frac{1}{2} \times 10 \times 6 \right) + 45 \times 4.5 - F_c \times 9 = 0.$$

$$\Rightarrow F_c = 29.16 \text{ lb (Ans).}$$

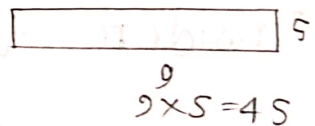
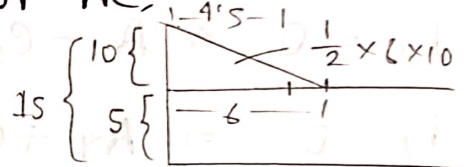
$$\sum F_y = 0$$

$$\Rightarrow A_y - 30 - 45 + F_c = 0$$

$$\Rightarrow A_y = 45.8 \text{ lb}$$

$$\sum F_x = 0$$

$$A_x = 0.$$



Reaction at A, $R_A = \sqrt{A_x^2 + A_y^2} = 45.8 \text{ lb.}$

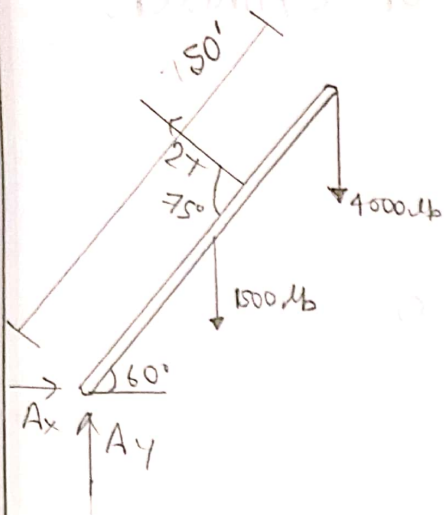
consider the free body diagram of BD

$$\sum M_B = 0 \Rightarrow F_c \times 3 + 20 - F_D \times 8 = 0$$

$$\Rightarrow F_D = 13.44 \text{ lb.}$$

(Ans)

Problem 77



Consider the free body diagram of boom,

$$\sum M_A = 0$$

$$\Rightarrow 1500 \times 25 \cos 60^\circ + 4000 \times 50 \cos 60^\circ -$$

$$2T \cos 75^\circ \times 35 = 0.$$

$$\Rightarrow T =$$

(Ans).

$$\sum F_x = 0 \Rightarrow A_x - 2T \cos 15^\circ = 0.$$

$$\Rightarrow A_x$$

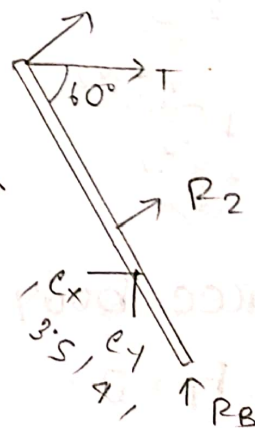
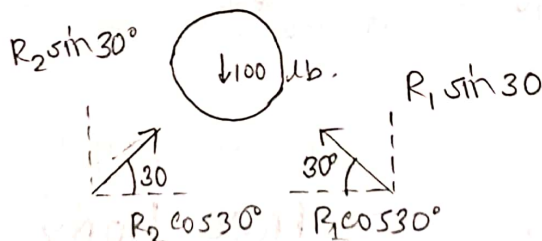
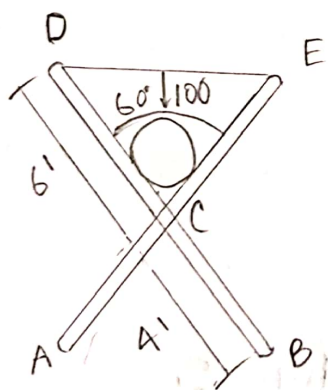
$$\sum F_y = 0 \Rightarrow A_y - 1500 - 4000 + 2T \sin 15^\circ = 0.$$

$$\Rightarrow A_y.$$

$$\text{Reaction at A, } R_A = \sqrt{A_x^2 + A_y^2} =$$

(Ans).

