5.84. Determine the largest weight of the oil drum that the floor crane can support without overturning. Also, what are the vertical reactions at the smooth wheels A, B, and C for this case. The floor crane has a weight of 300 lb, with its center of gravity located at C.

Equations of Equilibrium: The floor crane has a tendency to overturn about the y' axis, as shown on the free-body diagram in Fig. a. When the crane is about to overturn, the wheel at C loses contact with the ground. Thus

\[ N_C = 0 \quad \text{Ans.} \]

Applying the moment equation of equilibrium about the y' axis,

\[ \Sigma M_{y'} = 0; \quad W(10 \cos 30^\circ - 2 - 4) - 300(4) = 0 \]
\[ W = 451.08 \text{ lb} = 451 \text{ lb} \quad \text{Ans.} \]

Using this result and writing the moment equation of equilibrium about the x-axis and the force equation of equilibrium along the z-axis,

\[ \Sigma M_x = 0: \quad N_B (2.5) - N_A (2.5) = 0 \quad \text{(1)} \]
\[ \Sigma F_z = 0: \quad N_A + N_B - 300 - 451.08 = 0 \quad \text{(2)} \]

Solving Eqs. (1) and (2), yields

\[ N_A = N_B = 375.54 \text{ lb} = 376 \text{ lb} \quad \text{Ans.} \]
6-19. The truss is fabricated using members having a weight of 10 lb/ft. Remove the external forces from the truss, and determine the force in each member due to the weight of the members. State whether the members are in tension or compression. Assume that the total force acting on a joint is the sum of half of the weight of every member connected to the joint.

**Joint Loadings:**

\[ F_C = F_F = 10 \left( \frac{4 + 5}{2} \right) = 45 \text{ lb} \]
\[ F_E = F_B = 10 \left( \frac{4 + 4 + 3}{2} \right) = 55 \text{ lb} \]
\[ F_A = F_D = 10 \left( \frac{5 + 5 + 4 + 3}{2} \right) = 85 \text{ lb} \]

**Support Reactions:** Applying the moment equation of equilibrium about point C to the free-body diagram of the truss, Fig. a,

\[ \sum M_C = 0; \quad 45(4 + 4 + 4) + 55(4 + 4) + 85(4 + 4) + 85(4) + 55(4) - N_A(4 + 4) = 0 \]
\[ N_A = 277.5 \text{ lb} \]

**Method of Joints:** We will analyze the equilibrium of the joints in the following sequence:

\[ F \rightarrow E \rightarrow A \rightarrow B \rightarrow D \]

**Joint F:** From the free-body diagram in Fig. b,

\[ \Sigma F_y = 0; \quad F_{FA} \left( \frac{3}{5} \right) - 45 = 0 \]
\[ F_{FA} = 75 \text{ lb (C)} \] \hspace{1cm} \text{Ans.}

\[ \Sigma F_x = 0; \quad F_{FE} - 75 \left( \frac{4}{5} \right) = 0 \]
\[ F_{FE} = 60 \text{ lb (T)} \] \hspace{1cm} \text{Ans.}

**Joint E:** From the free-body diagram in Fig. c,

\[ \Sigma F_x = 0; \quad F_{ED} - 60 = 0 \]
\[ F_{ED} = 60 \text{ lb (T)} \] \hspace{1cm} \text{Ans.}

\[ \Sigma F_y = 0; \quad F_{EA} - 55 = 0 \]
\[ F_{EA} = 55 \text{ lb (C)} \] \hspace{1cm} \text{Ans.}

**Joint A:** From the free-body diagram in Fig. d,

\[ \Sigma F_y = 0; \quad 277.5 - 55 - 85 - 75 \left( \frac{3}{5} \right) - F_{AD} \left( \frac{3}{5} \right) = 0 \]
\[ F_{AD} = 154.17 \text{ lb} = 154 \text{ lb (C)} \] \hspace{1cm} \text{Ans.}

\[ \Sigma F_x = 0; \quad F_{AB} + 75 \left( \frac{4}{5} \right) - 154.17 \left( \frac{4}{5} \right) = 0 \]
\[ F_{AB} = 63.33 \text{ lb} = 63.3 \text{ lb (T)} \] \hspace{1cm} \text{Ans.}

**Joint B:** From the free-body diagram in Fig. e,

\[ \Sigma F_y = 0; \quad F_{BC} - 63.33 = 0 \]
\[ F_{BC} = 63.33 \text{ lb (T)} \] \hspace{1cm} \text{Ans.}

\[ \Sigma F_x = 0; \quad F_{BD} - 55 = 0 \]
\[ F_{BD} = 55 \text{ lb (T)} \] \hspace{1cm} \text{Ans.}

**Joint D:** From the free-body diagram in Fig. f,

\[ \Sigma F_y = 0; \quad 154.17 \left( \frac{3}{5} \right) - 60 - F_{DC} \left( \frac{4}{5} \right) = 0 \]
\[ F_{DC} = 79.17 \text{ lb} = 79.2 \text{ lb (C)} \] \hspace{1cm} \text{Ans.}

\[ \Sigma F_x = 0; \quad 154.17 \left( \frac{3}{5} \right) + 79.17 \left( \frac{3}{5} \right) - 85 - 55 = 0 \] \hspace{1cm} \text{(check)}
6-26. A sign is subjected to a wind loading that exerts horizontal forces of 300 lb on joints B and C of one of the side supporting trusses. Determine the force in each member of the truss and state if the members are in tension or compression.

