

***Engineering Mechanics Statics 9th edition Meriam
Solutions Manual***

SKU: 9781119392743-SOLUTIONS

$$\begin{aligned} \underline{2/1} \quad & \begin{cases} F_x = 600 \cos 40^\circ = \underline{460 \text{ N}} \\ F_y = -600 \sin 40^\circ = \underline{-386 \text{ N}} \end{cases} \\ & \underline{\underline{F = 460\hat{i} - 386\hat{j} \text{ N}}} \end{aligned}$$

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$$\begin{aligned} \underline{2/2} \quad \underline{\underline{\underline{F}}} &= 400 (-\cos 30^\circ \underline{i} + \sin 30^\circ \underline{j}) \\ &= -346 \underline{i} + 200 \underline{j} \text{ lb} \end{aligned}$$

$$\text{Scalar components: } \begin{cases} F_x = -346 \text{ lb} \\ F_y = 200 \text{ lb} \end{cases}$$

$$\text{Vector components: } \begin{cases} \underline{F}_x = -346 \underline{i} \text{ lb} \\ \underline{F}_y = 200 \underline{j} \text{ lb} \end{cases}$$

WILEY

2/3

$$\underline{F} = 6.5 \left(-\frac{12}{13} \underline{i} - \frac{5}{13} \underline{j} \right) \\ = -6 \underline{i} - 2.5 \underline{j} \text{ kN}$$

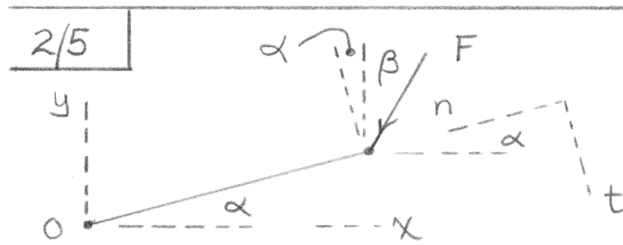
(Note: Writing 6, rather than 6.00, indicates an exact result.)

WILEY

$$\begin{aligned} \underline{2/4} \quad \underline{\underline{F}} &= F_{n_{AB}} = 3000 \left[\frac{15\mathbf{i} + 8\mathbf{j}}{\sqrt{15^2 + 8^2}} \right] \\ &= 2650\mathbf{i} + 1412\mathbf{j} \text{ lb} \end{aligned}$$

$$\text{Scalar components : } \begin{cases} F_x = 2650 \text{ lb} \\ F_y = 1412 \text{ lb} \end{cases}$$

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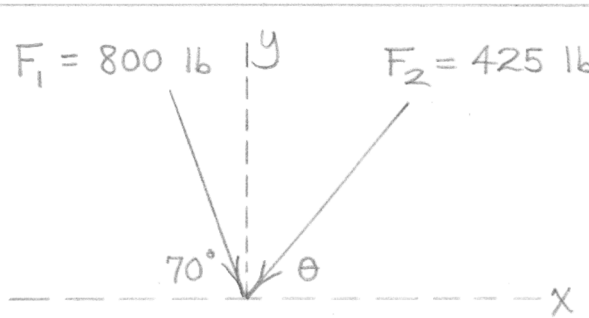


$$\begin{cases} F_x = -F \sin \beta \\ F_y = -F \cos \beta \end{cases}$$

$$\begin{cases} F_n = F \sin(\alpha + \beta) \\ F_t = F \cos(\alpha + \beta) \end{cases}$$

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2/6



$F_1 = 800 \text{ lb}$ $F_2 = 425 \text{ lb}$

70° θ

$R_x = \sum F_x = 800 \cos 70^\circ - 425 \cos \theta = 0$

$\theta = 49.9^\circ$

$R_y = \sum F_y = -800 \sin 70^\circ - 425 \sin 49.9^\circ$

$= -1077 \text{ lb}$

So $\underline{R = 1077 \text{ lb}}$

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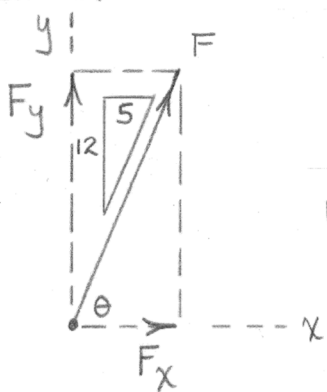
$$\begin{cases} \underline{R} = (500 + 350 \cos 60^\circ) \underline{i} + 350 \sin 60^\circ \underline{j} \\ \underline{R} = 675 \underline{i} + 303 \underline{j} \text{ N} \end{cases}$$

$$R = \sqrt{675^2 + 303^2} \longrightarrow \underline{R = 740 \text{ N}}$$

$$\theta_x = \cos^{-1} \left(\frac{R_x}{R} \right) = \cos^{-1} \left(\frac{675}{740} \right) \longrightarrow \underline{\theta_x = 24.2^\circ \text{ ABOVE } +X \text{ AXIS}}$$

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2/8



$\cos \theta = \frac{5}{13}, \quad \sin \theta = \frac{12}{13}$

$F_y = F \sin \theta = F \frac{12}{13} = 70$

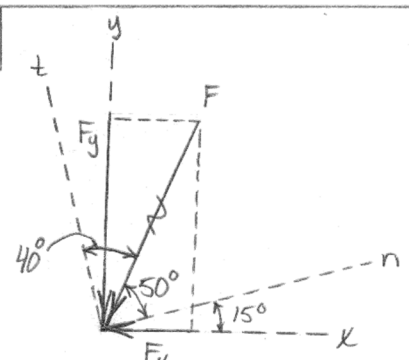
$F = 75.8 \text{ lb}$

$F_x = F \cos \theta = 75.8 \left(\frac{5}{13} \right)$

$= 29.2 \text{ lb}$

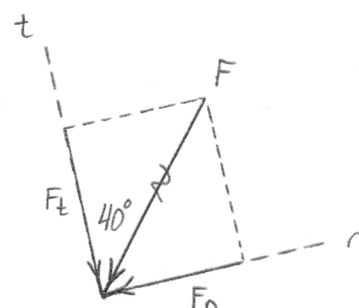
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$$\begin{cases} F_x = -F \cos 65^\circ = -13 \cos 65^\circ \\ F_x = -5.49 \text{ kips} \end{cases}$$

$$\begin{cases} F_y = -F \sin 65^\circ = -13 \sin 65^\circ \\ F_y = -11.78 \text{ kips} \end{cases}$$

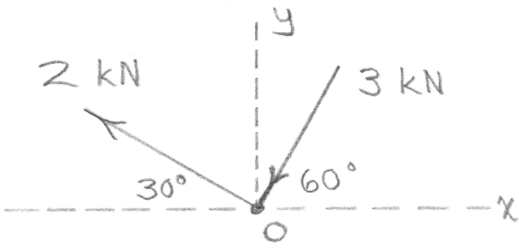


$$\begin{cases} F_n = -F \sin 40^\circ = -13 \sin 40^\circ \\ F_n = -8.36 \text{ kips} \end{cases}$$

$$\begin{cases} F_t = -F \cos 40^\circ = -13 \cos 40^\circ \\ F_t = -9.96 \text{ kips} \end{cases}$$

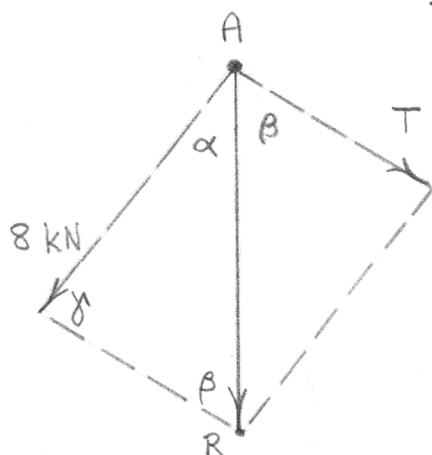
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$$R_x = \sum F_x = -2 \cos 30^\circ - 3 \cos 60^\circ = -3.23 \text{ kN}$$
$$R_y = \sum F_y = 2 \sin 30^\circ - 3 \sin 60^\circ = -1.598 \text{ kN}$$
$$R = \sqrt{R_x^2 + R_y^2} = 3.61 \text{ kN}$$
$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right) = \tan^{-1}\left(\frac{-1.598}{-3.23}\right) = 206^\circ$$

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$$\begin{cases} \alpha = \tan^{-1} \frac{40}{50} = 38.7^\circ \\ \beta = \tan^{-1} \frac{50}{30} = 59.0^\circ \end{cases}$$

$$\gamma = 180^\circ - \alpha - \beta$$

$$= 82.3^\circ$$

$$\frac{\sin \beta}{8} = \frac{\sin \alpha}{T}$$

$$\underline{T = 5.83 \text{ kN}}$$

$$\frac{\sin \beta}{8} = \frac{\sin \gamma}{R},$$

$$\underline{R = 9.25 \text{ kN}}$$

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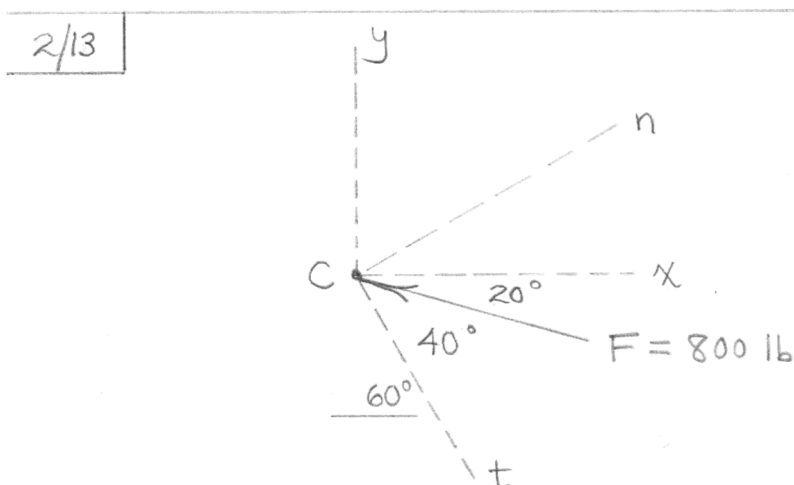
$$R_x = \sum F_x = 400 + 400 \cos 60^\circ = 600 \text{ N}$$

$$R_y = \sum F_y = 400 \sin 60^\circ = 346 \text{ N}$$

$$\Rightarrow \underline{R} = \underline{600\mathbf{i} + 346\mathbf{j} \text{ N}}$$

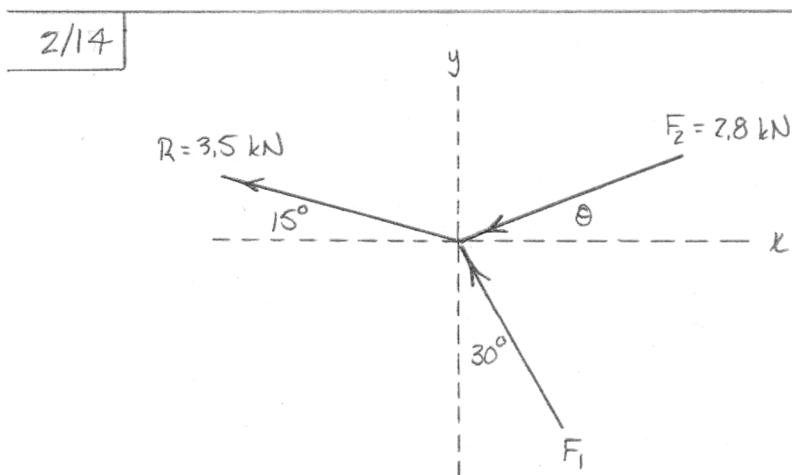
$$R = \sqrt{600^2 + 346^2} = \underline{693 \text{ N}}$$

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$$\begin{cases} F_x = -800 \cos 20^\circ = \underline{-752 \text{ lb}} \\ F_y = 800 \sin 20^\circ = \underline{274 \text{ lb}} \end{cases}$$

$$\begin{cases} F_n = -800 \sin 40^\circ = \underline{-514 \text{ lb}} \\ F_t = -800 \cos 40^\circ = \underline{-613 \text{ lb}} \end{cases}$$



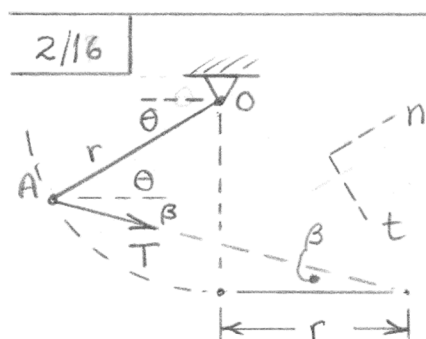
$$\begin{cases} R_x = \sum F_x: & -3.5 \cos 15^\circ = -F_1 \sin 30^\circ - 2.8 \cos \theta & (1) \\ R_y = \sum F_y: & 3.5 \sin 15^\circ = F_1 \cos 30^\circ - 2.8 \sin \theta & (2) \end{cases}$$

