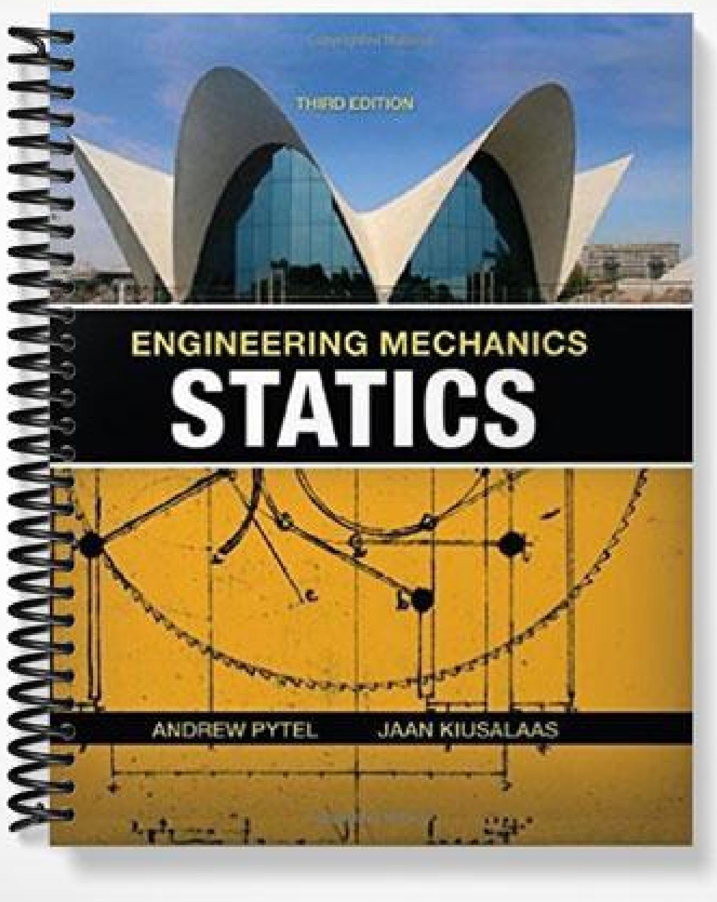
SOLUTIONS MANUAL



Chapter 2

2.1

The resultant of each force system is 500N ↑.

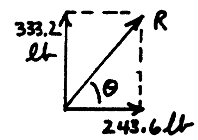
Each resultant force has the same line of action as the the force in (a), except (f) and (h)

Therefore (b), (c), (d), (e) and (g) are equivalent to (a) ◄

2.2

$$R_x = \Sigma F_x : \overset{+}{\rightarrow} \quad R_x = 300 \cos 70^\circ + 150 \cos 20^\circ = 243.6 \text{ lb}$$

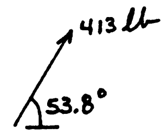
$$R_y = \Sigma F_y : +\uparrow \quad R_y = 300 \sin 70^\circ + 150 \sin 20^\circ = 333.2 \text{ lb}$$



$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{243.6^2 + 333.2^2} = 413 \text{ lb}$$

$$\theta = \tan^{-1}\left(\frac{333.2}{243.6}\right) = 53.8^\circ$$

R =

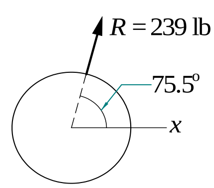


◆

2.3

$$\begin{aligned} R_x &= \Sigma F_x = -T_1 \cos 60^\circ + T_3 \cos 40^\circ \\ &= -110 \cos 60^\circ + 150 \cos 40^\circ = 59.91 \text{ lb} \\ R_y &= \Sigma F_y = T_1 \sin 60^\circ + T_2 + T_3 \sin 40^\circ \\ &= 110 \sin 60^\circ + 40 + 150 \sin 40^\circ = 231.7 \text{ lb} \end{aligned}$$

$$\begin{aligned} R &= \sqrt{59.91^2 + 231.7^2} = 239 \text{ lb} \quad ◄ \\ \theta &= \tan^{-1} \frac{231.7}{59.91} = 75.5^\circ \quad ◄ \end{aligned}$$



2.4

$$\begin{aligned} R_x &= \Sigma F_x \qquad + \longrightarrow \quad 85 = -30 + P\cos\theta + 40\cos 60^\circ \\ &\therefore \quad P\cos\theta = 95.0 \text{ kN} \\ R_y &= \Sigma F_y \qquad + \uparrow \quad 20 = P\sin\theta - 40\sin 60^\circ \\ &\therefore \quad P\sin\theta = 54.64 \text{ kN} \end{aligned}$$

$$\therefore \quad P = \sqrt{95.0^2 + 54.64^2} = 109.6 \text{ kN} \blacktriangleleft$$

$$\therefore \quad \theta = \tan^{-1}\frac{54.64}{95.0} = 29.9^\circ \blacktriangleleft$$

2.5

$\mathbf{R_x = \Sigma F_x}$: $+\swarrow$ $\mathbf{R_x = 40.0}$ **N**

$\mathbf{R_y = \Sigma F_y}$: $\overset{+}{\rightarrow}$ $\mathbf{R_y = -60\dfrac{120}{\sqrt{100^2 + 120^2}} = -46.1}$ **N**

$\mathbf{R_z = \Sigma F_z}$: $+\uparrow$ $\mathbf{R_z = 30 + 60\dfrac{100}{\sqrt{100^2 + 120^2}} = 68.4}$ **N**

$\therefore$ $\mathbf{R = 40.0\,i - 46.1\,j + 68.4\,k}$ **N acting through (0, 120 mm, 0)** ♦

2.6

(a) $\mathbf{P_1 = 110j}$ **lb** $\mathbf{P_2 = -200\cos 25^\circ i + 200\sin 25^\circ j = -181.26i + 84.52j}$ **lb**

$\mathbf{P_3 = -150\cos 40^\circ i + 150\sin 40^\circ k = -114.91i + 96.42k}$ **lb**

$\mathbf{R = \Sigma P = (-181.26 - 114.91)i + (110 + 84.52)j + 96.42k}$

$\mathbf{= -296.17i + 194.52j + 96.42k}$ **lb**

$\therefore$ $\mathbf{R = \sqrt{(-296.17)^2 + 194.52^2 + 96.42^2} = 367.2}$ **lb** ♦

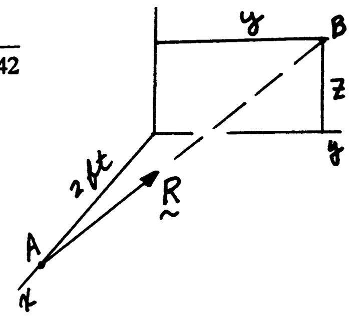
$$\frac{\overline{AB}_x}{|R_x|} = \frac{\overline{AB}_y}{|R_y|} = \frac{\overline{AB}_z}{|R_z|} : \quad \frac{2}{296.17} = \frac{y}{194.52} = \frac{z}{96.42}$$

$$y = \frac{2(194.52)}{296.17} = 1.314 \text{ ft}$$

$$z = \frac{2(96.42)}{296.17} = 0.651 \text{ ft}$$

$\therefore$ **R** passes through the point

(b) (0, 1.314 ft, 0.651 ft) ◆



2.7

$$\mathbf{R} = (-P_2\cos 25^\circ - P_3\cos 40^\circ)\mathbf{i} + (P_1 + P_2\sin 25^\circ)\mathbf{j} + P_3\sin 40^\circ\mathbf{k}$$

$$= -600\mathbf{i} + 500\mathbf{j} + 300\mathbf{k} \text{ lb}$$

Equating like coefficients:

$$0.9063P_2 + 0.7660P_3 = 600 \text{ lb}$$

$$P_1 + 0.4226P_2 = 500 \text{ lb}$$

$$0.6428P_3 = 300 \text{ lb}$$

Solving gives: $P_1 = 386.9$ lb ◆

$P_2 = 267.6$ lb ◆

$P_3 = 466.7$ lb ◆

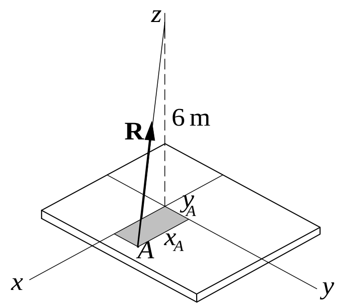
2.8

$$\mathbf{T}_1 = 100\frac{-\mathbf{i} + 2\mathbf{j} + 6\mathbf{k}}{\sqrt{(-1)^2 + 2^2 + 6^2}} = -15.617\mathbf{i} + 31.23\mathbf{j} + 93.70\mathbf{k} \text{ kN}$$

$$\mathbf{T}_2 = 80\frac{-2\mathbf{i} - 3\mathbf{j} + 6\mathbf{k}}{\sqrt{(-2)^2 + (-3)^2 + 6^2}} = -22.86\mathbf{i} - 34.29\mathbf{j} + 68.57\mathbf{k} \text{ kN}$$

$$\mathbf{T}_3 = 50\frac{2\mathbf{i} - 3\mathbf{j} + 6\mathbf{k}}{\sqrt{2^2 + (-3)^2 + 6^2}} = 14.286\mathbf{i} - 21.43\mathbf{j} + 42.86\mathbf{k} \text{ kN}$$

$$\mathbf{R} = \mathbf{T}_1 + \mathbf{T}_2 + \mathbf{T}_3 = (-15.617 - 22.86 + 14.286)\mathbf{i}$$
$$+(31.23 - 34.29 - 21.43)\mathbf{j} + (93.70 + 68.57 + 42.86)\mathbf{k}$$
$$= -24.19\mathbf{i} - 24.49\mathbf{j} + 205.1\mathbf{k} \text{ kN} \blacktriangleleft$$



Let $\mathbf{R}$ intersect the plate at point A. Using proportions:

$$\frac{x_A}{-R_x} = \frac{y_A}{-R_y} = \frac{6}{R_z} \qquad \frac{x_A}{24.19} = \frac{y_A}{24.49} = \frac{6}{205.1}$$
$$\therefore x_A = 0.708 \text{ m} \blacktriangleleft \qquad y_A = 0.716 \text{ m} \blacktriangleleft$$

2.9

$$\mathbf{T}_1 = T_1 \frac{-\mathbf{i} + 2\mathbf{j} + 6\mathbf{k}}{\sqrt{(-1)^2 + 2^2 + 6^2}} = T_1(-0.15617\mathbf{i} + 0.3123\mathbf{j} + 0.9370\mathbf{k})$$
$$\mathbf{T}_2 = T_2 \frac{-2\mathbf{i} - 3\mathbf{j} + 6\mathbf{k}}{\sqrt{(-2)^2 + (-3)^2 + 6^2}} = T_2(-0.2857\mathbf{i} - 0.4286\mathbf{j} + 0.8571\mathbf{k})$$
$$\mathbf{T}_3 = T_3 \frac{2\mathbf{i} - 3\mathbf{j} + 6\mathbf{k}}{\sqrt{2^2 + (-3)^2 + 6^2}} = T_3(0.2857\mathbf{i} - 0.4286\mathbf{j} + 0.8571\mathbf{k})$$

$$\mathbf{T}_1 + \mathbf{T}_2 + \mathbf{T}_3 = \mathbf{R}$$

Equating like components, we get

$$-0.15617T_1 - 0.2857T_2 + 0.2857T_3 = 0$$
$$0.3123T_1 - 0.4286T_2 - 0.4286T_3 = 0$$
$$0.9370T_1 + 0.8571T_2 + 0.8571T_3 = 210$$

Solution is

$$T_1 = 134.5 \text{ kN} \blacktriangleleft \qquad T_2 = 12.24 \text{ kN} \blacktriangleleft \qquad T_3 = 85.8 \text{ kN} \blacktriangleleft$$

2.10

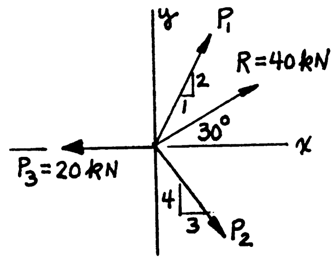
$R_x = \Sigma F_x$: $\overset{+}{\rightarrow}$ $\frac{1}{\sqrt{5}} P_1 + \frac{3}{5} P_2 - 20 = 40 \cos 30^\circ$ (1)

$R_y = \Sigma F_y$: $+\uparrow$ $\frac{2}{\sqrt{5}} P_1 - \frac{4}{5} P_2 = 40 \sin 30^\circ$ (2)

Solving (1) and (2) gives:

$P_1 = 62.3$ kN ◆

$P_2 = 44.6$ kN ◆

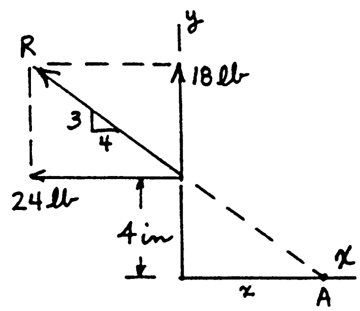


2.11

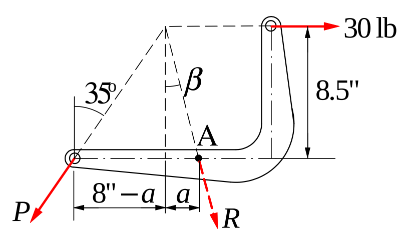
$R = \sqrt{24^2 + 18^2} = 30$ lb ◆

Using similar triangles:

$\frac{3}{4} = \frac{4}{x}$ $\quad \therefore\ x = \frac{16}{3} = 5.33$ in. ◆



2.12



First find the direction of **R** from geometry (the 3 forces must intersect at a common point).

$$8 - a = 8.5 \tan 35^\circ \qquad \therefore a = 2.048 \text{ in.}$$

$$\beta = \tan^{-1} \frac{a}{8.5} = \tan^{-1} \frac{2.048}{8.5} = 13.547^\circ$$

$$R_x = \Sigma F_x \qquad + \longrightarrow \quad R \sin 13.547^\circ = -P \sin 35^\circ + 30$$

$$R_y = \Sigma F_y \qquad + \downarrow \quad R \cos 13.547^\circ = P \cos 35^\circ$$

Solution is

$P = 38.9$ lb ◄ $\qquad R = 32.8$ lb ◄

2.13

By inspection:

$R_x = \Sigma F_x = 0$ ♦ $R_y = \Sigma F_y = 0$ ♦

$R_z = \Sigma F_z = (20 + 20 + 15 + 15)\sin 75^{\circ} = 67.6$ lb ♦

Point on line of action is the center of the plate ♦

2.14

$$\begin{aligned}
\mathbf{P}_1 &= 100\frac{3\mathbf{i}+4\mathbf{k}}{\sqrt{3^2+4^2}} = 60\mathbf{i}+80\mathbf{k} \text{ lb} \\
\mathbf{P}_2 &= 120\frac{3\mathbf{i}+3\mathbf{j}+4\mathbf{k}}{\sqrt{3^2+3^2+4^2}} = 61.74\mathbf{i}+61.74\mathbf{j}+82.32\mathbf{k} \text{ lb} \\
\mathbf{P}_3 &= 60\mathbf{j} \text{ lb}
\end{aligned}$$

$$\begin{aligned}
\mathbf{Q}_1 &= Q_1\mathbf{i} \\
\mathbf{Q}_2 &= Q_2\frac{-3\mathbf{i}-3\mathbf{j}}{\sqrt{3^2+3^2}} = Q_2\left(-0.7071\mathbf{i}-0.7071\mathbf{j}\right) \\
\mathbf{Q}_3 &= Q_3\frac{3\mathbf{j}+4\mathbf{k}}{\sqrt{3^2+4^2}} = Q_3(0.6\mathbf{j}+0.8\mathbf{k})
\end{aligned}$$

Equating similar components of $\Sigma\mathbf{Q} = \Sigma\mathbf{P}$:

$$\begin{aligned}
Q_1 - 0.7071Q_2 &= 60 + 61.74 \\
-0.7071Q_2 + 0.6Q_3 &= 61.74 + 60 \\
0.8Q_3 &= 80 + 82.32
\end{aligned}$$

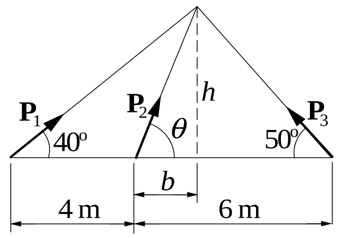
Solution is

$$Q_1 = 121.7 \text{ lb} \blacktriangleleft \qquad Q_2 = 0 \qquad Q_3 = 203 \text{ lb} \blacktriangleleft$$

2.15

$$\begin{aligned}
R_x &= \Sigma F_x \quad \overset{+}{\longrightarrow} \quad 10 = 50\sin 45^{\circ} - Q\sin 30^{\circ} \qquad Q = 50.71 \text{ lb} \\
R_y &= \Sigma F_y \quad +\uparrow \quad 0 = 50\cos 45^{\circ} - W + 50.71\cos 30^{\circ} \\
\therefore &\ W = 79.3 \text{ lb} \blacktriangleleft
\end{aligned}$$

2.16



The forces must be concurrent. From geometry:

$$h = (4+b)\tan 40^\circ = (6-b)\tan 50^\circ \qquad \therefore b = 1.8682 \text{ m} \blacktriangleleft$$
$$\therefore \quad h = (4+1.8682)\tan 40^\circ = 4.924 \text{ m}$$
$$\theta = \tan^{-1}\frac{h}{b} = \tan^{-1}\frac{4.924}{1.8682} = 69.22^\circ \blacktriangleleft$$

$$\begin{aligned}\mathbf{R} = \Sigma\mathbf{F} &= (25\cos 40^\circ + 60\cos 69.22^\circ - 80\cos 50^\circ)\mathbf{i} \\ &\quad + (25\sin 40^\circ + 60\sin 69.22^\circ + 80\sin 50^\circ)\mathbf{j} \\ &= -10.99\mathbf{i} + 133.45\mathbf{j} \text{ kN} \blacktriangleleft\end{aligned}$$

2.17

The three forces intersect at C.

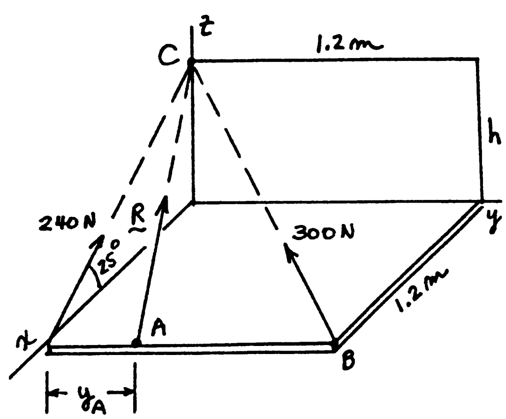
$h = 1.2 \tan 25^\circ = 0.5596$ **m**

For the 240-N force :

$-240(\cos 25^\circ\, \mathbf{i} - \sin 25^\circ\, \mathbf{k}) =$
$-217.5\,\mathbf{i} + 101.4\,\mathbf{k}$ **N**

For the 300-N force $\left(300\ \vec{\lambda}_{BC}\right)$:

$$300\left(\frac{-1.2\,\mathbf{i} - 1.2\,\mathbf{j} + 0.5596\,\mathbf{k}}{1.787}\right) =$$
$-201.5\,\mathbf{i} - 201.5\,\mathbf{j} + 93.95\,\mathbf{k}$ **N**



$\mathbf{R} = \Sigma\mathbf{F}$
$= (-217.5 - 201.5)\mathbf{i} - 201.5\,\mathbf{j} + (101.4 + 93.95)\mathbf{k} = -419.0\,\mathbf{i} - 201.5\,\mathbf{j} + 195.4\,\mathbf{k}$ **N** ♦

Since R acts along $\overline{AC}$: $\dfrac{|R_y|}{y_A} = \dfrac{|R_x|}{1.2} \qquad \therefore y_A = \dfrac{|R_y|}{|R_x|}(1.2) = \dfrac{201.5}{419.0}(1.2) = 0.577$ **m** ♦

2.18

$$\mathbf{T}_1 = 200\left(\frac{3\mathbf{i}-2\mathbf{j}-6\mathbf{k}}{7}\right) = 85.71\mathbf{i} - 57.14\mathbf{j} - 171.43\mathbf{k} \text{ lb}$$

$$\mathbf{T}_2 = 400\left(\frac{3\mathbf{j}-6\mathbf{k}}{\sqrt{45}}\right) = 178.89\mathbf{j} - 357.77\mathbf{k} \text{ lb}$$

$$\mathbf{T}_3 = 350\left(\frac{-4\mathbf{i}-6\mathbf{k}}{\sqrt{52}}\right) = -194.15\mathbf{i} - 291.22\mathbf{k} \text{ lb}$$

$$\mathbf{R} = \Sigma\mathbf{T} = (85.71 - 194.15)\mathbf{i} + (-57.14 + 178.89)\mathbf{j} + (-171.43 - 357.77 - 291.22)\mathbf{k}$$

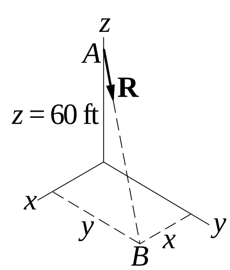
$$\therefore \ \mathbf{R} = -108.4\mathbf{i} + 121.8\mathbf{j} - 820.4\mathbf{k} \text{ lb (acting through point A)} \ \blacklozenge$$

2.19

(a)

$$\begin{aligned} R_x &= \Sigma F_x = 160\sin 30^\circ \cos 50^\circ = 51.42 \text{ lb} \\ R_y &= \Sigma F_y = -80\sin 30^\circ + 160\sin 30^\circ \sin 50^\circ = 21.28 \text{ lb} \\ R_z &= \Sigma F_z = -120 - 80\cos 30^\circ - 160\cos 30^\circ = -327.8 \text{ lb} \\ R &= \sqrt{51.42^2 + 21.28^2 + (-327.8)^2} = 332.5 \text{ lb} \ \blacktriangleleft \end{aligned}$$

(b)

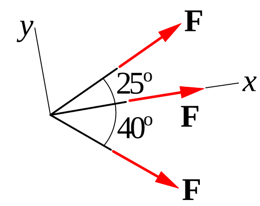


$$\frac{R_x}{x} = \frac{R_y}{y} = \frac{-R_z}{z} \qquad \frac{51.42}{x} = \frac{21.28}{y} = \frac{327.8}{60}$$

$$x = \frac{51.42(60)}{327.8} = 9.41 \text{ ft} \ \blacktriangleleft \qquad y = \frac{21.28(60)}{327.8} = 3.90 \text{ ft} \ \blacktriangleleft$$

2.20

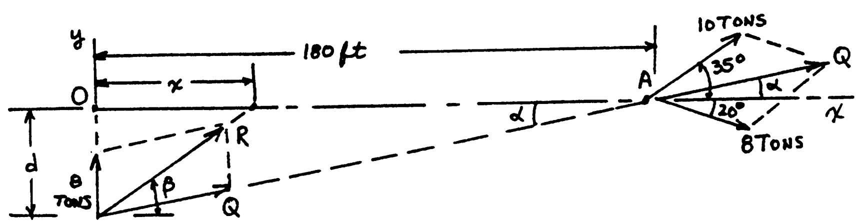
Choose the line of action of the middle force as the x-axis.



$$R_x = \Sigma F_x = F(\cos 25° + 1 + \cos 40°) = 2.672F$$
$$R_y = \Sigma F_y = F(\sin 25° - \sin 40°) = -0.2202F$$

$$R = F\sqrt{2.672^2 + (-0.2202)^2} = 2.681F$$
$$600 = 2.681F \qquad \therefore F = 234 \text{ lb} \blacktriangleleft$$

*2.21



Let **Q** be the resultant of the two forces at **A**.

$\overset{+}{\rightarrow}$ $Q_x = \Sigma F_x = 10 \cos 35^o + 8 \cos 20^o = 15.71$ tons

$+\uparrow$ $Q_y = \Sigma F_y = 10 \sin 35^o - 8 \sin 20^o = 3.00$ tons

$\therefore$ $\tan \alpha = Q_y/Q_x = 3.00/15.71 = 0.1910$

Let **R** be the resultant of **Q** and the 8-ton vertical force.

$\overset{+}{\rightarrow}$ $R_x = \Sigma F_x = Q_x = 15.71$ tons

$+\uparrow$ $R_y = \Sigma F_y = 8 + Q_y = 8 + 3 = 11$ tons

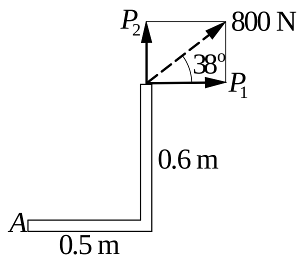
$\therefore$ $\mathbf{R} = 15.71\,\mathbf{i} + 11.00\,\mathbf{j}$ tons ♦

(Note that $\tan \beta = R_y/R_x = 11.00/15.71 = 0.7002$)

To find x: $d = 180 \tan \alpha = 180(0.1910) = 34.38$ ft

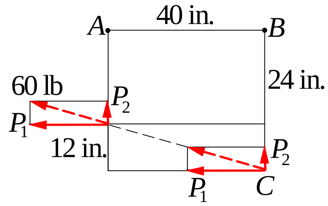
$x = d/\tan \beta = 34.38/0.7002 = 49.1$ ft ♦

2.22



$$\begin{aligned} +\circlearrowleft \quad M_A &= -0.6P_1 + 0.5P_2 \\ &= -0.6(800\cos 38°) + 0.5(800\sin 38°) = -132.0 \text{ N}\cdot\text{m} \\ \therefore &\quad M_A = 132.0 \text{ N}\cdot\text{m} \circlearrowright \quad \blacktriangleleft \end{aligned}$$

2.23



$$P_1 = 60\frac{40}{\sqrt{40^2 + 12^2}} = 57.47 \text{ lb}$$

With the force in the original position:

$$M_A = 24P_1 = 24(57.47) = 1379 \text{ lb}\cdot\text{in.} \circlearrowleft \quad \blacktriangleleft$$

With the force moved to point C:

$$M_B = 36P_1 = 36(57.47) = 2070 \text{ lb}\cdot\text{in.} \circlearrowleft \blacktriangleleft$$

2.24

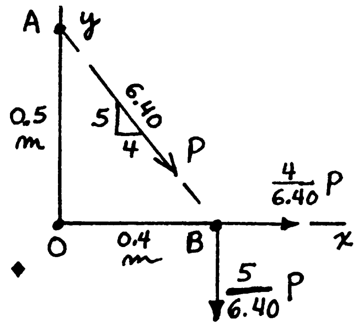
$$\mathbf{R} = P\mathbf{j} + P\frac{-2.5\mathbf{i} + 3.5\mathbf{j}}{\sqrt{(-2.5)^2 + 3.5^2}} = P\left(-0.5812\mathbf{i} + 1.8137\mathbf{j}\right)$$

Choosing C as the moment center, the combined moment of the two forces is $M_C = 2.5P$ and the moment of $\mathbf{R}$ is $M_C = R_y b$. Equating the moments, we get

$$2.5P = b\,(1.8137P) \qquad \therefore b = 1.378 \text{ m} \quad \blacktriangleleft$$

2.25

Since M_A and M_B equal zero, the force P passes through A and B, as shown.