Joint C:

\[
\begin{align*}
\sum F_x &= 0; \quad 300 - F_{CD} \sin 22.62^\circ = 0 \\
F_{CD} &= 780 \text{ lb (C)} \quad \text{Ans} \\
\sum F_y &= 0; \quad -F_{CD} + 780 \cos 22.62^\circ = 0 \\
F_{CB} &= 720 \text{ lb (T)} \quad \text{Ans}
\end{align*}
\]

Joint D:

\[
\begin{align*}
\sum F_x &= 0; \quad F_{DB} = 0 \quad \text{Ans} \\
\sum F_y &= 0; \quad 780 - F_{DB} = 0 \\
F_{DB} &= 780 \text{ lb (C)} \quad \text{Ans}
\end{align*}
\]
6-29. If the maximum force that any member can support is 4 kN in tension and 3 kN in compression, determine the maximum force $P$ that can be applied at joint $B$. Take $d = 1$ m.

**Support Reactions:**

\[ + \sum M_B = 0; \quad P(2d) - E_0 \left( \frac{3}{2} d \right) = 0 \quad A_0 = \frac{4}{3} P \]

\[ + \sum F_y = 0; \quad \frac{4}{3} P - E_2 = 0 \quad E_2 = \frac{4}{3} P \]

\[ \rightarrow \sum F_x = 0 \quad E_4 - P = 0 \quad E_4 = P \]

**Method of Joints:** By inspection of joint $C$, members $CB$ and $CD$ are zero force members. Hence

\[ F_{CB} = F_{CD} = 0 \]

**Joint A**

\[ + \sum F_y = 0; \quad -F_{BA} \left( \frac{1}{\sqrt{3.25}} \right) - \frac{4}{3} P = 0 \quad F_{BA} = 2.404P \quad (C) \]

\[ \rightarrow \sum F_x = 0; \quad F_{EA} - 2.404P \left( \frac{1.5}{\sqrt{3.25}} \right) = 0 \quad F_{EA} = 2.000P \quad (T) \]

**Joint B**

\[ \rightarrow \sum F_x = 0; \quad 2.404P \left( \frac{1.5}{\sqrt{3.25}} \right) - P \]

\[ -F_{FR} \left( \frac{0.5}{\sqrt{1.25}} \right) - F_{BD} \left( \frac{0.5}{\sqrt{1.25}} \right) = 0 \]

\[ 1.00P - 0.4472F_{FR} - 0.4472F_{BD} = 0 \quad [1] \]
+ \sum \Sigma F_x = 0; \quad 2.404 P \left( \frac{1}{\sqrt{1.25}} \right) - F_{F_0} \left( \frac{1}{\sqrt{1.25}} \right) - F_{R_0} \left( \frac{1}{\sqrt{1.25}} \right) = 0 \quad \text{[2]}

1.333 P + 0.8944 F_{R_0} - 0.8944 F_{F_0} = 0

Solving Eqs. [1] and [2] yield,
\[ F_{R_0} = 1.863 P \quad (T) \quad F_{F_0} = 0.3727 P \quad (C) \]

**Joint F**
\[ \sum \Sigma F_z = 0; \quad 1.863 P \left( \frac{1}{\sqrt{1.25}} \right) - F_{F_0} \left( \frac{1}{\sqrt{1.25}} \right) = 0 \quad F_{F_0} = 1.863 P \quad (T) \]

\[ \sum \Sigma F_y = 0; \quad F_{F_0} + 2 \left[ 1.863 P \left( \frac{0.5}{\sqrt{1.25}} \right) \right] - 2.00 P = 0 \quad F_{F_0} = 0.3333 P \quad (T) \]

**Joint D**
\[ \sum \Sigma F_z = 0; \quad F_{D_0} \left( \frac{1}{\sqrt{1.25}} \right) - 0.3727 P \left( \frac{1}{\sqrt{1.25}} \right) = 0 \quad F_{D_0} = 0.3727 P \quad (C) \]

\[ \sum \Sigma F_y = 0; \quad 2 \left[ 0.3727 P \left( \frac{0.5}{\sqrt{1.25}} \right) \right] - 0.3333 P = 0 \quad (Check?) \]

From the above analysis, the maximum compression and tension in the truss members are 2.404P and 2.00P, respectively. For this case, compression controls which requires

\[ 2.404P = 3 \]
\[ P = 1.25 \text{ kN} \]

6-34. Determine the force in members JK, CJ, and CD of the truss, and state if the members are in tension or compression.