Solving (1) AND (2)...

$$\begin{cases} F_1 = 1.165 \text{ kN} \\ \theta = 2.11^\circ \end{cases}$$

OR

$$\begin{cases} F_1 = 3.78 \text{ kN} \\ \theta = 57.9^\circ \end{cases}$$



From solution to previous problem:

$$\beta = \tan^{-1} \left[\frac{1 - \sin \theta}{1 + \cos \theta} \right]$$

$$\begin{cases} T_n = T \cos(\theta + \beta) \\ T_t = T \sin(\theta + \beta) \end{cases}$$

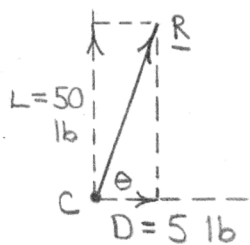
For $T = 100 \text{ N}$ and $\theta = 35^\circ$:

$$\beta = 13.19^\circ$$

$$\begin{cases} T_n = 66.7 \text{ N} \\ T_t = 74.5 \text{ N} \end{cases}$$

2/17

$$\frac{L}{D} = \frac{50}{5} = 10 ; D = 5 \text{ lb}$$



$$R = \sqrt{L^2 + D^2} = \sqrt{50^2 + 5^2}$$
$$= 50.2 \text{ lb}$$

$$\theta = \tan^{-1}\left(\frac{L}{D}\right) = \tan^{-1}\left(\frac{50}{5}\right)$$
$$= 84.3^\circ$$

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Using the coordinates of the problem figure:

$$\begin{aligned} R_x = \sum F_x &= 200 \cos 35^\circ - 150 \sin 30^\circ \\ &= 88.8 \text{ N} \end{aligned}$$

$$\begin{aligned} R_y = \sum F_y &= 200 \sin 35^\circ + 150 \cos 30^\circ \\ &= 245 \text{ N} \end{aligned}$$

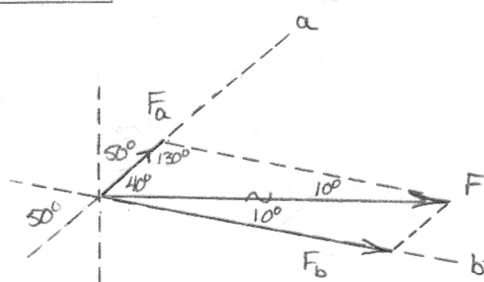
$$\therefore \underline{R = 88.8 \underline{i} + 245 \underline{j} \text{ N}}$$

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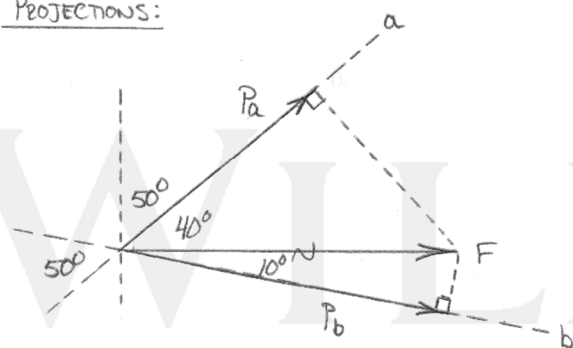
$F = 2.5 \text{ kN}$

• COMPONENTS:



$$\frac{F}{\sin 130^\circ} = \frac{F_a}{\sin 10^\circ} = \frac{F_b}{\sin 40^\circ} \rightarrow \begin{cases} F_a = 0.567 \text{ kN} \\ F_b = 2.10 \text{ kN} \end{cases}$$

• PROJECTIONS:



$$\begin{cases} P_a = F \cos 40^\circ = 2.5 \cos 40^\circ \rightarrow P_a = 1.915 \text{ kN} \\ P_b = F \cos 10^\circ = 2.5 \cos 10^\circ \rightarrow P_b = 2.46 \text{ kN} \end{cases}$$

2/20

Diagram showing a force $R = 800\text{ N}$ being resolved into components R_a and R_b . The angle between R and R_a is 40° . The angle between R and R_b is 30° . The angle between R_a and R_b is 110° .

Law of sines :

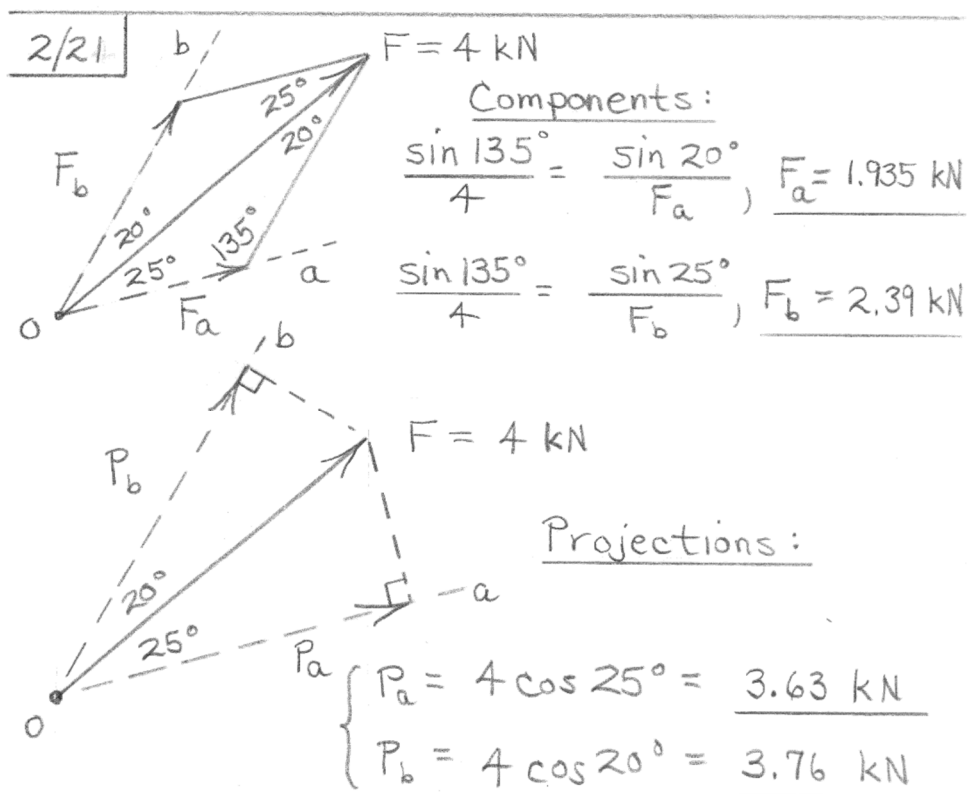
$$\frac{800}{\sin 40^\circ} = \frac{R_a}{\sin 110^\circ} = \frac{R_b}{\sin 30^\circ}$$

$R_a = 1170\text{ N}$

$R_b = 622\text{ N}$

Projection $P_a = R \cos 30^\circ = 800 \cos 30^\circ = \underline{693\text{ N}}$

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2/23

$\alpha = \tan^{-1} \frac{4}{8} = 26.57^\circ$
 $\theta = \tan^{-1} \frac{6}{8} = 36.87^\circ$
 $\beta = 180 - (\alpha + \theta) = 116.57^\circ$

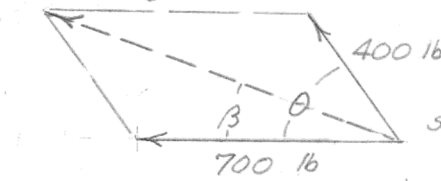
$\frac{P}{\sin 36.87^\circ} = \frac{400}{\sin 26.57^\circ}$
 $P = 400 \frac{0.6}{0.4472} = 537 \text{ lb}$

$\frac{T}{\sin 116.56^\circ} = \frac{400}{\sin 26.57^\circ}, T = 400 \frac{0.8944}{0.4472} = 800 \text{ lb}$

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2/24 Law of cosines: $1000^2 = 400^2 + 700^2 + 2(400)(700)\cos\theta$
 $\cos\theta = 0.6250$, $\theta = 51.3^\circ$

$R = 1000$ lb



Law of sines:

$$\frac{1000}{\sin(180 - 51.3)^\circ} = \frac{400}{\sin\beta}$$

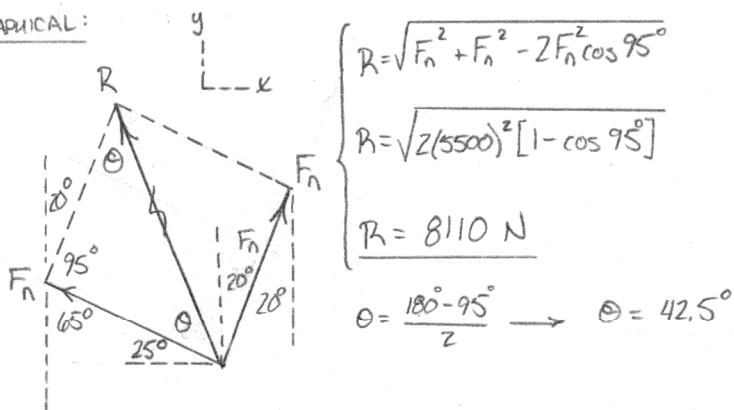
$$\sin\beta = \frac{400}{1000} 0.7806 = 0.312$$

$$\beta = 18.19^\circ$$

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• GRAPHICAL:



$R = 8110 \text{ N @ } 112.5^\circ \text{ CCW FROM } +X \text{ AXIS}$

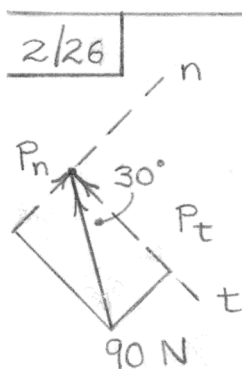
• VECTORS:

$$\begin{aligned} \underline{R} &= (F_1 \sin 20^\circ - F_2 \sin 65^\circ) \underline{i} + (F_1 \cos 20^\circ + F_2 \cos 65^\circ) \underline{j} \\ \underline{R} &= 5500 [\sin 20^\circ - \sin 65^\circ] \underline{i} + (\cos 20^\circ + \cos 65^\circ) \underline{j} \\ \underline{R} &= -3100 \underline{i} + 7490 \underline{j} \text{ N} \end{aligned}$$

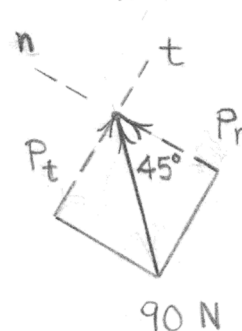
$$R = \sqrt{3100^2 + 7490^2} \rightarrow R = 8110 \text{ N}$$

$$\theta_x = \cos^{-1} \left(\frac{R_x}{R} \right) = \cos^{-1} \left(\frac{-3100}{8110} \right) \rightarrow \theta_x = 112.5^\circ \text{ CCW FROM } +X \text{ AXIS}$$

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BC

$$P_t = -90 \cos 30^\circ = -77.9 \text{ N}$$
$$P_n = 90 \sin 30^\circ = 45.0 \text{ N}$$


AB

$$P_t = 90 \sin 45^\circ = 63.6 \text{ N}$$
$$P_n = 90 \cos 45^\circ = 63.6 \text{ N}$$

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Diagram showing a force of 4 kN acting at point A (1.2, 1.5). The force is perpendicular to the line segment from the origin O to point A. The perpendicular distance from the origin to the line of action of the force is labeled as the moment M_o . The coordinates of the intercepts of the line of action are $(-1.3, 0)$ and $(0, 0.78)$.

$$M_o = 4 \left[\frac{5}{\sqrt{34}} (1.5) - \frac{3}{\sqrt{34}} (1.2) \right] = 2.68 \text{ kN}\cdot\text{m}$$

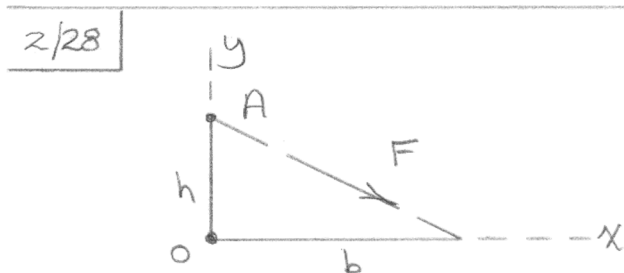
As a vector, $\underline{M_o} = 2.68 \underline{k} \text{ kN}\cdot\text{m}$

$$\frac{1.5}{d_x + 1.2} = \frac{3}{5}, \quad d_x = 1.3 \text{ m}$$

$$\frac{d_y}{1.3} = \frac{3}{5}, \quad d_y = 0.78 \text{ m}$$

Coordinates of intercepts: $(-1.3, 0), (0, 0.78)$
(in m)