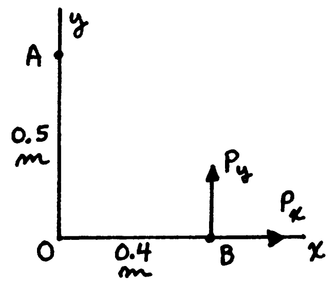
$$\circlearrowleft + \quad M_O = -\frac{5}{6.40}P(0.4) = -200 \text{ kN}\bullet\text{m}$$

$$\therefore P = 640 \text{ N}$$

$$\mathbf{P} = \frac{4}{6.40}(640)\mathbf{i} - \frac{5}{6.40}(640)\mathbf{j} = 400\mathbf{i} - 500\mathbf{j} \text{ N} \ \blacklozenge$$

2.26

Since $M_B = 0$, **P** passes though B.



$$\circlearrowleft + \quad M_O = 0.4 P_y = 80 \text{ N}\bullet\text{m}$$

$$P_y = 200 \text{ N}$$

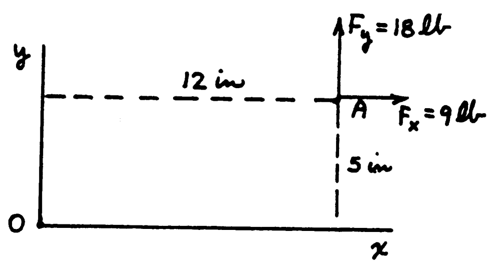
$$\circlearrowleft + \quad M_A = 0.4(200) + 0.5 P_x = -200 \text{ N}\bullet\text{m}$$

$$P_x = -280/0.5 = -560 \text{ N}$$

$$\therefore \mathbf{P} = -560\mathbf{i} + 200\mathbf{j} \text{ N} \ \blacklozenge$$

2.27

$\mathbf{F} = 9\,\mathbf{i} + 18\,\mathbf{j}$ lb



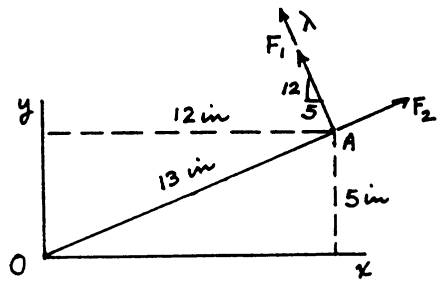
(a) $$\mathbf{M}_O = \mathbf{r}_{OA} \times \mathbf{F} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 12 & 5 & 0 \\ 9 & 18 & 0 \end{vmatrix}$$

$$= \mathbf{k}\left[18(12) - 5(9)\right] = 171\,\mathbf{k} \text{ lb}\bullet\text{in.} \ \blacklozenge$$

(b) $\circlearrowleft + \ M_O = 18(12) - 9(5) = 171$ lb•in. $\quad \therefore M_O = 171$ lb•in CCW ♦

(c) Unit vector perpendicular to OA is

$$\vec{\lambda} = -\frac{5}{13}\mathbf{i} + \frac{12}{13}\mathbf{j}$$



$$F_1 = \mathbf{F}\bullet\vec{\lambda}$$

$$= (9\,\mathbf{i} + 18\,\mathbf{j})\bullet\left(-\frac{5}{13}\,\mathbf{i} + \frac{12}{13}\,\mathbf{j}\right)$$

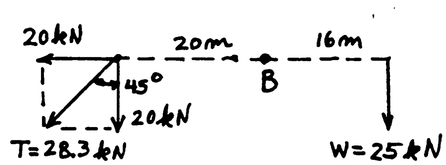
$$= \frac{-45 + 216}{13} = 13.15 \text{ lb}\bullet\text{in.}$$

$\circlearrowleft +$ $M_O = 13\,F_1 = 13(13.15) = 171$ lb•in. $\quad \therefore\ M_O = 171$ lb•in CCW ◆

2.28

(a) For T: $\circlearrowleft +$ $M_B = 20(20) = 400$ kN•m

$\therefore\ M_B = 400$ kN•m CCW ◆



(b) For W: $\circlearrowright +$ $M_B = 25(16) = 400$ kN•m

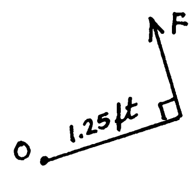
$\therefore\ M_B = 400$ kN•m CW ◆

(c) For T and W: $\circlearrowleft +$ $\Sigma M_B = +400 - 400 = 0$ ◆

2.29

The moment of F about O is maximum

when $\theta = 90^\circ$ ◆



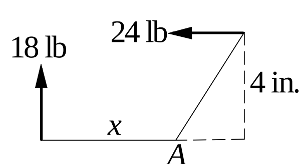
$M_O = F(1.25) = 50$ lb•ft $\quad \therefore\ F = \dfrac{50}{1.25} = 40$ lb ◆

2.30

Note that the horizontal component of **P** has no moment about A. Thus the combined moment about A is

$$+\circlearrowleft \quad 30(8.5) - (P\cos 35^\circ)\,(8) = 0 \qquad \therefore P = 38.9 \text{ lb} \ ◄$$

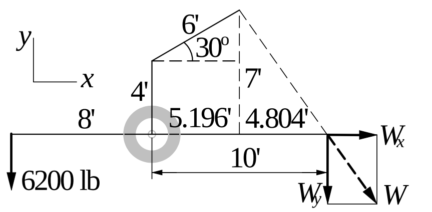
2.31



Because the resultant passes through point A, we have

$$\Sigma M_A = 0 \qquad +\circlearrowleft \quad 24(4) - 18x = 0 \qquad x = 5.33 \text{ in.} \blacktriangleleft$$

2.32

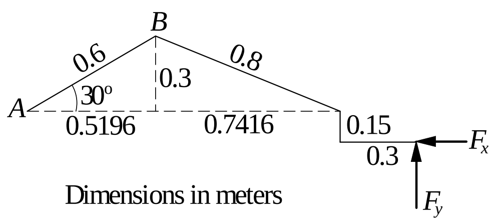


$$W_y = W\frac{7}{\sqrt{7^2 + 4.804^2}} = 0.8245W$$

Largest W occurs when the moment about the rear axle is zero.

$$+ \circlearrowleft \qquad M_{\text{axle}} = 6200(8) - (0.8245W)(10) = 0$$
$$\therefore \quad W = 6020 \text{ lb} \blacktriangleleft$$

2.33



$$\begin{aligned}
+\circlearrowleft \quad M_A &= -F_x(0.15) + F_y(0.5196 + 0.7416 + 0.3) \\
210 &= -0.15F_x + 1.5612F_y \qquad \text{(a)} \\
+\circlearrowleft \quad M_B &= -F_x(0.3 + 0.15) + F_y(0.7416 + 0.3) \\
90 &= -0.45F_x + 1.0416F_y \qquad \text{(b)}
\end{aligned}$$

Solution of Eqs. (a) and (b) is $F_x = 143.2$ N and $F_y = 148.3$ N

$$\therefore \quad F = \sqrt{143.2^2 + 148.3^2} = 206 \text{ N} \blacktriangleleft$$
$$\theta = \tan^{-1}\frac{F_x}{F_y} = \tan^{-1}\frac{143.2}{148.3} = 44.0^\circ \blacktriangleleft$$

2.34

$$\mathbf{P} = 200\frac{-70\mathbf{i} - 100\mathbf{k}}{\sqrt{(-70)^2 + (-100)^2}} = -114.69\mathbf{i} - 163.85\mathbf{k}\ \text{N}$$

$$\mathbf{r} = \overrightarrow{AB} = -0.07\mathbf{i} + 0.09\mathbf{j}\ \text{m}$$

$$\mathbf{M}_A = \mathbf{r}\times\mathbf{P} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -0.07 & 0.09 & 0 \\ -114.69 & 0 & -163.85 \end{vmatrix}$$

$$= -14.75\mathbf{i} - 11.47\mathbf{j} + 10.32\mathbf{k}\ \text{N}\cdot\text{m}\ \blacktriangleleft$$

2.35

$$\mathbf{P} = 100\,\vec{\lambda}_{AB} = 100\left(\frac{-0.500\mathbf{i} - 0.600\mathbf{j} + 0.360\mathbf{k}}{0.860}\right) = -58.14\mathbf{i} - 69.77\mathbf{j} + 41.86\mathbf{k}\ \text{N}$$

(a) $\mathbf{M}_O = \mathbf{r}_{OB}\times\mathbf{P}$ $\quad \mathbf{r}_{OB} = 0.360\mathbf{k}$ m $\quad$ ($\mathbf{r}_{OA}$ is also convenient)

$$\therefore\ \mathbf{M}_O = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 0 & 0.360 \\ -58.14 & -69.77 & 41.86 \end{vmatrix} = 25.11\mathbf{i} - 20.93\mathbf{j}\ \text{N}\bullet\text{m}\ \blacklozenge$$

(b) $\mathbf{M}_C = \mathbf{r}_{CB}\times\mathbf{P}$ $\quad \mathbf{r}_{CB} = -0.600\mathbf{j}$ m $\quad$ ($\mathbf{r}_{CA}$ is also convenient)

$$\therefore\ \mathbf{M}_C = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & -0.600 & 0 \\ -58.14 & -69.77 & 41.86 \end{vmatrix} = -25.12\mathbf{i} - 34.88\mathbf{k}\ \text{N}\bullet\text{m}\ \blacklozenge$$

2.36

$$\mathbf{Q} = 250\,\vec{\lambda}_{BD} = 250\left(\frac{-0.500\mathbf{i} + 0.360\mathbf{k}}{0.6161}\right) = -202.9\,\mathbf{i} + 146.1\,\mathbf{k}\ \text{N}$$

(a) $\mathbf{M}_O = \mathbf{r}_{OB}\times\mathbf{Q}$ $\quad \mathbf{r}_{OB} = 0.360\,\mathbf{k}$ m $\quad$ ($\mathbf{r}_{OD}$ is also convenient)

$$\therefore\ \mathbf{M}_O = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 0 & 0.360 \\ -202.9 & 0 & 146.1 \end{vmatrix} = -73.0\mathbf{j}\ \text{N}\bullet\text{m}\ \blacklozenge$$

(b) $\mathbf{M}_C = \mathbf{r}_{CB}\times\mathbf{Q}$ $\quad \mathbf{r}_{CB} = -0.600\mathbf{j}$ m $\quad$ ($\mathbf{r}_{CD}$ is also convenient)

$$\therefore\ \mathbf{M}_C = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & -0.600 & 0 \\ -202.9 & 0 & 146.1 \end{vmatrix} = -87.7\mathbf{i} - 121.7\mathbf{k}\ \text{N}\bullet\text{m}\ \blacklozenge$$

2.37

$\mathbf{M_O} = \mathbf{r_{OC}} \times \mathbf{P} \qquad \mathbf{r_{OC}} = 2\mathbf{i} + 4\mathbf{j} - 3\mathbf{k}\ \text{m} \qquad \mathbf{P} = P(-\cos 25^\circ \mathbf{i} + \sin 25^\circ \mathbf{k})$

$$\mathbf{M_O} = P\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 2 & 4 & -3 \\ -\cos 25^\circ & 0 & \sin 25^\circ \end{vmatrix} = P(1.6905\mathbf{i} + 1.8737\mathbf{j} + 3.6252\mathbf{k})$$

$$\therefore\ M_O = P\sqrt{1.6905^2 + 1.8737^2 + 3.6252^2} = 4.417P = 200\ \text{kN}\bullet\text{m}$$

which gives $P = 200/4.417 = 45.3$ kN ♦

2.38

$\mathbf{P} = 50(-\cos 25^\circ \mathbf{i} + \sin 25^\circ \mathbf{k}) = -45.32\mathbf{i} + 21.13\mathbf{k}$ kN

(a) $\mathbf{M_A} = \mathbf{r_{AC}} \times \mathbf{P} \qquad \mathbf{r_{AC}} = 4\mathbf{j} - 3\mathbf{k}$ m

$$\therefore\ \mathbf{M_A} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 4 & -3 \\ -45.32 & 0 & 21.13 \end{vmatrix} = 84.52\mathbf{i} + 135.96\mathbf{j} + 181.28\mathbf{k}\ \text{kN}\bullet\text{m}$$

(b) $\mathbf{M_B} = \mathbf{r_{BC}} \times \mathbf{P} \qquad \mathbf{r_{BC}} = 4\mathbf{j}$ m

$$\therefore\ \mathbf{M_B} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 4 & 0 \\ -45.32 & 0 & 21.13 \end{vmatrix} = 84.52\mathbf{i} + 181.28\mathbf{k}\ \text{kN}\bullet\text{m}$$

2.39

$$\mathbf{Q} = 20\vec{\lambda}_{AB} = 20\left(\frac{-3\mathbf{i} + 4\mathbf{j} - 8\mathbf{k}}{9.434}\right) = -6.360\mathbf{i} + 8.480\mathbf{j} - 16.96\mathbf{k}\ \text{lb}$$

(a) $\mathbf{M_O} = \mathbf{r_{OA}} \times \mathbf{Q} \qquad \mathbf{r_{OA}} = 8\mathbf{k}$ ft $\qquad$ ($\mathbf{r_{OB}}$ is also convenient)

$$\therefore\ \mathbf{M_O} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 0 & 8 \\ -6.360 & 8.480 & -16.96 \end{vmatrix} = -67.8\mathbf{i} - 50.9\mathbf{j}\ \text{lb}\bullet\text{ft}$$ ♦

(b) $\mathbf{M}_C = \mathbf{r}_{CB} \times \mathbf{Q}$ $\mathbf{r}_{CB} = -3\mathbf{i}$ ft   ($\mathbf{r}_{CA}$ is also convenient)

$$\therefore \mathbf{M}_C = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -3 & 0 & 0 \\ -6.360 & 8.480 & -16.96 \end{vmatrix} = -50.9\mathbf{j} - 25.4\mathbf{k} \text{ lb}\bullet\text{ft} \;\blacklozenge$$

2.40

Noting that both **P** and **Q** pass through A, we have

$$\mathbf{M}_O = \mathbf{r}_{OA}(\mathbf{P} + \mathbf{Q})$$

$$\begin{aligned} \mathbf{P} &= 80\frac{-4.2\mathbf{i} - 2\mathbf{j} + 2\mathbf{k}}{\sqrt{(-4.2)^2 + (-2)^2 + 2^2}} = -66.36\mathbf{i} - 31.60\mathbf{j} + 31.60\mathbf{k} \text{ lb} \\ \mathbf{Q} &= 60\frac{-2\mathbf{i} - 3\mathbf{j} + 2\mathbf{k}}{\sqrt{(-2)^2 + (-3)^2 + 2^2}} = -29.10\mathbf{i} - 43.66\mathbf{j} + 29.10\mathbf{k} \text{ lb} \end{aligned}$$

$$\mathbf{P} + \mathbf{Q} = -95.46\mathbf{i} - 75.26\mathbf{j} + 60.70\mathbf{k} \text{ lb}$$

$$\therefore \mathbf{M}_O = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 0 & 2 \\ -95.46 & -75.26 & 60.70 \end{vmatrix} = 150.5\mathbf{i} - 190.9\mathbf{j} \text{ lb} \cdot \text{ft} \;\blacktriangleleft$$

2.41

$\mathbf{M}_O = \mathbf{r} \times \mathbf{F}$ $\mathbf{r} = -8\mathbf{i} + 12\mathbf{j}$ in. $\mathbf{F} = -120\mathbf{k}$ lb

$$\therefore \mathbf{M}_O = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -8 & 12 & 0 \\ 0 & 0 & -120 \end{vmatrix} = -1440\mathbf{i} - 960\mathbf{j} \text{ lb}\bullet\text{in.} = -120\mathbf{i} - 80\mathbf{j} \text{ lb}\bullet\text{ft} \;\blacklozenge$$

2.42

$\mathbf{P} = -16\cos 40^\circ\mathbf{i} + 16\sin 40^\circ\mathbf{k} = -12.257\mathbf{i} + 10.285\mathbf{k}$ lb $\qquad \mathbf{Q} = -22.00\mathbf{j}$ lb

$\therefore\ \mathbf{P} + \mathbf{Q} = -12.257\mathbf{i} - 22.00\mathbf{j} + 10.285\mathbf{k}$ lb

$\mathbf{M}_O = \mathbf{r}_{OA} \times (\mathbf{P} + \mathbf{Q}) \qquad \mathbf{r}_{OA} = -(3 + 8\cos 40^\circ)\mathbf{i} + (8\sin 40^\circ)\mathbf{k} = -9.128\mathbf{i} + 5.142\mathbf{k}$ in.