Problem 81



Consider the free body diagram of the frame,

$$\sum M_A = 0 \Rightarrow 100 \times 4 \cos 60^\circ - R_B \times 2 \times 4 \cos 60^\circ = 0$$

$$\Rightarrow R_B = 50 \text{ lb.}$$

$$\sum F_y = 0 \Rightarrow R_A + R_B - 100 = 0 \Rightarrow R_A = 50 \text{ lb}$$

Consider the free body diagram of cylinders

$$\sum F_x = 0 \Rightarrow R_2 \cos 30^\circ - R_1 \cos 30^\circ = 0$$

$$\Rightarrow R_1 = R_2$$

$$\sum F_y = 0 \Rightarrow R_2 \sin 30^\circ + R_1 \sin 30^\circ - 100 = 0.$$

$$\Rightarrow 2R_1 \sin 30^\circ = 100$$

$$\Rightarrow R_1 = 100 \text{ lb.} = R_2$$

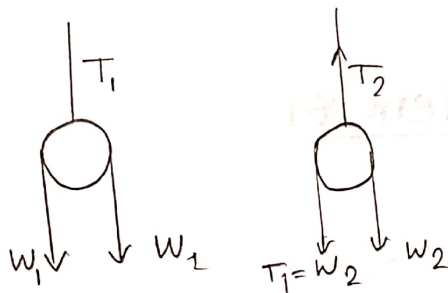
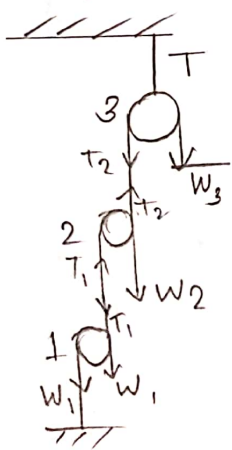
Consider the free body diagram of BD,

$$\sum M_c = 0$$

$$\Rightarrow T \sin 60^\circ \times 6 - R_2 \times 3.5 - R_B \sin 30^\circ \times 4 = 0.$$

$$\Rightarrow T = 86.6 \text{ lb.}$$

Problem 88



Free body for 1,

$$\sum F_y = 0.$$

$$\Rightarrow T_1 - W_1 - W_1 = 0$$

$$\Rightarrow T_1 = 2W_1 = 20 \text{ lb} = W_2$$

Free body for 2,

$$\sum F_y = 0$$

$$\Rightarrow W_2 + W_2 - T_2 = 0 \quad [T_1 = W_2].$$

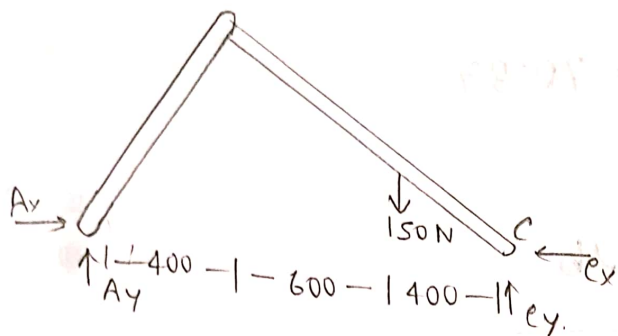
$$\Rightarrow 2W_2 = T_2 = 2 \times 20 = 40 \text{ lb}$$

Free body for 3

$$T_2 = W_3 = 40 \text{ lb}$$

$$\sum F_y = 0 \Rightarrow T - W_3 - T_2 = 0 \Rightarrow T = T_2 + W_3 = 40 + 40 = 80 \text{ lb}$$

Problem 107



$$\sum M_B = 0 \Rightarrow A_y \times 400 - A_x \times 500 = 0 \Rightarrow A_x = 0.8 A_y$$

$$\sum M_A = 0 \Rightarrow 150 \times 1000 - C_y \times 1400 = 0 \Rightarrow C_y = 107.14 \text{ N}$$

