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5–1.

Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 20$ kN, $P_2 = 10$ kN.

SOLUTION

Method of Joints. Start at joint C and then proceed to joint D.

Joint *C*. Fig. *a*

$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{CB} = 0$ **Ans.**

$+\uparrow \Sigma F_y = 0; \qquad F_{CD} - 20 = 0 \qquad F_{CD} = 20.0 \text{ kN (C)}$ **Ans.**

Joint *D*. Fig. *b*

$+\uparrow \Sigma F_y = 0; \qquad F_{DB}\left(\frac{3}{5}\right) - 20.0 = 0 \qquad F_{DB} = 33.33 \text{ kN (T)} = 33.3 \text{ kN (T)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0; \qquad 10 + 33.33\left(\frac{4}{5}\right) - F_{DA} = 0$

$F_{DA} = 36.67 \text{ kN (C)} = 36.7 \text{ kN (C)}$ **Ans.**

Ans:
$F_{CB} = 0$
$F_{CD} = 20.0$ kN (C)
$F_{DB} = 33.3$ kN (T)
$F_{DA} = 36.7$ kN (C)

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5–2.

Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 45$ kN, $P_2 = 30$ kN.

SOLUTION

Method of Joints. Start at joint C and then proceed to joint D.

Joint *C*. Fig. *a*

$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{CB} = 0$ **Ans.**

$+\uparrow \Sigma F_y = 0; \qquad F_{CD} - 45 = 0 \qquad F_{CD} = 45.0 \text{ kN } (C)$ **Ans.**

Joint *D*. Fig. *b*

$+\uparrow \Sigma F_y = 0; \qquad F_{DB}\left(\frac{3}{5}\right) - 45.0 = 0 \qquad F_{DB} = 75.0 \text{ kN } (T)$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0; \qquad 30 + 75.0\left(\frac{4}{5}\right) - F_{DA} = 0 \qquad F_{DA} = 90.0 \text{ kN } (C)$ **Ans.**

Ans:
$F_{CB} = 0$
$F_{CD} = 45.0$ kN (C)
$F_{DB} = 75.0$ kN (T)
$F_{DA} = 90.0$ kN (C)

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5–3.

Determine the force in each member of the truss and state if the members are in tension or compression.

SOLUTION

Joint A:

$$+\uparrow \Sigma F_y = 0; \qquad \frac{4}{5}(F_{AC}) - \frac{12}{13}(130) = 0$$

$$F_{AC} = 150 \text{ lb (C)} \qquad \textbf{Ans.}$$

$$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{AB} - \frac{3}{5}(150) - \frac{5}{13}(130) = 0$$

$$F_{AB} = 140 \text{ lb (T)} \qquad \textbf{Ans.}$$

Joint B:

$$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{BD} - 140 = 0$$

$$F_{BD} = 140 \text{ lb (T)} \qquad \textbf{Ans.}$$

$$+\uparrow \Sigma F_y = 0; \qquad F_{BC} = 0 \qquad \textbf{Ans.}$$

Joint C:

$$+\uparrow \Sigma F_y = 0; \qquad \left(\frac{4}{5}\right) F_{CD} - \left(\frac{4}{5}\right) 150 = 0$$

$$F_{CD} = 150 \text{ lb (T)} \qquad \textbf{Ans.}$$

$$\xrightarrow{+} \Sigma F_x = 0; \qquad -F_{CE} + \frac{3}{5}(150) + \frac{3}{5}(150) = 0$$

$$F_{CE} = 180 \text{ lb (C)} \qquad \textbf{Ans.}$$

Joint D:

$$+\uparrow \Sigma F_y = 0; \qquad F_{DE} - \frac{4}{5}(150) = 0$$

$$F_{DE} = 120 \text{ lb (C)} \qquad \textbf{Ans.}$$

$$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{DF} - 140 - \frac{3}{5}(150) = 0$$

$$F_{DF} = 230 \text{ lb (T)} \qquad \textbf{Ans.}$$

Joint E:

$$\xrightarrow{+} \Sigma F_x = 0; \qquad 180 - \frac{3}{5}(F_{EF}) = 0$$

$$F_{EF} = 300 \text{ lb (C)} \qquad \textbf{Ans.}$$

Ans:
$F_{AC} = 150$ lb (C)
$F_{AB} = 140$ lb (T)
$F_{BD} = 140$ lb (T)
$F_{BC} = 0$
$F_{CD} = 150$ lb (T)
$F_{CE} = 180$ lb (C)
$F_{DE} = 120$ lb (C)
$F_{DF} = 230$ lb (T)
$F_{EF} = 300$ lb (C)

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***5–4.**

Determine the force in each member of the truss and state if the members are in tension or compression.

SOLUTION

$\circlearrowleft + \Sigma M_E = 0;\quad A_y(40) + 1.5(4) + 2(12) - 3(10) - 3(20) = 0 \qquad A_y = 1.5 \text{ kip}$

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad 1.5 + 2 - E_x = 0 \qquad E_x = 3.5 \text{ kip}$

$+\uparrow \Sigma F_y = 0;\quad E_y + 1.5 - 3 - 3 = 0 \qquad E_y = 4.5 \text{ kip}$

Joint A:

$+\uparrow \Sigma F_y = 0;\quad 1.5 - F_{Al} \sin 21.80° = 0$

$F_{Al} = 4.039 \text{ kip} = 4.04 \text{ kip (C)}$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad F_{AB} - 4.039 \cos 21.80° = 0 \qquad F_{AB} = 3.75 \text{ kip (T)}$ **Ans.**

Joint E:

$+\uparrow \Sigma F_y = 0;\quad 4.5 - F_{EF} \sin 21.80° = 0$

$F_{EF} = 12.12 \text{ kip} = 12.1 \text{ kip (C)}$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad -F_{ED} - 3.5 + 12.12 \cos 21.80° = 0$

$F_{ED} = 7.75 \text{ kip (T)}$ **Ans.**

Joint B:

$+\uparrow \Sigma F_y = 0;\quad F_{BI} = 0$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad F_{BC} - 3.75 = 0 \qquad F_{BC} = 3.75 \text{ kip (T)}$ **Ans.**

Joint D:

$+\uparrow \Sigma F_y = 0;\quad F_{DF} = 0$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad -F_{DC} + 7.75 = 0 \qquad F_{DC} = 7.75 \text{ kip (T)}$ **Ans.**

Joint F:

$+\nearrow \Sigma F_{y'} = 0;\quad F_{FC} \cos 46.40° - 3 \cos 21.80° = 0$

$F_{FC} = 4.039 \text{ kip} = 4.04 \text{ kip (C)}$ **Ans.**

$+\searrow \Sigma F_{x'} = 0;\quad F_{FG} + 3 \sin 21.80° + 4.039 \sin 46.40° - 12.12 = 0$

$F_{FG} = 8.078 \text{ kip} = 8.08 \text{ kip (C)}$ **Ans.**

Joint H:

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad 2 - F_{HG} \cos 21.80° = 0$

$F_{HG} = 2.154 \text{ kip} = 2.15 \text{ kip (C)}$ **Ans.**

$+\uparrow \Sigma F_y = 0;\quad 2.154 \sin 21.80° - F_{HI} = 0 \qquad F_{HI} = 0.8 \text{ kip (T)}$ **Ans.**

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***5–4. Continued**

Joint C:

$\xrightarrow{+} \Sigma F_x = 0; \qquad -F_{CI}\cos 21.80° - 4.039\cos 21.80° - 3.75 + 7.75 = 0$

$F_{CI} = 0.2692 \text{ kip} = 0.269 \text{ kip (T)}$ **Ans.**

$+\uparrow \Sigma F_y = 0; \qquad F_{CG} + 0.2692\sin 21.80° - 4.039\sin 21.80° = 0$

$F_{CG} = 1.40 \text{ kip (T)}$ **Ans.**

Joint G:

$+\nearrow \Sigma F_{y'} = 0; \qquad F_{GI}\cos 46.40° - 3\cos 21.80° - 1.40\cos 21.80° = 0$

$F_{GI} = 5.924 \text{ kip} = 5.92 \text{ kip (C)}$ **Ans.**

$+\searrow \Sigma F_{x'} = 0; \qquad 2.154 + 3\sin 21.80° + 5.924\sin 46.40°$

$+ 1.40\sin 21.80° - 8.081 = 0 \text{ (Check)}$

Ans:
$F_{AI} = 4.04$ kip (C)
$F_{AB} = 3.75$ kip (T)
$F_{EF} = 12.1$ kip (C)
$F_{ED} = 7.75$ kip (T)
$F_{BI} = 0$
$F_{BC} = 3.75$ kip (T)
$F_{DF} = 0$
$F_{DC} = 7.75$ kip (T)
$F_{FC} = 4.04$ kip (C)
$F_{FG} = 8.08$ kip (C)
$F_{HG} = 2.15$ kip (C)
$F_{HI} = 0.8$ kip (T)
$F_{CI} = 0.269$ kip (T)
$F_{CG} = 1.40$ kip (T)
$F_{GI} = 5.92$ kip (C)

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5–5.

Determine the force in each member of the truss, and state if the members are in tension or compression. Set $\theta = 0°$.

SOLUTION

Support Reactions: Applying the equations of equilibrium to the free-body diagram of the entire truss, Fig. *a*, we have

(a)

$\circlearrowleft + \Sigma M_A = 0;$ $\quad N_C(2 + 2) - 4(2) - 3(1.5) = 0$

$N_C = 3.125 \text{ kN}$

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 3 - A_x = 0$

$A_x = 3 \text{ kN}$

$+\uparrow \Sigma F_y = 0;$ $\quad A_y + 3.125 - 4 = 0$

$A_y = 0.875 \text{ kN}$

Method of Joints: We will use the above result to analyze the equilibrium of joints C and A, and then proceed to analyze the equilibrium of joint B.

(b)

Joint C: From the free-body diagram in Fig. *b*, we can write

$+\uparrow \Sigma F_y = 0;$ $\quad 3.125 - F_{CD}\left(\frac{3}{5}\right) = 0$

$F_{CD} = 5.208 \text{ kN} = 5.21 \text{ kN (C)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 5.208\left(\frac{4}{5}\right) - F_{CB} = 0$

$F_{CB} = 4.167 \text{ kN} = 4.17 \text{ kN (T)}$ **Ans.**

(c)

Joint A: From the free-body diagram in Fig. *c*, we can write

$+\uparrow \Sigma F_y = 0;$ $\quad 0.875 - F_{AD}\left(\frac{3}{5}\right) = 0$

$F_{AD} = 1.458 \text{ kN} = 1.46 \text{ kN (C)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{AB} - 3 - 1.458\left(\frac{4}{5}\right) = 0$

$F_{AB} = 4.167 \text{ kN} = 4.17 \text{ kN (T)}$ **Ans.**

(d)

Joint B: From the free-body diagram in Fig. *d*, we can write

$+\uparrow \Sigma F_y = 0;$ $\quad F_{BD} - 4 = 0$

$F_{BD} = 4 \text{ kN (T)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 4.167 - 4.167 = 0$ (check!)

Note: The equilibrium analysis of joint D can be used to check the accuracy of the solution obtained above.

Ans:
$F_{CD} = 5.21 \text{ kN (C)}$
$F_{CB} = 4.17 \text{ kN (T)}$
$F_{AD} = 1.46 \text{ kN (C)}$
$F_{AB} = 4.17 \text{ kN (T)}$
$F_{BD} = 4 \text{ kN (T)}$

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5–6.

Determine the force in each member of the truss, and state if the members are in tension or compression. Set $\theta = 30°$.

SOLUTION

Support Reactions: From the free-body diagram of the truss, Fig. *a*, and applying the equations of equilibrium, we have

(a)

$\circlearrowleft + \Sigma M_A = 0;$ $\quad N_C \cos 30°(2 + 2) - 3(1.5) - 4(2) = 0$

$N_C = 3.608 \text{ kN}$

$\overset{+}{\rightarrow} \Sigma F_x = 0;$ $\quad 3 - 3.608 \sin 30° - A_x = 0$

$A_x = 1.196 \text{ kN}$

$+\uparrow \Sigma F_y = 0;$ $\quad A_y + 3.608 \cos 30° - 4 = 0$

$A_y = 0.875 \text{ kN}$

Method of Joints: We will use the above result to analyze the equilibrium of joints C and A, and then proceed to analyze the equilibrium of joint B.