$$\mathbf{M}_O = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -9.128 & 0 & 5.142 \\ -12.257 & -22.00 & 10.285 \end{vmatrix} = 113.12\mathbf{i} + 30.86\mathbf{j} + 200.82\mathbf{k} \text{ lb}\bullet\text{in.}$$

$$M_O = \sqrt{113.12^2 + 30.86^2 + 200.82^2} = 232.5 \text{ lb}\bullet\text{in.} \ \blacklozenge$$

$$\cos\theta_x = \frac{113.12}{232.5} = 0.4865; \quad \cos\theta_y = \frac{30.86}{232.5} = 0.1327; \quad \cos\theta_z = \frac{200.82}{232.5} = 0.8637 \ \blacklozenge$$

2.43

$$\mathbf{M}_O = \mathbf{r} \times \mathbf{F} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ x & 0 & z \\ 50 & -100 & -70 \end{vmatrix} = 100z\mathbf{i} + (70x + 50z)\mathbf{j} - 100x\mathbf{k}$$

Equating the x- and z-components of $\mathbf{M}_O$ to the given values yields

$$\begin{aligned} 100z &= 400 \qquad \therefore z = 4 \text{ ft} \ \blacktriangleleft \\ -100x &= -300 \qquad \therefore x = 3 \text{ ft} \ \blacktriangleleft \end{aligned}$$

Check y-component:

$$70x + 50z = 70(3) + 50(4) = 410 \text{ lb}\cdot\text{ft} \quad \text{O.K.}$$

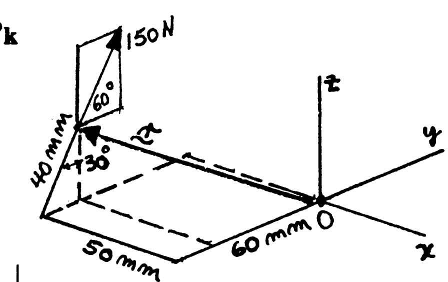
2.44

$\mathbf{r} = -50\mathbf{i} - (60 - 40\sin 30^\circ)\mathbf{j} + 40\cos 30^\circ\mathbf{k}$

$= -50.00\mathbf{i} - 40.00\mathbf{j} + 34.64\mathbf{k}$ mm

$\mathbf{F} = -150\cos 60^\circ\mathbf{j} + 150\sin 60^\circ\mathbf{k}$

$= -75.00\mathbf{j} + 129.90\mathbf{k}$ N



$$\mathbf{M}_O = \mathbf{r} \times \mathbf{F} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -50.00 & -40.00 & 34.64 \\ 0 & -75.00 & 129.90 \end{vmatrix} \left(10^{-3}\right) = -2.598\mathbf{i} + 6.495\mathbf{j} - 3.750\mathbf{k} \text{ N}\bullet\text{m} \ \blacklozenge$$

$$M_O = \sqrt{(-2.598)^2 + (6.495)^2 + (-3.750)^2} = 7.937\ \text{N}\bullet\text{m} \ \blacklozenge$$

$$\cos\theta_x = -\frac{2.598}{7.937} = -0.3273;\ \cos\theta_y = \frac{6.495}{7.937} = 0.8183;\ \cos\theta_z = -\frac{3.750}{7.937} = -0.4725 \ \blacklozenge$$

2.45

$$\mathbf{P}_1 = \frac{P}{\sqrt{2}}(\mathbf{j} - \mathbf{k}) \qquad \mathbf{r}_1 = -d\mathbf{i} \qquad\qquad \mathbf{P}_2 = \frac{P}{\sqrt{3}}(\mathbf{i} + \mathbf{j} - \mathbf{k}) \qquad \mathbf{r}_2 = (a-d)\mathbf{i}$$

$$\mathbf{M}_A = \mathbf{r}_1 \times \mathbf{P}_1 + \mathbf{r}_2 \times \mathbf{P}_2 = \frac{P}{\sqrt{2}}\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -d & 0 & 0 \\ 0 & 1 & -1 \end{vmatrix} + \frac{P}{\sqrt{3}}\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ (a-d) & 0 & 0 \\ 1 & 1 & -1 \end{vmatrix} = \mathbf{0}$$

Canceling P and expanding the determinants gives: $\frac{d}{\sqrt{2}}(-\mathbf{j} - \mathbf{k}) + \frac{a-d}{\sqrt{3}}(\mathbf{j} + \mathbf{k}) = \mathbf{0}$

Equating either the j-components or the k-components yields: $\frac{d}{\sqrt{2}} = \frac{a-d}{\sqrt{3}}$

from which we find: $d = \frac{a\sqrt{2}}{\sqrt{2} + \sqrt{3}} = 0.449a$ ◆

2.46

$$\begin{aligned} \mathbf{M}_B &= \mathbf{r}_{BA} \times \mathbf{F} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 3 & 4-y & 2-z \\ -20 & 4 & 6 \end{vmatrix} \\ &= (-6y + 4z + 16)\mathbf{i} - (58 - 20z)\mathbf{j} + (92 - 20y)\,\mathbf{k} = \mathbf{0} \end{aligned}$$

Setting y- and z-components to zero:

$$\begin{aligned} 58 - 20z &= 0 \qquad z = 2.9 \text{ ft} \ \blacktriangleleft \\ 92 - 20y &= 0 \qquad y = 4.6 \text{ ft} \ \blacktriangleleft \end{aligned}$$

Check x-component:

$$-6y + 4z + 16 = -6(4.6) + 4(2.9) + 16 = 0 \quad \text{O.K.}$$

2.47

(a)

$$
\begin{aligned}
M_x &= -75(0.85) = -63.75 \text{ kN} \cdot \text{m} \blacktriangleleft \\
M_y &= 75(0.5) = 37.5 \text{ kN} \cdot \text{m} \blacktriangleleft \\
M_z &= 160(0.5) - 90(0.85) = 3.5 \text{ kN} \cdot \text{m} \blacktriangleleft
\end{aligned}
$$

(b)

$$
\mathbf{M}_O = \mathbf{r}_{OA} \times \mathbf{F} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0.5 & 0.85 & 0 \\ 90 & 160 & -75 \end{vmatrix} = -63.75\mathbf{i} + 37.5\mathbf{j} + 3.5\mathbf{k} \text{ kN} \cdot \text{m}
$$

The components of $\mathbf{M}_O$ agree with those computed in part (a).

2.48

(a) moment arm is BF $\quad M_{AB} = 40(0.9) = 36$ kN•m ◆

(b) moment arm is DH $\quad M_{CD} = 40(0.9) = 36$ kN•m ◆

(c) moment arm is GH $\quad M_{CG} = 40(0.8) = 32$ kN•m ◆

(d) moment arm is zero $\quad M_{CH} = 0$ ◆

(e) force is parallel to EG $\quad M_{EG} = 0$ ◆

2.49

$$\overline{FG} = \sqrt{9^2 + 7.5^2} = 11.715 \text{ ft}$$

$$P_x = 400\left(\frac{9}{11.715}\right) = 307.3 \text{ lb}$$

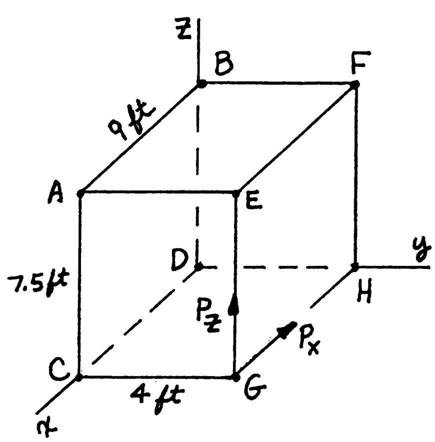
$$P_z = 400\left(\frac{7.5}{11.715}\right) = 256.1 \text{ lb}$$

(a) $M_{AB} = P_z(\overline{AE})\mathbf{i} = 256.1(4)\mathbf{i}$

$= 1024\mathbf{i}$ lb•ft ◆

(b) $M_{CD} = P_z(\overline{CG})\mathbf{i} = 256.1(4)\mathbf{i}$

$= 1024\mathbf{i}$ lb•ft ◆



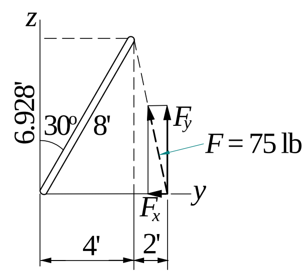
(c) $\mathbf{M}_{BF} = \mathbf{0}$ (because the force passes through F) ◆

(d) $\mathbf{M}_{DH} = -P_z(\overline{GH})\mathbf{j} = -256.1(9)\mathbf{j} = -2305\mathbf{j}$ lb•ft ◆

(e) $\mathbf{M}_{BD} = P_x(\overline{DH})\mathbf{k} = 307.3(4)\mathbf{k} = 1229\mathbf{k}$ lb•ft ◆

2.50

(a)



Only F_y has a moment about x-axis (since F_x intersects x-axis, it has no moment about that axis).

$$F_y = 75\frac{6.928}{\sqrt{6.928^2 + 2^2}} = 72.06 \text{ lb}$$

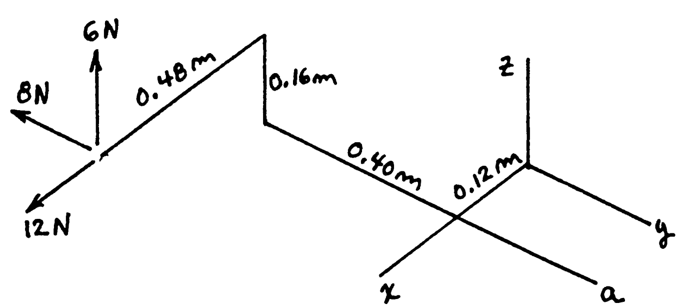
$$+ \circlearrowleft \quad M_x = 6F_y = 6(72.06) = 432 \text{ lb} \cdot \text{ft} \blacktriangleleft$$

(b)

$$\mathbf{F} = 75\frac{-2\mathbf{i} + 6.928\mathbf{k}}{\sqrt{6.928^2 + 2^2}} = -20.80\mathbf{j} + 72.06\mathbf{k} \text{ lb} \qquad \mathbf{r} = 6\mathbf{j} \text{ ft}$$

$$M_x = \mathbf{r} \times \mathbf{F} \cdot \boldsymbol{\lambda} = \begin{vmatrix} 0 & 6 & 0 \\ 0 & -20.80 & 72.06 \\ 1 & 0 & 0 \end{vmatrix} = 432 \text{ lb} \cdot \text{ft} \blacktriangleleft$$

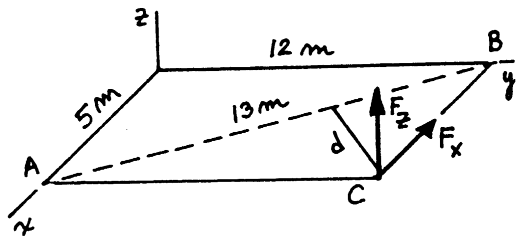
2.51



(a) $\mathbf{M}_a = \left[-6(0.480) + 12(0.160)\right]\mathbf{j} = -0.960\,\mathbf{j}$ N•m ♦

(b) $\mathbf{M}_z = \left[-8(0.480 + 0.120) + 12(0.4)\right]\mathbf{k} = 0$ ♦

2.52



$M_x = 1080 = F_z(\overline{AC})$

$\therefore\ F_z = 1080/12 = 90$ N

$M_{AB} = F_z d$

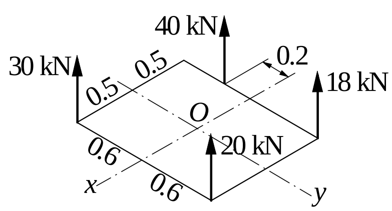
A convenient way to compute d:

area ABC $= \frac{1}{2}(12)(5) = \frac{1}{2}(13)d$

which gives $d = 4.615$ m

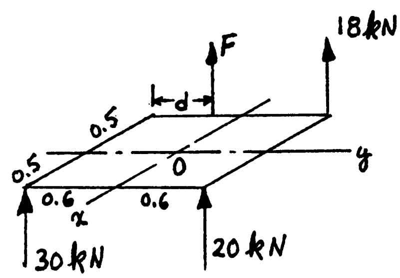
$\therefore\ M_{AB} = 90(4.615) = 415$ N•m ♦

2.53



$$
\begin{aligned}
M_x &= (20+18)(0.6) - 40(0.2) - 30(0.6) = -3.20\ \text{N}\cdot\text{m} \\
M_y &= (40+18)(0.5) - (30+20)(0.5) = 4.00\ \text{N}\cdot\text{m} \\
\mathbf{M}_O &= -3.20\mathbf{i} + 4.00\mathbf{j}\ \text{N}\cdot\text{m}\ \blacktriangleleft
\end{aligned}
$$

2.54



$M_y = (F + 18)(0.5) - (30 + 20)(0.5) = 0$

$\therefore\ F = \dfrac{25 - 9}{0.5} = 32.0$ N ♦

$M_x = (20 + 18)(0.6) - 30(0.6) - F(0.6 - d) = 0$

Substituting F = 32.0 N, and solving for d gives:

$\therefore\ d = \dfrac{-22.8 + 18 + 32.0(0.6)}{32.0} = 0.450$ m ♦

2.55

$$M_{aa} = 30(4 - y_0) + 20(6 - y_0) - 40y_0 = 0 \qquad \text{Solving gives:} \quad y_0 = 2.67 \text{ ft} \ \blacklozenge$$

$$M_{bb} = (20 + 40)x_0 - 30(6 - x_0) = 0 \qquad \text{Solving gives:} \quad x_0 = 2.00 \text{ ft} \ \blacklozenge$$

2.56

Only the component T_z has a moment about the y-axis: $M_y = -4T_z$.

$$\begin{aligned} T_z &= T\frac{\overline{AB}_z}{\overline{AB}} = 40\frac{3}{\sqrt{4^2 + 4^2 + 3^2}} = 18.741 \text{ lb} \\ \therefore & \quad M_y = -4(18.741) = -75.0 \text{ lb} \cdot \text{ft} \ \blacktriangleleft \end{aligned}$$

2.57

Only the x-component of each force has a moment about the z-axis.

$$\begin{aligned} \therefore M_z &= (P\cos 30^\circ + Q\cos 25^\circ)\,15 \\ &= (32\cos 30^\circ + 36\cos 25^\circ)\,15 = 905 \text{ lb} \cdot \text{in.} \ \blacktriangleleft \end{aligned}$$