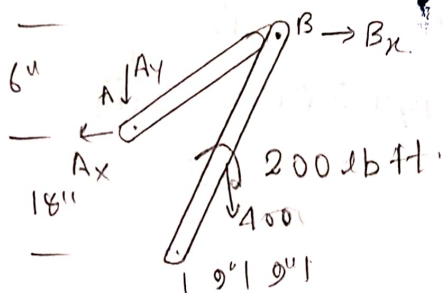
$$\sum F_y = 0 \Rightarrow A_y + C_y - 150 = 0 \Rightarrow A_y = 42.86 \text{ N}$$

$$\therefore A_x = 34.286 \text{ N} = C_x \quad [\sum F_x = 0]$$

Reaction at A, $R_A = \sqrt{A_x^2 + A_y^2} = 54.89 \text{ N}$

Reaction at C, $R_C = \sqrt{C_x^2 + C_y^2} = 112.49 \text{ N}$ (Ans)

Problem 108



consider F.B.D of frame

$$\sum M_e = 0 \Rightarrow 4000 \times 9 - A_x \cdot 18 + 200 = 0$$

$$A_x = 211.11 \text{ lb}$$

$$\sum F_x = 0 \Rightarrow C_x - A_x = 0 \Rightarrow C_x = A_x = 211.11 \text{ lb}$$

$$\sum F_y = 0 \Rightarrow C_y - A_y - 400 = 0 \Rightarrow C_y - A_y = 400 \text{ --- (i)}$$

$$\sum M_B = 0$$

$$\Rightarrow A_x \times 6 - A_y \times 18 = 0 \Rightarrow A_y = 70.37$$

From equation (i),

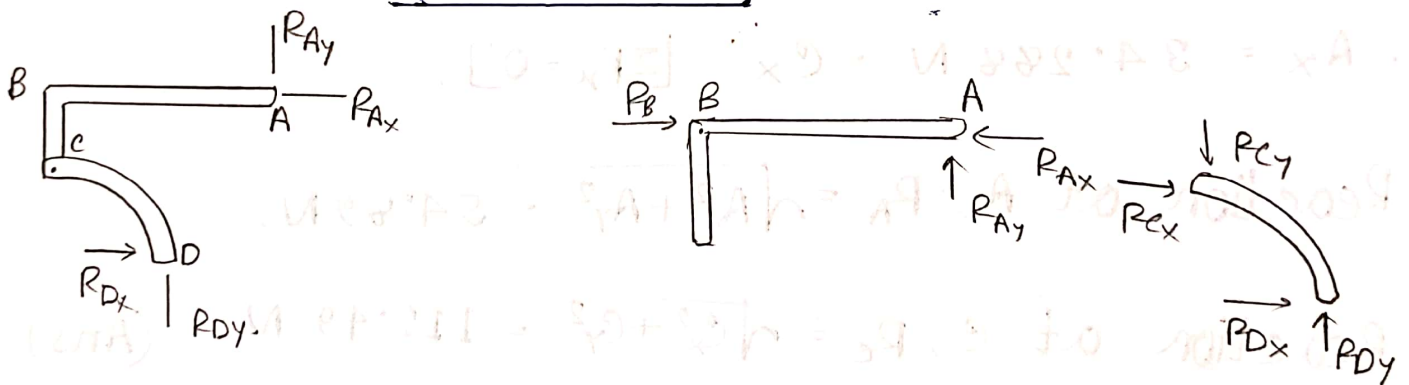
$$C_y = 400 + 70.37 = 470.37 \text{ lb}$$

$$\text{Reaction at A, } R_A = \sqrt{A_x^2 + A_y^2} = 222.53 \text{ lb}$$

$$\text{Reaction at C, } R_C = \sqrt{C_x^2 + C_y^2} = 515.573 \text{ lb}$$

(Ans)

Problem 109



Free body of frame,

$$\sum F_x = 0 \Rightarrow R_{Ax} - R_{Dx} = 0 \Rightarrow R_{Ax} = R_{Dx} \text{ --- (i)}$$