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$$\underline{F} = F \left[\frac{bi - hj}{\sqrt{b^2 + h^2}} \right]$$

Acting at A:

$$+ \circlearrowleft M_o = \frac{Fb}{\sqrt{h^2 + b^2}} (h) = \frac{Fbh}{\sqrt{h^2 + b^2}} \quad \text{CW}$$

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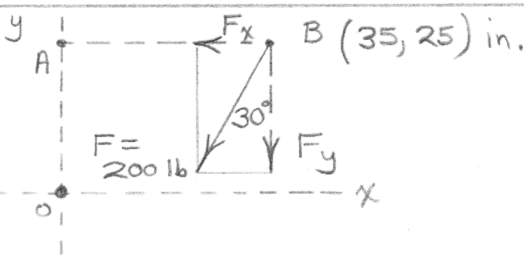
2/29

$$|F_x| = 200 \sin 30^\circ$$

$$= 100 \text{ lb}$$

$$|F_y| = 200 \cos 30^\circ$$

$$= 173.2 \text{ lb}$$



$$+\curvearrowright M_A = 173.2(35) = 6060 \text{ lb-in. (505 lb-ft)}$$

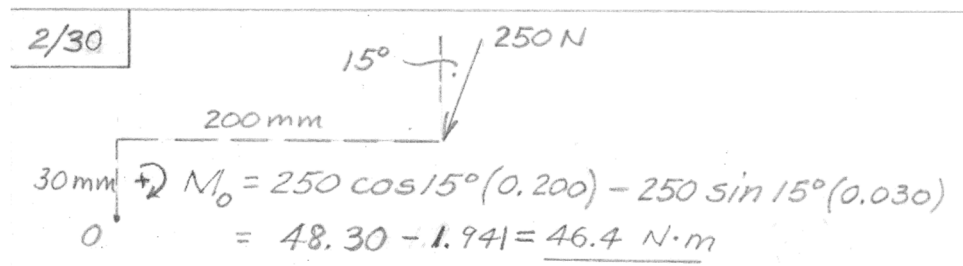
CW

$$+\curvearrowright M_O = 173.2(35) - 100(25)$$

$$= 3560 \text{ lb-in. (297 lb-ft) CW}$$

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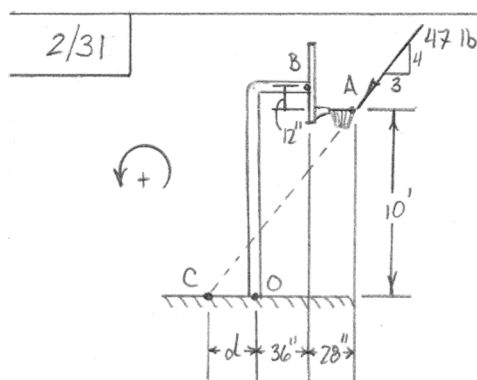
2/30



The diagram shows an L-shaped member with a horizontal arm of 200 mm and a vertical arm of 30 mm. A force of 250 N is applied at the end of the horizontal arm, directed at an angle of 15° below the horizontal. The origin of the member is labeled 'O'.

$$\begin{aligned} +\circlearrowleft M_O &= 250 \cos 15^\circ (0.200) - 250 \sin 15^\circ (0.030) \\ &= 48.30 - 1.941 = \underline{46.4 \text{ N}\cdot\text{m}} \end{aligned}$$

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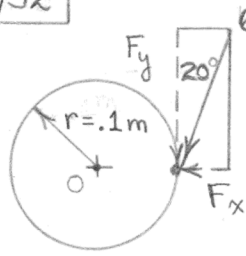
$$a) M_O = 10\left(\frac{3}{5} 47\right) - \left(\frac{36+28}{12}\right)\left(\frac{4}{5} 47\right) = 81.5 \rightarrow M_O = 81.5 \text{ lb-ft CCW}$$

$$b) M_B = -\frac{12}{12}\left(\frac{3}{5} 47\right) - \frac{28}{12}\left(\frac{4}{5} 47\right) = -115.9 \rightarrow M_B = 115.9 \text{ lb-ft CW}$$

$$c) M_C = 0 = 10\left(\frac{3}{5} 47\right) - \left(\frac{36+28+d}{12}\right)\left(\frac{4}{5} 47\right) \rightarrow d = 26 \text{ in. LEFT OF O}$$

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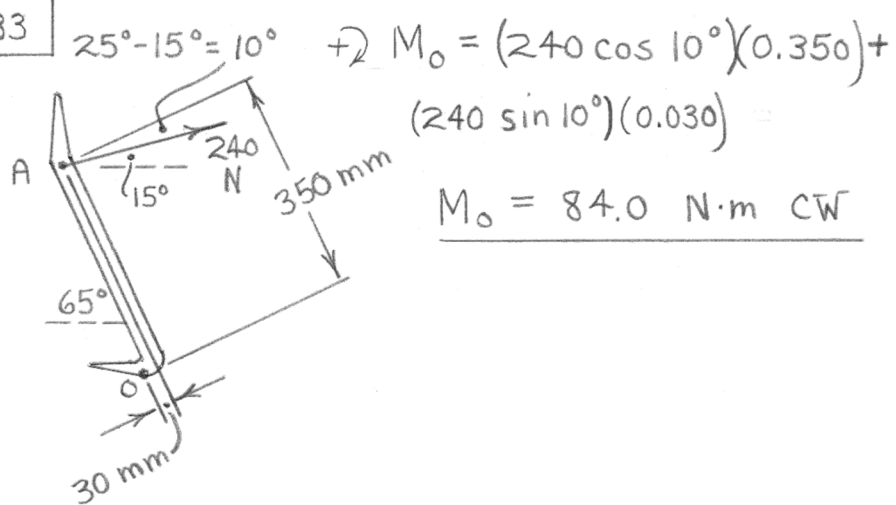
2/32



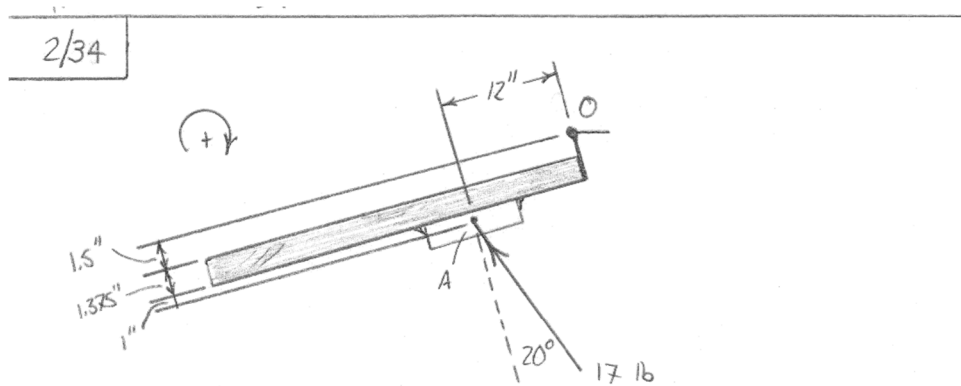
$$\begin{aligned} 60 \text{ N} + 2 M_o &= r F_y \\ &= (0.1) (60 \cos 20^\circ) \\ &= \underline{5.64 \text{ N}\cdot\text{m}} \end{aligned}$$

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2/33



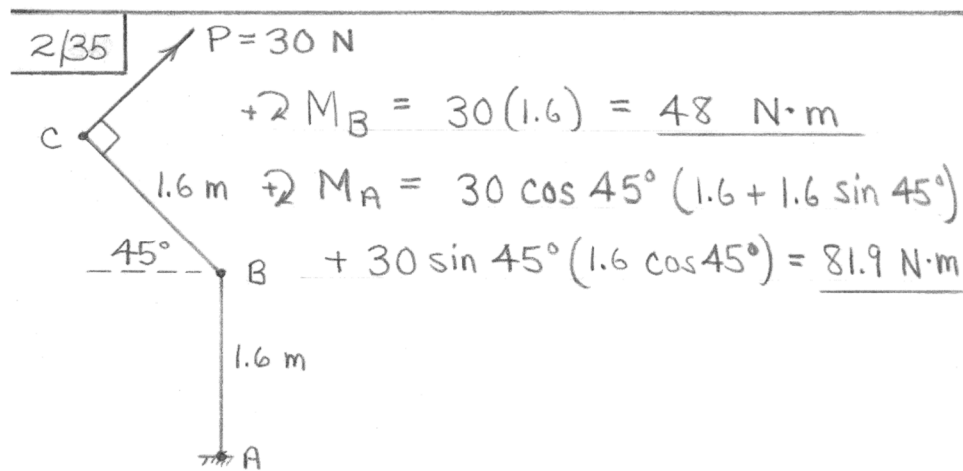
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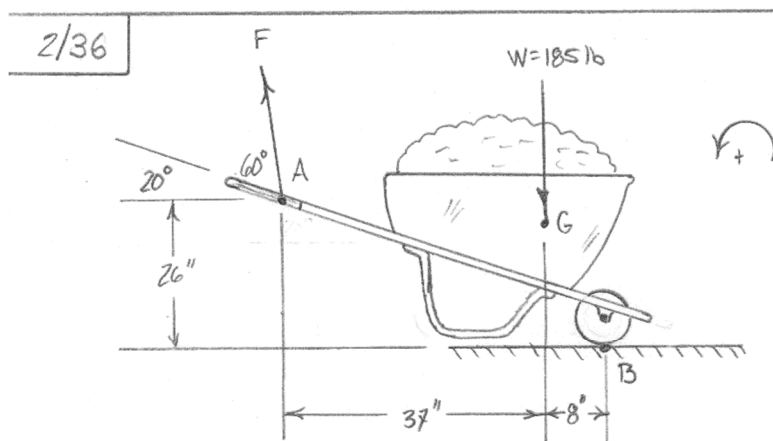
$$M_O = 12(17\cos 20^\circ) + (1 + 1.375 + 1.5)(17\sin 20^\circ)$$

$$M_O = 214 \text{ lb-in. CW}$$

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$$\sum M_B = 0: 185(8) - F \sin(20^\circ + 60^\circ)(37 + 8) + F \cos(20^\circ + 60^\circ)(26) = 0$$

$$\therefore \underline{F = 37.2 \text{ lb}}$$

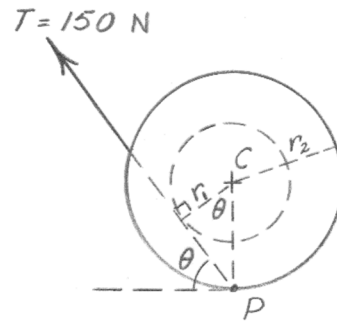
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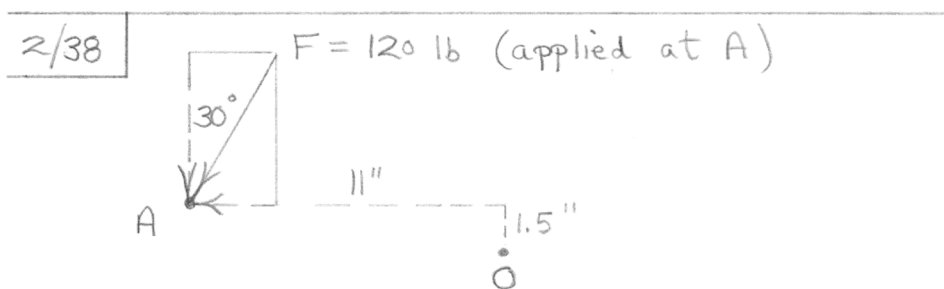
$$\begin{aligned}\curvearrowright M_C &= Tr_1 = 150(0.125) \\ &= \underline{18.75 \text{ N}\cdot\text{m CW}}\end{aligned}$$

$$\cos \theta = \frac{r_1}{r_2} = \frac{125}{200}$$

$$\underline{\theta = 51.3^\circ}$$



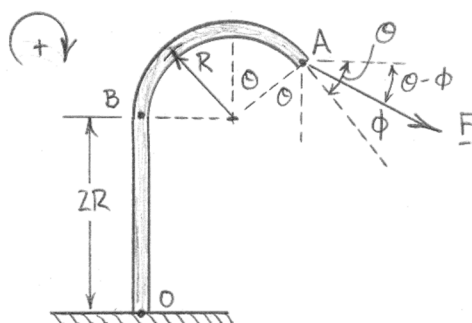
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$$\begin{aligned} \uparrow M_O &= 120 \cos 30^\circ (11) + 120 \sin 30^\circ (1.5) \\ &= \underline{1233 \text{ lb-in.}} \text{ or } \underline{102.8 \text{ lb-ft CCW}} \end{aligned}$$