2.58

$$\mathbf{P} = 480\frac{-0.42\mathbf{i} - 0.81\mathbf{j} + 0.54\mathbf{k}}{\sqrt{(-0.42)^2 + (-0.81)^2 + 0.54^2}} = -190.15\mathbf{i} - 366.7\mathbf{j} + 244.5\mathbf{k} \text{ N}$$

$$\mathbf{r}_{CA} = 0.42\mathbf{i} \text{ m} \qquad \boldsymbol{\lambda}_{CD} = \frac{0.42\mathbf{i} + 0.54\mathbf{k}}{\sqrt{0.42^2 + 0.54^2}} = 0.6139\mathbf{i} + 0.7894\mathbf{k}$$

$$M_{CD} = \mathbf{r}_{CA} \times \mathbf{P} \cdot \boldsymbol{\lambda}_{\mathbf{CD}} = \begin{vmatrix} 0.42 & 0 & 0 \\ -190.15 & -366.7 & 244.5 \\ 0.6139 & 0 & 0.7894 \end{vmatrix} = -121.58 \text{ N} \cdot \text{m}$$

$$\mathbf{M}_{CD} = M_{CD}\boldsymbol{\lambda}_{CD} = -121.58(0.6139\mathbf{i} + 0.7894\mathbf{k}) = -74.6\mathbf{i} - 96.0\mathbf{k} \text{ N} \cdot \text{m} \ \blacktriangleleft$$

2.59

Let the 20-lb force be Q:

$$\mathbf{Q} = 20\,\vec{\lambda}_{ED} = 20\left(\frac{-12\,\mathbf{j} - 4\,\mathbf{k}}{12.649}\right) = -18.974\mathbf{j} - 6.324\mathbf{k} \text{ lb}$$

$$\mathbf{P} = P\,\vec{\lambda}_{AF} = P\left(\frac{-4\,\mathbf{i} + 4\,\mathbf{k}}{4\sqrt{2}}\right) = P(-0.7071\,\mathbf{i} + 0.7071\,\mathbf{k}) \text{ lb}$$

$$M_{GB} = \mathbf{r}_{BE} \times \mathbf{Q} \bullet \vec{\lambda}_{GB} + \mathbf{r}_{BA} \times \mathbf{P} \bullet \vec{\lambda}_{GB} = 0$$

$$\mathbf{r}_{BE} = 4\,\mathbf{i} + 4\mathbf{k} \text{ in.} \qquad \mathbf{r}_{BA} = 4\,\mathbf{i} \text{ in.} \qquad \vec{\lambda}_{GB} = \frac{12\mathbf{j} - 4\mathbf{k}}{12.649}$$

$$M_{GB} = \frac{1}{12.649}\begin{vmatrix} 4 & 0 & 4 \\ 0 & -18.974 & -6.324 \\ 0 & 12 & -4 \end{vmatrix} + \frac{P}{12.649}\begin{vmatrix} 4 & 0 & 0 \\ -0.7071 & 0 & 0.7071 \\ 0 & 12 & -4 \end{vmatrix} = 0$$

Expanding the determinants gives: $\frac{607.1}{12.649} + \frac{P}{12.649}(-33.94) = 0 \quad \therefore\ P = 17.89 \text{ lb}$ ◆

2.60

$$M_{BC} = \mathbf{r}_{BA} \times \mathbf{F} \cdot \boldsymbol{\lambda}_{BC}$$

$$\mathbf{r}_{BA} = 5\mathbf{i} \qquad \mathbf{F} = F\frac{-3\mathbf{i} + 3\mathbf{j} - 3\mathbf{k}}{\sqrt{(-3)^2 + 3^2 + (-3)^2}} = 0.5774F(-\mathbf{i} + \mathbf{j} - \mathbf{k})$$

$$\boldsymbol{\lambda}_{BC} = \frac{4\mathbf{j} - 2\mathbf{k}}{\sqrt{4^2 + (-2)^2}} = 0.8944\mathbf{j} - 0.4472\mathbf{k}$$

$$M_{BC} = \mathbf{r}_{BA} \times \mathbf{F} \cdot \boldsymbol{\lambda}_{BC} = 0.5774F\begin{vmatrix} 5 & 0 & 0 \\ -1 & 1 & -1 \\ 0 & 0.8944 & -0.4472 \end{vmatrix} = 1.2911F$$

$$M_{BC} = 150 \text{ lb} \cdot \text{ft} \qquad 1.2911F = 150 \text{ lb} \cdot \text{ft} \qquad F = 116.2 \text{ lb}$$ ◄

*2.61

Let $\vec{\lambda}$ be a unit vector perpendicular to the plane ABC:

$$\vec{\lambda} = \frac{\overrightarrow{AB} \times \overrightarrow{AC}}{\left|\overrightarrow{AB} \times \overrightarrow{AC}\right|} \quad \text{where} \quad \overrightarrow{AB} = -3\mathbf{j} + 4\mathbf{k} \text{ m} \quad \text{and} \quad \overrightarrow{AC} = 3\mathbf{i} - 3\mathbf{j} \text{ m}$$

$$\overrightarrow{AB} \times \overrightarrow{AC} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & -3 & 4 \\ 3 & -3 & 0 \end{vmatrix} = 12\mathbf{i} + 12\mathbf{j} + 9\mathbf{k} \text{ m}^2 \qquad \therefore \ \vec{\lambda} = \frac{12\mathbf{i} + 12\mathbf{j} + 9\mathbf{k}}{19.21}$$

$$M_\lambda = \mathbf{r}_{OA} \times \mathbf{F} \bullet \vec{\lambda} \qquad \mathbf{r}_{OA} = 3\mathbf{j} \text{ m}$$

$$\mathbf{F} = 250\,\vec{\lambda}_{AB} = 250\left(\frac{-3\mathbf{j} + 4\mathbf{k}}{5}\right) = -150\mathbf{j} + 200\mathbf{k} \text{ N}$$

$$\therefore \ M_\lambda = \frac{1}{19.21}\begin{vmatrix} 0 & 3 & 0 \\ 0 & -150 & 200 \\ 12 & 12 & 9 \end{vmatrix} = 374.8 \text{ N·m}$$

Written in vector form, we have:

$$\mathbf{M}_\lambda = M_\lambda \vec{\lambda} = 374.8\left(\frac{12\mathbf{i} + 12\mathbf{j} + 9\mathbf{k}}{19.21}\right) = 234\mathbf{i} + 234\mathbf{j} + 176\mathbf{k} \text{ N·m} \ ◆$$

2.62

$$\mathbf{P} = 240\,\vec{\lambda}_{CE} = 240\left(\frac{-3\mathbf{i} + 2\mathbf{j} - 7\mathbf{k}}{\sqrt{62}}\right) \text{ lb} \qquad \vec{\lambda}_{AD} = \frac{-3\mathbf{i} + 6\mathbf{j} + 7\mathbf{k}}{\sqrt{94}}$$

(a) $\mathbf{r} = \mathbf{r}_{AC} = 6\mathbf{j} + 7\mathbf{k}$ ft

$$M_{AD} = \mathbf{r}_{AC} \times \mathbf{P} \bullet \vec{\lambda}_{AD} = \frac{240}{\sqrt{62}\sqrt{94}}\begin{vmatrix} 0 & 6 & 7 \\ -3 & 2 & -7 \\ -3 & 6 & 7 \end{vmatrix} = \frac{240}{\sqrt{62}\sqrt{94}}(168) = 528 \text{ lb·ft} \ ◆$$

(b) $\mathbf{r} = \mathbf{r}_{DC} = 3\mathbf{i}$ ft

$$M_{AD} = \mathbf{r}_{DC} \times \mathbf{P} \bullet \vec{\lambda}_{AD} = \frac{240}{\sqrt{62}\sqrt{94}}\begin{vmatrix} 3 & 0 & 0 \\ -3 & 2 & -7 \\ -3 & 6 & 7 \end{vmatrix} = \frac{240}{\sqrt{62}\sqrt{94}}(168) = 528 \text{ lb·ft} \ ◆$$

2.63

(a)

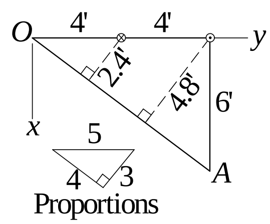
$$\mathbf{P} = -1200\mathbf{k}\text{ lb} \qquad \mathbf{Q} = 800\mathbf{k}\text{ lb} \qquad \mathbf{r}_{OP} = 4\mathbf{j}\text{ ft} \qquad \mathbf{r}_{OQ} = 8\mathbf{j}\text{ ft}$$

$$\boldsymbol{\lambda}_{OA} = \frac{6\mathbf{i}+8\mathbf{j}}{\sqrt{6^2+8^2}} = 0.6\mathbf{i}+0.8\mathbf{j}$$

$$M_{OA} = \mathbf{r}_{OP}\times\mathbf{P}\cdot\boldsymbol{\lambda}_{OA} + \mathbf{r}_{OQ}\times\mathbf{Q}\cdot\boldsymbol{\lambda}_{OA}$$

$$= \begin{vmatrix} 0 & 4 & 0 \\ 0 & 0 & -1200 \\ 0.6 & 0.8 & 0 \end{vmatrix} + \begin{vmatrix} 0 & 8 & 0 \\ 0 & 0 & 800 \\ 0.6 & 0.8 & 0 \end{vmatrix} = 960\text{ lb}\cdot\text{ft} \blacktriangleleft$$

(b)



$$M_{OA} = -2.4P + 4.8Q = -2.4(1200) + 4.8(800) = 960\text{ lb}\cdot\text{ft} \blacktriangleleft$$

2.64

$$\mathbf{M}_{BC} = \mathbf{M}_B\cdot\vec{\lambda}_{BC} = \mathbf{r}_{BD}\times\mathbf{F}\cdot\vec{\lambda}_{BC} = 0 \qquad \mathbf{r}_{BD} = -1.6\mathbf{j} - (1.2 - z_D)\mathbf{k}\text{ m}$$

$$\mathbf{F} = F(0.6\mathbf{i}+0.8\mathbf{j}) \qquad \vec{\lambda}_{BC} = \frac{\overrightarrow{BC}}{|\overrightarrow{BC}|} = \frac{1.2\mathbf{i}-0.6\mathbf{j}-1.2\mathbf{k}}{1.8}$$

$$\therefore\ \mathbf{M}_{BC} = \frac{F}{1.8}\begin{vmatrix} 0 & -1.6 & -(1.2-z_D) \\ 0.6 & 0.8 & 0 \\ 1.2 & -0.6 & -1.2 \end{vmatrix} = 0$$

Expanding the determinant: $1.6(0.6)(-1.2) - (1.2 - z_D)(-0.36 - 0.96) = 0$

which gives: $z_D = 0.327\text{ m}$ ♦

2.65

$$\vec{\lambda}_{AB} = \frac{-3\mathbf{i} + 4\mathbf{j}}{5} = -0.600\mathbf{i} + 0.800\mathbf{j}$$

For the pulley at A:

$$M_A = M_x = 20(0.5) - 60(0.5) = -20 \text{ kN}\bullet\text{m} \qquad \therefore\ \mathbf{M}_A = -20\mathbf{i} \text{ kN}\bullet\text{m}$$

For the pulley at B:

$$M_B = M_y = 40(0.8) - 20(0.8) = 16 \text{ kN}\bullet\text{m} \qquad \therefore\ \mathbf{M}_B = 16\mathbf{j} \text{ kN}\bullet\text{m}$$

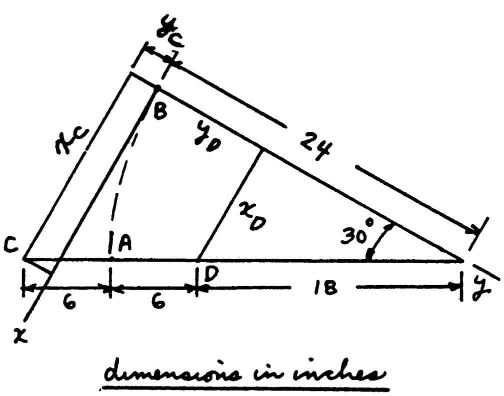
For both pulleys combined:

$$M_{AB} = \left(\mathbf{M}_A + \mathbf{M}_B\right) \bullet \vec{\lambda}_{AB} = (-20\mathbf{i} + 16\mathbf{j}) \bullet (-0.600\mathbf{i} + 0.800\mathbf{j})$$

$$= 12 + 12.8 = 24.8 \text{ kN}\bullet\text{m} \ \blacklozenge$$

2.66

From the figure at the right:



$x_C = 30 \sin 30^\circ = 15.000$ in.

$y_C = 30 \cos 30^\circ - 24 = 1.981$ in.

$x_D = 18 \sin 30^\circ = 9.000$ in.

$y_D = 24 - 18 \cos 30^\circ = 8.412$ in.

$(M_B)_x = \mathbf{r}_{BC} \times \mathbf{P}_C \bullet \mathbf{i} + \mathbf{r}_{BD} \times \mathbf{P}_D \bullet \mathbf{i}$

$\mathbf{P}_C = 20\,\mathbf{k}$ lb $\quad \mathbf{P}_D = -20\,\mathbf{k}$ lb

$\mathbf{r}_{BC} = x_C\,\mathbf{i} - y_C\,\mathbf{j} = 15.000\,\mathbf{i} - 1.981\,\mathbf{j}$ in.

$\mathbf{r}_{BD} = x_D\,\mathbf{i} + y_D\,\mathbf{j} = 9.000\,\mathbf{i} + 8.412\,\mathbf{j}$ in.

$$\therefore\ (M_B)_x = \begin{vmatrix} 15.000 & -1.981 & 0 \\ 0 & 0 & 20 \\ 1 & 0 & 0 \end{vmatrix} + \begin{vmatrix} 9.000 & 8.412 & 0 \\ 0 & 0 & -20 \\ 1 & 0 & 0 \end{vmatrix} = -39.62 - 168.2 = -208 \text{ lb}\bullet\text{in}$$

Written in vector form: $(\mathbf{M}_B)_x = (M_B)_x\,\mathbf{i} = -208\,\mathbf{i}$ lb•in $\blacklozenge$

2.67

(a)

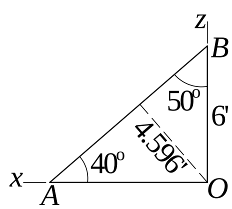
$$\mathbf{F} = 120\frac{4\mathbf{i}+8\mathbf{j}+10\mathbf{k}}{\sqrt{4^2+8^2+10^2}} = 35.78\mathbf{i}+71.55\mathbf{j}+89.44\mathbf{k} \text{ lb}$$

$$\mathbf{r}_{BO} = -6\mathbf{k} \text{ ft} \qquad \boldsymbol{\lambda}_{AB} = \frac{(-6\cot 40^\circ)\,\mathbf{i}+6\mathbf{k}}{\sqrt{(-6\cot 40^\circ)^2+6^2}} = -0.7660\mathbf{i}+0.6428\mathbf{k}$$

: $71.554\,2j + 89.442\,7k + 0.0 + 35.777\,1i$

$$M_{AB} = \mathbf{r}_{BO}\times\mathbf{F}\cdot\boldsymbol{\lambda}_{AB} = \begin{vmatrix} 0 & 0 & -6 \\ 35.78 & 71.55 & 89.44 \\ -0.7660 & 0 & 0.6428 \end{vmatrix} = -329 \text{ lb}\cdot\text{ft} \quad ◄$$

(b)



Note that only $F_y = 71.55$ lb has a moment about AB. From trigonometry, the moment arm is $d = 6\sin 50^\circ = 4.596$ ft.

$$\therefore M_{AB} = -F_y d = -71.55(4.596) = -329 \text{ lb}\cdot\text{ft} \quad ◄$$

2.68

Assume counterclockwise couples are positive.