(b)

Joint C: From the free-body diagram in Fig. *b,* we can write

$+\uparrow \Sigma F_y = 0;$ $\quad 3.608 \cos 30° - F_{CD}\left(\frac{3}{5}\right) = 0$

$F_{CD} = 5.208 \text{ kN} = 5.21 \text{ kN (C)}$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0;$ $\quad 5.208\left(\frac{4}{5}\right) - 3.608 \sin 30° - F_{CB} = 0$

$F_{CB} = 2.362 \text{ kN} = 2.36 \text{ kN (T)}$ **Ans.**

(c)

Joint A: From the free-body diagram in Fig. *c,* we can write

$+\uparrow \Sigma F_y = 0;$ $\quad 0.875 - F_{AD}\left(\frac{3}{5}\right) = 0$

$F_{AD} = 1.458 \text{ kN} = 1.46 \text{ kN (C)}$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0;$ $\quad F_{AB} - 1.458\left(\frac{4}{5}\right) - 1.196 = 0$

$F_{AB} = 2.362 \text{ kN} = 2.36 \text{ kN (T)}$ **Ans.**

Joint B: From the free-body diagram in Fig. *d,* we can write

$+\uparrow \Sigma F_y = 0;$ $\quad F_{BD} - 4 = 0$

$F_{BD} = 4 \text{ kN (T)}$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0;$ $\quad 2.362 - 2.362 = 0$ (check!)

Note: The equilibrium analysis of joint D can be used to check the accuracy of the solution obtained above.

(d)

Ans:
$F_{CD} = 5.21 \text{ kN (C)}$
$F_{CB} = 2.36 \text{ kN (T)}$
$F_{AD} = 1.46 \text{ kN (C)}$
$F_{AB} = 2.36 \text{ kN (T)}$
$F_{BD} = 4 \text{ kN (T)}$

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5–7.

Determine the force in each member of the truss and state if the members are in tension or compression.

SOLUTION

Support Reactions:

$\circlearrowleft + \Sigma M_D = 0;$ $\quad 4(6) + 5(9) - E_y(3) = 0 \qquad E_y = 23.0\text{ kN}$

$+\uparrow \Sigma F_y = 0;$ $\quad 23.0 - 4 - 5 - D_y = 0 \qquad D_y = 14.0\text{ kN}$

$\xrightarrow{+} \Sigma F_x = 0 \qquad D_x = 0$

Method of Joints:

Joint D:

$+\uparrow \Sigma F_y = 0;$ $\quad F_{DE}\left(\dfrac{5}{\sqrt{34}}\right) - 14.0 = 0$

$F_{DE} = 16.33\text{ kN (C)} = 16.3\text{ kN (C)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 16.33\left(\dfrac{3}{\sqrt{34}}\right) - F_{DC} = 0$

$F_{DC} = 8.40\text{ kN (T)}$ **Ans.**

Joint E:

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{EA}\left(\dfrac{3}{\sqrt{10}}\right) - 16.33\left(\dfrac{3}{\sqrt{34}}\right) = 0$

$F_{EA} = 8.854\text{ kN (C)} = 8.85\text{ kN (C)}$ **Ans.**

$+\uparrow \Sigma F_y = 0;$ $\quad 23.0 - 16.33\left(\dfrac{5}{\sqrt{34}}\right) - 8.854\left(\dfrac{1}{\sqrt{10}}\right) - F_{EC} = 0$

$F_{EC} = 6.20\text{ kN (C)}$ **Ans.**

Joint C:

$+\uparrow \Sigma F_y = 0;$ $\quad 6.20 - F_{CF}\sin 45° = 0$

$F_{CF} = 8.768\text{ kN (T)} = 8.77\text{ kN (T)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 8.40 - 8.768\cos 45° - F_{CB} = 0$

$F_{CB} = 2.20\text{ kN (T)}$ **Ans.**

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5–7. Continued

Joint B:

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 2.20 - F_{BA} \cos 45° = 0$

$F_{BA} = 3.111 \text{ kN (T)} = 3.11 \text{ kN (T)}$ **Ans.**

$+\uparrow \Sigma F_y = 0;$ $\quad F_{BF} - 4 - 3.111 \sin 45° = 0$

$F_{BF} = 6.20 \text{ kN (C)}$ **Ans.**

Joint F:

$+\uparrow \Sigma F_y = 0;$ $\quad 8.768 \sin 45° - 6.20 = 0$ **(Check!)**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 8.768 \cos 45° - F_{FA} = 0$

$F_{FA} = 6.20 \text{ kN (T)}$ **Ans.**

Ans:
$F_{DE} = 16.3$ kN (C)
$F_{DC} = 8.40$ kN (T)
$F_{EA} = 8.85$ kN (C)
$F_{EC} = 6.20$ kN (C)
$F_{CF} = 8.77$ kN (T)
$F_{CB} = 2.20$ kN (T)
$F_{BA} = 3.11$ kN (T)
$F_{BF} = 6.20$ kN (C)
$F_{FA} = 6.20$ kN (T)

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***5–8.**

Determine the force in each member of the truss in terms of the load P and state if the members are in tension or compression.

SOLUTION

Joint A:

$$\xrightarrow{+} \Sigma F_x = 0; \qquad \frac{4}{\sqrt{14}}(F_{AD}) - \frac{1}{\sqrt{2}}F_{AB} = 0$$

$$+\uparrow \Sigma F_y = 0; \qquad \frac{P}{2} - \frac{1}{\sqrt{2}}(F_{AB}) + \frac{1}{\sqrt{17}}(F_{AD}) = 0$$

$$F_{CD} = F_{AD} = 0.687\,P \text{ (T)} \qquad \textbf{Ans.}$$

$$F_{CB} = F_{AB} = 0.943\,P \text{ (C)} \qquad \textbf{Ans.}$$

Joint D:

$$+\uparrow \Sigma F_y = 0; \qquad F_{DB} - 0.687\,P\left(\frac{1}{\sqrt{17}}\right) - \frac{1}{\sqrt{17}}(0.687\,P) - P = 0$$

$$F_{DB} = 1.33\,P \text{ (T)} \qquad \textbf{Ans.}$$

Ans:
$F_{CD} = F_{AD} = 0.687P$ (T)
$F_{CB} = F_{AB} = 0.943P$ (C)
$F_{DB} = 1.33P$ (T)

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5–9.

Members AB and BC can each support a maximum compressive force of 800 lb, and members AD, DC, and BD can support a maximum tensile force of 1500 lb. If $a = 10$ ft, determine the greatest load P the truss can support.

SOLUTION

Assume $F_{AB} = 800$ lb (C)

Joint A:

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad -800\left(\frac{1}{\sqrt{2}}\right) + F_{AD}\left(\frac{4}{\sqrt{17}}\right) = 0$

$F_{AD} = 583.0952 \text{ lb} < 1500 \text{ lb}$ **OK**

$+\uparrow \Sigma F_y = 0;$ $\quad \frac{P}{2} - \frac{1}{\sqrt{2}}(800) + \frac{1}{\sqrt{17}}(583.0952) = 0$

$P = 848.5297$ lb

Joint D:

$+\uparrow \Sigma F_y = 0;$ $\quad -848.5297 - 583.0952(2)\left(\frac{1}{\sqrt{17}}\right) + F_{DB} = 0$

$F_{BD} = 1131.3724 \text{ lb} < 1500 \text{ lb}$ **OK**

Thus,

$P_{max} = 849$ lb **Ans.**

Ans:
$P_{\max} = 849$ lb

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5–10.

Members AB and BC can each support a maximum compressive force of 800 lb, and members AD, DC, and BD can support a maximum tensile force of 2000 lb. If $a = 6$ ft, determine the greatest load P the truss can support.

SOLUTION

Assume $F_{AB} = 800$ lb (C).

Joint A:

$\xrightarrow{+}\Sigma F_x = 0;\qquad -800\left(\frac{1}{\sqrt{2}}\right) + F_{AD}\left(\frac{4}{\sqrt{17}}\right) = 0$

$F_{AD} = 583.0952 \text{ lb} < 2000 \text{ lb}$ **OK**

$+\uparrow\Sigma F_y = 0;\qquad \frac{P}{2} - \frac{1}{\sqrt{2}}(800) + \frac{1}{\sqrt{17}}(583.0952) = 0$

$P = 848.5297$ lb **OK**

Joint D:

$+\uparrow\Sigma F_y = 0;\qquad -848.5297 - 583.0952(2)\left(\frac{1}{\sqrt{17}}\right) + F_{DB} = 0$

$F_{BD} = 1131.3724 \text{ lb} < 2000 \text{ lb}$ **OK**

Thus, $P_{max} = 849$ lb **Ans.**

Ans:
$P_{\max} = 849$ lb

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5–11.

Determine the force in each member of the truss and state if the members are in tension or compression. Set $P = 8$ kN.

SOLUTION

Method of Joints: In this case, the support reactions are not required for determining the member forces.

Joint D:

$+\uparrow \Sigma F_y = 0;\qquad F_{DC}\sin 60° - 8 = 0$

$$F_{DC} = 9.238 \text{ kN (T)} = 9.24 \text{ kN (T)} \qquad \textbf{Ans.}$$

$\xrightarrow{+} \Sigma F_x = 0;\qquad F_{DE} - 9.238\cos 60° = 0$

$$F_{DE} = 4.619 \text{ kN (C)} = 4.62 \text{ kN (C)} \qquad \textbf{Ans.}$$

Joint C:

$+\uparrow \Sigma F_y = 0;\qquad F_{CE}\sin 60° - 9.238\sin 60° = 0$

$$F_{CE} = 9.238 \text{ kN (C)} = 9.24 \text{ kN (C)} \qquad \textbf{Ans.}$$

$\xrightarrow{+} \Sigma F_x = 0;\qquad 2(9.238\cos 60°) - F_{CB} = 0$

$$F_{CB} = 9.238 \text{ kN (T)} = 9.24 \text{ kN (T)} \qquad \textbf{Ans.}$$

Joint B:

$+\uparrow \Sigma F_y = 0;\qquad F_{BE}\sin 60° - F_{BA}\sin 60° = 0$

$$F_{BE} = F_{BA} = F$$

$\xrightarrow{+} \Sigma F_x = 0;\qquad 9.238 - 2F\cos 60° = 0$

$$F = 9.238 \text{ kN}$$

Thus,

$$F_{BE} = 9.24 \text{ kN (C)} \qquad F_{BA} = 9.24 \text{ kN (T)} \qquad \textbf{Ans.}$$

Joint E:

$+\uparrow \Sigma F_y = 0;\qquad E_y - 2(9.238\sin 60°) = 0 \qquad E_y = 16.0 \text{ kN}$

$\xrightarrow{+} \Sigma F_x = 0;\qquad F_{EA} + 9.238\cos 60° - 9.238\cos 60° - 4.619 = 0$

$$F_{EA} = 4.62 \text{ kN (C)} \qquad \textbf{Ans.}$$

Note: The support reactions A_x and A_y can be determined by analyzing Joint A using the results obtained above.

Ans:
$F_{DC} = 9.24$ kN (T)
$F_{DE} = 4.62$ kN (C)
$F_{CE} = 9.24$ kN (C)
$F_{CB} = 9.24$ kN (T)
$F_{BE} = 9.24$ kN(C)
$F_{BA} = 9.24$ kN (T)
$F_{EA} = 4.62$ kN (C)

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***5–12.**

If the maximum force that any member can support is 8 kN in tension and 6 kN in compression, determine the maximum force P that can be supported at joint D.

SOLUTION

Method of Joints: In this case, the support reactions are not required for determining the member forces.

Joint D:

$+\uparrow \Sigma F_y = 0;$ $\quad F_{DC} \sin 60° - P = 0 \quad F_{DC} = 1.1547P \text{ (T)}$

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{DE} - 1.1547P \cos 60° = 0 \quad F_{DE} = 0.57735P \text{ (C)}$

Joint C:

$+\uparrow \Sigma F_y = 0;$ $\quad F_{CE} \sin 60° - 1.1547P \sin 60° = 0$

$F_{CE} = 1.1547P \text{ (C)}$

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 2(1.1547P \cos 60°) - F_{CB} = 0 \quad F_{CB} = 1.1547P \text{ (T)}$

Joint B:

$+\uparrow \Sigma F_y = 0;$ $\quad F_{BE} \sin 60° - F_{BA} \sin 60° = 0 \quad F_{BE} = F_{BA} = F$

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 1.1547P - 2F \cos 60° = 0 \quad F = 1.1547P$

Thus,

$F_{BE} = 1.1547P \text{ (C)} \qquad F_{BA} = 1.1547P \text{ (T)}$

Joint E:

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{EA} + 1.1547P \cos 60° - 1.1547P \cos 60°$

$- 0.57735P = 0$

$F_{EA} = 0.57735P \text{ (C)}$

From the above analysis, the maximum compression and tension in the truss member is $1.1547P$. For this case, compression controls, which requires

$1.1547P = 6$

$P = 5.20 \text{ kN}$ **Ans.**

Ans:
$P = 5.20 \text{ kN}$

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5–13.

Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 10$ kN, $P_2 = 8$ kN.

SOLUTION

Support Reactions. Not required.

Method of Joints. We will perform the joint equilibrium analysis according to the sequence of joints D, C, E, B and F.