WILEY

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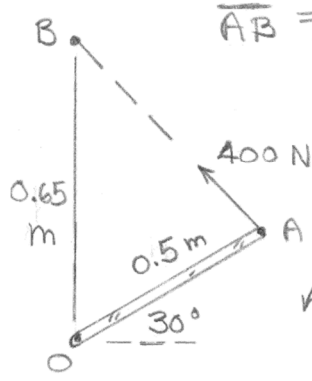
$$\begin{cases} M_B = F \sin(\theta - \phi)(R + R \sin \theta) + F \cos(\theta - \phi)(R \cos \theta) \\ \underline{M_B = FR [\cos \phi + \sin(\theta - \phi)]} \end{cases}$$

$$\begin{cases} M_O = F \sin(\theta - \phi)(R + R \sin \theta) + F \cos(\theta - \phi)(2R + R \cos \theta) \\ \underline{M_O = FR [2 \cos(\theta - \phi) + \cos \phi + \sin(\theta - \phi)]} \end{cases}$$

If $F = 750 \text{ N}$, $R = 2.4 \text{ m}$, $\theta = 30^\circ$, and $\phi = 15^\circ \dots$

$$\begin{cases} \underline{M_B = 2200 \text{ N}\cdot\text{m CW}} \\ \underline{M_O = 5680 \text{ N}\cdot\text{m CW}} \end{cases}$$

2/40



$$\overline{AB}^2 = 0.65^2 + 0.5^2 - 2(0.65)(0.5)\cos 60^\circ$$

$$\overline{AB} = 0.589 \text{ m}$$

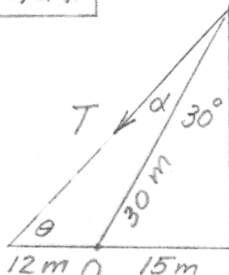
$$\frac{\sin 60^\circ}{\overline{AB}} = \frac{\sin \angle OAB}{0.65}$$

$$\angle OAB = 72.7^\circ$$

$$\begin{aligned} \curvearrowright M_O &= 0.5 (400 \sin 72.7^\circ) \\ &= \underline{191.0 \text{ N}\cdot\text{m} \text{ CCW}} \end{aligned}$$

WILEY

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$$\theta = \tan^{-1} \frac{30(0.866)}{12 + 15} = 43.90^\circ$$

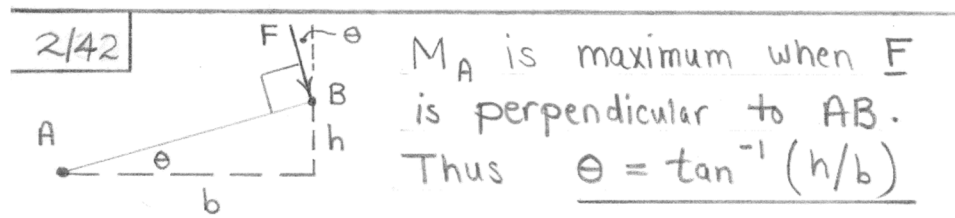
$$\alpha = 90^\circ - (30^\circ + 43.90^\circ) = 16.10^\circ$$

$$M_o = 72 \text{ kN}\cdot\text{m}$$

$$= T \sin 16.10^\circ (30) = 8.32T$$

$$T = \frac{72}{8.32} = \underline{8.65 \text{ kN}}$$

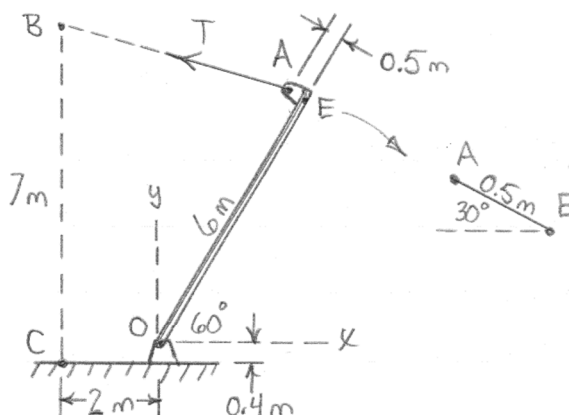
WILEY



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2/43

$$T = 6.75 \text{ kN}$$



$$\begin{aligned} \underline{r}_{OA} &= (6 \cos 60^\circ - 0.5 \cos 30^\circ) \underline{i} + (6 \sin 60^\circ + 0.5 \sin 30^\circ) \underline{j} \\ &= 2.57 \underline{i} + 5.45 \underline{j} \text{ m} \end{aligned}$$

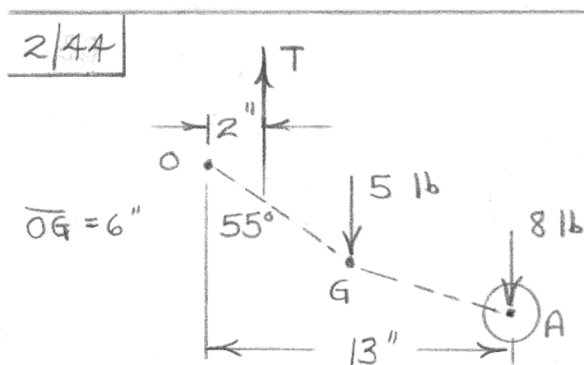
$$\underline{r}_{OB} = -2 \underline{i} + (7 - 0.4) \underline{j} = -2 \underline{i} + 6.6 \underline{j} \text{ m}$$

$$\underline{n}_{AB} = \frac{\underline{r}_{OB} - \underline{r}_{OA}}{|\underline{r}_{OB} - \underline{r}_{OA}|} \rightarrow \underline{n}_{AB} = -0.970 \underline{i} + 0.245 \underline{j}$$

$$\underline{T} = T \underline{n}_{AB} = 6.75 (-0.970 \underline{i} + 0.245 \underline{j}) = -6.54 \underline{i} + 1.653 \underline{j} \text{ kN}$$

$$\underline{M}_O = \underline{r}_{OA} \times \underline{T} = (2.57 \underline{i} + 5.45 \underline{j}) \times (-6.54 \underline{i} + 1.653 \underline{j})$$

$$\underline{M}_O = 39.9 \underline{k} \text{ kN}\cdot\text{m}$$



The combined moment about O of the 5-lb and 8-lb weights is

$$+\circlearrowright M_o = 5(6 \sin 55^\circ) + 8(13) = 128.6 \text{ lb-in. (CW)}$$

$$+\circlearrowright \sum M_o = 0 : -T(2) + 128.6 = 0$$

$$T = 64.3 \text{ lb}$$

WILEY

2/45 ↺

(1) $M_A = 200 \cos 15^\circ (0.280) + 200 \sin 15^\circ (0.400) = \underline{74.8 \text{ N}\cdot\text{m}}$

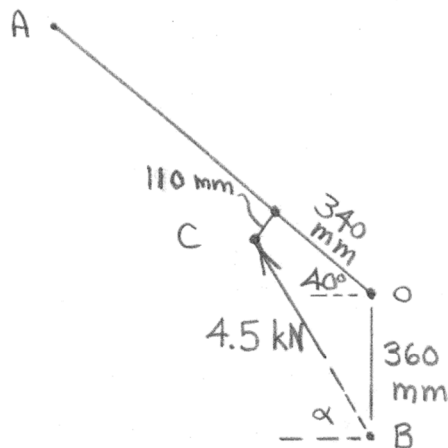
(2) $AE = 0.280 \cos 15^\circ + 0.400 \sin 15^\circ$
 $= 0.374 \text{ m} ; M_A = 200(0.374) = \underline{74.8 \text{ N}\cdot\text{m}}$

(3) Apply force at C
 $CD = 0.400 \tan 15^\circ = 0.1072 \text{ m}$
 $CA = 0.280 + 0.1072 = 0.387 \text{ m}$
 $M_A = (200 \cos 15^\circ)(0.387) = \underline{74.8 \text{ N}\cdot\text{m}}$

(4) $\underline{M}_A = \underline{r} \times \underline{F} = (0.400\underline{i} + 0.280\underline{j}) \times 200(-\cos 15^\circ\underline{i} + \sin 15^\circ\underline{j}) = \underline{74.8 \underline{k} \text{ N}\cdot\text{m}}$

WILEY

2/46



$$\alpha = \tan^{-1} \left[\frac{360 + 340 \sin 40^\circ - 110 \sin 50^\circ}{340 \cos 40^\circ + 110 \cos 50^\circ} \right]$$

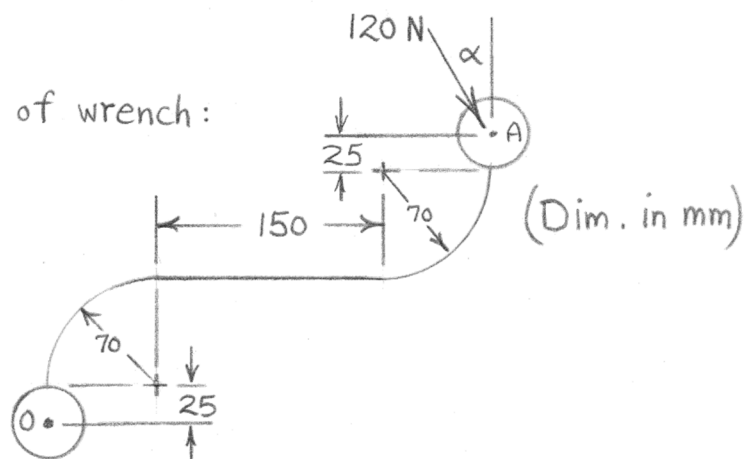
$$= 56.2^\circ$$

$$+ \curvearrowright M_o = 4.5 (0.360 \cos 56.2^\circ) = \underline{0.902 \text{ kN} \cdot \text{m CW}}$$

WILEY

2/47

Elements of wrench:



$$\alpha = 30^\circ:$$

$$\begin{aligned} +\circlearrowleft M_o &= 120 \cos 30^\circ [70 + 150 + 70] \\ &\quad + 120 \sin 30^\circ [25 + 70 + 70 + 25] = 41\,500 \text{ N}\cdot\text{mm} \end{aligned}$$

$$\text{or } M_o = 41.5 \text{ N}\cdot\text{m CW}$$

For maximum M_o :

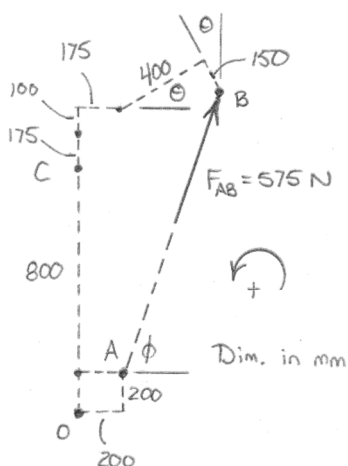
$$\alpha = \tan^{-1} \left[\frac{25 + 70 + 25 + 70}{70 + 150 + 70} \right] = 33.2^\circ$$

$$\begin{aligned} (M_o)_{\max} &= 120 \sqrt{(25 + 70 + 25 + 70)^2 + (70 + 150 + 70)^2} \\ &= 41\,600 \text{ N}\cdot\text{mm} \text{ or } \underline{41.6 \text{ N}\cdot\text{m CW}} \end{aligned}$$

2/48

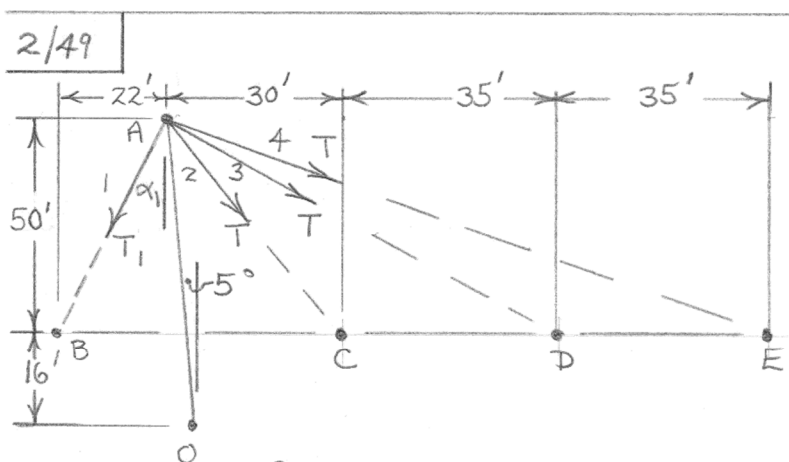
$$\theta = 30^\circ$$

$$\phi = \tan^{-1} \left(\frac{800 + 175 + 100 + 400 \sin \theta - 150 \cos \theta}{175 + 400 \cos \theta + 150 \sin \theta - 200} \right) = 70.9^\circ$$



$$M_O = 575 \sin \phi (0.200) - 575 \cos \phi (0.200) \rightarrow \underline{M_O = 71.1 \text{ N}\cdot\text{m CCW}}$$