(a) C = – 10(0.6)= – 6 N•m

(b) C = – 6 N•m

(c) C = – 15(0.4) = – 6 N•m

(d) C = – 6 N•m

(e) C = 9 – 3 = 6 N•m

(f) C = – 5(O.6) – 7.5(0.4) = – 6 N•m

(g) C = – 22.5(0.4) + 5(0.6) = – 6 N•m

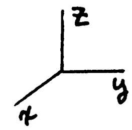
(h) C = – 5 + 5(0.3) = – 3.5 N•m

(i) C = 3 – 4 – 6 + 3 = – 4 N•m

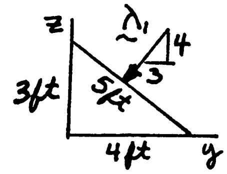
2.69

(a) $\mathbf{C} = -60(5)\mathbf{k} = -300\mathbf{k}$ lb•ft

(b) $\mathbf{C} = -75(4)\mathbf{k} = -300\mathbf{k}$ lb•ft



(c) $\mathbf{C}_1 = 75(5)\vec{\lambda}_1 = 375\left(-\frac{3}{5}\mathbf{j} - \frac{4}{5}\mathbf{k}\right) = -225\mathbf{j} - 300\mathbf{k}$ lb•ft



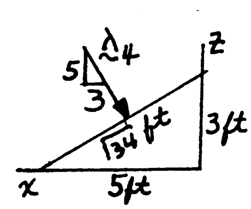
(d) $\mathbf{C} = 100(3)\mathbf{i} = 300\mathbf{i}$ lb•ft

(e) 75-lb forces: $\mathbf{C}_1 = -225\mathbf{j} - 300\mathbf{k}$ lb•ft [as in (c)]

45-lb forces: $\mathbf{C}_2 = 45(5)\mathbf{j} = 225\mathbf{j}$ lb•ft

$\mathbf{C}_1 + \mathbf{C}_2 = -300\mathbf{k}$ lb•ft

(f) 45-lb forces: $\mathbf{C}_3 = 45(4)\mathbf{i} = 180\mathbf{i}$ lb•ft



50-lb forces: $\mathbf{C}_4 = 50\left(\sqrt{34}\right)\vec{\lambda}_4$

$$= 50\left(\sqrt{34}\right)\left(\frac{-3\mathbf{i} - 5\mathbf{k}}{\sqrt{34}}\right) = -150\mathbf{i} - 250\mathbf{k} \text{ lb•ft}$$

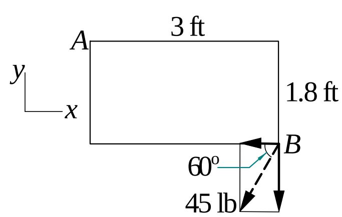
$\mathbf{C}_3 + \mathbf{C}_4 = 30\mathbf{i} - 250\mathbf{k}$ lb•ft

Comparing the above results: (b) and (e) are equivalent to (a). ◆

2.70

$$C = (75\sin 45^\circ)(1.5) - 60 = 19.55 \text{ lb}\cdot\text{ft} \circlearrowright \blacktriangleleft$$

2.71



Moment of a couple is the same about any point. Choosing A as the moment center, we get

$$+\circlearrowright \quad C = M_A = (45\cos 60^\circ)(1.8) + (45\sin 60^\circ)(3) = 157.4 \text{ lb}\cdot\text{ft}$$

$$\therefore \quad \mathbf{C} = -157.4\mathbf{k} \text{ lb}\cdot\text{ft} \blacktriangleleft$$

2.72

$$\begin{aligned}\mathbf{C} &= -30(5)\mathbf{i} + 60(2)\mathbf{k} = -150\mathbf{i} + 120\mathbf{k} \text{ lb} \cdot \text{ft} \\ &\therefore \quad C = \sqrt{(-150)^2 + 120^2} = 192.1 \text{ lb} \cdot \text{ft} \quad \blacktriangleleft\end{aligned}$$

2.73

$$\mathbf{C} = 80\vec{\lambda}_{DB} = 80\left(\frac{0.4\mathbf{i} - 0.3\mathbf{j} + 0.4\mathbf{k}}{0.6403}\right) = 49.98\mathbf{i} - 37.48\mathbf{j} + 49.98\mathbf{k} \text{ N}\bullet\text{m}$$

$$\mathbf{P} = -400\mathbf{k} \text{ N} \qquad \mathbf{r}_{AD} = -0.4\mathbf{i} \text{ m} \qquad \vec{\lambda}_{AB} = \frac{-0.3\mathbf{j} + 0.4\mathbf{k}}{0.5} = -0.6\mathbf{j} + 0.8\mathbf{k}$$

<u>For Couple C</u>:

$$\begin{aligned}M_{AB} = \mathbf{C} \bullet \vec{\lambda}_{AB} &= (49.98\mathbf{i} - 37.48\mathbf{j} + 49.98\mathbf{k}) \bullet (-0.6\mathbf{j} + 0.8\mathbf{k}) \\ &= (-37.48)(-0.6) + (49.98)(0.8) = 62.47 \text{ N}\bullet\text{m}\end{aligned}$$

<u>For Force P</u>:

$$M_{AB} = \mathbf{r}_{AD} \times \mathbf{P} \bullet \vec{\lambda}_{AB} = \begin{vmatrix} -0.4 & 0 & 0 \\ 0 & 0 & -400 \\ 0 & -0.6 & 0.8 \end{vmatrix} = -0.4(-240) = 96.00 \text{ N}\bullet\text{m}$$

$$\therefore \ \Sigma M_{AB} = 62.47 + 96.00 = 158.5 \text{ N}\bullet\text{m} \quad \blacklozenge$$

*2.74

$\mathbf{C}_1 = -200\mathbf{i}$ lb•in. $\quad \mathbf{C}_2 = 140\mathbf{k}$ lb•in.

Identify the three points at the corners of the triangle:

A(9 in., 3 in., 6 in.); B(3 in., 7 in., 6 in.); C(9 in., 7 in., 2 in.)

$\mathbf{C}_3 = 220\,\vec{\lambda}$ lb•in. where $\vec{\lambda}$ is the unit vector that is perpendicular to triangle ABC, with its sense consistent with the sense of $\mathbf{C}_3$.

$$\vec{\lambda} = \frac{\overrightarrow{AC} \times \overrightarrow{AB}}{\left|\overrightarrow{AC} \times \overrightarrow{AB}\right|} \quad \text{where } \overrightarrow{AC} = 4\mathbf{j} - 4\mathbf{k} \text{ in. and } \overrightarrow{AB} = -6\mathbf{i} + 4\mathbf{j} \text{ in.}$$

$$\overrightarrow{AC} \times \overrightarrow{AB} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 4 & -4 \\ -6 & 4 & 0 \end{vmatrix} = 16\mathbf{i} + 24\mathbf{j} + 24\mathbf{k} \text{ in.}^2$$

$$\therefore\ \vec{\lambda} = \frac{16\mathbf{i} + 24\mathbf{j} + 24\mathbf{k}}{37.52} = 0.4264\mathbf{i} + 0.6397\mathbf{j} + 0.6397\mathbf{k}$$

$$\mathbf{C}_3 = 220(0.4264\mathbf{i} + 0.6397\mathbf{j} + 0.6397\mathbf{k}) = 93.81\mathbf{i} + 140.73\mathbf{j} + 140.73\mathbf{k} \text{ lb}\bullet\text{in.}$$

$$\therefore\ \mathbf{C}^R = \mathbf{C}_1 + \mathbf{C}_2 + \mathbf{C}_3 = -200\mathbf{i} + 140\mathbf{k} + (93.81\mathbf{i} + 140.73\mathbf{j} + 140.73\mathbf{k})$$

$$= -106.2\mathbf{i} + 140.7\mathbf{j} + 280.7\mathbf{k} \text{ lb}\bullet\text{in.} \quad \blacklozenge$$

2.75

Moment of a couple is the same about any point. Choosing B as the moment center, we have

$$\mathbf{F} = -24\mathbf{i} \text{ kN} \qquad \mathbf{r}_{BA} = -1.8\mathbf{j} - 1.2\mathbf{k} \text{ m}$$

$$\mathbf{C} = \mathbf{M}_B = \mathbf{r}_{BA} \times \mathbf{F} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & -1.8 & -1.2 \\ -24 & 0 & 0 \end{vmatrix} = 28.8\mathbf{j} - 43.2\mathbf{k} \text{ kN} \cdot \text{m} \quad \blacktriangleleft$$

2.76

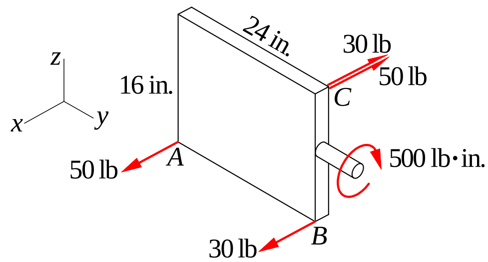
Moment of a couple is the same about any point. Choosing B as the moment center, we have

$$\mathbf{r}_{BA} = 180\mathbf{i} - b\mathbf{j} \text{ mm}$$

$$C_z = (M_B)_z = \mathbf{r}_{BA} \times \mathbf{F} \cdot \mathbf{k} = \begin{vmatrix} 180 & -b & 0 \\ 200 & -110 & -80 \\ 0 & 0 & 1 \end{vmatrix} = 200b - 19\,800 \text{ kN} \cdot \text{mm}$$

$$\therefore\quad 200b - 19\,800 = 0 \qquad b = 99.0 \text{ mm} \quad \blacktriangleleft$$

2.77



As seen in the figure, the forces form two couples (30-lb pair and 50-lb pair).
Couple of the 30-lb forces:

$$\mathbf{C}_1 = -30(16)\mathbf{j} = -480\mathbf{j} \text{ lb} \cdot \text{ in.}$$

Couple of the 50-lb forces:

$$\mathbf{C}_2 = \mathbf{r}_{AC} \times (-50\mathbf{i}) = (24\mathbf{j} + 16\mathbf{k}) \times (-50\mathbf{i}) = 1200\mathbf{k} - 800\mathbf{j} \text{ lb} \cdot \text{in.}$$

Applied couple:

$$\mathbf{C}_3 = -500\mathbf{j} \text{ lb} \cdot \text{in.}$$

Resultant:

$$\mathbf{C}^R = \Sigma\mathbf{C}_i = -480\mathbf{j} + (1200\mathbf{k} - 800\mathbf{j}) - 500\mathbf{j} = -1780\mathbf{j} + 1200\mathbf{k} \text{ lb} \cdot \text{in.} \quad ◀$$

2.78

$$\mathbf{C} = -360\cos 30^\circ\,\mathbf{i} - 360\sin 30^\circ\,\mathbf{j} = -311.8\,\mathbf{i} - 180.0\,\mathbf{j}\ \text{lb}\bullet\text{ft}$$

$$\vec{\lambda}_{CD} = -\cos 30^\circ\,\mathbf{i} - \sin 30^\circ \cos 40^\circ\,\mathbf{j} + \sin 30^\circ \sin 40^\circ\,\mathbf{k} = -0.8660\,\mathbf{i} - 0.3830\,\mathbf{j} + 0.3214\,\mathbf{k}$$

$$\therefore\ M_{CD} = \mathbf{C}\bullet\vec{\lambda}_{CD} = (-311.8)(-0.8660) + (-180.0)(-0.3830) = 339\ \text{lb}\bullet\text{ft} \quad ◆$$

2.79

$$\vec{\lambda}_{DC} = \sin 30^\circ \sin 40^\circ\,\mathbf{i} - \sin 30^\circ \cos 40^\circ\,\mathbf{j} + \cos 30^\circ\,\mathbf{k} = 0.3214\,\mathbf{i} - 0.3830\,\mathbf{j} + 0.8660\,\mathbf{k}$$

(a) $\mathbf{C} = 52\,\vec{\lambda}_{DC} = 16.71\,\mathbf{i} - 19.92\,\mathbf{j} + 45.03\,\mathbf{k}\ \text{lb}\bullet\text{ft}$ ◆

(b) $\mathbf{M}_z = \mathbf{C}_z = 45.03\,\mathbf{k}\ \text{lb}\bullet\text{ft}$ ◆

2.80

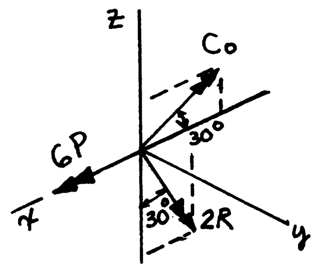
$\mathbf{C}_P = 600(6)\mathbf{i} = 3600\mathbf{i}$ lb•in.

$\mathbf{C}_0 = -C_0 \cos 30^\circ \mathbf{i} + C_0 \sin 30^\circ \mathbf{k}$

$= -0.8660 C_0 \mathbf{i} + 0.5000 C_0 \mathbf{k}$ lb•in.

$\mathbf{C}_R = -2R \sin 30^\circ \mathbf{i} - 2R \cos 30^\circ \mathbf{k}$

$= -R\mathbf{i} - 1.7321R\mathbf{k}$ lb•in.