---

**Method of Joints:** Applying the equations of equilibrium to the free-body diagram of the truss, Fig. a,

\[ \sum \Sigma F_x = 0; \quad A_x = 0 \]
\[ \sum \Sigma M_G = 0; \quad 6(2) + 8(4) + 5(8) + 4(10) - A_y(12) = 0 \]
\[ A_y = 10.33 \text{ kN} \]

**Method of Sections:** Using the left portion of the free-body diagram, Fig. a,

\[ \sum \Sigma M_C = 0; \quad F_{JK} (3) + 4(2) - 10.33(4) = 0 \quad F_{JK} = 11.111 \text{ kN} = 11.1 \text{ kN} \quad (C) \quad \text{Ans.} \]

\[ \sum \Sigma M_J = 0; \quad F_{CD} (3) + 5(2) + 4(4) - 10.33(6) = 0 \quad F_{CD} = 12 \text{ kN} \quad (T) \quad \text{Ans.} \]

\[ \sum \Sigma F_y = 0; \quad 10.33 - 4 - 5 - F_{CJ} \sin 56.31^\circ = 0 \quad F_{CJ} = 1.6024 \text{ kN} = 1.60 \text{ kN} \quad (C) \quad \text{Ans.} \]
6–40. Determine the force in members \( GF, GD, \) and \( CD \) of the truss and state if the members are in tension or compression.

\[
\begin{align*}
\sum \text{EM}_G &= 0; \quad \frac{12}{13} (260)(8) - F_{GD} \sin 36.87^\circ (16) = 0 \\
F_{GD} &= 200 \text{ lb (C)} \quad \text{Ans}
\end{align*}
\]

\[
\begin{align*}
\sum \text{EM}_O &= 0; \quad F_{CD}(3) - \left(\frac{12}{13}\right) (260)(4) - \left(\frac{5}{13}\right) (260)(3) = 0 \\
F_{CD} &= 420 \text{ lb (C)} \quad \text{Ans}
\end{align*}
\]

\[
\begin{align*}
\sum \text{EM}_O &= 0; \quad F_{CD} \cos 14.04^\circ (4) - \left(\frac{12}{13}\right) (260)(8) = 0 \\
F_{CD} &= 495 \text{ lb (T)} \quad \text{Ans}
\end{align*}
\]

6–47. Determine the force in members \( CD \) and \( GF \) of the truss and state if the members are in tension or compression. Also indicate all zero-force members.
Entire truss:
\( \Sigma M_f = 0; \quad -2(0.8) - 1.5(2) + E_f(6) = 0 \)
\( E_f = 1.15 \text{ kN} \)

Section:
\( \Sigma M_f = 0; \quad 1.15(1) - F_{CD} \sin 36.87^\circ (1) = 0 \)
\( F_{CD} = 1.92 \text{ kN} \) \( C \) \text{ Ans} \\
\( \Sigma M_c = 0; \quad -F_{CD}(1.5) + 1.15(2) = 0 \)
\( F_{CF} = 1.53 \text{ kN} \) \( C \) \text{ Ans} \\

Joint D:
\( \Sigma F_x = 0; \quad F_{DB} = 0 \) \text{ Ans} \\

Joint F:
\( \Sigma F_y = 0; \quad F_{EC} \cos \theta = 0 \)
\( F_{EC} = 0 \) \text{ Ans} \\

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6-52. Determine the force in members \( KJ, NJ, ND, \) and \( CD \) of the \( K \) truss. Indicate if the members are in tension or compression. \( Hint: \) Use sections \( aa \) and \( bb. \)
Support Reactions:

\[ \sum M_0 = 0; \quad 1.20(100) + 1.50(80) + 1.80(60) - A_y(120) = 0 \]

\[ A_y = 2.90 \text{ kip} \]

\[ \sum F_x = 0; \quad A_x = 0 \]

Method of Sections: From section a - a, \( F_{KD} \) and \( F_{CD} \) can be obtained directly by summing moments about points C and K respectively.

\[ \sum M_C = 0; \quad F_{KD}(30) + 1.20(20) - 2.90(40) = 0 \]

\[ F_{KD} = 3.067 \text{ kip (C)} = 3.07 \text{ kip (C)} \quad \text{Ans} \]

\[ \sum M_K = 0; \quad F_{CD}(30) + 1.20(20) - 2.90(40) = 0 \]

\[ F_{CD} = 3.067 \text{ kip (T)} = 3.07 \text{ kip (T)} \quad \text{Ans} \]

From sec b - b, summing forces along x and y axes yields:

\[ \sum F_x = 0; \quad F_{WD}(\frac{4}{5}) - F_{WU}(\frac{4}{5}) + 3.067 - 3.067 = 0 \]

\[ F_{WD} = F_{WU} \quad [1] \]

\[ \sum F_y = 0; \quad 2.90 - 1.20 - 1.50 - F_{WD}(\frac{2}{5}) - F_{WU}(\frac{2}{5}) = 0 \]

\[ F_{WD} + F_{WU} = 0.3333 \quad [2] \]

Solving Eqs. [1] and [2] yields:

\[ F_{WD} = 0.167 \text{ kip (T)} \quad F_{WU} = 0.167 \text{ kip (C)} \quad \text{Ans} \]