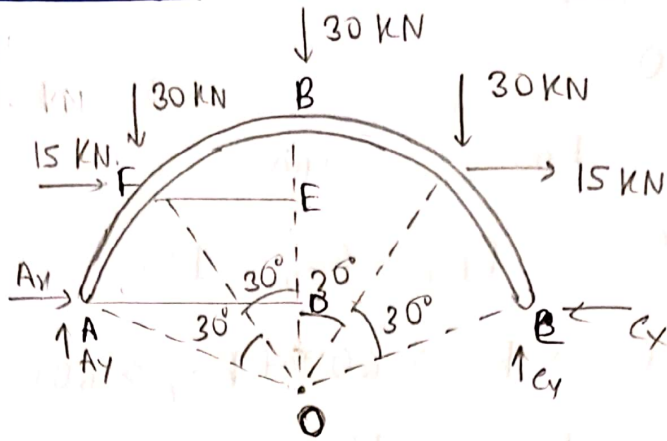
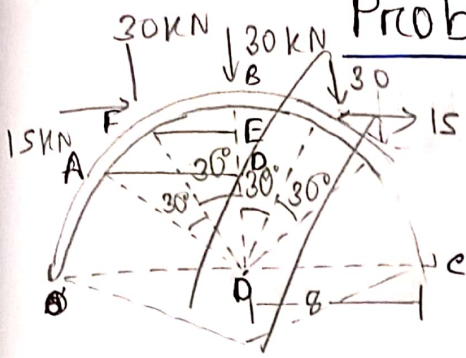
$$\sum F_y = 0 \Rightarrow R_{Dy} + R_{Ay} - 300 = 0 \Rightarrow R_{Ay} = R_{Dy} + 300 \text{ --- (ii)}$$

Free body of AB,

$$\sum M_B = 0 \Rightarrow 300 \times 600 - R_{Ay} \times 1200 = 0$$

$$\therefore R_{Ay} = 150 \text{ N} = R_{Dy}$$

Problem 114



From figure,

$$AD = 8 \sin 60^\circ$$

$$= 6.93$$

$$OD = 8 \cos 60^\circ = 4 \quad OE = 8 \cos 30^\circ = 6.93 \text{ m} \quad EF = 8 \sin 30^\circ = 4$$

$$BE = (8 - 6.93) = 1.07 \quad DE = 6.93 - 4 = 2.93$$

Free body of frame,

$$\sum M_A = 0.$$

$$\Rightarrow 15 \times 2.93 + 30 \times (6.93 + 4) + 30 \times 6.93 + 30 \times (6.93 + 4) + 15 \times 2.93 - C_y \times 2 \times 6.93 = 0.$$

$$\Rightarrow 13.86 C_y = 711.6$$

$$\Rightarrow C_y = 51.34 \text{ kN.}$$

$$\sum F_y = 0. \Rightarrow A_y + C_y - 30 - 30 - 30 = 0.$$

$$\Rightarrow A_y = 38.66 \text{ kN.}$$

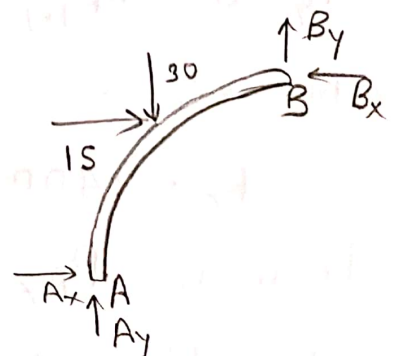
$$\sum F_x = 0. \Rightarrow A_x + 15 + 15 - C_x = 0 \Rightarrow A_x - C_x + 30 = 0. \quad \text{--- (i)}$$