Joint *D*. Fig. *a*

$+\uparrow \Sigma F_y = 0;\quad F_{DE}\left(\frac{2}{\sqrt{5}}\right) - 8 = 0 \qquad F_{DE} = 4\sqrt{5}\text{ kN (T)} = 8.94\text{ kN (T)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;\quad F_{DC} - \left(4\sqrt{5}\right)\left(\frac{1}{\sqrt{5}}\right) = 0 \qquad F_{DC} = 4.00\text{ kN (C)}$ **Ans.**

Joint *C*. Fig. *b*

$\xrightarrow{+} \Sigma F_x = 0;\quad F_{CB} - 4.00 = 0 \qquad F_{CB} = 4.00\text{ kN(C)}$ **Ans.**

$+\uparrow \Sigma F_y = 0;\quad F_{CE} = 0$ **Ans.**

Joint *E*. Fig. *c*

$+\uparrow \Sigma F_y = 0;\quad F_{EB}\left(\frac{1}{\sqrt{2}}\right) - \left(4\sqrt{5}\right)\left(\frac{2}{\sqrt{5}}\right) = 0$

$F_{EB} = 8\sqrt{2}\text{ kN (C)} = 11.3\text{ kN (C)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;\quad \left(8\sqrt{2}\right)\left(\frac{1}{\sqrt{2}}\right) + \left(4\sqrt{5}\right)\left(\frac{1}{\sqrt{5}}\right) - F_{EF} = 0$

$F_{EF} = 12.0\text{ kN (T)}$ **Ans.**

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5–13. Continued

Joint *B*. Fig. *d*

$\xrightarrow{+}\Sigma F_x = 0; \quad F_{BA} - 4.00 - \left(8\sqrt{2}\right)\left(\frac{1}{\sqrt{2}}\right) = 0 \quad F_{BA} = 12.0 \text{ kN (C)}$ **Ans.**

$+\uparrow\Sigma F_y = 0; \quad F_{BF} - 10 - \left(8\sqrt{2}\right)\left(\frac{1}{\sqrt{2}}\right) = 0 \quad F_{BF} = 18.0 \text{ kN (T)}$ **Ans.**

Joint *F*. Fig. *e*

$+\uparrow\Sigma F_y = 0; \quad F_{FA}\left(\frac{2}{\sqrt{5}}\right) - 18.0 = 0 \quad F_{FA} = 9\sqrt{5} \text{ kN (C)} = 20.1 \text{ kN (C)}$ **Ans.**

$\xrightarrow{+}\Sigma F_x = 0; \quad 12.0 + \left(9\sqrt{5}\right)\left(\frac{1}{\sqrt{5}}\right) - F_{FG} = 0 \quad F_{FG} = 21.0 \text{ kN (T)}$ **Ans.**

Ans:

$F_{DE} = 8.94$ kN (T)
$F_{DC} = 4.00$ kN (C)
$F_{CB} = 4.00$ kN (C)
$F_{CE} = 0$
$F_{EB} = 11.3$ kN (C)
$F_{EF} = 12.0$ kN (T)
$F_{BA} = 12.0$ kN (C)
$F_{BF} = 18.0$ kN (T)
$F_{FA} = 20.1$ kN (C)
$F_{FG} = 21.0$ kN (T)

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5–14.

Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 8$ kN, $P_2 = 12$ kN.

SOLUTION

Support Reactions. Not required.

Method of Joints. We will perform the joint equilibrium analysis according to the sequence of joints D, C, E, B and F.

Joint *D*. Fig. *a*

$+\uparrow \Sigma F_y = 0; \quad F_{DE}\left(\frac{2}{\sqrt{5}}\right) - 12 = 0 \quad F_{DE} = 6\sqrt{5}\text{ kN (T)} = 13.4\text{ kN (T)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0; \quad F_{DC} - \left(6\sqrt{5}\right)\left(\frac{1}{\sqrt{5}}\right) = 0 \quad F_{DC} = 6.00\text{ kN (C)}$ **Ans.**

Joint *C*. Fig. *b*

$\xrightarrow{+} \Sigma F_x = 0; \quad F_{CB} - 6.00 = 0 \quad F_{CB} = 6.00\text{ kN (C)}$ **Ans.**

$+\uparrow \Sigma F_y = 0; \quad F_{CE} = 0$ **Ans.**

Joint *E*. Fig. *c*

$+\uparrow \Sigma F_y = 0; \quad F_{EB}\left(\frac{1}{\sqrt{2}}\right) - \left(6\sqrt{5}\right)\left(\frac{2}{\sqrt{5}}\right) = 0$

$F_{EB} = 12\sqrt{2}\text{ kN (C)} = 17.0\text{ kN (C)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0; \quad \left(12\sqrt{2}\right)\left(\frac{1}{\sqrt{2}}\right) + \left(6\sqrt{5}\right)\left(\frac{1}{\sqrt{5}}\right) - F_{EF} = 0$

$F_{EF} = 18.0\text{ kN (T)}$ **Ans.**

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5–14. Continued

Joint *B*. Fig. *d*

$\xrightarrow{+} \Sigma F_x = 0; \quad F_{BA} - 6.00 - \left(12\sqrt{2}\right)\left(\frac{1}{\sqrt{2}}\right) = 0 \quad F_{BA} = 18.0 \text{ kN (C)}$ **Ans.**

$+\uparrow \Sigma F_y = 0; \quad F_{BF} - 8 - \left(12\sqrt{2}\right)\left(\frac{1}{\sqrt{2}}\right) = 0 \quad F_{BF} = 20.0 \text{ kN (T)}$ **Ans.**

Joint *F*. Fig. *e*

$+\uparrow \Sigma F_y = 0; \quad F_{FA}\left(\frac{2}{\sqrt{5}}\right) - 20.0 = 0 \quad F_{FA} = 10\sqrt{5} \text{ kN (C)} = 22.4 \text{ kN (C)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0; \quad \left(10\sqrt{5}\right)\left(\frac{1}{\sqrt{5}}\right) + 18.0 - F_{FG} = 0 \quad F_{FG} = 28.0 \text{ kN(T)}$ **Ans.**

Ans:
$F_{DE} = 13.4$ kN (T)
$F_{DC} = 6.00$ kN (C)
$F_{CB} = 6.00$ kN (C)
$F_{CE} = 0$
$F_{EB} = 17.0$ kN (C)
$F_{EF} = 18.0$ kN (T)
$F_{BA} = 18.0$ kN (C)
$F_{BF} = 20.0$ kN (T)
$F_{FA} = 22.4$ kN (C)
$F_{FG} = 28.0$ kN (T)

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5–15.

Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 9$ kN, $P_2 = 15$ kN.

SOLUTION

Support Reactions. Referring to the FBD of the entire truss shown in Fig. *a*,

$\circlearrowleft + \Sigma M_A = 0; \quad N_C(6) - 15(3) - 9(4) = 0 \quad N_C = 13.5 \text{ kN}$

$\circlearrowleft + \Sigma M_C = 0; \quad 15(3) - 9(4) - A_y(6) = 0 \quad A_y = 1.50 \text{ kN}$

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad 9 - A_x = 0 \quad A_x = 9.00 \text{ kN}$

Method of Joints: By inspecting joints D and F, we notice that members DE, DC and FA are zero force members. Thus,

$$F_{CD} = F_{DE} = F_{AF} = 0 \qquad \textbf{Ans.}$$

We will perform the joint equilibrium analysis by following the sequence of joints C, B, A and F.

Joint *C*. Fig. *b*

$+\uparrow \Sigma F_y = 0; \quad 13.5 - F_{CE}\left(\frac{4}{5}\right) = 0$

$F_{CE} = 16.875 \text{ kN (C)} = 16.9 \text{ kN (C)} \qquad \textbf{Ans.}$

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad 16.875\left(\frac{3}{5}\right) - F_{CB} = 0 \quad F_{CB} = 10.125 \text{ kN (T)} = 10.1 \text{ kN (T)} \qquad \textbf{Ans.}$

Joint *B*. Fig. *c*

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad 10.125 - F_{BA} = 0 \quad F_{BA} = 10.125 \text{ kN (T)} = 10.1 \text{ kN (T)} \qquad \textbf{Ans.}$

$+\uparrow \Sigma F_y = 0; \quad F_{BE} - 15 = 0 \quad F_{BE} = 15.0 \text{ kN (T)} \qquad \textbf{Ans.}$

(a)

(b)

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5–15. Continued

Joint *A*. Fig. *d*

$+\uparrow \Sigma F_y = 0; \qquad 1.50 - F_{AE}\left(\frac{4}{5}\right) = 0 \qquad F_{AE} = 1.875 \text{ kN (C)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0; \qquad 10.125 - 1.875\left(\frac{3}{5}\right) - 9.00 = 0$ (Check!!)

Joint *F*. Fig. *e*

$\xrightarrow{+} \Sigma F_x = 0; \qquad 9 - F_{FE} = 0 \qquad F_{FE} = 9.00 \text{ kN (C)}$ **Ans.**

Ans:
$F_{CD} = F_{DE} = F_{AF} = 0$
$F_{CE} = 16.9$ kN (C)
$F_{CB} = 10.1$ kN (T)
$F_{BA} = 10.1$ kN (T)
$F_{BE} = 15.0$ kN (T)
$F_{AE} = 1.875$ kN (C)
$F_{FE} = 9.00$ kN (C)

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***5–16.**

Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 30$ kN, $P_2 = 15$ kN.

SOLUTION

Support Reactions.

$\circlearrowleft + \Sigma M_A = 0; \quad N_C(6) - 15(3) - 30(4) = 0 \quad N_C = 27.5 \text{ kN}$

Method of Joints: By inspecting joints D and F, we notice that members DE, DC and FA are zero force members. Thus,

$$F_{DE} = F_{DC} = F_{FA} = 0 \qquad \textbf{Ans.}$$

We will perform the joint equilibrium analysis by following the sequence of joints C, B, F and E.

Joint *C*. Fig. *b*

$+\uparrow \Sigma F_y = 0; \quad 27.5 - F_{CE}\left(\frac{4}{5}\right) = 0 \quad F_{CE} = 34.375 \text{ kN (C)} = 34.4 \text{ kN (C)} \qquad \textbf{Ans.}$

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad 34.375\left(\frac{3}{5}\right) - F_{CB} = 0 \quad F_{CB} = 20.625 \text{ kN (T)} = 20.6 \text{ kN (T)} \qquad \textbf{Ans.}$

Joint *B*. Fig. *c*

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad 20.625 - F_{BA} = 0 \quad F_{BA} = 20.625 \text{ kN (T)} = 20.6 \text{ kN (T)} \qquad \textbf{Ans.}$

$+\uparrow \Sigma F_y = 0; \quad F_{BE} - 15 = 0 \quad F_{BE} = 15.0 \text{ kN (T)} \qquad \textbf{Ans.}$

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***5–16. Continued**

Joint *F*. Fig. *d*

$\xrightarrow{+} \Sigma F_x = 0; \qquad 30 - F_{FE} = 0 \qquad F_{FE} = 30.0 \text{ kN (C)}$ **Ans.**

Joint *E*. Fig. *e*

$+\uparrow \Sigma F_y = 0; \qquad 34.375\left(\frac{4}{5}\right) - 15.0 - F_{EA}\left(\frac{4}{5}\right) = 0$

$F_{EA} = 15.625 \text{ kN (T)} = 15.6 \text{ kN (T)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0; \qquad 30.0 - 15.625\left(\frac{3}{5}\right) - 34.375\left(\frac{3}{5}\right) = 0$ (Check!!)

Ans:
$F_{DE} = F_{DC} = F_{FA} = 0$
$F_{CE} = 34.4$ kN (C)
$F_{CB} = 20.6$ kN (T)
$F_{BA} = 20.6$ kN (T)
$F_{BE} = 15.0$ kN (T)
$F_{FE} = 30.0$ kN (C)
$F_{EA} = 15.6$ kN (T)

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5–17.

Determine the force in members DC, HC, and HI of the truss and state if the members are in tension or compression.

SOLUTION

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

$\circlearrowleft + \Sigma M_A = 0;$ $\quad 40(1.5) + 30(3) + 40(2) - F_y(4) = 0$

$F_y = 57.5 \text{ kN}$

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad A_x - 30 - 40 = 0;$ $\quad A_x = 70 \text{ kN}$

$+\uparrow \Sigma F_y = 0;$ $\quad 57.5 - 40 - 50 + A_y = 0;$ $\quad A_y = 32.5 \text{ kN}$

(a)

Method of Sections: Using the bottom portion of the free-body diagram, Fig. b,

$\circlearrowleft + \Sigma M_C = 0;$ $\quad 70(3) - 32.5(2) - 40(1.5) - F_{HI}(2) = 0$

$F_{HI} = 42.5 \text{ kN (T)}$ **Ans.**

$\circlearrowleft + \Sigma M_D = 0;$ $\quad 70(4.5) - 40(3) - 30(1.5) - F_{HC}(1.5) = 0$

$F_{HC} = 100 \text{ kN (T)}$ **Ans.**

$+\uparrow \Sigma F_y = 0;$ $\quad 32.5 + 42.5 - F_{DC}\left(\frac{3}{5}\right) = 0$

$F_{DC} = 125 \text{ kN (C)}$ **Ans.**

(b)

Ans:
$F_{HI} = 42.5 \text{ kN (T)}$
$F_{HC} = 100 \text{ kN (T)}$
$F_{DC} = 125 \text{ kN (C)}$

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5–18.