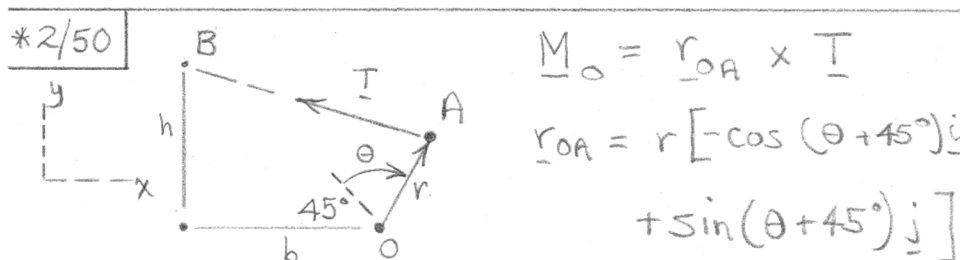
$$M_C = 575 \sin \phi (0.200) + 575 \cos \phi (0.800) \rightarrow \underline{M_C = 259 \text{ N}\cdot\text{m CCW}}$$



$$\alpha_1 = \tan^{-1} \frac{22}{50} = 23.7^\circ; \text{ Similarly, } \alpha_2 = 31.0^\circ, \\ \alpha_3 = 52.4^\circ, \alpha_4 = 63.4^\circ \text{ (all relative to vertical)} \\ \sum M_O = 0: [T_1 \sin(\alpha_1 + 5^\circ) - T \sin(\alpha_2 - 5^\circ) - T \sin(\alpha_3 - 5^\circ) \\ - T \sin(\alpha_4 - 5^\circ)] \frac{50+16}{\cos 5^\circ} = 0$$

$$T_1 = 4.21T$$

$$+\downarrow \sum F = P = T_1 \cos(\alpha_1 + 5^\circ) + T [\cos(\alpha_2 - 5^\circ) \\ \cos(\alpha_3 - 5^\circ) + \cos(\alpha_4 - 5^\circ)] \\ \text{or } P = 5.79T \quad (\text{with } T_1 = 4.21T)$$



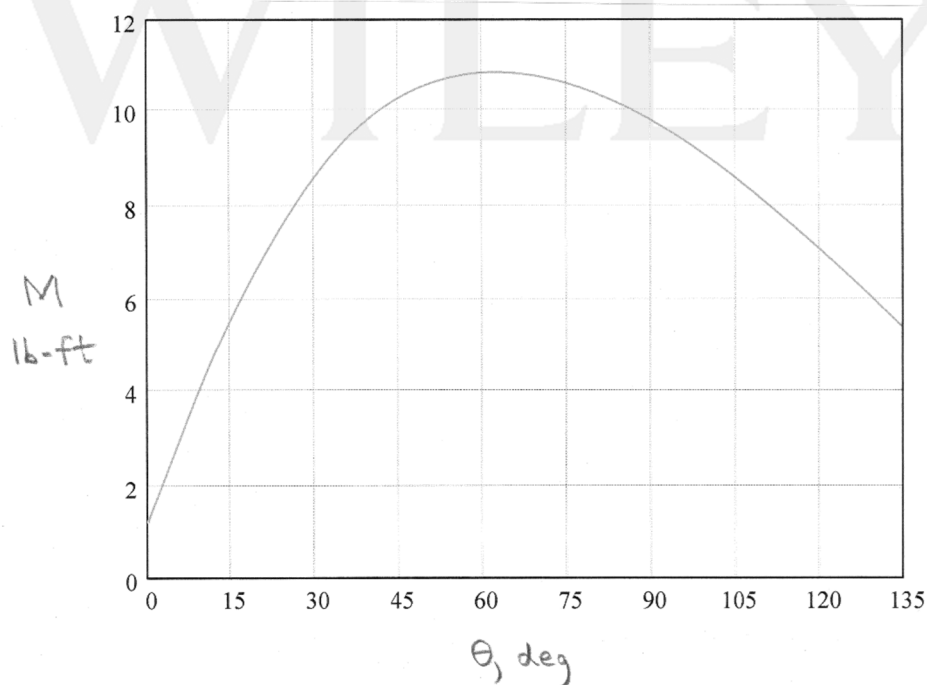
$\underline{T} = W \underline{n}_{AB}$, where

$$\underline{n}_{AB} = \frac{[-b + r \cos(\theta + 45^\circ)] \underline{i} + [h - r \sin(\theta + 45^\circ)] \underline{j}}{\{[-b + r \cos(\theta + 45^\circ)]^2 + [h - r \sin(\theta + 45^\circ)]^2\}^{1/2}}$$

With $r = \frac{13}{12}$ ft, $h = \frac{21}{12}$ ft, $b = \frac{24}{12}$ ft, and

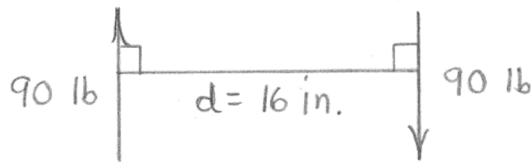
$W = 10$ lb, vary θ and take the z-comp. of $\underline{M}_O$ to obtain the following plot.

Note that $M_{\max} = 10.83$ lb-ft at $\theta = 62.1^\circ$



$$\boxed{2/51} \quad \curvearrowright M = M_o = M_A = Fd = 90(16) = 1440 \text{ lb-in.}$$

CW

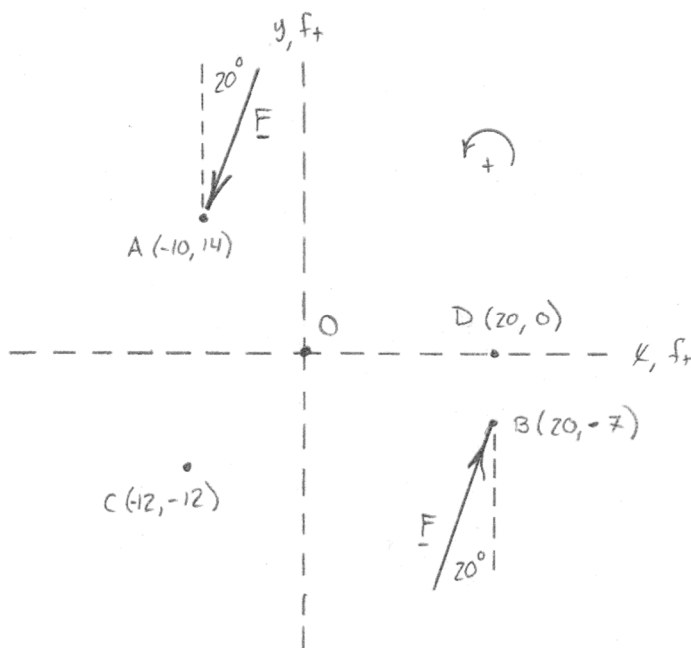


WILEY

2/52 $\therefore M = Fd = 80(1.4) = \underline{112 \text{ lb-in. CW}}$
(or 9.33 lb-ft CW)

2/53

$$F = 65 \text{ lb}$$



$$a) M_O = 65 \cos 20^\circ (20 + 10) + 65 \sin 20^\circ (14 + 7)$$

$$M_O = 2300 \text{ lb-ft CCW}$$

b) By INSPECTION...

$$M_C = 2300 \text{ lb-ft CCW}$$

c) By INSPECTION...

$$M_D = 2300 \text{ lb-ft CCW}$$

2/55

Diagram description: A coordinate system with a vertical y-axis and a horizontal x-axis. Point A is on the x-axis at a distance of 4 m from the origin O. A force of 12 kN is applied at point A, directed at an angle of 30° above the horizontal. Point B is on the y-axis at a distance of 5 m from the origin O. The origin O is labeled at the intersection of the axes.

At O:

$$F = 12 \text{ kN}$$

$$\circlearrowleft M_O = (12 \sin 30^\circ)(4)$$

$$= 24 \text{ kN}\cdot\text{m CW}$$

At B:

$$F = 12 \text{ kN}$$

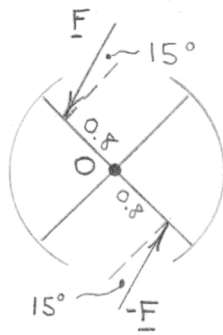
$$\circlearrowleft M_B = (12 \sin 30^\circ)(4) +$$

$$(12 \cos 30^\circ)(5) = 76.0 \text{ kN}\cdot\text{m}$$

CW

WILEY

2/56



$$\curvearrowright M_O = \sum Fd$$

$$25 = 2 F(\cos 15^\circ)(0.8)$$

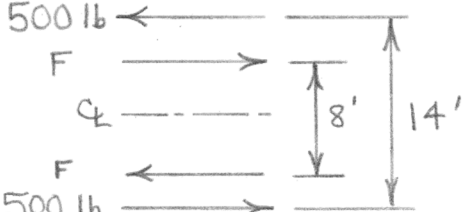
$$F = \underline{16.18 \text{ N}}$$

WILEY

2/57

$\curvearrowright \sum M = 500(14) - F(8) = 0$

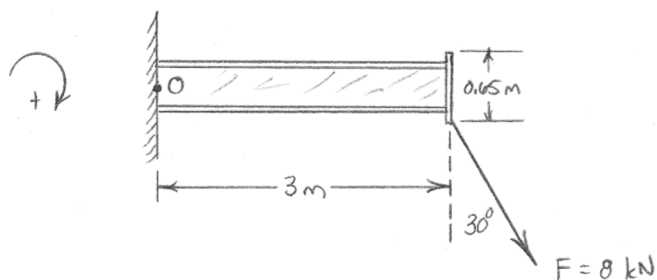
$F = 875 \text{ lb}$



The diagram shows a vertical member with a horizontal line representing its axis. On the left side, there are four horizontal arrows: the top one is labeled '500 lb' and points left; the second is labeled 'F' and points right; the third is labeled 'C_L' and is a dashed line; the bottom one is labeled 'F' and points left. On the right side, there are two vertical arrows: the top one is labeled '14\'' and points up; the bottom one is labeled '8\'' and points down. The '8\'' arrow starts from the horizontal axis and points down to the level of the bottom 'F' force.

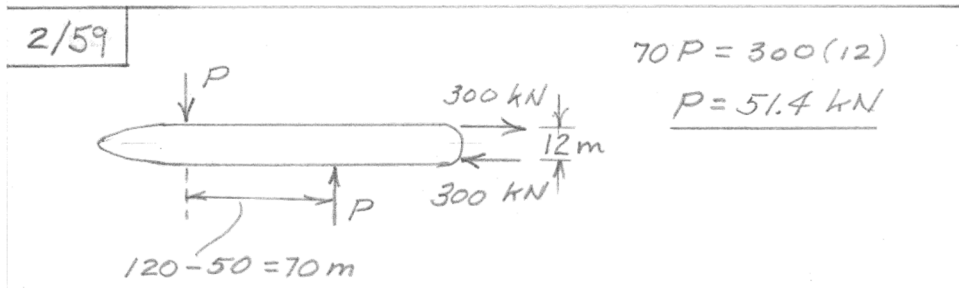
WILEY

2/58



$$\left\{ \begin{array}{l} F = 8 \text{ kN @ } 60^\circ \text{ CW BELOW HORIZONTAL} \\ M_o = 8 \cos 30^\circ (3) - 8 \sin 30^\circ \left(\frac{0.65}{2} \right) \rightarrow M_o = 19.48 \text{ kN}\cdot\text{m CW} \end{array} \right.$$

WILEY



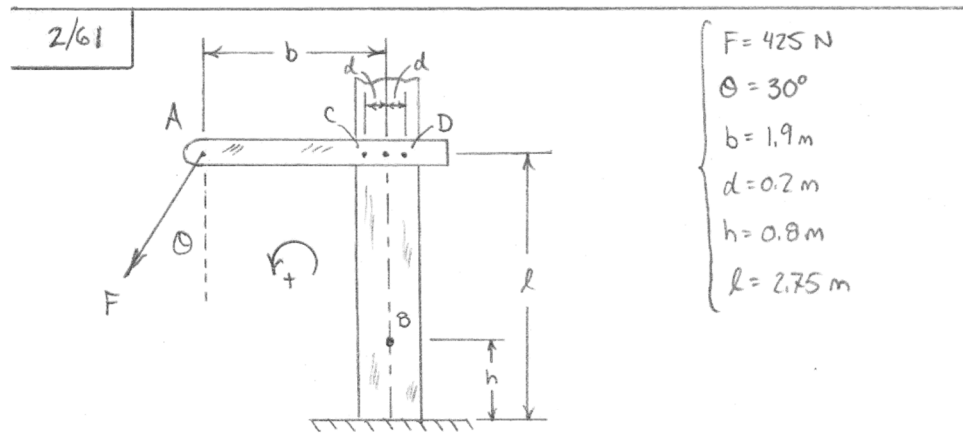
WILEY

2/60

$M = 50(28) = 2F(1)$

$F = 700 \text{ lb}$

WILEY



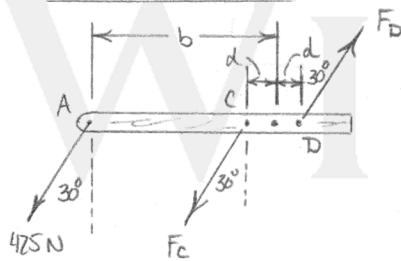
a) FORCE - COUPLE AT B:

$$F = 425 \text{ N @ } -120^\circ \text{ CW BELOW HORIZONTAL}$$

$$M_B = F \cos \theta b + F \sin \theta (l - h) = 425 \cos 30^\circ (1.9) + 425 \sin 30^\circ (2.75 - 0.8)$$

$$\therefore M_B = 1114 \text{ N}\cdot\text{m CCW}$$

b) FORCES AT C AND D:

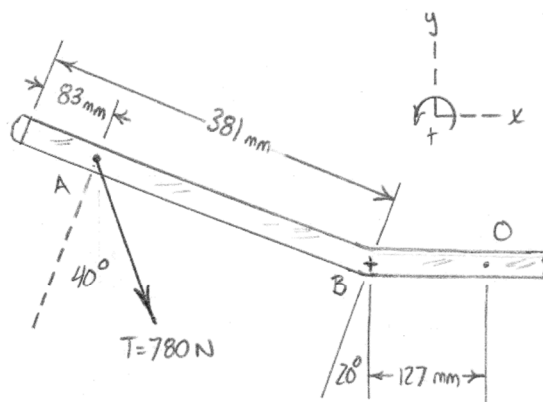


$$\begin{cases} \sum F_x: & F_C - F_D = 425 \\ \sum F_y: & F_D \cos 30^\circ (b+d) - F_C \cos 30^\circ (b+d) = 0 \end{cases}$$

SOLVING...

$$\begin{cases} F_C = 2230 \text{ N @ } 120^\circ \text{ CW BELOW HORIZONTAL} \\ F_D = 1806 \text{ N @ } 60^\circ \text{ CCW ABOVE HORIZONTAL} \end{cases}$$

2/62

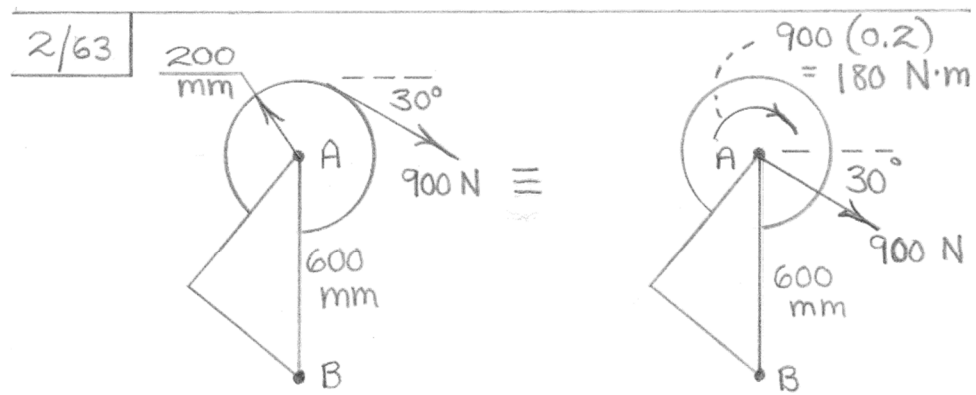


$$\underline{T} = 780 \sin 20^\circ \underline{i} - 780 \cos 20^\circ \underline{j} \longrightarrow \underline{T} = 267 \underline{i} - 733 \underline{j} \text{ N}$$

$$\underline{M}_B = 780 \cos 40^\circ \left(\frac{381 - 83}{1000} \right) \underline{k} \longrightarrow \underline{M}_B = 178.1 \underline{k} \text{ N}\cdot\text{m}$$

$$\underline{M}_O = \underline{M}_B + T \cos 20^\circ (\overline{OB}) = \left(178.1 + 780 \cos 20^\circ \left(\frac{127}{1000} \right) \right) \underline{k}$$

$$\therefore \underline{M}_O = 271 \hat{k} \text{ N}\cdot\text{m}$$

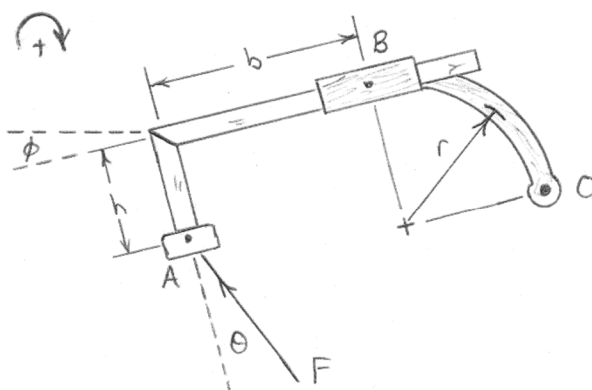


$$+\curvearrowright M_B = 180 + 900 \cos 30^\circ (0.6) = \underline{648 \text{ N}\cdot\text{m CW}}$$

WILEY

2/64

$$b = 450 \text{ mm}, h = 215 \text{ mm}, r = 325 \text{ mm}, F = 520 \text{ N}, \theta = 15^\circ, \phi = 10^\circ$$

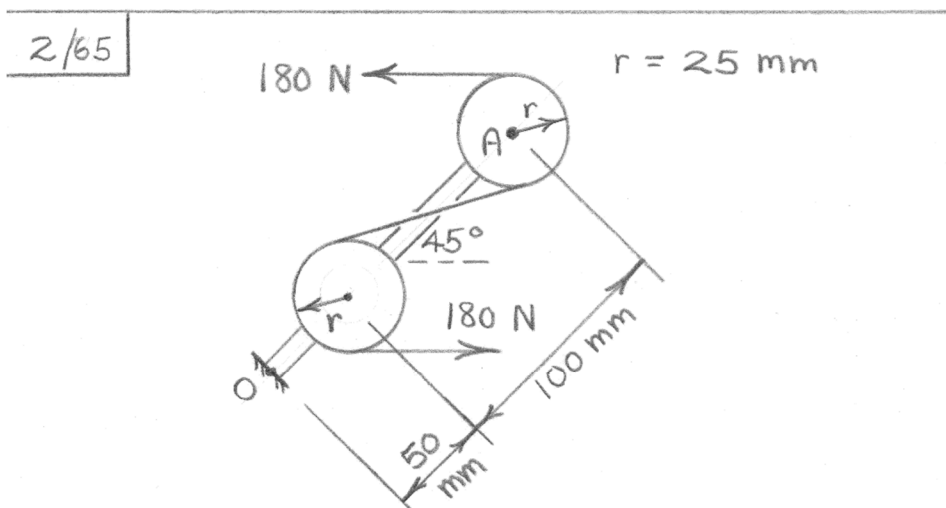


$$F = 520 \text{ N @ } 115^\circ \text{ CCW ABOVE HORIZONTAL}$$

$$M_o = F \cos \theta (b + r) - F \sin \theta (r - h)$$

$$= 520 \cos 15^\circ \left(\frac{450 + 325}{1000} \right) - 520 \sin 15^\circ \left(\frac{325 - 215}{1000} \right)$$

$$\therefore M_o = 374 \text{ N}\cdot\text{m CW}$$



The system at O is a couple.

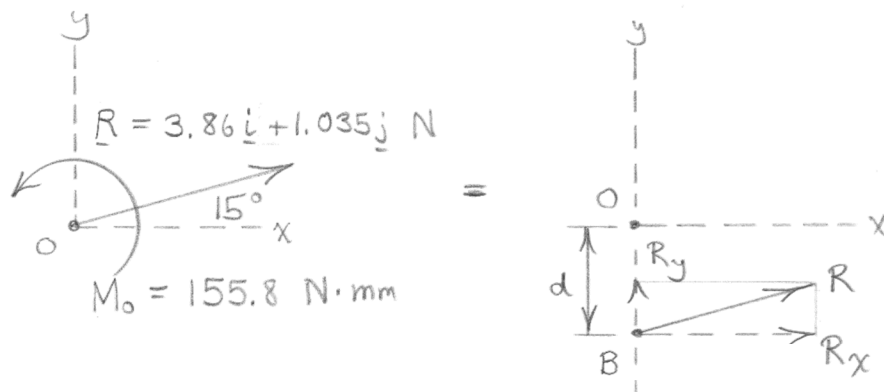
$$\begin{aligned}\curvearrowright M &= Fd = 180(100 \sin 45^\circ + 25 + 25) \\ &= 21\,700 \text{ N}\cdot\text{mm} \text{ or } \underline{21.7 \text{ N}\cdot\text{m CCW}}\end{aligned}$$

WILEY

2/66 At O:

$$\underline{R} = 4 (\cos 15^\circ \underline{i} + \sin 15^\circ \underline{j}) = 3.86 \underline{i} + 1.035 \underline{j} \text{ N}$$

$$\begin{aligned} \curvearrowright M_o &= 300 - 4 \cos 15^\circ (40) + 4 \sin 15^\circ (10) \\ &= 155.8 \text{ N}\cdot\text{mm} \text{ CCW} \end{aligned}$$

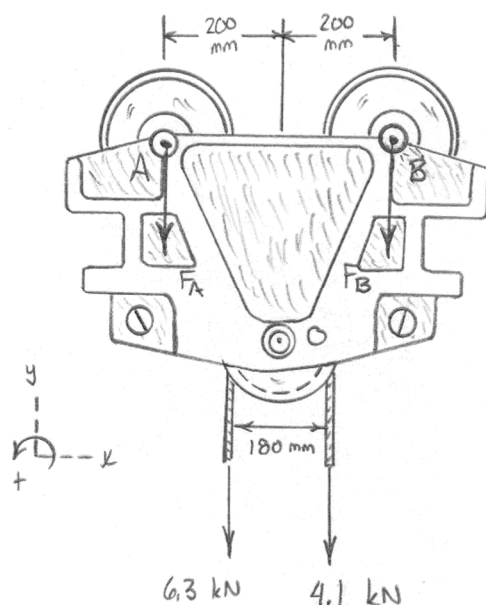


Condition: $R_x d = M_o$

$$3.86 d = 155.8, \quad d = 40.3 \text{ mm}$$

So $y = -40.3 \text{ mm}$

2/67

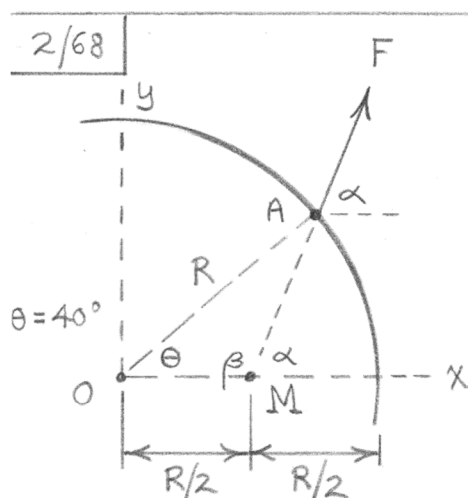


F_A & F_B ARE DOWN AT A & B.

$$\begin{cases} \sum F_y: F_A + F_B = 6.3 + 4.1 \\ \sum M_o: 200 F_A - 200 F_B = 90(6.3) - 90(4.1) \end{cases}$$

Solving...

$$\begin{cases} F_A = 5.70 \text{ kN} \\ F_B = 4.70 \text{ kN} \end{cases} \quad (\text{Both Down As Shown})$$



$$\overline{AM}^2 = R^2 + \left(\frac{R}{2}\right)^2 - 2(R)\left(\frac{R}{2}\right)\cos 40^\circ$$

$$= 0.484R^2, \quad \overline{AM} = 0.696R$$

$$\frac{\sin \beta}{R} = \frac{\sin 40^\circ}{0.696R}, \quad \beta = 112.5^\circ$$

$$\alpha = 180^\circ - \beta = 180^\circ - 112.5^\circ = 67.5^\circ$$

$$\begin{aligned} \uparrow M_o &= (F \sin \alpha) \frac{R}{2} = (F \sin 67.5^\circ) \frac{R}{2} \\ &= 0.462FR \end{aligned}$$