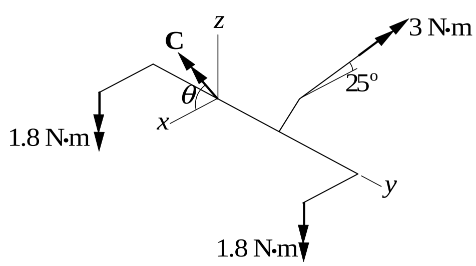
$\therefore\ \Sigma\mathbf{C} = 3600\mathbf{i} + (-0.8660 C_0 \mathbf{i} + 0.5000 C_0 \mathbf{k}) + (-R\mathbf{i} - 1.7321R\mathbf{k}) = \mathbf{0}$

Equating like components: (i) $3600 - 0.8660 C_0 - R = 0$

(k) $0.5000 C_0 - 1.7321R = 0$

Solving gives: $R = 900$ lb ◆ and $C_0 = 3120$ lb•in. ◆

2.81



The system consists of the four couples shown, where

$$\mathbf{C} = 0.36F(\mathbf{i}\cos\theta + \mathbf{k}\sin\theta)\ \mathrm{N\cdot m}$$

$$\Sigma\mathbf{C} = -2(1.8)\mathbf{k} + 3(-\mathbf{i}\cos 25^\circ + \mathbf{k}\sin 25^\circ) + 0.36F(\mathbf{i}\cos\theta + \mathbf{k}\sin\theta) = 0$$

Equating like components:

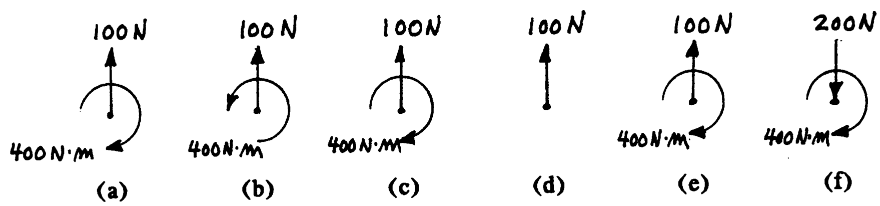
$$\begin{aligned} -3\cos 25^\circ + 0.36F\cos\theta &= 0 \\ -3.6 + 3\sin 25^\circ + 0.36F\sin\theta &= 0 \end{aligned}$$

$$\begin{aligned} F\cos\theta &= \frac{3\cos 25^\circ}{0.36} = 7.553 \\ F\sin\theta &= \frac{3.6 - 3\sin 25^\circ}{0.36} = 6.478 \end{aligned}$$

$$\tan\theta = \frac{6.478}{7.553} = 0.8577 \qquad \theta = 40.6^\circ \blacktriangleleft$$
$$F = \sqrt{7.553^2 + 6.478^2} = 9.95 \text{ N} \blacktriangleleft$$

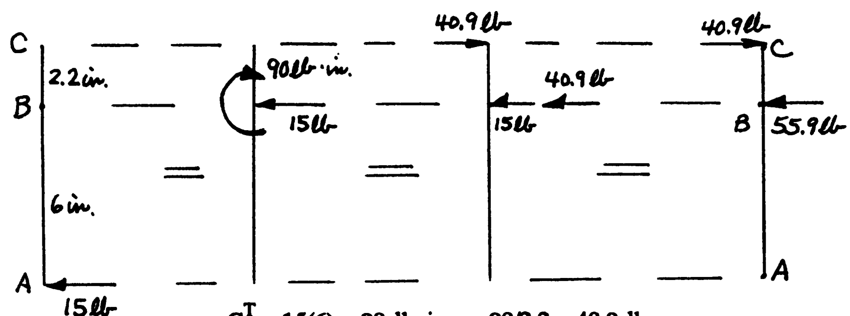
2.82

Represent each of the systems by an eqivalent force-couple system with the force acting at the upper left corner of the figure.



By inspection, the systems in (c) and (e) are equivalent to the system in (a). ♦

2.83



C^T = 15(6) = 90 lb•in. 90/2.2 = 40.9 lb

Original system

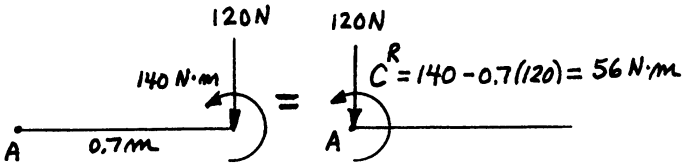
(i) Equivalent system with force at B.

(ii) Equivalent system: one force at B and one force at C.

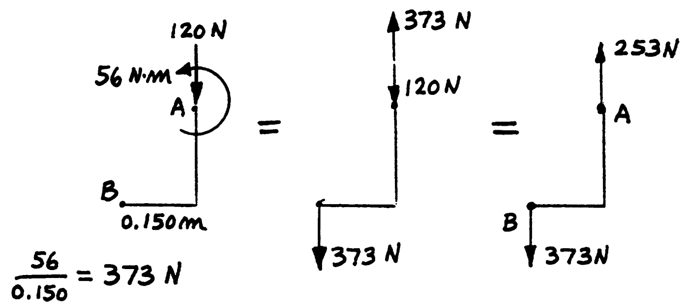
(a) Fig. (i): A 15-lb force acting to the left at B, and a 90 lb-in. clockwise couple. ♦

(b) Fig. (ii): A 55.9-lb force acting to the left at B, and a 40.9-lb force acting to the right at C. ♦

2.84



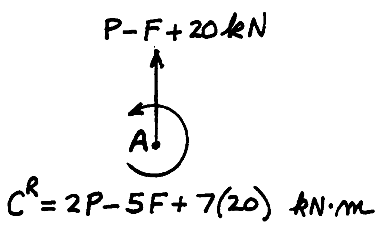
(a) From above figure: a 120-N downward force at A, and a 56 N•m CCW couple. ◆



(b) From above figure: a 253-N upward force at A, and a 373-N downward force at B. ◆

2.85

Moving the three forces to A:



Therefore,

$$P - F + 20 = 50 \text{ N} \qquad (1)$$
$$2P - 5F + 140 = 170 \text{ kN•m} \qquad (2)$$

Solving (1) and (2) gives

P= 40 kN and F = 10 kN ◆

2.86

$$\mathbf{R} = -90\mathbf{j} + 50(\mathbf{i}\sin 30^\circ - \mathbf{j}\cos 30^\circ) = 25.0\mathbf{i} - 133.3\mathbf{j} \text{ lb} \blacktriangleleft$$
$$+ \circlearrowleft \quad C^R = 90(9) - 50(12) = 210 \text{ lb} \cdot \text{in.} \qquad \mathbf{C}^R = 210\mathbf{k} \text{ lb} \cdot \text{in.} \blacktriangleleft$$

2.87

The resultant force R equals V.

$$\therefore V = R = 1200 \text{ lb} \blacktriangleleft$$

$$C^R = \Sigma M_D = 0: \qquad 20V - 10H - C = 0$$
$$20\,(1200) - 10H - 900 \times 12 = 0 \qquad H = 1320 \text{ lb} \blacktriangleleft$$

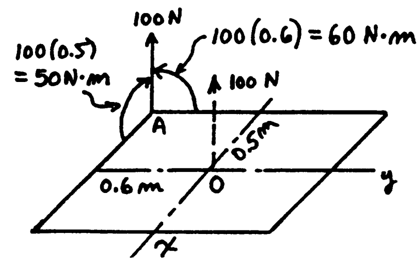
2.88

Transferring force from O to A gives

force = 100 k N ◆

$(C^T)_x = 60$ **N•m;** $(C^T)_y = -50$ **N•m**

$\therefore$ $\mathbf{C}^R = 60\,\mathbf{i} - 50\,\mathbf{j}$ **N•m** ◆



2.89

The force acting at O equals F, and the couple equals the moment about O.

$$\mathbf{F} = 160\,\vec{\lambda}_{AB} = 160\left(\frac{-2.2\mathbf{i} + 2.0\mathbf{j} - 2.0\mathbf{k}}{3.583}\right) = -98.24\mathbf{i} + 89.31\mathbf{j} - 89.31\mathbf{k}\ \text{kN} \quad \blacklozenge$$

$$\mathbf{C}^R = \mathbf{M}_O = \mathbf{r}_{OB} \times \mathbf{F} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 2 & 0 \\ -98.24 & 89.31 & -89.31 \end{vmatrix} = -178.6\mathbf{i} + 196.5\mathbf{k}\ \text{kN}\cdot\text{m} \quad \blacklozenge$$

2.90

$$\begin{aligned}
\text{40-lb force:} \quad \mathbf{P} &= 40\frac{-3\mathbf{i} - 2\mathbf{k}}{\sqrt{(-3)^2 + (-2)^2}} = -33.28\mathbf{i} - 22.19\mathbf{k}\ \text{lb} \\
\text{90-lb}\cdot\text{ft couple:} \quad \mathbf{C} &= 90\frac{-3\mathbf{i} - 5\mathbf{j}}{\sqrt{(-3)^2 + (-5)^2}} = -46.30\mathbf{i} - 77.17\mathbf{j}\ \text{lb}\cdot\text{ft} \\
\mathbf{r}_{OA} &= 3\mathbf{i} + 5\mathbf{j}\ \text{ft}
\end{aligned}$$

$$\begin{aligned}
\mathbf{R} &= \mathbf{P} = -33.28\mathbf{i} - 22.19\mathbf{k}\ \text{lb} \quad \blacktriangleleft \\
\mathbf{C}^R &= \mathbf{C} + \mathbf{r}_{OA} \times \mathbf{P} = -46.30\mathbf{i} - 77.17\mathbf{j} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 3 & 5 & 0 \\ -33.28 & 0 & -22.19 \end{vmatrix} \\
&= -157.3\mathbf{i} - 10.6\mathbf{j} + 166.4\mathbf{k}\ \text{lb}\cdot\text{ft} \quad \blacktriangleleft
\end{aligned}$$

*2.91

(a)

$$\begin{aligned}
\mathbf{R} &= \mathbf{F} = -2800\mathbf{i} + 1600\mathbf{j} + 3000\mathbf{k} \text{ lb} \quad \blacktriangleleft \\
\mathbf{r}_{OA} &= 10\mathbf{i} + 5\mathbf{j} - 4\mathbf{k} \text{ in.} \\
\mathbf{C}^R &= \mathbf{r}_{OA} \times \mathbf{F} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 10 & 5 & -4 \\ -2800 & 1600 & 3000 \end{vmatrix} \\
&= 21\ 400\mathbf{i} - 18\ 800\mathbf{j} + 30\ 000\mathbf{k} \text{ lb} \cdot \text{in.} \quad \blacktriangleleft
\end{aligned}$$

(b)

Normal component of **R** : $P = |R_y| = 1600$ lb ◀

Shear component of **R** : $V = \sqrt{R_x^2 + R_z^2} = \sqrt{(-2800)^2 + 3000^2} = 4100$ lb ◀

(c)

$$\begin{aligned}
\text{Torque:}\quad T &= \left|C_y^R\right| = 18\ 800 \text{ lb} \cdot \text{in.} \quad \blacktriangleleft \\
\text{Bending moment:}\quad M &= \sqrt{(C_x^R)^2 + (C_z^R)^2} = \sqrt{21\ 400^2 + 30\ 000^2} \\
&= 36\ 900 \text{ lb} \cdot \text{in.} \quad \blacktriangleleft
\end{aligned}$$

2.92

$$\vec{\lambda}_{DC} = \sin 30^\circ \sin 40^\circ\, \mathbf{i} - \sin 30^\circ \cos 40^\circ\, \mathbf{j} + \cos 30^\circ \mathbf{k}$$

$$= 0.3214\mathbf{i} - 0.3830\mathbf{j} + 0.8660\mathbf{k}$$

The force at O equals the original force:

$$\mathbf{F} = 9.8\,\vec{\lambda}_{DC} = 9.8(0.3214\mathbf{i} - 0.3830\mathbf{j} + 0.8660\mathbf{k}) = 3.150\mathbf{i} - 3.753\mathbf{j} + 8.487\mathbf{k} \text{ lb}$$

The given couple is:

$$\mathbf{C} = 52\,\vec{\lambda}_{DC} = 52(0.3214\mathbf{i} - 0.3830\mathbf{j} + 0.8660\mathbf{k}) = 16.71\mathbf{i} - 19.92\mathbf{j} + 45.03\mathbf{k} \text{ lb}\bullet\text{ft}$$

Moving the force to O, and letting $\mathbf{C}^R$ be the resultant couple, we have: $\mathbf{C}^R = \mathbf{C} + \mathbf{M}_O$

$$\mathbf{M}_O = \mathbf{r}_{OD} \times \mathbf{F} \qquad \mathbf{r}_{OD} = -4.2\sin 40^\circ\, \mathbf{i} + 4.2\cos 40^\circ\, \mathbf{j} + 2.800\mathbf{k}$$

$$= -2.700\mathbf{i} + 3.217\mathbf{j} + 2.800\mathbf{k} \text{ ft}$$

$$\mathbf{M}_O = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -2.700 & 3.217 & 2.800 \\ 3.150 & -3.753 & 8.487 \end{vmatrix} = 37.81\mathbf{i} + 31.73\mathbf{j} \text{ lb}\cdot\text{ft}$$

$$\therefore\ \mathbf{C}^R = \mathbf{C} + \mathbf{M}_O = (16.71\mathbf{i} - 19.92\mathbf{j} + 45.03\mathbf{k}) + (37.81\mathbf{i} + 31.73\mathbf{j})$$

$$= 54.52\mathbf{i} + 11.81\mathbf{j} + 45.03\mathbf{k} \text{ lb}\cdot\text{ft}$$

The equivalent force-couple system with the force acting at O is:

Force: $3.150\mathbf{i} - 3.753\mathbf{j} + 8.487\mathbf{k}$ lb; Couple: $54.52\mathbf{i} + 11.81\mathbf{j} + 45.03\mathbf{k}$ lb•ft ♦

2.93

Original system:

$$\begin{aligned} \mathbf{F} &= 80\frac{-1.8\mathbf{i} + 0.9\mathbf{k}}{\sqrt{(-1.8)^2 + 0.9^2}} = -71.55\mathbf{i} + 35.78\mathbf{k} \text{ N} \\ \mathbf{C} &= 250\frac{-1.8\mathbf{i} + 1.3\mathbf{j}}{\sqrt{(-1.8)^2 + 1.3^2}} = -202.7\mathbf{i} + 146.37\mathbf{j} \text{ N}\cdot\text{m} \end{aligned}$$

(a) Since the 80-N force passes through B, it has no moment about B. Thus the equivalent force-couple system at B is

$$\begin{aligned} \mathbf{R} &= \mathbf{F} = -71.55\mathbf{i} + 35.78\mathbf{k} \text{ N} \blacktriangleleft \\ \mathbf{C}^R &= \mathbf{C} = -202.7\mathbf{i} + 146.37\mathbf{j} \text{ N}\cdot\text{m} \blacktriangleleft \end{aligned}$$

(b) The equivalent force-couple system at D is

$$\begin{aligned} \mathbf{R} &= \mathbf{F} = -71.55\mathbf{i} + 35.78\mathbf{k} \text{ N} \blacktriangleleft \\ \mathbf{C}^R &= \mathbf{C} + \mathbf{r}_{DA} \times \mathbf{F} = -202.7\mathbf{i} + 146.37\mathbf{j} + \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 1.8 & -1.3 & 0 \\ -71.55 & 0 & 35.78 \end{vmatrix} \\ &= -249\mathbf{i} + 82.0\mathbf{j} - 93.0\mathbf{k} \text{ N}\cdot\text{m} \blacktriangleleft \end{aligned}$$