Determine the force in members ED, EH, and GH of the truss and state if the members are in tension or compression.

SOLUTION

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

$\circlearrowleft + \Sigma M_A = 0;$ $\quad 40(1.5) + 30(3) + 40(2) - F_y(4) = 0$

$F_y = 57.5 \text{ kN}$

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad A_x - 30 - 40 = 0;$ $\quad A_x = 70 \text{ kN}$

$+\uparrow \Sigma F_y = 0;$ $\quad 57.5 - 40 - 50 + A_y = 0;$ $\quad A_y = 32.5 \text{ kN}$

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

$\circlearrowleft + \Sigma M_E = 0;$ $\quad -57.5(2) + F_{GH}(1.5) = 0$

$F_{GH} = 76.7 \text{ kN (T)}$ **Ans.**

$\circlearrowleft + \Sigma M_H = 0;$ $\quad -57.5(4) + F_{ED}(1.5) + 40(2) = 0$

$F_{ED} = 100 \text{ kN (C)}$ **Ans.**

$+\uparrow \Sigma F_y = 0;$ $\quad 57.5 - F_{EH}\left(\frac{3}{5}\right) - 40 = 0$

$F_{EH} = 29.2 \text{ kN (T)}$ **Ans.**

(a)

(b)

Ans:
$F_{GH} = 76.7 \text{ kN (T)}$
$F_{ED} = 100 \text{ kN (C)}$
$F_{EH} = 29.2 \text{ kN (T)}$

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5–19.

Determine the force in members HG, HE, and DE of the truss and state if the members are in tension or compression.

SOLUTION

Method of Sections: The forces in members HG, HE, and DE are exposed by cutting the truss into two portions through section a–a and using the upper portion of the free-body diagram, Fig. a. From this free-body diagram, F_{HG} and F_{DE} can be obtained by writing the moment equations of equilibrium about points E and H, respectively. $\mathbf{F}_{HE}$ can be obtained by writing the force equation of equilibrium along the y axis.

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

$\circlearrowleft + \Sigma M_E = 0;$ $\quad F_{HG}(4) - 1500(3) = 0$

$F_{HG} = 1125 \text{ lb (T)}$ **Ans.**

$\circlearrowleft + \Sigma M_H = 0;$ $\quad F_{DE}(4) - 1500(6) - 1500(3) = 0$

$F_{DE} = 3375 \text{ lb (C)}$ **Ans.**

$+\uparrow \Sigma F_y = 0;$ $\quad F_{HE}\left(\frac{4}{5}\right) - 1500 - 1500 = 0$

$F_{EH} = 3750 \text{ lb (T)}$ **Ans.**

Ans:
$F_{HG} = 1125$ lb (T)
$F_{DE} = 3375$ lb (C)
$F_{EH} = 3750$ lb (T)

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***5–20.**

Determine the force in members CD, HI, and CH of the truss and state if the members are in tension or compression.

SOLUTION

Method of Sections: The forces in members HI, CH, and CD are exposed by cutting the truss into two portions through section $b–b$ on the right portion of the free-body diagram, Fig. a. From this free-body diagram, F_{CD} and F_{HI} can be obtained by writing the moment equations of equilibrium about points H and C, respectively. F_{CH} can be obtained by writing the force equation of equilibrium along the y axis.

(a)

$\circlearrowleft + \Sigma M_H = 0;$ $\quad F_{CD}(4) - 1500(6) - 1500(3) = 0$

$F_{CD} = 3375 \text{ lb (C)}$ **Ans.**

$\circlearrowleft + \Sigma Mc = 0;$ $\quad F_{HI}(4) - 1500(3) - 1500(6) - 1500(9) = 0$

$F_{HI} = 6750 \text{ lb (T)}$ **Ans.**

$+\uparrow \Sigma F_y = 0;$ $\quad F_{CH}\left(\frac{4}{5}\right) - 1500 - 1500 = 0$

$F_{CH} = 5625 \text{ lb (C)}$ **Ans.**

(b)

Ans:
$F_{CD} = 3375 \text{ lb (C)}$
$F_{HI} = 6750 \text{ lb (T)}$
$F_{CH} = 5625 \text{ lb (C)}$

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5–21.

Determine the force in members CD, CJ, KJ, and DJ of the truss which serves to support the deck of a bridge. State if these members are in tension or compression.

SOLUTION

$\circlearrowleft + \Sigma M_C = 0;$ $\quad -9500(18) + 4000(9) + F_{KJ}(12) = 0$

$F_{KJ} = 11\,250 \text{ lb} = 11.2 \text{ kip (T)}$ **Ans.**

$\circlearrowleft + \Sigma M_J = 0;$ $\quad -9500(27) + 4000(18) + 8000(9) + F_{CD}(12) = 0$

$F_{CD} = 9375 \text{ lb} = 9.38 \text{ kip (C)}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad -9375 + 11\,250 - \frac{3}{5}F_{CJ} = 0$

$F_{CJ} = 3125 \text{ lb} = 3.125 \text{ kip (C)}$ **Ans.**

Joint D: $\quad F_{DJ} = 0$ **Ans.**

Ans:
$F_{KJ} = 11.25$ kip (T)
$F_{CD} = 9.375$ kip (C)
$F_{CJ} = 3.125$ kip (C)
$F_{DJ} = 0$

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5–22.

Determine the force in members EI and JI of the truss which serves to support the deck of a bridge. State if these members are in tension or compression.

SOLUTION

$\circlearrowleft + \Sigma M_E = 0;$ $\quad -5000(9) + 7500(18) - F_{JI}(12) = 0$

$F_{JI} = 7500 \text{ lb} = 7.50 \text{ kip (T)}$ **Ans.**

$+\uparrow \Sigma F_y = 0;$ $\quad 7500 - 5000 - F_{EI} = 0$

$F_{EI} = 2500 \text{ lb} = 2.50 \text{ kip (C)}$ **Ans.**

Ans:
$F_{JI} = 7.50$ kip (T)
$F_{EI} = 2.50$ kip (C)

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5–23.

The *Howe truss* is subjected to the loading shown. Determine the force in members *GF*, *CD*, and *GC* and state if the members are in tension or compression.

SOLUTION

$\circlearrowleft + \Sigma M_A = 0; \qquad E_y(8) - 2(8) - 5(6) - 5(4) - 5(2) = 0 \qquad E_y = 9.5\text{kN}$

$\circlearrowleft + \Sigma M_D = 0; \qquad -\frac{4}{5}F_{GF}(1.5) - 2(2) + 9.5(2) = 0$

$F_{GF} = 12.5 \text{ kN (C)}$ **Ans.**

$\circlearrowleft + \Sigma M_G = 0; \qquad 9.5(4) - 2(4) - 5(2) - F_{CD}(3) = 0$

$F_{CD} = 6.67 \text{ kN (T)}$ **Ans.**

Joint *C*:

$+\uparrow \Sigma F_y = 0; \qquad F_{GC} = 0$ **Ans.**

Ans:
$F_{GF} = 12.5 \text{ kN (C)}$
$F_{CD} = 6.67 \text{ kN (T)}$
$F_{GC} = 0$

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***5–24.**

The *Howe truss* is subjected to the loading shown. Determine the force in members GH, BC, and BG of the truss and state if the members are in tension or compression.

SOLUTION

$\circlearrowleft + \Sigma M_B = 0; \qquad -7.5(2) + F_{GH} \sin 36.87°(2) = 0$

$F_{GH} = 12.5 \text{ kN (C)}$ **Ans.**

$\circlearrowleft + \Sigma M_A = 0; \qquad -5\,(2) + F_{BG} \sin 56.31°(2) = 0$

$F_{BG} = 6.01 \text{ kN (T)}$ **Ans.**

$\circlearrowleft + \Sigma M_H = 0; \qquad -7.5(4) + 5(2) + F_{BC}(3) = 0$

$F_{BC} = 6.67 \text{ kN (T)}$ **Ans.**

Ans:
$F_{GH} = 12.5 \text{ kN (C)}$
$F_{BG} = 6.01 \text{ kN (T)}$
$F_{BC} = 6.67 \text{ kN (T)}$

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5–25.

Determine the force in members EF, CF, and BC, and state if the members are in tension or compression.

SOLUTION

Support Reactions. Not required.

Method of Sections. $\mathbf{F}_{BC}$ and $\mathbf{F}_{EF}$ can be determined directly by writing the moment equations of equilibrium about points F and C, respectively, by referring to the *FBD* of the upper portion of the truss section through *a–a* shown in Fig. *a*.

$\circlearrowleft + \Sigma M_F = 0; \qquad F_{BC}(1.5) - 4(2) = 0$

$$F_{BC} = 5.333 \text{ kN (C)} = 5.33 \text{ kN (C)} \qquad \textbf{Ans.}$$

$\circlearrowleft + \Sigma M_C = 0; \qquad F_{EF}(1.5) - 4(2) = 0$

$$F_{EF} = 5.333 \text{ kN (T)} = 5.33 \text{ kN (T)} \qquad \textbf{Ans.}$$

Also, by writing the force equation of equilibrium along the x axis,

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 4 - F_{CF} = 0 \qquad F_{CF} = 4.00 \text{ kN (T)} \qquad \textbf{Ans.}$$

Ans:
$F_{BC} = 5.33$ kN (C)
$F_{EF} = 5.33$ kN (T)
$F_{CF} = 4.00$ kN (T)

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5–26.

Determine the force in members AF, BF, and BC, and state if the members are in tension or compression.

SOLUTION

Support Reactions. Not required.

Method of Sections: Referring to the *FBD* of the upper portion of the truss section through *a–a* shown in Fig. *a*, $\mathbf{F}_{AF}$ and $\mathbf{F}_{BC}$ can be determined directly by writing the moment equations of equilibrium about points *B* and *F*, respectively.

$\circlearrowleft + \Sigma M_B = 0;\qquad F_{AF}(1.5) - 8(2) - 4(4) = 0$

$F_{AF} = 21.33 \text{ kN (T)} = 21.3 \text{ kN (T)}$ **Ans.**

$\circlearrowleft + \Sigma M_F = 0;\qquad F_{BC}(1.5) - 4(2) = 0$

$F_{BC} = 5.333 \text{ kN (C)} = 5.33 \text{ kN (C)}$ **Ans.**

Also, write the force equation of equilibrium along the *x* axis, we can obtain $\mathbf{F}_{BF}$ directly.

$\overset{+}{\rightarrow} \Sigma F_x = 0;\qquad 4 + 8 - F_{BF}\left(\frac{3}{5}\right) = 0 \qquad F_{BF} = 20.0 \text{ kN (C)}$ **Ans.**

Ans:
$F_{AF} = 21.3$ kN (T)
$F_{BC} = 5.33$ kN (C)
$F_{BF} = 20.0$ kN (C)

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5–27.

Determine the force in members EF, BE, BC, and BF of the truss and state if these members are in tension or compression. Set $P_1 = 9$ kN, $P_2 = 12$ kN, and $P_3 = 6$ kN.

SOLUTION

Support Reactions. Referring to the *FBD* of the entire truss shown in Fig. *a*, $\mathbf{N}_D$ can be determined directly by writing the moment equation of equilibrium about point A.

$$\circlearrowleft + \Sigma M_A = 0; \qquad N_D(9) - 12(6) - 9(3) - 6(3) = 0 \qquad N_D = 13.0 \text{ kN}$$

Method of Sections. Referring to the *FBD* of the right portion of the truss sectioned through *a–a* shown in Fig. *b*, $\mathbf{F}_{EF}$ and $\mathbf{F}_{BC}$ can be determined directly by writing the moment equation of equilibrium about points B and E, respectively.

$$\circlearrowleft + \Sigma M_B = 0; \qquad 13.0(6) - 12(3) - F_{EF}(3) = 0 \qquad F_{EF} = 14.0 \text{ kN (C)} \qquad \textbf{Ans.}$$

$$\circlearrowleft + \Sigma M_E = 0; \qquad 13.0(3) - F_{BC}(3) = 0 \qquad F_{BC} = 13.0 \text{ kN (T)} \qquad \textbf{Ans.}$$

Also, $\mathbf{F}_{BE}$ can be determined by writing the force equation of equilibrium along the y axis.

$$+\uparrow \Sigma F_y = 0; \; 13.0 - 12 - F_{BE}\left(\frac{1}{\sqrt{2}}\right) = 0 \; F_{BE} = \sqrt{2} \text{ kN (T)} = 1.41 \text{ kN (T)} \; \textbf{Ans.}$$

Method of Joints. Using the result of $\mathbf{F}_{BE}$, the equilibrium of joint B, Fig. *c*, requires

$$+\uparrow \Sigma F_y = 0; \qquad F_{BF} + \left(\sqrt{2}\right)\left(\frac{1}{\sqrt{2}}\right) - 9 = 0 \qquad F_{BF} = 8.00 \text{ kN (T)} \qquad \textbf{Ans.}$$

Ans:
$F_{EF} = 14.0$ kN (C)
$F_{BC} = 13.0$ kN (T)
$F_{BE} = 1.41$ kN (T)
$F_{BF} = 8.00$ kN (T)

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***5–28.**

Determine the force in members BC, BE, and EF of the truss and state if these members are in tension or compression. Set $P_1 = 6$ kN, $P_2 = 9$ kN, and $P_3 = 12$ kN.