Free body of AB

$$\sum M_B = 0.$$

$$\Rightarrow A_y \times 6.93 - A_x \times 4 - 15 \times 1.07 - 30 \times 4 = 0.$$

$$\Rightarrow A_x = 32.97 \text{ kN.}$$



Free body of CD,

$$\sum F_x = 0.$$

$$\Rightarrow R_{ex} = -R_{Dx} \text{ (iii)}$$

$$\sum F_y = 0 \Rightarrow R_{Dy} = R_{ey} = 150.$$

$$\sum M_D = 0 \Rightarrow R_{ex} \times 600 + R_{ey} \times 600 = 0.$$

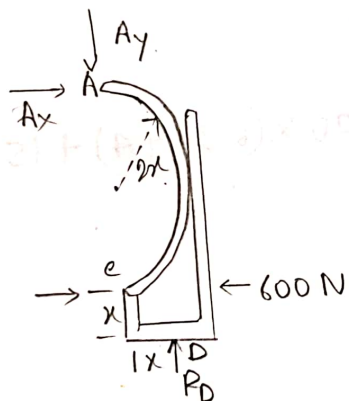
$$\Rightarrow R_{ex} = -R_{ey} = -150.$$

$$\therefore \text{Reaction at A, } R_A = \sqrt{R_{Ax}^2 + R_{Ay}^2} = \sqrt{150^2 + (-150)^2} = 212.13 \text{ N}$$

$$\text{Reaction at C, } R_C = \sqrt{R_{Cx}^2 + R_{Cy}^2} = 212.13 \text{ N}$$

(Ans)

Problem 112.



Free body of frame,

$$\sum F_x = 0 \Rightarrow R_{Ax} - R_C = 0 \Rightarrow R_{Ax} = R_C \text{ (i)}$$

$$\sum F_y = 0 \Rightarrow -R_{Ay} + 600 = 0 \Rightarrow R_{Ay} = 600$$

$$\sum M_C = 0 \Rightarrow -R_{Ay} \cdot 4x + R_C \cdot x = 0 \Rightarrow -600 \cdot 4x + R_C \cdot x = 0$$

$$\therefore R_C = 2400 \text{ N}$$

$$\text{From (i) } R_{Ax} = 2400 \text{ N}$$

$$\therefore \text{Reaction at A, } R_A = \sqrt{600^2 + 2400^2} = 2473.8 \text{ N}$$

$$\sum F_x = 0 \Rightarrow A_x + 15 - B_x = 0. \Rightarrow B_x = 47.97 \text{ kN.}$$

$$\sum F_y = 0 \Rightarrow A_y - 30 - B_y = 0 \Rightarrow B_y = 5.66 \text{ kN.}$$

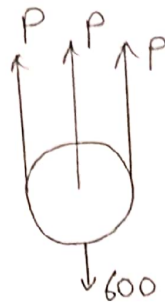
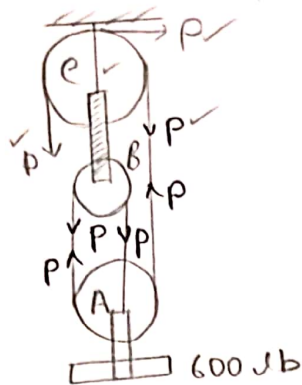
Reaction at A, $R_A = \sqrt{A_x^2 + A_y^2} = 50.81 \text{ kN}$

" " B, $R_B = \sqrt{B_x^2 + B_y^2} = 48.75 \text{ kN.}$

" " C, $R_C = \sqrt{C_x^2 + C_y^2} = 57.43 \text{ kN.}$

for 131, 119

Problem 140



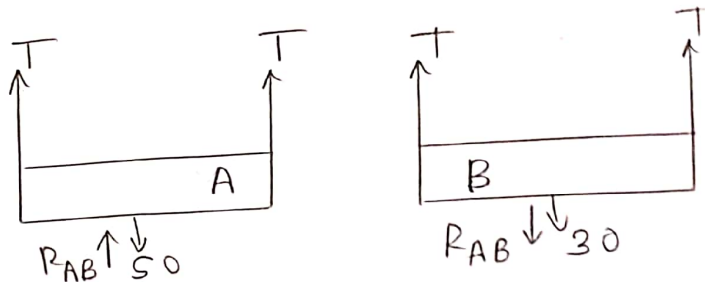
free body of A,

$$\sum F_y = 0 \Rightarrow P + P + P - 600 = 0.$$

$$\Rightarrow P = 200 \text{ lb.}$$

$$\text{now, } T_{CB} - P - P - P - P = 0 \Rightarrow T_{CB} = 4P = 800 \text{ lb.} \quad (\text{Ans})$$