So the force-couple system for $\theta = 40^\circ$ is

$$\begin{cases} F \nearrow 67.5^\circ \\ M_o = 0.462FR \text{ CCW} \end{cases}$$

2/69

$$R = R_y = 15 = T \sin \theta + 8 \cos 30^\circ$$

$$R_x = 0 = T \cos \theta - 6 - 8 \sin 30^\circ$$

So $T \sin \theta = 8.07$

$T \cos \theta = 10$

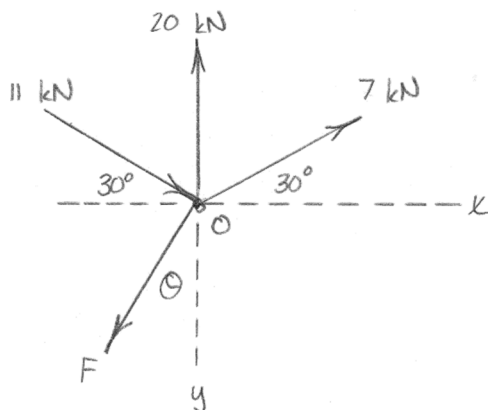
Divide & get $\theta = \tan^{-1} \frac{8.07}{10}$

$\theta = 38.9^\circ$

$$T = \frac{10}{\cos 38.9^\circ} = 12.85 \text{ kN}$$

WILEY

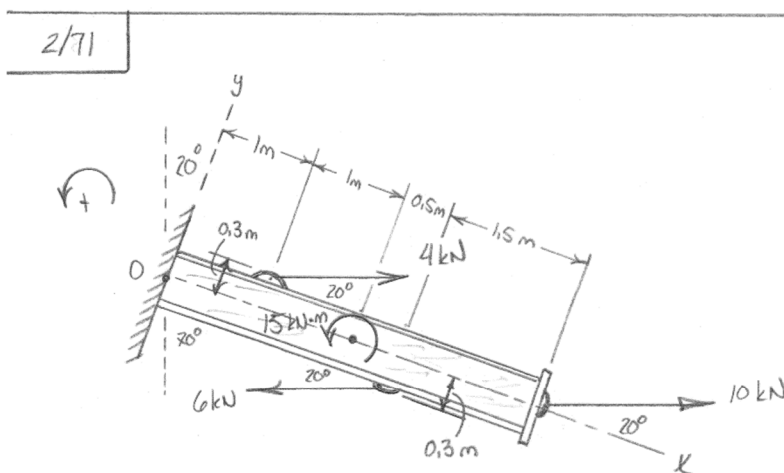
2/70 $R = 9 \text{ kN, RIGHTWARD}$



$$\begin{cases} R_x = 9 = 11 \cos 30^\circ + 7 \cos 30^\circ - F \sin \theta \\ R_y = 0 = 11 \sin 30^\circ - 7 \sin 30^\circ + F \cos \theta - 20 \end{cases}$$

Solving... $F = 19.17 \text{ kN}$ AND $\theta = 20.1^\circ$

WILEY



$$\left\{ \begin{array}{l} R = 10 + 4 - 6 \rightarrow R = 8 \text{ kN} \end{array} \right.$$

$$\left\{ \begin{array}{l} \underline{R} = 8 \cos 20^\circ \underline{i} + 8 \sin 20^\circ \underline{j} \rightarrow \underline{R} = 7.52 \underline{i} + 2.74 \underline{j} \text{ kN} \end{array} \right.$$

$$M_o = 15 + 4 \sin 20^\circ (1) - 6 \sin 20^\circ (2) + 10 \sin 20^\circ (4) - 4 \cos 20^\circ (0.3) - 6 \cos 20^\circ (0.3)$$

$$\therefore \underline{M_o} = 22.1 \text{ kN}\cdot\text{m CCW}$$

• LINE-OF-ACTION:

$$\underline{r} \times \underline{R} = \underline{M_o} \rightarrow (x \underline{i} + y \underline{j}) \times (7.52 \underline{i} + 2.74 \underline{j}) = 22.1 \underline{k}$$

$$\underline{k}: 2.74x - 7.52y = 22.1$$

$$\therefore \underline{y} = 0.364x - 2.94 \text{ (m)}$$

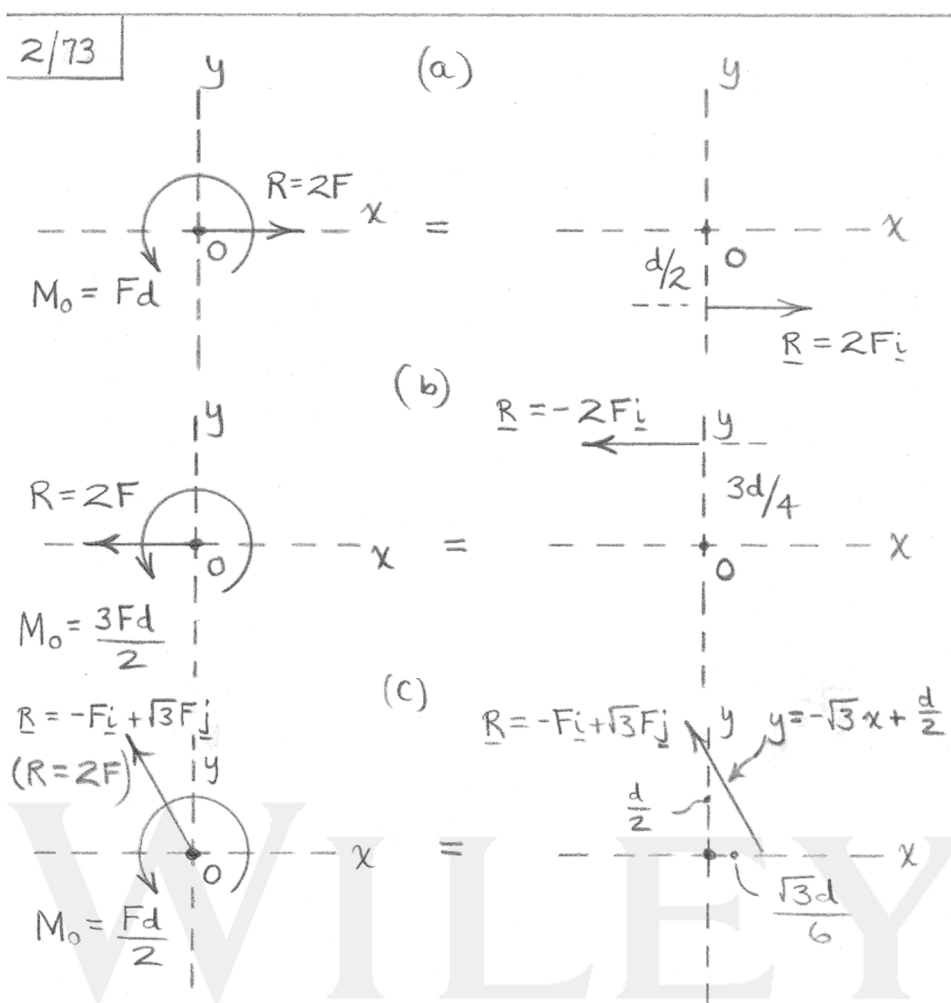
2/72

(a) $\underline{R} = -2F\underline{j}$, $\underline{M}_O = \underline{0}$

(b) $\underline{R} = \underline{0}$, $\underline{M}_O = Fd\underline{k}$ (+ $\underline{k}$ is out)

(c) $\underline{R} = -F\underline{i} + F\underline{j}$, $\underline{M}_O = \underline{0}$

WILEY



2/74

$$R = \sum F = 650 - 250 - 300$$

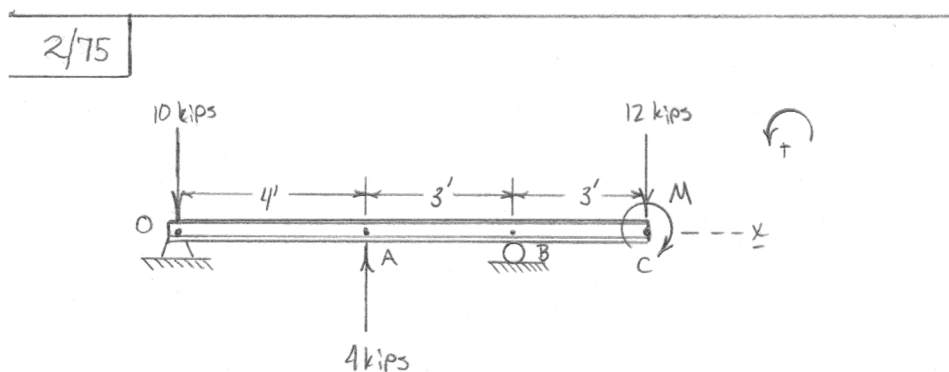
$$= 100 \text{ lb}$$

$$Rh = \sum M_B;$$

$$100h = 650(60) - 300(90) - 250(30)$$

$$h = 45 \text{ in.}$$

WILEY



$$R = 18 \text{ kips DOWN}$$

$$\sum M_B = 0: 7(10) - 4(3) - 12(3) - M = 0 \rightarrow M = 22 \text{ kip-ft CW}$$

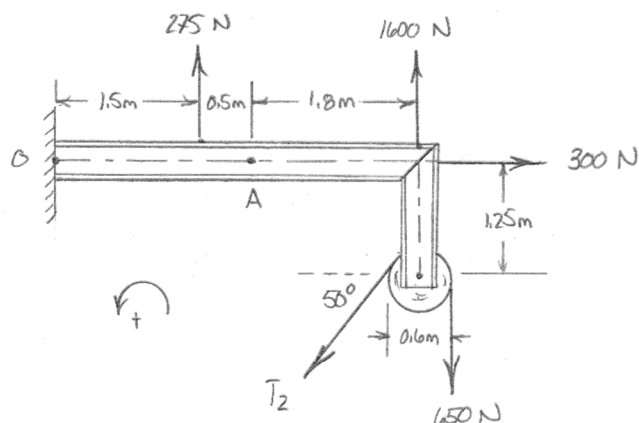
$$M_O = 4(4) - 12(10) - 22 = -126 \quad \text{so... } M_O = 126 \text{ kip-ft CW}$$

WILEY

$$\boxed{2/76} \quad M_o = 0, \text{ so}$$
$$\curvearrowright_+ M - 400(0.150 \cos 30^\circ) - 320(0.300) = 0$$
$$\underline{M = 148.0 \text{ N}\cdot\text{m}}$$

WILEY

2/77



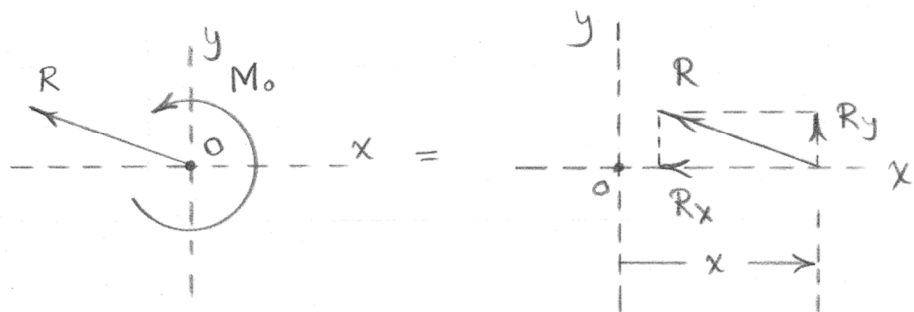
$$\Sigma M_A = 0: -275(0.5) + 1.8(1600) - 650(1.8 + 0.3) + T_2(0.3) - T_2 \sin 50^\circ(1.8) - T_2 \cos 50^\circ(1.25) = 0$$

$$T_2 = 732 \text{ N}$$

WILEY

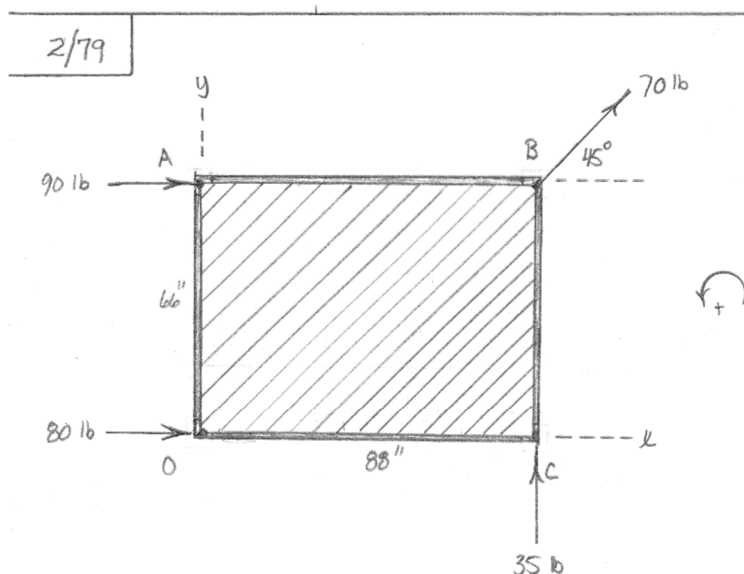
$$2/78 \quad \underline{R} = -50\mathbf{i} + 20\mathbf{j} \text{ lb}$$

$$\curvearrowright M_o = -40(10) + 60(20) + 50(10) = 1300 \text{ lb-in.}$$



$$R_y x = M_o, \quad x = \frac{1300}{20} = \underline{65 \text{ in. (off pipe)}}$$