SOLUTION

Support Reactions. Referring to the *FBD* of the entire truss shown in Fig. *a*, $\mathbf{N}_D$ can be determined directly by writing the moment equation of equilibrium about point A.

$$\circlearrowleft + \Sigma M_A = 0; \qquad N_D(9) - 12(3) - 6(3) - 9(6) = 0 \qquad N_D = 12.0 \text{ kN}$$

Method of Sections. Referring to the *FBD* of the right portion of the truss sectioned through *a–a* shown in Fig. *b*, $\mathbf{F}_{EF}$ and $\mathbf{F}_{BC}$ can be determined directly by writing the moment equation of equilibrium about points B and E, respectively.

$$\circlearrowleft + \Sigma M_B = 0; \qquad 12.0(6) - 9(3) - F_{EF}(3) = 0 \qquad F_{EF} = 15.0 \text{ kN (C)} \qquad \textbf{Ans.}$$

$$\circlearrowleft + \Sigma M_E = 0; \qquad 12.0(3) - F_{BC}(3) = 0 \qquad F_{BC} = 12.0 \text{ kN (T)} \qquad \textbf{Ans.}$$

Also, $\mathbf{F}_{BE}$ can be obtained directly by writing the force equation of equilibrium along the y axis.

$$+\uparrow \Sigma F_y = 0; \qquad 12.0 - 9 - F_{BE}\left(\frac{1}{\sqrt{2}}\right) = 0$$

$$F_{BE} = 3\sqrt{2} \text{ kN} = 4.24 \text{ kN (T)} \qquad \textbf{Ans.}$$

Ans:
$F_{EF} = 15.0$ kN (C)
$F_{BC} = 12.0$ kN (T)
$F_{BE} = 4.24$ kN (T)

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5–29.

Determine the force in members BC, HC, and HG. After the truss is sectioned use a single equation of equilibrium for the calculation of each force. State if these members are in tension or compression.

SOLUTION

$\circlearrowleft + \Sigma M_E = 0;\qquad -A_y(20) + 2(20) + 4(15) + 4(10) + 5(5) = 0$

$A_y = 8.25\text{ kN}$

$\circlearrowleft + \Sigma M_H = 0;\qquad -8.25(5) + 2(5) + F_{BC}(3) = 0$

$F_{BC} = 10.4\text{ kN (C)}$ **Ans.**

$\circlearrowleft + \Sigma M_C = 0;\qquad -8.25(10) + 2(10) + 4(5) + \dfrac{5}{\sqrt{29}}F_{HG}(5) = 0$

$F_{HG} = 9.155 = 9.16\text{ kN (T)}$ **Ans.**

$\circlearrowleft + \Sigma M_{O'} = 0;\qquad -2(2.5) + 8.25(2.5) - 4(7.5) + \dfrac{3}{\sqrt{34}}F_{HC}(12.5) = 0$

$F_{HC} = 2.24\text{ kN (T)}$ **Ans.**

Ans:
$F_{BC} = 10.4\text{ kN (C)}$
$F_{HG} = 9.16\text{ kN (T)}$
$F_{HC} = 2.24\text{ kN (T)}$

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5–30.

Determine the force in members CD, CF, and CG and state if these members are in tension or compression.

SOLUTION

$\xrightarrow{+} \Sigma F_x = 0; \qquad E_x = 0$

$\circlearrowleft + \Sigma M_A = 0; \qquad -4(5) - 4(10) - 5(15) - 3(20) + E_y(20) = 0$

$E_y = 9.75 \text{ kN}$

$\circlearrowleft + \Sigma M_C = 0; \qquad -5(5) - 3(10) + 9.75(10) - \dfrac{5}{\sqrt{29}} F_{FG}(5) = 0$

$F_{FG} = 9.155 \text{ kN (T)}$

$\circlearrowleft + \Sigma M_F = 0; \qquad -3(5) + 9.75(5) - F_{CD}(3) = 0$

$F_{CD} = 11.25 = 11.2 \text{ kN (C)}$ **Ans.**

$\circlearrowleft + \Sigma M_{O'} = 0; \qquad -9.75(2.5) + 5(7.5) + 3(2.5) - \dfrac{3}{\sqrt{34}} F_{CF}(12.5) = 0$

$F_{CF} = 3.21 \text{ kN (T)}$ **Ans.**

Joint G:

$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{GH} = 9.155 \text{ kN (T)}$

$+\uparrow \Sigma F_y = 0; \qquad \dfrac{2}{\sqrt{29}}(9.155)(2) - F_{CG} = 0$

$F_{CG} = 6.80 \text{ kN (C)}$ **Ans.**

Ans:
$F_{CD} = 11.2 \text{ kN (C)}$
$F_{CF} = 3.21 \text{ kN (T)}$
$F_{CG} = 6.80 \text{ kN (C)}$

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5–31.

Determine the force developed in members *FE*, *EB*, and *BC* of the truss and state if these members are in tension or compression.

SOLUTION

Support Reactions. Referring to the *FBD* of the entire truss shown in Fig. *a*, $\mathbf{N}_D$ can be determined directly by writing the moment equation of equilibrium about point A.

$$\circlearrowleft + \Sigma M_A = 0; \qquad N_D(5.5) - 11(2) - 22(3.5) = 0 \qquad N_D = 18.0 \text{ kN}$$

Method of Sections. Referring to the *FBD* of the right portion of the truss sectioned through *a–a* shown in Fig. *b*, $\mathbf{F}_{BC}$ and $\mathbf{F}_{FE}$ can be determined directly by writing the moment equations of equilibrium about point *E* and *B*, respectively.

$$\circlearrowleft + \Sigma M_E = 0; \qquad 18.0(2) - F_{BC}(2) = 0 \qquad F_{BC} = 18.0 \text{ kN (T)} \qquad \textbf{Ans.}$$

$$\circlearrowleft + \Sigma M_B = 0; \qquad 18.0(3.5) - 22(1.5) - F_{FE}(2) = 0 \qquad F_{FE} = 15.0 \text{ kN (C)} \qquad \textbf{Ans.}$$

Also, $\mathbf{F}_{EB}$ can be obtained directly by writing force equation of equilibrium along the *y* axis

$$+\uparrow \Sigma F_y = 0; \qquad F_{EB}\left(\frac{4}{5}\right) + 18.0 - 22 = 0 \qquad F_{EB} = 5.00 \text{ kN (C)} \qquad \textbf{Ans.}$$

(a)

(b)

Ans:
$F_{BC} = 18.0$ kN (T)
$F_{FE} = 15.0$ kN (C)
$F_{EB} = 5.00$ kN (C)

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***5–32.**

Determine the force **P** required to hold the 100-lb weight in equilibrium.

SOLUTION

Equations of Equilibrium: Applying the force equation of equilibrium along the y axis of pulley A on the free-body diagram, Fig. a,

$+\uparrow \Sigma F_y = 0;$ $\quad 2T_A - 100 = 0$ $\quad T_A = 50\text{ lb}$

Applying $\Sigma F_y = 0$ to the free-body diagram of pulley B, Fig. b,

$+\uparrow \Sigma F_y = 0;$ $\quad 2T_B - 50 = 0$ $\quad T_B = 25\text{ lb}$

From the free-body diagram of pulley C, Fig. c,

$+\uparrow \Sigma F_y = 0;$ $\quad 2P - 25 = 0$ $\quad P = 12.5\text{ lb}$ **Ans.**

Ans:
$P = 12.5\text{ lb}$

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5–33.

In each case, determine the force **P** required to maintain equilibrium of the 100-lb block.

(a) (b) (c)

SOLUTION

Equations of Equilibrium:

(a) $+\uparrow \Sigma F_y = 0; \quad 4P - 100 = 0$

$P = 25.0 \text{ lb}$ **Ans.**

(b) $+\uparrow \Sigma F_y = 0; \quad 3P - 100 = 0$

$P = 33.3 \text{ lb}$ **Ans.**

(c) $+\uparrow \Sigma F_y = 0; \quad 3P' - 100 = 0$

$P' = 33.33 \text{ lb}$

$+\uparrow \Sigma F_y = 0; \quad 3P - 33.33 = 0$

$P = 11.1 \text{ lb}$ **Ans.**

Ans:
a) $P = 25.0$ lb
b) $P = 33.3$ lb
c) $P = 11.1$ lb

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5–34.

Determine the force **P** required to hold the 50-kg block in equilibrium.

SOLUTION

Equations of Equilibrium: Applying the force equation of equilibrium along the y axis of each pulley.

$+\uparrow \Sigma F_y = 0; \qquad R - 3P = 0; \qquad R = 3P$

$+\uparrow \Sigma F_y = 0; \qquad T - 3R = 0; \qquad T = 3R = 9P$

$+\uparrow \Sigma F_y = 0; \qquad 2P + 2R + 2T - 50(9.81) = 0$

Substituting Eqs.(1) and (2) into Eq.(3) and solving for P,

$$2P + 2(3P) + 2(9P) = 50(9.81)$$

$$P = 18.9\text{ N} \qquad \textbf{Ans.}$$

(a)

Ans:
$P = 18.9\text{ N}$

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5–35.

Determine the force **P** required to hold the 150-kg crate in equilibrium.

SOLUTION

Equations of Equilibrium: Applying the force equation of equilibrium along the y axis of pulley A on the free-body diagram, Fig. a,

$$+\uparrow \Sigma F_y = 0; \qquad 2T_A - 150(9.81) = 0 \quad T_A = 735.75 \text{ N}$$

Using the above result and writing the force equation of equilibrium along the y' axis of pulley C on the free-body diagram in Fig. b,

$$\Sigma F_{y'} = 0; \quad 735.75 - 2P = 0 \qquad P = 367.88 \text{ N} = 368 \text{ N} \qquad \textbf{Ans.}$$

(a)

(b)

Ans:
$P = 368$ N

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***5–36.**

Determine the reactions at the supports A, C, and E of the compound beam.

SOLUTION

Free-Body Diagram. The compound beam is being dismembered into members AB, BD and DE, of which their respective *FBDs* are shown in Fig. *a*, *b* and *c*.

Equations of Equilibrium. Equilibrium of member DE will be considered first by referring to Fig. *c*.

$\circlearrowleft + \Sigma M_D = 0; \quad N_E(6) - 12(9) = 0 \quad N_E = 18.0\text{ kN}$ **Ans.**

$\circlearrowleft + \Sigma M_E = 0; \quad D_y(6) - 12(3) = 0 \quad D_y = 6.00\text{ kN}$

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad D_x = 0$

Next, member BD, Fig. *b*.

$\circlearrowleft + \Sigma M_C = 0; \quad 6.00(2) + 3(6)(1) - B_y(4) = 0 \quad B_y = 7.50\text{ kN}$

$\circlearrowleft + \Sigma M_B = 0; \quad N_C(4) + 6.00(6) - 3(6)(3) = 0 \quad N_C = 4.50\text{ kN}$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad B_x = 0$

Finally, member AB, Fig. *a*.

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad A_x = 0$ **Ans.**

$+\uparrow \Sigma F_y = 0; \quad A_y - 7 - 50 = 0 \quad A_y = 7.50\text{ kN}$ **Ans.**

$\circlearrowleft + \Sigma M_A = 0; \quad M_A - 7.50(3) = 0 \quad M_A = 22.5\text{ kN}\cdot\text{m}$ **Ans.**

Ans:
$N_E = 18.0\text{ kN}$
$N_C = 4.50\text{ kN}$
$A_x = 0$
$A_y = 7.50\text{ kN}$
$M_A = 22.5\text{ kN}\cdot\text{m}$

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5–37.

Determine the resultant force at pins A, B, and C on the three-member frame.

SOLUTION

Free-Body Diagram. The frame is being dismembered into members AC and BC, of which their respective $FBDs$ are shown in Fig. a and b.

Equations of Equilibrium. Write the moment equation of equilibrium about point A for member AC, Fig. a, and point B for member BC, Fig. b.

$$\circlearrowleft + \Sigma M_A = 0; \qquad C_y\left(\frac{2}{\tan 60°}\right) + C_x(2) - 200\left(\frac{2}{\sin 60°}\right)\left(\frac{1}{\sin 60°}\right) = 0 \qquad \textbf{(1)}$$

$$\circlearrowleft + \Sigma M_B = 0; \qquad C_y(2) - C_x(2) + 800(2) = 0 \qquad \textbf{(2)}$$

Solving Eqs. (1) and (2),

$$C_y = -338.12 \text{ N} \quad C_x = 461.88 \text{ N}$$

The negative sign indicates that $\mathbf{C}_y$ acts in the sense opposite to that shown in the FBD. Write the force equation of equilibrium for member AC, Fig. a.