2.94

$$\mathbf{M}_{AB} = \mathbf{r}_{AO} \times \mathbf{P} \bullet \vec{\lambda}_{AB} = 600 \text{ lb}\cdot\text{ft}$$

$$\mathbf{r}_{AO} = -8\mathbf{j} \text{ ft} \qquad \mathbf{P} = P\cos 20^\circ\mathbf{i} + P\sin 20^\circ\mathbf{k} \qquad \vec{\lambda}_{AB} = -\cos 30^\circ\mathbf{i} + \sin 30^\circ\mathbf{k}$$

$$\therefore\ \mathbf{M}_{AB} = \begin{vmatrix} 0 & -8 & 0 \\ P\cos 20^\circ & 0 & P\sin 20^\circ \\ -\cos 30^\circ & 0 & \sin 30^\circ \end{vmatrix} = 8(P\cos 20^\circ\sin 30^\circ + P\sin 20^\circ\cos 30^\circ) = 600 \text{ lb}\cdot\text{ft}$$

Solving for P gives: P = 97.9 lb ♦

2.95

Given force and couple:

$$\mathbf{F} = 32\frac{-3\mathbf{i}-4\mathbf{j}+6\mathbf{k}}{\sqrt{(-3)^2+(-4)^2+6^2}} = -12.292\mathbf{i}-16.389\mathbf{j}+24.58\mathbf{k}\ \text{kN}$$

$$\mathbf{C} = 180\frac{3\mathbf{i}-4\mathbf{j}}{\sqrt{3^2+(-4)^2}} = 108.0\mathbf{i}-144.0\mathbf{j}\ \text{kN}\cdot\text{m}$$

Equivalent force-couple ststem at A:

$$\mathbf{R} = \mathbf{F} = -12.29\mathbf{i}-16.39\mathbf{j}+24.6\mathbf{k}\ \text{kN} \blacktriangleleft$$

$$\mathbf{C}^R = \mathbf{C}+\mathbf{r}_{AB}\times\mathbf{F} = 108.0\mathbf{i}-144.0\mathbf{j}+\begin{vmatrix}\mathbf{i} & \mathbf{j} & \mathbf{k}\\ -3 & 4 & 0\\ -12.292 & -16.389 & 24.58\end{vmatrix}$$

$$= 206\mathbf{i}-70.3\mathbf{j}+98.3\mathbf{k}\ \text{kN}\cdot\text{m} \blacktriangleleft$$

2.96

$$\mathbf{T_1} = \mathbf{T_1}\vec{\lambda}_{AB} = \mathbf{T_1}\left(\frac{-10\mathbf{j}-12\mathbf{k}}{\sqrt{244}}\right) = \mathbf{T_1}(-0.6402\mathbf{j}-0.7682\mathbf{k})$$

$$\mathbf{T_2} = \mathbf{T_2}\vec{\lambda}_{AC} = \mathbf{T_2}\left(\frac{6\mathbf{i}-12\mathbf{k}}{\sqrt{180}}\right) = \mathbf{T_2}(0.4472\mathbf{i}-0.8944\mathbf{k})$$

$$\mathbf{T_3} = \mathbf{T_3}\vec{\lambda}_{AD} = \mathbf{T_3}\left(\frac{-4\mathbf{i}+3\mathbf{j}-12\mathbf{k}}{13}\right) = \mathbf{T_3}(-0.3077\mathbf{i}+0.2308\mathbf{j}-0.9231\mathbf{k})$$

$\mathbf{R} = \mathbf{T_1}+\mathbf{T_2}+\mathbf{T_3}$ Equating like components gives:

(i-components) $0.4472\,T_2 - 0.3077\,T_3 = 0$

(j-components) $-0.6402\,T_1 \quad 0.2308\,T_3 = 0$

(k-components) $-0.7682\,T_1 - 0.8944\,T_2 - 0.9231\,T_3 = -400$

Solving yields: $T_1 = 79.4$ N; $T_2 = 151.6$ N; $T_3 = 220.3$ N ◆

2.97

$$\mathbf{M}_O = \mathbf{r}_{OA}\times\mathbf{F} = \begin{vmatrix}\mathbf{i} & \mathbf{j} & \mathbf{k}\\ b & 0.25 & 0.3\\ 10 & 20 & -5\end{vmatrix}$$

$$= -7.25\mathbf{i}+(3+5b)\mathbf{j}+(-2.5+20b)\mathbf{k}\ \text{kN}\cdot\text{m}$$

$$M_y = 3+5b = 8 \qquad \therefore b = 1.0\ \text{m} \blacktriangleleft$$

$$\mathbf{M}_O = -7.25\mathbf{i}+8\mathbf{j}+17.5\mathbf{k}\ \text{kN}\cdot\text{m} \blacktriangleleft$$

2.98

$\mathbf{M}_{CD} = \mathbf{r}_{CA} \times \mathbf{P} \bullet \vec{\lambda}_{CD} = 50 \text{ lb}\bullet\text{in.}$

$\mathbf{r}_{CA} = 6\mathbf{i} - 2\mathbf{j} \text{ in.} \qquad \mathbf{P} = P\vec{\lambda}_{AB} = P\left(\dfrac{-3\mathbf{i} - 2\mathbf{j} + 5\mathbf{k}}{\sqrt{38}}\right) \text{ lb} \qquad \vec{\lambda}_{CD} = \dfrac{-4\mathbf{j} + 5\mathbf{k}}{\sqrt{41}}$

Using the determinant form of the scalar triple product:

$$M_{CD} = \frac{P}{\sqrt{38}\sqrt{41}}\begin{vmatrix} 6 & -2 & 0 \\ -3 & -2 & 5 \\ 0 & -4 & 5 \end{vmatrix} = \frac{P}{\sqrt{38}\sqrt{41}}\left[6(-10+20)+2(-15)\right] = 50 \text{ lb}\bullet\text{in.}$$

Solving for P gives: $P = \dfrac{50\sqrt{38}\sqrt{41}}{30} = 65.8 \text{ lb}$ ◆

2.99

The resultant couple in Fig. (a) is

$$+\circlearrowleft \quad C^R = 400 + 120 - 160(2) = 200 \text{ N} \cdot \text{m}$$

The couple in Fig. (b) must equal C^R:

$$(2-b)F_y = C^R \qquad (2-b)120 = 200 \qquad b = 0.333 \text{ m} \blacktriangleleft$$

2.100

(a) $\mathbf{M}_O = \mathbf{r}_{OA} \times \mathbf{P} + \mathbf{C}$

$\mathbf{r}_{OA} = 4\mathbf{k} \text{ ft} \quad \mathbf{P} = P\vec{\lambda}_{AB} = 500\left(\dfrac{3\mathbf{i} - 4\mathbf{k}}{5}\right) = 300\mathbf{i} - 400\mathbf{k} \text{ lb} \quad \mathbf{C} = 1200\mathbf{k} \text{ lb}\bullet\text{ft}$

$$\therefore \mathbf{M}_O = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 0 & 4 \\ 300 & 0 & -400 \end{vmatrix} + 1200\mathbf{k} = 1200\mathbf{j} + 1200\mathbf{k} \text{ lb}\bullet\text{ft} \;◆$$

The magnitude of the moment about O is: $M_O = \sqrt{1200^2 + 1200^2} = 1697 \text{ lb}\bullet\text{ft}$

(b) $M_{OF} = \mathbf{M}_O \bullet \vec{\lambda}_{OF} = (1200\mathbf{j} + 1200\mathbf{k})\bullet\left(\dfrac{3\mathbf{i} + 12\mathbf{j} + 4\mathbf{k}}{13}\right)$

$$= \frac{1200(12)}{13} + \frac{1200(4)}{13} = 1477 \text{ lb}\bullet\text{ft} \;◆$$

2.101

$$\overset{+}{\rightarrow} \quad R_x = \Sigma F_x = T_1 \sin 45^\circ - T_3 \sin 30^\circ = 0 \qquad (1)$$

$$+\uparrow \quad R_y = \Sigma F_y = T_1 \cos 45^\circ + T_3 \cos 30^\circ + 300 = 500 \text{ lb} \qquad (2)$$

Solving (1) and (2) simultaneously gives: $T_1 = 103.5$ lb and $T_3 = 146.4$ lb ◆

2.102

(a) $\mathbf{F} \bullet \mathbf{C} = 200(-400) + 100(300) + 250(200) = 0$

Because **F** and **C** are perpendicular, they can be reduced to a single force. Q.E.D.

(b) Let A(x, y, 0) be the point in the xy plane where the combined moment of **F** and **C** is zero, and let O be the origin of the coordinate system. Since F acts at O, we have:

$\mathbf{M}_A = \mathbf{r}_{AO} \times \mathbf{F} + \mathbf{C} = \mathbf{0}$ (where $\mathbf{r}_{AO} = -x\mathbf{i} - y\mathbf{j}$ in.).

$$\therefore \mathbf{M}_A = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ -x & -y & 0 \\ 200 & 100 & 250 \end{vmatrix} + (-400\mathbf{i} + 300\mathbf{j} + 200\mathbf{k})$$

$$= (-250y)\mathbf{i} + (250x)\mathbf{j} + (-100x + 200y)\mathbf{k} - 400\mathbf{i} + 300\mathbf{j} + 200\mathbf{k} = \mathbf{0}$$

Equating the **i**- and **j**-components to zero gives:

$$-250y - 400 = 0 \qquad 250x + 300 = 0$$

$$y = -1.60 \text{ in.} \qquad x = -1.20 \text{ in.}$$

Check using **k**-components:

$-100(-1.2) + 200(-1.6) + 200 = 0$ it checks!

Therefore, the coordinates of point A are $(-1.2 \text{ in.}, -1.6 \text{ in.}, 0)$ ◆

2.103

$$\mathbf{R} = \Sigma\mathbf{F} = 50\mathbf{j} + 30\mathbf{k} \text{ kN} \quad ◄$$

Note that the 30-kN force has a moment only about the x-axis. Also, the 50-kN force has a moment only about the z-axis.

$$\therefore \mathbf{C}^R = 30(4)\mathbf{i} + 50(2)\mathbf{k} = 120\mathbf{i} + 100\mathbf{k} \text{ kN} \cdot \text{m} \quad ◄$$

2.104

$\overset{+}{\rightarrow}$ $R_x = \Sigma F_x = P - P = 0$

$+\uparrow$ $R_y = \Sigma F_y = P$

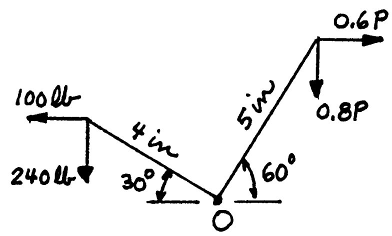
Therfore, the force acting at A is R = P (acting upward) ◆

Because **R** passes through point A, the moment of the three forces about A is zero.

$\circlearrowleft^{+}$ $\Sigma M_A = P(L - x) - P(L/2) = 0$ which gives $x = L/2$ ◆

2.105

Because the resultant force passes through O and there is no resultant couple, the combined moment of the two forces about O is zero.



$\circlearrowleft^{+}$ $\Sigma M_O = 240(4\cos 30^\circ) + 100(4\sin 30^\circ) - 0.8P(5\cos 60^\circ) - 0.6P(5\sin 60^\circ) = 0$

Solving for P gives: P = 224 lb ◆

2.106

$\overrightarrow{BA} = -3\mathbf{i} - 3\cos 20^\circ \mathbf{j} + (4 - 3\sin 20^\circ)\mathbf{k} = -3\mathbf{i} - 2.819\mathbf{j} + 2.974\mathbf{k}$ lb

$\overrightarrow{CA} = 2\mathbf{i} - 2.819\mathbf{j} + 2.974\mathbf{k}$ lb

$$\mathbf{T}_1 = 30\,\vec{\lambda}_{BA} = 30\left(\frac{-3\mathbf{i} - 2.819\mathbf{j} + 2.974\mathbf{k}}{5.0785}\right) = -17.722\mathbf{i} - 16.653\mathbf{j} + 17.568\mathbf{k} \text{ lb}$$

$$\mathbf{T}_2 = 90\,\vec{\lambda}_{CA} = 90\left(\frac{2\mathbf{i} - 2.819\mathbf{j} + 2.974\mathbf{k}}{4.5600}\right) = 39.474\mathbf{i} - 55.638\mathbf{j} + 58.697\mathbf{k} \text{ lb}$$

$\mathbf{R} = \mathbf{T}_1 + \mathbf{T}_2 = 21.752\mathbf{i} - 72.291\mathbf{j} + 76.265\mathbf{k}$ lb

$$\therefore\ R = \sqrt{21.752^2 + (-72.291)^2 + 76.265^2} = 107.3 \text{ lb}$$ ◆

2.107

$\mathbf{P} = -300\mathbf{i} + 200\mathbf{j} + 150\mathbf{k}$ lb $\qquad \mathbf{C} = C\vec{\lambda}_{BE} = C(-0.6\mathbf{j} + 0.8\mathbf{k})$ lb•ft

$\mathbf{r}_{DA} = 3\mathbf{j}$ ft $\qquad \vec{\lambda}_{DE} = -0.6\mathbf{i} + 0.8\mathbf{k}$

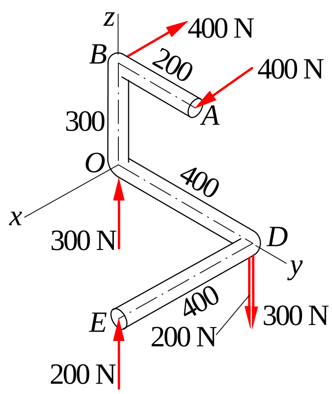
<u>For **P**</u>: $M_{DE} = \mathbf{r}_{DA} \times \mathbf{P} \bullet \vec{\lambda}_{DE} = \begin{vmatrix} 0 & 3 & 0 \\ -300 & 200 & 150 \\ -0.6 & 0 & 0.8 \end{vmatrix} = -3(-240 + 90) = 450$ lb•ft

<u>For **C**</u>: $M_{DE} = \mathbf{C} \bullet \vec{\lambda}_{DE} = C(-0.6\mathbf{j} + 0.8\mathbf{k}) \bullet (-0.6\mathbf{i} + 0.8\mathbf{k}) = 0.640C$

<u>Combined moment of **P** and **C**</u>: $\Sigma M_{DE} = 450 + 0.640C = 800$ lb•ft

which gives: $C = 547$ lb•ft ◆

2.108



Split the 500-N force at D into the 200-N and 300-N forces as shown. We now see that the force system consists of three couples.

$$\begin{aligned} \mathbf{C}^R &= \Sigma\mathbf{C} = -300(0.4)\mathbf{i} - 200(0.4)\mathbf{j} - 400(0.2)\mathbf{k} \\ &= -120\mathbf{i} - 80\mathbf{j} - 80\mathbf{k} \text{ N} \cdot \text{m} \quad \blacktriangleleft \end{aligned}$$