Problem 145



Free body of A,

$$\sum F_y = 0 \Rightarrow 2T - 50 + R_{AB} = 0.$$

$$\Rightarrow 2T + R_{AB} = 50. \quad \text{_____ (i)}$$

free body of B,

$$\sum F_y = 0 \Rightarrow T + T - R_{AB} - 30 = 0$$

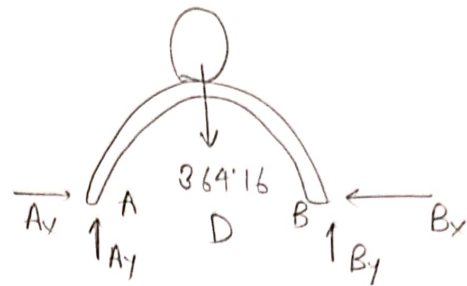
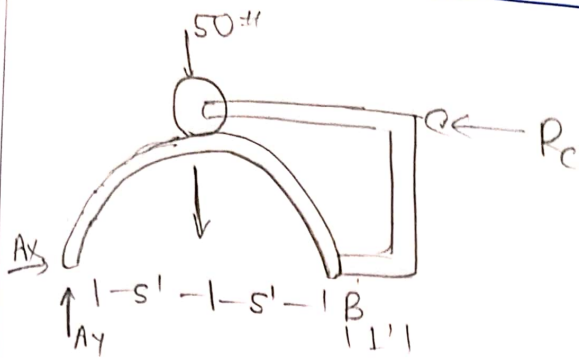
$$\Rightarrow 2T - R_{AB} = 30 \quad \text{_____ (ii)}$$

$$(i) + (ii) \Rightarrow 4T = 80 \Rightarrow T = 20 \text{ lb.}$$

$$\text{From (i)} \Rightarrow R_{AB} = 50 - 40 = 10 \text{ lb.}$$

(Ans)

Problem 148



free body of frame.

weight of arc $AB = \frac{1}{2} \times 2\pi \times 20 = 314.16 \text{ lb}$.

$$\sum M_A = 0 \Rightarrow (314.16 + 50) \times 5 - R_c \times 6 = 0.$$

$$\Rightarrow R_c = 303.5 \text{ lb}.$$

$$\sum F_y = 0 \Rightarrow A_y - 50 - 314.16 = 0.$$

$$\Rightarrow A_y = 364.16 \text{ lb}.$$

$$\sum F_x = 0 \Rightarrow A_x - R_c = 0 \Rightarrow A_x = R_c = 303.5 \text{ lb}.$$

free body of AB.

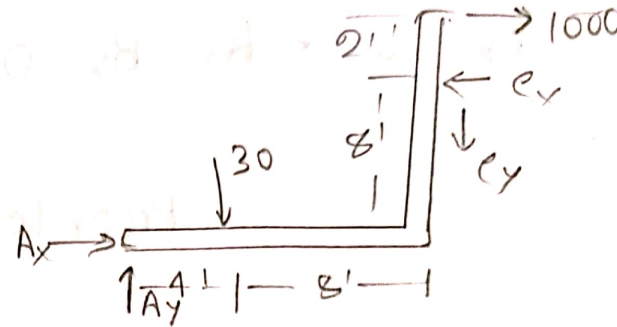
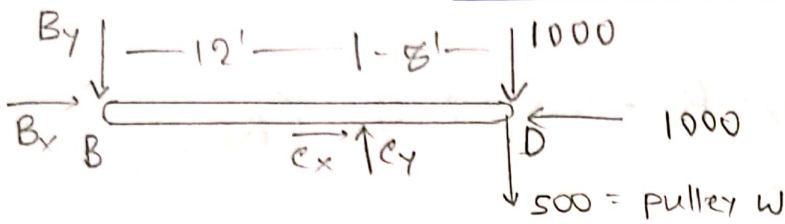
$$\sum M_A = 0 \Rightarrow 364.16 \times 5 - B_y \times 10 = 0.$$

$$\Rightarrow B_y = 182.08 \text{ lb}$$

$$\sum F_x = 0 \Rightarrow A_x - B_x = 0. \Rightarrow A_x = B_x = 303.5 \text{ lb. (Ans)}$$