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad A_x + 200\left(\frac{2}{\sin 60°}\right)\sin 60° - 461.88 = 0 \qquad A_x = 61.88 \text{ N}$$

$$+\uparrow \Sigma F_y = 0; \qquad A_y + (-338.12) - 200\left(\frac{2}{\sin 60°}\right)\cos 60° = 0 \qquad A_y = 569.06 \text{ N}$$

Also, for member BC, Fig. b,

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad B_x + 461.88 - 800 = 0 \qquad B_x = 338.12 \text{ N}$$

$$+\uparrow \Sigma F_y = 0; \qquad -B_y - (-338.12) = 0 \qquad B_y = 338.12 \text{ N}$$

Thus,

$$F_C = \sqrt{C_x^2 + C_y^2} = \sqrt{461.88^2 + (-338.12)^2} = 572.41 \text{ N} = 572 \text{ N} \qquad \textbf{Ans.}$$

$$F_A = \sqrt{A_x^2 + A_y^2} = \sqrt{61.88^2 + 569.06^2} = 572.41 \text{ N} = 572 \text{ N} \qquad \textbf{Ans.}$$

$$F_B = \sqrt{B_x^2 + B_y^2} = \sqrt{338.12^2 + 338.12^2} = 478.17 \text{ N} = 478 \text{ N} \qquad \textbf{Ans.}$$

Ans:
$F_C = 572$ N
$F_A = 572$ N
$F_B = 478$ N

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5–38.

Determine the reactions at the supports at A, E, and B of the compound beam.

SOLUTION

Free-Body Diagram. The solution will be very much simplified if one realizes that member CD is a two-force member.

Equation of Equilibrium. Consider the equilibrium of member BD, Fig. b.

$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad F_{CD} = 0$

$\circlearrowleft + \Sigma M_B = 0; \qquad \frac{1}{2}(900)(6)(4) - N_E(3) = 0 \quad N_E = 3600\text{ N} = 3.60\text{ kN}$ **Ans.**

$\circlearrowleft + \Sigma M_E = 0; \qquad \frac{1}{2}(900)(6)(1) - N_B(3) = 0 \quad N_B = 900\text{ N}$ **Ans.**

Then the equilibrium of member AC gives

$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad A_x = 0$ **Ans.**

$+\uparrow \Sigma F_y = 0; \qquad A_y - \frac{1}{2}(900)(6) = 0 \quad A_y = 2700\text{ N} = 2.70\text{ kN}$ **Ans.**

$\circlearrowleft + \Sigma M_A = 0; \qquad M_A - \frac{1}{2}(900)(6)(3) = 0 \quad M_A = 8100\text{ N}\cdot\text{m} = 8.10\text{ kN}\cdot\text{m}$ **Ans.**

Ans:
$N_E = 3.60\text{ kN}$
$N_B = 900\text{ N}$
$A_x = 0$
$A_y = 2.70\text{ kN}$
$M_A = 8.10\text{ kN}\cdot\text{m}$

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5–39.

The wall crane supports a load of 700 lb. Determine the horizontal and vertical components of reaction at the pins A and D. Also, what is the force in the cable at the winch W?

SOLUTION

Pulley E:

$+\uparrow \Sigma F_y = 0;$ $\quad 2T - 700 = 0$

$T = 350 \text{ lb}$ **Ans.**

Member ABC:

$\circlearrowleft + \Sigma M_A = 0;$ $\quad T_{BD} \sin 45°(4) - 350 \sin 60°(4) \cdot 700\,(8) = 0$

$T_{BD} = 2409 \text{ lb}$

$+\uparrow \Sigma F_y = 0;$ $\quad -A_y + 2409 \sin 45° - 350 \sin 60° - 700 = 0$

$A_y = 700 \text{ lb}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad -A_y - 2409 \cos 45° - 350 \cos 60° + 350 - 350 = 0$

$A_x = 1.88 \text{ kip}$ **Ans.**

At D:

$D_x = 2409 \cos 45° = 1703.1 \text{ lb} = 1.70 \text{ kip}$ **Ans.**

$D_y = 2409 \sin 45° = 1.70 \text{ kip}$ **Ans.**

Ans:
$T = 350 \text{ lb}$
$A_y = 700 \text{ lb}$
$A_x = 1.88 \text{ kip}$
$D_x = 1.70 \text{ kip}$
$D_y = 1.70 \text{ kip}$

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***5–40.**

The wall crane supports a load of 700 lb. Determine the horizontal and vertical components of reaction at the pins A and D. Also, what is the force in the cable at the winch W? The jib ABC has a weight of 100 lb and member BD has a weight of 40 lb. Each member is uniform and has a center of gravity at its center.

SOLUTION

Pulley E:

$+\uparrow \Sigma F_y = 0;$ $\quad 2T - 700 = 0$

$T = 350 \text{ lb}$ **Ans.**

Member ABC:

$\circlearrowleft + \Sigma M_A = 0;$ $\quad B_y(4) - 700(8) - 100(4) - 350 \sin 60°(4) = 0$

$B_y = 1803.1 \text{ lb}$

$+\uparrow \Sigma F_y = 0;$ $\quad -A_y - 350 \sin 60° - 100 - 700 + 1803.1 = 0$

$A_y = 700 \text{ lb}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad A_x - 350 \cos 60° - B_x + 350 - 350 = 0$

$A_x = B_x + 175$ **(1)**

Member DB:

$\circlearrowleft + \Sigma M_D = 0;$ $\quad -40(2) - 1803.1(4) + B_x(4) = 0$

$B_x = 1823.1 \text{ lb}$

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad -D_x + 1823.1 = 0$

$D_x = 1.82 \text{ kip}$ **Ans.**

$+\uparrow \Sigma F_y = 0;$ $\quad D_y - 40 - 1803.1 = 0$

$D_y = 1843.1 = 1.84 \text{ kip}$ **Ans.**

From Eq. (1),

$A_x = 2.00 \text{ kip}$ **Ans.**

Ans:
$T = 350$ lb
$A_y = 700$ lb
$D_x = 1.82$ kip
$D_y = 1.84$ kip
$A_x = 2.00$ kip

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5–41.

Determine the horizontal and vertical components of force which the pins at A and B exert on the frame.

SOLUTION

Free-Body Diagram. The frame will be dismembered into members AD, EF, CD and BC. The solution will be very much simplified if one realizes that members CD and EF are two-force members. Therefore, only the FBD of members AD and BC, Fig. a and b, respectively, need to be drawn.

Equations of Equilibrium. Write the moment equations of equilibrium about point A for member AD, Fig. a, and point B for member BC, Fig. b.

$$\circlearrowleft + \Sigma M_A = 0; \qquad F_{EF}\left(\frac{4}{5}\right)(3) - F_{CD}(4.5) - 400\,(4.5)(2.25) = 0 \qquad \textbf{(1)}$$

$$\circlearrowleft + \Sigma M_B = 0; \qquad -F_{EF}\left(\frac{4}{5}\right)(1.5) + F_{CD}(4.5) = 0 \qquad \textbf{(2)}$$

Solving Eqs. (1) and (2),

$$F_{EF} = 3375 \text{ N} \quad F_{CD} = 900 \text{ N}$$

Write the force equation of equilibrium for member AD, Fig. a.

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad A_x + 400(4.5) + 900 - 3375\left(\frac{4}{5}\right) = 0 \quad A_x = 0 \qquad \textbf{Ans.}$$

$$+\uparrow \Sigma F_y = 0; \qquad 3375\left(\frac{3}{5}\right) - A_y = 0 \quad A_y = 2025 \text{ N} = 2.025 \text{ kN} \qquad \textbf{Ans.}$$

Also, for member BC, Fig. b,

$$\overset{+}{\rightarrow}\Sigma F_x = 0; \qquad 3375\left(\frac{4}{5}\right) - 900 - B_x = 0 \quad B_x = 1800 \text{ N} = 1.80 \text{ kN} \qquad \textbf{Ans.}$$

$$+\uparrow \Sigma F_y = 0; \qquad B_y - 3375\left(\frac{3}{5}\right) = 0 \qquad B_y = 2025 \text{ N} = 2.025 \text{ kN} \qquad \textbf{Ans.}$$

(a)

(b)

Ans:
$A_x = 0$
$A_y = 2.025$ kN
$B_x = 1.80$ kN
$B_y = 2.025$ kN

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5–42.

Determine the force in members *FD* and *DB* of the frame. Also, find the horizontal and vertical components of reaction the pin at *C* exerts on member *ABC* and member *EDC*.

SOLUTION

Free-Body Diagram. The assembly will be dismembered into members *GFE*, *EDC*, *FD*, *BD* and *ABC*. The solution will be very much simplified if one recognizes members *FD* and *BD* are two-force members. The *FBDs* of members *GFE*, *EDC* and *ABC* are shown in Figs. *a*, *b* and *c*, respectively.

Equations of Equilibrium. First, consider the equilibrium of member *GFE*, Fig. *a*.

$\circlearrowleft + \Sigma M_E = 0;\quad 6(3) - F_{FD}\left(\frac{2}{\sqrt{5}}\right)(1) = 0 \quad F_{FD} = 9\sqrt{5}\text{ kN} = 20.1\text{ kN}$ **Ans.**

$\circlearrowleft + \Sigma M_F = 0;\quad 6(2) - E_y(1) = 0 \quad E_y = 12.0\text{ kN}$

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad E_x - \left(9\sqrt{5}\right)\left(\frac{1}{\sqrt{5}}\right) = 0 \quad E_x = 9.00\text{ kN}$

Next, for member *EDC*, Fig. *b*,

$\circlearrowleft + \Sigma M_C = 0;\quad 9.00(3) - \left(9\sqrt{5}\right)\left(\frac{1}{\sqrt{5}}\right)(1) - F_{BD}\left(\frac{1}{\sqrt{2}}\right)(1) = 0$

$F_{BD} = 18\sqrt{2}\text{ kN} = 25.5\text{ kN}$ **Ans.**

$\circlearrowleft + \Sigma M_D = 0;\quad 9.00(2) - C'_x(1) = 0 \quad C'_x = 18.0\text{ kN}$ **Ans.**

$+\uparrow \Sigma F_y = 0;\quad 12.0 + \left(18\sqrt{2}\right)\left(\frac{1}{\sqrt{2}}\right) - \left(9\sqrt{5}\right)\left(\frac{2}{\sqrt{5}}\right) - C'_y = 0$

$C'_y = 12.0\text{ kN}$ **Ans.**

Finally, for member *ABC*, Fig. *c*,

$\circlearrowleft + \Sigma M_A = 0;\quad C''_y(3) - \left(18\sqrt{2}\right)\left(\frac{1}{\sqrt{2}}\right)(2) = 0 \quad C''_y = 12.0\text{ kN}$ **Ans.**

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad C''_x - \left(18\sqrt{2}\right)\left(\frac{1}{\sqrt{2}}\right) = 0 \quad C''_x = 18.0\text{ kN}$ **Ans.**

Ans:
$F_{FD} = 20.1$ kN
$F_{BD} = 25.5$ kN
Member *EDC*:
$C'_x = 18.0$ kN
$C'_y = 12.0$ kN
Member *ABC*:
$C''_x = 18.0$ kN
$C''_y = 12.0$ kN

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5–43.

Determine the force that the smooth 20-kg cylinder exerts on members AB and CDB. Also, what are the horizontal and vertical components of reaction at pin A?

SOLUTION

Free-Body Diagram. The *FBDs* of the entire assembly, member CDB and the cylinder are shown in Figs. a, b and c, respectively.

Equations of Equilibrium. First consider the equilibrium of the entire assembly, Fig. a.

$\circlearrowleft + \Sigma M_A = 0;\quad N_D(1) - 20(9.81)(1.5) = 0 \quad N_D = 294.3\text{ N}$

$\overset{+}{\rightarrow} \Sigma F_x = 0;\quad A_x - 294.3 = 0 \quad A_x = 294.3\text{ N} = 294\text{ N}$ **Ans.**

$+\uparrow \Sigma F_y = 0;\quad A_y - 20(9.81) = 0 \quad A_y = 196.2\text{ N} = 196\text{ N}$ **Ans.**

Next, for member CDB, Fig. b,

$\circlearrowleft + \Sigma M_B = 0;\quad 294.3(1) - N_C(2) = 0 \quad N_C = 147.15\text{ N} = 147\text{ N}$ **Ans.**

Finally, for the cylinder, Fig. c,

$+\uparrow \Sigma F_y = 0;\quad N_E - 20(9.81) - 147.15 = 0 \quad N_E = 343.35\text{ N} = 343\text{ N}$ **Ans.**

Ans:
$A_x = 294\text{ N}$
$A_y = 196\text{ N}$
$N_C = 147\text{ N}$
$N_E = 343\text{ N}$

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***5–44.**

The three power lines exert the forces shown on the pin-connected members at joints B, C, and D, which in turn are pin connected to the poles AH and EG. Determine the force in the guy cable AI and the pin reaction at the support H.