Problem 150

Problem 153



free body of BD,

$$\sum M_B = 0 \Rightarrow 1500 \times 20 - C_y \times 12 = 0 \Rightarrow C_y = 2500 \text{ lb}$$

free body of AC,

$$\sum M_A = 0 \Rightarrow 30 \times 4 + C_y \times 12 - C_x \times 8 + 1000 \times 10 = 0$$

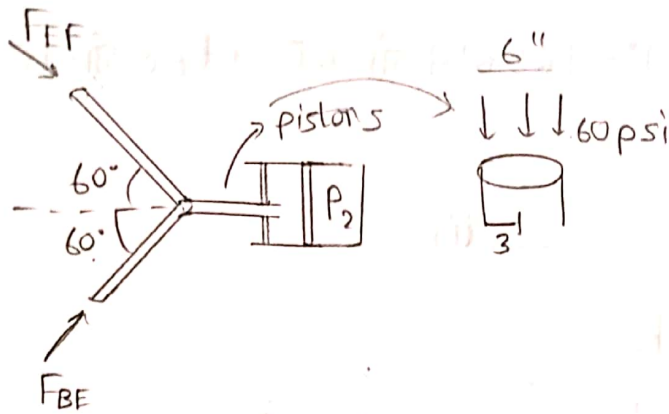
$$\Rightarrow C_x = 5015 \text{ lb}$$

∴ Force transmitted at C, $F_C = (5015i + 2500j) \text{ lb}$.

$$\text{OR } F_C = \sqrt{C_x^2 + C_y^2}$$

$$= 5603.59 \text{ lb (Ans)}$$

Problem 159



here,

$$P_2 = \pi(3)^2 \times 60 = 1696.4 \text{ lb}$$

From this free body diagram,

$$\sum F_y = 0 \Rightarrow F_{EF} \sin 60^\circ - F_{BE} \sin 60^\circ = 0.$$

$$\Rightarrow F_{EF} = F_{BE}$$

$$\sum F_x = 0 \Rightarrow F_{EF} \cos 60^\circ + F_{BE} \cos 60^\circ - 1696.4 = 0.$$

$$\therefore F_{EF} = F_{BE} = 1696.4 \text{ lb}.$$

For other part of P_1 ,

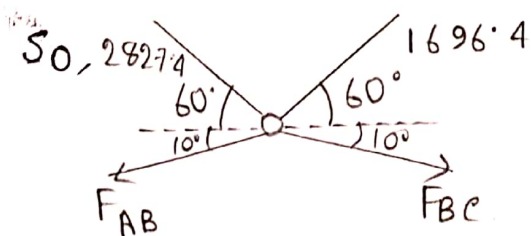
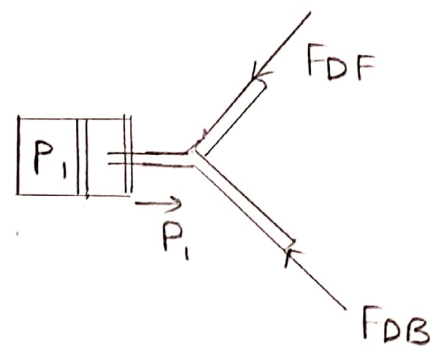
$$P_1 = \pi(3)^2 \times 100 = 2827.44$$

$$\sum F_y = 0 \Rightarrow F_{DF} \sin 60^\circ - F_{DB} \sin 60^\circ = 0.$$

$$\Rightarrow F_{DF} = F_{DB}.$$

$$\sum F_x = 0 \Rightarrow F_{DF} \cos 60^\circ + F_{DB} \cos 60^\circ - 2827.44 = 0.$$