SOLUTION

AH is a two-force member.

Joint B:

$+\uparrow \Sigma F_y = 0;\qquad F_{AB}\sin 45° - 800 = 0$

$F_{AB} = 1131.37 \text{ lb}$

Joint C:

$+\uparrow \Sigma F_y = 0;\qquad 2F_{CA}\sin 18.435° - 800 = 0$

$F_{CA} = 1264.91 \text{ lb}$

Joint A:

$\xrightarrow{+} \Sigma F_x = 0;\qquad -T_{AI}\sin 21.801° - F_H\cos 76.504° + 1264.91\cos 18.435° + 1131.37\cos 45° = 0$

$+\uparrow \Sigma F_y = 0;\qquad -T_{AI}\cos 21.801° + F_H\sin 76.504° - 1131.37\sin 45° - 1264.91\sin 18.435° = 0$

$T_{AI}(0.3714) + F_H(0.2334) = 2000$

$-T_{AI}(0.9285) + F_H(0.97239) = 1200$

Solving,

$T_{AI} = T_{EF} = 2.88 \text{ kip}$ **Ans.**

$F_H = F_G = 3.99 \text{ kip}$ **Ans.**

Ans:
$T_{AI} = 2.88 \text{ kip}$
$F_H = 3.99 \text{ kip}$

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5–45.

The pumping unit is used to recover oil. When the walking beam ABC is horizontal, the force acting in the wireline at the well head is 250 lb. Determine the torque **M** which must be exerted by the motor in order to overcome this load. The horse-head C weighs 60 lb and has a center of gravity at G_C. The walking beam ABC has a weight of 130 lb and a center of gravity at G_B, and the counterweight has a weight of 200 lb and a center of gravity at G_W. The pitman, AD, is pin connected at its ends and has negligible weight.

SOLUTION

Free-Body Diagram: The solution for this problem will be simplified if one realizes that the pitman AD is a two-force member.

Equations of Equilibrium: From FBD (a),

$\circlearrowleft + \Sigma M_B = 0;$ $\quad F_{AD} \sin 70°(5) - 60(6) - 250(7) = 0$

$$F_{AD} = 449.08 \text{ lb}$$

From FBD (b),

$\circlearrowleft + \Sigma M_E = 0;$ $\quad 449.08(3) - 200 \cos 20°(5.5) - M = 0$

$$M = 314 \text{ lb} \cdot \text{ft} \qquad \textbf{Ans.}$$

Ans:
$M = 314 \text{ lb} \cdot \text{ft}$

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5–46.

Determine the force that the jaws J of the metal cutters exert on the smooth cable C if 100-N forces are applied to the handles. The jaws are pinned at E and A, and D and B. There is also a pin at F.

SOLUTION

Free-Body Diagram: The solution for this problem will be simplified if one realizes that member ED is a two-force member.

Equations of Equilibrium: From FBD (b),

$\xrightarrow{+} \Sigma F_x = 0; \qquad A_x = 0$

From FBD (a),

$\circlearrowleft + \Sigma M_F = 0; \qquad A_y \sin 15°(20) + 100 \sin 15°(20)$

$$- 100 \cos 15°(400) = 0$$

$$A_y = 7364.10 \text{ N}$$

From FBD (b),

$\circlearrowleft + \Sigma M_E = 0; \qquad 7364.10(80) - F_C(30) = 0$

$$F_C = 19637.60 \text{ N} = 19.6 \text{ kN} \qquad \textbf{Ans.}$$

Ans:
$F_C = 19.6$ kN

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5–47.

The machine shown is used for forming metal plates. It consists of two toggles ABC and DEF, which are operated by the hydraulic cylinder H. The toggles push the movable bar G forward, pressing the plate p into the cavity. If the force which the plate exerts on the head is $P = 12$ kN, determine the force F in the hydraulic cylinder when $\theta = 30°$.

SOLUTION

Member EF:

$$\circlearrowleft + \Sigma M_E = 0; \qquad -F_y(0.2\cos 30°) + 6\,(0.2\sin 30°) = 0$$

$$F_y = 3.464 \text{ kN}$$

Joint E:

$$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{DE}\cos 30° - 6 = 0$$

$$F_{DE} = 6.928 \text{ kN}$$

$$+\uparrow \Sigma F_y = 0; \qquad F - 3.464 - 6.928\sin 30° = 0$$

$$F = 6.93 \text{ kN} \qquad \textbf{Ans.}$$

Ans:
$F = 6.93$ kN

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***5–48.**

Determine the horizontal and vertical components of force which pin C exerts on member ABC. The 600-N force is applied to the pin.

SOLUTION

Free-Body Diagram. The solution will be very much simplified if one determines the support reactions first and then considers the equilibrium of two of its three members after they are dismembered. The *FBDs* of the entire assembly, member DBF and member ABC are shown in Figs. *a*, *b* and *c*, respectively.

Equations of Equilibrium. Consider the equilibrium of the entire assembly, Fig. *a*.

$\circlearrowleft + \Sigma M_E = 0; \qquad N_A(3) - 300(4.5) - 600(4) = 0 \quad N_A = 1250\text{ N}$

Next, write the moment equation of equilibrium about point D for member DBF, Fig. *b*.

$\circlearrowleft + \Sigma M_D = 0; \qquad B_x(1.5) - 300(3) = 0 \quad B_x = 600\text{ N}$

Finally, consider the equilibrium of member ABC, Fig. *c*.

$\xrightarrow{+} \Sigma F_x = 0; \qquad 1250 - 600 - C_x = 0 \quad C_x = 650\text{ N}$ **Ans.**

$\circlearrowleft + \Sigma M_B = 0; \qquad C_y = 0$ **Ans.**

Ans:
$C_x = 650\text{ N}$
$C_y = 0$

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5–49.

The pipe cutter is clamped around the pipe P. If the wheel at A exerts a normal force of $F_A = 80\text{ N}$ on the pipe, determine the normal forces of wheels B and C on the pipe. Also calculate the pin reaction on the wheel at C. The three wheels each have a radius of 7 mm and the pipe has an outer radius of 10 mm.

SOLUTION

$$\theta = \sin^{-1}\left(\frac{10}{17}\right) = 36.03°$$

Equations of Equilibrium:

$+\uparrow \Sigma F_y = 0;\qquad N_B \sin 36.03° - N_C \sin 36.03° = 0$

$N_B = N_C$

$\xrightarrow{+} \Sigma F_x = 0;\qquad 80 - N_C \cos 36.03° - N_C \cos 36.03° = 0$

$N_B = N_C = 49.5\text{ N}$ **Ans.**

Ans:
$N_B = N_C = 49.5\text{ N}$

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5–50.

Determine the force created in the hydraulic cylinders *EF* and *AD* in order to hold the shovel in equilibrium. The shovel load has a mass of 1.25 Mg and a center of gravity at *G*. All joints are pin connected.

SOLUTION

Assembly *FHG*:

$\circlearrowleft + \Sigma M_H = 0; \qquad -1250(9.81)(0.5) + F_{EF}(1.5 \sin 30°) = 0$

$F_{EF} = 8175 \text{ N} = 8.18 \text{ kN (T)}$ **Ans.**

Assembly *CEFHG*:

$\circlearrowleft + \Sigma M_C = 0; \qquad F_{AD} \cos 40° (0.25) - 1250(9.81)(2 \cos 10° + 0.5) = 0$

$F_{AD} = 158\,130 \text{ N} = 158 \text{ kN (C)}$ **Ans.**

Ans:
$F_{EF} = 8.18 \text{ kN (T)}$
$F_{AD} = 158 \text{ kN (C)}$

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5–51.

The hydraulic crane is used to lift the 1400-lb load. Determine the force in the hydraulic cylinder AB and the force in links AC and AD when the load is held in the position shown.

SOLUTION

$\circlearrowleft + \Sigma M_D = 0;$ $\quad F_{CA}(\sin 60°)(1) - 1400(8) = 0$

$F_{CA} = 12\,932.65 \text{ lb} = 12.9 \text{ kip}$ **Ans.**

$+\uparrow \Sigma F_y = 0;$ $\quad 12\,932.65 \sin 60° - F_{AB} \sin 70° = 0$

$F_{AB} = 11\,918.79 \text{ lb} = 11.9 \text{ kip}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad -11\,918.79 \cos 70° + 12\,932.65 \cos 60° - F_{AD} = 0$

$F_{AD} = 2389.86 \text{ lb} = 2.39 \text{ kip}$ **Ans.**

Ans:
$F_{CA} = 12.9$ kip
$F_{AB} = 11.9$ kip
$F_{AD} = 2.39$ kip

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***5–52.**

Determine force **P** on the cable if the spring is compressed 25 mm when the mechanism is in the position shown. The spring has a stiffness of $k = 6$ kN/m.

SOLUTION

Free-Body Diagram. The assembly will be dismembered into members *ACF*, *CDE* and *BD*. The solution will be very much simplified if one recognizes member *BD* is a two-force member. Here, the spring force is $F_{SP} = kx = 600(0.025) = 150$ N. The *FBDs* of members *ACF* and *CDE* are shown in Figs. *a* and *b*, respectively.

Equations of Equilibrium. Write the moment equation of equilibrium about point *A* for member *ACF*, Fig. *a*.

$$\circlearrowleft + \Sigma M_A = 0; \qquad C_y(0.2) + C_x(0.2) - 150(1) = 0 \qquad \textbf{(1)}$$

Next, consider the equilibrium of member *CDE*.

$$\circlearrowleft + \Sigma M_C = 0; \qquad F_{BD}\sin 30°(0.2) - P(0.35) = 0 \qquad \textbf{(2)}$$

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad C_x + P - F_{BD}\sin 30° = 0 \qquad \textbf{(3)}$$

$$+\uparrow \Sigma F_y = 0; \qquad F_{BD}\cos 30° - C_y = 0 \qquad \textbf{(4)}$$

Solving Eqs. (1) to (4),

$$C_x = 148.77 \text{ N} \quad C_y = 601.23 \text{ N} \quad F_{BD} = 694.24 \text{ N}$$

$$P = 198.36 \text{ N} = 198 \text{ N} \qquad \textbf{Ans.}$$

Ans:
$P = 198$ N

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5–53.

If $d = 0.75$ ft and the spring has an unstretched length of 1 ft, determine the force F required for equilibrium.

SOLUTION

Spring Force Formula: The elongation of the spring is $x = 2(0.75) - 1 = 0.5$ ft. Thus, the force in the spring is given by

$$F_{sp} = kx = 150(0.5) = 75 \text{ lb}$$

Equations of Equilibrium: First, we will analyze the equilibrium of joint B. From the free-body diagram in Fig. a,

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad F_{AB}\cos 48.59° - F_{BC}\cos 48.59° = 0$

$F_{AB} = F_{BC} = F'$

$+\uparrow \Sigma F_y = 0;$ $\quad 2F'\sin 48.59° - 75 = 0$

$F' = 50$ lb

From the free-body diagram in Fig. b, using the result $F_{BC} = F' = 50$ lb, and analyzing the equilibrium of joint C, we have

$+\uparrow \Sigma F_y = 0;$ $\quad F_{CD}\sin 48.59° - 50\sin 48.59° = 0 \qquad F_{CD} = 50$ lb

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad 2(50\cos 48.59°) - F = 0$

$F = 66.14 \text{ lb} = 66.1 \text{ lb}$ **Ans.**

Ans:
$F = 66.1$ lb

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5–54.

If a force of $F = 50$ lb is applied to the pads at A and C, determine the smallest dimension d required for equilibrium if the spring has an unstretched length of 1 ft.

SOLUTION

Geometry: From the geometry shown in Fig. *a*, we can write

$$\sin\theta = d \qquad \cos\theta = \sqrt{1 - d^2}$$

(a)

Spring Force Formula: The elongation of the spring is $x = 2d - 1$. Thus, the force in the spring is given by

$$F_{sp} = kx = 150(2d - 1)$$

Equations of Equilibrium: First, we will analyze the equilibrium of joint B. From the free-body diagram in Fig. *b*,

$$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{AB}\cos\theta - F_{BC}\cos\theta = 0 \qquad F_{AB} = F_{BC} = F'$$

$$+\uparrow \Sigma F_y = 0; \qquad 2F'(d) - 150(2d - 1) = 0 \qquad F' = \frac{150d - 75}{d}$$

(b)

From the free-body diagram in Fig. *c*, using the result $F_{BC} = F' = \dfrac{150d - 75}{d}$, and analyzing the equilibrium of joint C, we have

$$+\uparrow \Sigma F_y = 0; \qquad F_{CD}\sin\theta - \left(\frac{150d - 75}{d}\right)\sin\theta = 0 \qquad F_{CD} = \frac{150d - 75}{d}$$

$$\xrightarrow{+} \Sigma F_x = 0; \qquad 2\left[\left(\frac{150d - 75}{d}\right)\left(\sqrt{1-d^2}\right)\right] - 50 = 0$$

Solving the above equation using a graphing utility, we obtain
$d = 0.6381$ ft $= 0.638$ ft or $d = 0.9334$ ft $= 0.933$ ft **Ans.**

(c)

Ans:
$d = 0.638$ ft

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5–55.