$$\Rightarrow F_{DF} = 2827.44 = F_{DB}.$$



consider this free body,

$$\sum F_x = 0$$

$$\Rightarrow F_{AB} \cos 10^\circ + 2827.4 \cos 60^\circ - 1696.4 \cos 60^\circ - F_{BC} \cos 10^\circ = 0$$

$$\Rightarrow F_{AB} - F_{BC} = -574.22 \text{ lb.} \quad \text{--- (i)}$$

$$\sum F_y = 0.$$

$$\Rightarrow F_{AB} \sin 10^\circ - 2827.4 \sin 60^\circ - 1696.4 \sin 60^\circ + F_{BC} \sin 10^\circ$$

$$= 0.$$

$$\Rightarrow F_{AB} + F_{BC} = 22561.28 \quad \text{--- (ii)}$$

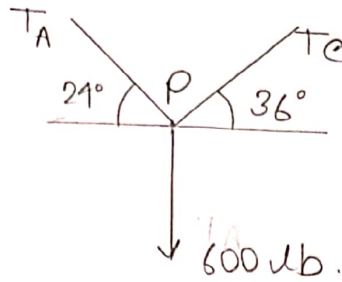
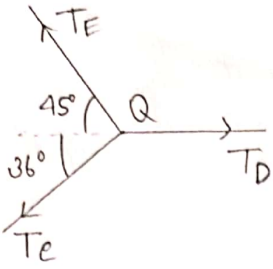
$$\therefore F_{AB} = 10993.53 \text{ lb}$$

$$F_{BC} = 11567.75 \text{ lb}$$

(Ans).

Problem 167

Problem 174



Free body of P,

$$\sum F_x = 0 \Rightarrow T_A \cos 24^\circ - T_c \cos 36^\circ = 0$$

$$\Rightarrow T_A = \frac{T_c \cos 36^\circ}{\cos 24^\circ}$$

$$\sum F_y = 0 \Rightarrow T_A \sin 24^\circ + T_c \sin 36^\circ = 6000$$

$$\Rightarrow \frac{T_c \cos 36^\circ}{\cos 24^\circ} \cdot \sin 24^\circ + T_c \sin 36^\circ = 6000$$

$$\Rightarrow T_c = 6329.229 \text{ lb}$$

Free body of Q,

$$\sum F_y = 0 \Rightarrow T_E \sin 45^\circ - T_c \sin 36^\circ = 0$$

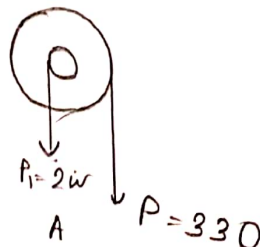
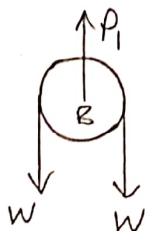
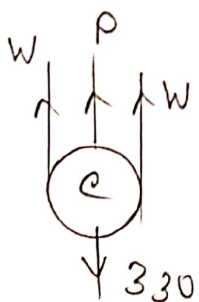
$$\Rightarrow T_E = \frac{6329.229 \times \sin 36^\circ}{\sin 45^\circ} = 5261.195 \text{ lb}$$

$$\sum F_x = 0 \Rightarrow T_E \cos 45^\circ + T_c \cos 36^\circ = T_D$$

$$\Rightarrow T_D = 8840.68 \text{ lb}$$

(Ans).

Problem 184



Free body of c,

$$\Sigma F_y = 0 \Rightarrow P + 2w = 330 \Rightarrow P = 330 - 2w$$

Free body of B,

$$\Sigma F_y = 0 \Rightarrow P_1 = 2w$$

Free body of A,

$$\Sigma M_A = 0 \Rightarrow 3 \times P_1 - 8 \times P = 0.$$

$$\Rightarrow 6w - 8(330 - 2w) = 0.$$

$$\Rightarrow 6w - 2640 + 16w = 0 \Rightarrow w = 120 \text{ lb. (Ans) .}$$

$$= 5261.195 \text{ lb}$$

(Ans).