The skid-steer loader has a mass of 1.18 Mg, and in the position shown the center of mass is at G_1. If there is a 300-kg stone in the bucket, with center of mass at G_2, determine the reactions of each pair of wheels A and B on the ground and the force in the hydraulic cylinder CD and at the pin E. There is a similar linkage on each side of the loader.

SOLUTION

Entire system:

$\circlearrowleft + \Sigma M_A = 0;\quad 300(9.81)(1.5) - 1.18(10^3)(9.81)(0.6) + N_B(0.75) = 0$

$N_B = 3374.6\text{ N} = 3.37\text{ kN}$ (Both wheels) **Ans.**

$+\uparrow \Sigma F_y = 0;\quad 3374.6 - 300(9.81) - 1.18(10^3)(9.81) + N_A = 0$

$N_A = 11.1\text{ kN}$ (Both wheels) **Ans.**

Upper member:

$\circlearrowleft + \Sigma M_E = 0;\quad 300(9.81)(2.75) - F_{CD}\sin 30°(1.25) = 0$

$F_{CD} = 12\,949\text{ N} = 12.9\text{ kN}$

$F'_{CD} = \dfrac{F_{CD}}{2} = \dfrac{12\,949}{2} = 6.47\text{ kN}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0;\quad E_x - 12\,949\cos 30° = 0$

$E_x = 11\,214\text{ N}$

$+\uparrow \Sigma F_y = 0;\quad -E_y - 300(9.81) + 12\,949\sin 30° = 0$

$E_y = 3532\text{ N}$

$F_E = \sqrt{(11\,214)^2 + (3532)^2} = 11\,757\text{ N}$

Since there are two members,

$F'_E = \dfrac{F_E}{2} = \dfrac{11\,757}{2} = 5.88\text{ kN}$ **Ans.**

Ans:
$N_B = 3.37\text{ kN}$ (Both wheels)
$N_A = 11.1\text{ kN}$ (Both wheels)
$F'_{CD} = 6.47\text{ kN}$
$F'_E = 5.88\text{ kN}$

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***5–56.**

Determine the force **P** on the cable if the spring is compressed 0.5 in. when the mechanism is in the position shown. The spring has a stiffness of $k = 800$ lb/ft.

SOLUTION

$$F_E = ks = 800\left(\frac{0.5}{12}\right) = 33.33 \text{ lb}$$

$\circlearrowleft + \Sigma M_A = 0;$ $\quad B_x(6) + B_y(6) - 33.33(30) = 0$

$B_x + B_y = 166.67$ lb **(1)**

$\circlearrowleft + \Sigma M_D = 0;$ $\quad B_y(6) - P(4) = 0$

$B_y = 0.6667P$ **(2)**

$\xrightarrow{+} \Sigma F_x = 0;$ $\quad -B_x + F_{CD}\cos 30° = 0$ **(3)**

$\circlearrowleft + \Sigma M_B = 0;$ $\quad F_{CD}\sin 30°(6) - P(10) = 0$

$F_{CD} = 3.333\,P$

Thus from Eq. (3)

$B_x = 2.8867\,P$

Using Eqs. (1) and (2):

$2.8867\,P + 0.6667\,P = 166.67$

$P = 46.9$ lb **Ans.**

Ans:
$P = 46.9$ lb

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5–57.

The spring has an unstretched length of 0.3 m. Determine the angle θ for equilibrium if the uniform bars each have a mass of 20 kg.

SOLUTION

Free-Body Diagram. The assembly is being dismembered into members AB and BC, of which their respective FBD are shown in Fig. b and a. Here, the spring stretches $x = 2(2\sin\theta) - 0.3 = 4\sin\theta - 0.3$. Thus, $F_{SP} = kx = 150\,(4\sin\theta - 0.3) = 600\sin\theta - 45$.

Equations of Equilibrium. Considered the equilibrium of member BC, Fig. a,

$$\circlearrowleft + \Sigma M_C = 0; \qquad B_y(2\cos\theta) - B_x(2\sin\theta) - 20(9.81)\cos\theta = 0 \qquad \textbf{(1)}$$

Also, member AB, Fig. b,

$$\circlearrowleft + \Sigma M_A = 0; \qquad -B_y(2\cos\theta) - B_x(2\sin\theta) - 20(9.81)\cos\theta = 0 \qquad \textbf{(2)}$$

$$+\uparrow \Sigma F_y = 0; \qquad (600\sin\theta - 45) - 20(9.81) - B_y = 0 \qquad \textbf{(3)}$$

Solving Eq. (1) and (2),

$$B_y = 0 \quad B_x = -\frac{9.81\cos\theta}{\sin\theta}$$

Substitute the result of $B_y = 0$ into Eq. (3).

$$600\sin\theta - 45 - 20(9.81) = 0$$

$$\sin\theta = 0.402$$

$$\theta = 23.7^\circ \qquad \textbf{Ans.}$$

Ans:
$\theta = 23.7^\circ$

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5–58.

The spring has an unstretched length of 0.3 m. Determine the mass m of each uniform bar if each angle $\theta = 30°$ for equilibrium.

SOLUTION

Free-Body Diagram. The assembly is being dismembered into members AB and BC, of which their respective FBD are shown in Fig. b and a. Here, the spring stretches $x = 2(2 \sin 30°) - 0.3 = 1.7$ m. Thus, $F_{SP} = kx = 150(1.7) = 255$ N.

Equations of Equilibrium. Consider the equilibrium of member BC, Fig. a.

$$\circlearrowleft + \Sigma M_C = 0; \qquad B_x(2 \sin 30°) + B_y(2 \cos 30°) - \text{m}(9.81) \cos 30° = 0 \qquad \textbf{(1)}$$

Also, member AB, Fig. b,

$$\circlearrowleft + \Sigma M_A = 0; \qquad B_x(2 \sin 30°) - B_y(2 \cos 30°) - \text{m}(9.81) \cos 30° = 0 \qquad \textbf{(2)}$$

$$+\uparrow \Sigma F_y = 0; \qquad 255 - \text{m}(9.81) - B_y = 0 \qquad \textbf{(3)}$$

Solving Eqs. (1) and (2),

$$B_x = 8.4957 \text{ m} \quad B_y = 0$$

Substitute the result of $B_y = 0$ into Eq. (3).

$$255 - m(9.81) = 0$$

$$m = 26.0 \text{ kg} \qquad \textbf{Ans.}$$

Ans:
$m = 26.0$ kg

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5–59.

The piston C moves vertically between the two smooth walls. If the spring has a stiffness of $k = 15\ \text{lb/in.}$, and is unstretched when $\theta = 0°$, determine the couple moment that must be applied to AB to hold the mechanism in equilibrium when $\theta = 30°$.

SOLUTION

Geometry:

$$\frac{\sin\psi}{8} = \frac{\sin 30°}{12} \qquad \psi = 19.47°$$

$$\phi = 180° - 30° - 19.47 = 130.53°$$

$$\frac{l'_{AC}}{\sin 130.53°} = \frac{12}{\sin 30°} \qquad l'_{AC} = 18.242\ \text{in.}$$

Free-Body Diagram: The solution for this problem will be simplified if one realizes that member CB is a two-force member. Since the spring stretches $x = l_{AC} - l'_{AC} = 20 - 18.242 = 1.758\ \text{in}$, the spring force is $F_{sp} = kx = 15\,(1.758) = 26.37\ \text{lb}$.

Equations of Equilibrium: Using the method of joints [FBD (a)],

$$+\uparrow \Sigma F_y = 0; \qquad F_{CB}\cos 19.47° - 26.37 = 0$$

$$F_{CB} = 27.97\ \text{lb}$$

From FBD (b),

$$\circlearrowleft + \Sigma M_A = 0; \qquad 27.97\cos 40.53°\,(8) - M = 0$$

$$M = 170.08\ \text{lb}\cdot\text{in} = 14.2\ \text{lb}\cdot\text{ft} \qquad \textbf{Ans.}$$

Ans:
$M = 14.2\ \text{lb}\cdot\text{ft}$

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***5–60.**

The platform scale consists of a combination of third and first class levers so that the load on one lever becomes the effort that moves the next lever. Through this arrangement, a small weight can balance a massive object. If $x = 450$ mm, determine the required mass of the counterweight S required to balance the load L having a mass of 90 kg.

SOLUTION

Equations of Equilibrium: Applying the moment equation of equilibrium about point A to the free-body diagram of member AB in Fig. *a*,

$$\circlearrowleft + \Sigma M_A = 0; \qquad F_{BG}(500) - 90(9.81)(150) = 0$$

$$F_{BG} = 264.87 \text{ N}$$

Using the result of F_{BG} and writing the moment equation of equilibrium about point F on the free-body diagram of member EFG in Fig. *b*,

$$\circlearrowleft + \Sigma M_F = 0; \qquad F_{ED}(250) - 264.87(150) = 0$$

$$F_{ED} = 158.922 \text{ N}$$

Using the result of F_{ED} and writing the moment equation of equilibrium about point C on the free-body diagram of member CDI in Fig. *c*,

$$\circlearrowleft + \Sigma M_C = 0; \qquad 158.922(100) - m_S(9.81)(950) = 0$$

$$m_S = 1.705 \text{ kg} = 1.71 \text{ kg} \qquad \textbf{Ans.}$$

Ans:
$m_S = 1.71$ kg

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5–61.

The platform scale consists of a combination of third and first class levers so that the load on one lever becomes the effort that moves the next lever. Through this arrangement, a small weight can balance a massive object. If $x = 450$ mm, and the mass of the counterweight S is 2 kg, determine the mass of the load L required to maintain the balance.

SOLUTION

Equations of Equilibrium: Applying the moment equation of equilibrium about point A to the free-body diagram of member AB in Fig. a,

$$\circlearrowleft + \Sigma M_A = 0; \qquad F_{BG}(500) - M_L(9.81)(150) = 0$$

$$F_{BG} = 2.943 \text{ lb}$$

Using the result of F_{BG} and writing the moment equation of equilibrium about point F on the free-body diagram of member EFG in Fig. b,

$$\circlearrowleft + \Sigma M_F = 0; \qquad F_{ED}(250) - 2.943 m_L(150) = 0$$

$$F_{ED} = 1.7658 m_L$$

Using the result of F_{ED} and writing the moment equation of equilibrium about point C on the free-body diagram of member CDI in Fig. c,

$$\circlearrowleft + \Sigma M_C = 0; \qquad 1.7658 m_L(100) - 2(9.81)(950) = 0$$

$$m_L = 105.56 \text{ kg} = 106 \text{ kg} \qquad \textbf{Ans.}$$

Ans:
$m_L = 106$ kg

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***R5–4.**

Determine the force in members *GF*, *FB*, and *BC* of the *Fink truss* and state if the members are in tension or compression.

SOLUTION

Support Reactions: Due to symmetry,

$+\uparrow \Sigma F_y = 0;\qquad 2A_y - 800 - 600 - 800 = 0 \qquad A_y = 1100 \text{ lb}$

$\xrightarrow{+} \Sigma F_x = 0;\qquad A_x = 0$

Method of Sections:

$\circlearrowleft + \Sigma M_B = 0;\qquad F_{GF} \sin 30°(10) + 800(10 - 10\cos^2 30°) - 1100(10) = 0$

$F_{GF} = 1800 \text{ lb (C)} = 1.80 \text{ kip (C)}$ **Ans.**

$\circlearrowleft + \Sigma M_A = 0;\qquad F_{FB} \sin 60°(10) - 800(10\cos^2 30°) = 0$

$F_{FB} = 692.82 \text{ lb (T)} = 693 \text{ lb (T)}$ **Ans.**

$\circlearrowleft + \Sigma M_F = 0;\qquad F_{BC}(15 \tan 30°) + 800(15 - 10\cos^2 30°) - 1100(15) = 0$

$F_{BC} = 1212.43 \text{ lb (T)} = 1.21 \text{ kip (T)}$ **Ans.**

Ans:
$F_{GF} = 1.80$ kip (C)
$F_{FB} = 693$ lb (T)
$F_{BC} = 1.21$ kip (T)

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***R5–8.**

Determine the resultant forces at pins B and C on member ABC of the four-member frame.

SOLUTION

$\circlearrowleft + \Sigma M_F = 0; \qquad F_{CD}(7) - \frac{4}{5}F_{BE}(2) = 0$

$\circlearrowleft + \Sigma M_A = 0; \qquad -150(7)(3.5) + \frac{4}{5}F_{BE}(5) - F_{CD}(7) = 0$

$F_{BE} = 1531 \text{ lb} = 1.53 \text{ kip}$ **Ans.**

$F_{CD} = 350 \text{ lb}$ **Ans.**

Ans:
$F_{BE} = 1.53$ kip
$F_{CD} = 350$ lb