WILEY



$$\begin{cases} \underline{R} = (90 + 80 + 70 \cos 45^\circ) \underline{i} + (35 + 70 \sin 45^\circ) \underline{j} \\ \underline{R} = 219 \underline{i} + 84.5 \underline{j} \text{ lb} \end{cases}$$

$$\begin{cases} M_O = -90(66) + 35(88) + 70 \sin 45^\circ (88) - 70 \cos 45^\circ (66) = -1771 \\ M_O = 1771 \text{ lb-in. CW} \end{cases}$$

$$\begin{cases} \text{To produce a CW moment about O with } R_x \text{ positive, } R_x \text{ is placed above O.} \\ R_x y = M_O \rightarrow 219 y = 1771 \rightarrow y = 8.07 \text{ in. ABOVE O} \end{cases}$$

$$\begin{cases} \text{To produce a CW moment about O with } R_y \text{ positive, } R_y \text{ is placed left of O.} \\ R_y x = M_O \rightarrow 84.5 x = 1771 \rightarrow x = 21.0 \text{ in. LEFT OF O} \end{cases}$$

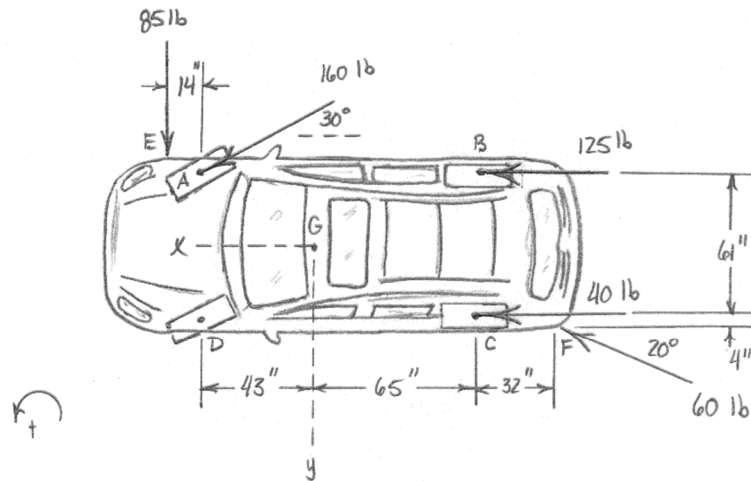
2/80 $\Sigma M_O = 0$ since R passes through O .

$$40(8) + 60(4) - 5P \cos 20^\circ = 0, \quad P = 119.2 \text{ lb}$$

Moment of 40-lb & 60-lb forces unaffected by θ
So result for P is not dependent on θ .

WILEY

2/81



$$\underline{R} = \Sigma \underline{F} = (160 \cos 30^\circ + 40 + 125 + 60 \cos 20^\circ) \underline{i} + (85 + 160 \sin 30^\circ - 60 \sin 20^\circ) \underline{j}$$

$$\therefore \underline{R} = 360 \underline{i} + 144.5 \underline{j} \text{ lb}$$

$$\Sigma M_G = 85(14 + 43) + 160 \cos 30^\circ \left(\frac{61}{2}\right) + 160 \sin 30^\circ (43) + 125 \left(\frac{61}{2}\right) - 40 \left(\frac{61}{2}\right) + 60 \sin 20^\circ (65 + 32) - 60 \cos 20^\circ \left(4 + \frac{61}{2}\right)$$

$$\Sigma M_G = 15,150 \text{ lb-in. or } 1262 \text{ lb-ft CCW}$$

For CCW M_G WITH POSITIVE R_x , R IS PLACED ABOVE G , IN NEGATIVE y .

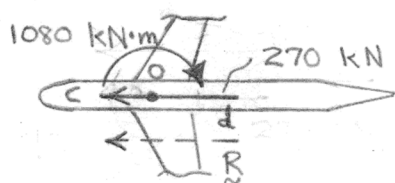
$$M_G = R_x |y| \rightarrow 15,150 = 360 |y| \rightarrow |y| = 42.1 \text{ in. so } (0, -42.1) \text{ in.}$$

For CCW M_G WITH POSITIVE R_y , R IS PLACED LEFT OF G , IN POSITIVE x .

$$M_G = R_y x \rightarrow 15,150 = 144.5 x \rightarrow x = 104.9 \text{ in. so } (104.9, 0) \text{ in.}$$

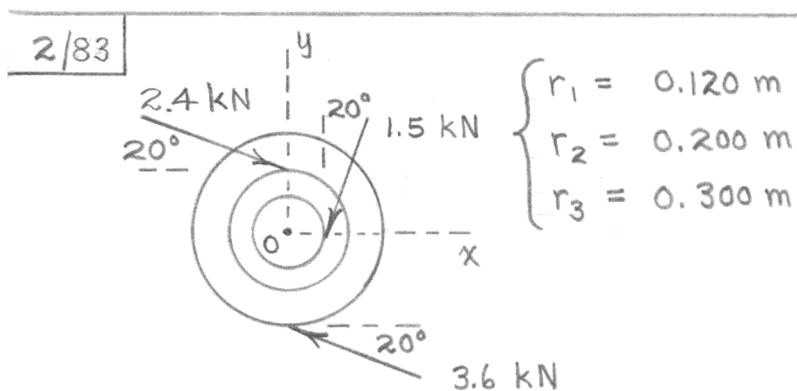
2/82 Force - Couple system at point O:

$$\begin{cases} R = 3(90) = 270 \text{ kN } (\leftarrow) \\ +2 M_o = 12(90) = 1080 \text{ kN}\cdot\text{m} \end{cases}$$



$$d = \frac{M_o}{R} = \frac{1080}{270} = 4 \text{ m}$$

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$$\underline{R} = \sum \underline{F} = 2.4(\cos 20^\circ \underline{i} - \sin 20^\circ \underline{j}) + 1.5(-\sin 20^\circ \underline{i} - \cos 20^\circ \underline{j}) + 3.6(-\cos 20^\circ \underline{i} + \sin 20^\circ \underline{j}) = -1.641 \underline{i} - 0.999 \underline{j} \text{ kN}$$

$$2M_o = (2.4(0.2) + 1.5(0.12) + 3.6(0.3)) \cos 20^\circ = 1.635 \text{ kN}\cdot\text{m}$$

$$\underline{r} \times \underline{R} = M_o: (x \underline{i} + y \underline{j}) \times (-1.641 \underline{i} - 0.999 \underline{j}) = -1.635$$

$$\Rightarrow -0.999x + 1.641y = -1.635$$

$$\text{Axis intercepts: } x = 1.637 \text{ m, } y = -0.997 \text{ m}$$

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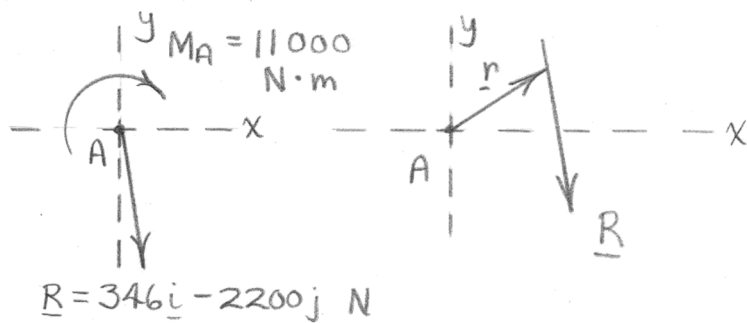
2/84 Equivalent force-couple system at A:

$$\underline{R} = \sum \underline{F} = [-2(250) - 3(500)]\underline{j} + 400[\cos 30^\circ \underline{i} - \sin 30^\circ \underline{j}]$$

$$= 346\underline{i} - 2200\underline{j} \text{ N}$$

$$\Rightarrow M_A = 500[2.5 + 5 + 7.5] + 250[10] + 400(2.5)$$

$$= 11,000 \text{ N}\cdot\text{m} \text{ CW}$$

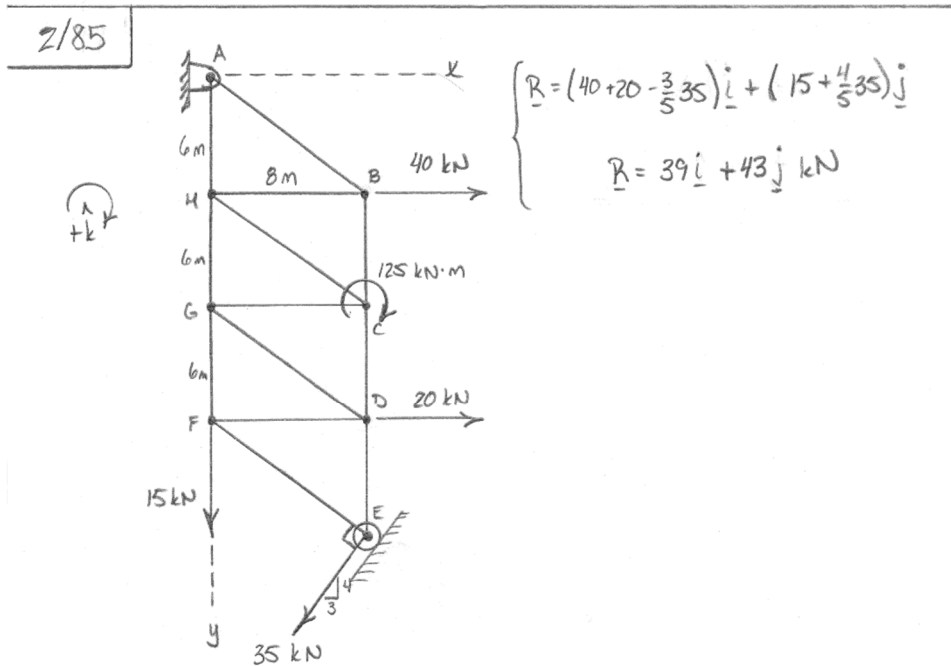


Condition: $\underline{M}_A = \underline{r} \times \underline{R}$

$$-11,000\underline{k} = (x\underline{i} + y\underline{j}) \times (346\underline{i} - 2200\underline{j})$$

$$= (-2200x - 346y)\underline{k}$$

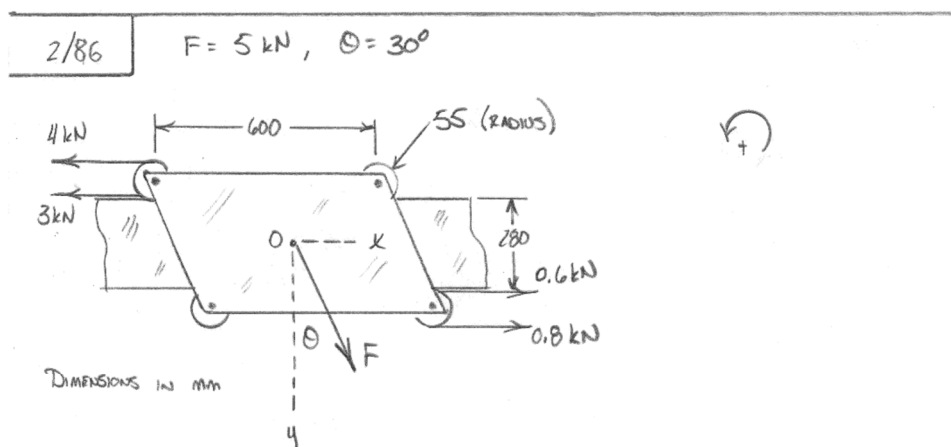
Set $y = 0$ & obtain $x = 5 \text{ m} (!)$



$$\underline{M}_A = [-40(6) - 20(18) + 125 + 35(10) + \frac{3}{5}35(10)]\underline{k} \rightarrow \underline{M}_A = 253 \underline{k} \text{ kN}\cdot\text{m}$$

$$\begin{cases} \underline{r} \times \underline{R} = \underline{M}_A \rightarrow (x\underline{i} + y\underline{j}) \times (39\underline{i} - 43\underline{j}) = 253\underline{k} \\ \underline{k}: 43x - 39y = 253 \rightarrow y = 1.103x - 6.49 \text{ (m)} \end{cases}$$

$$\begin{cases} \underline{x}\text{-Axis: } y = 0 = 1.103x - 6.49 \rightarrow x = 5.88 \text{ m so } (5.88, 0) \text{ m} \\ \underline{y}\text{-Axis: } x = 0 \rightarrow y = -6.49 \text{ m so } (0, -6.49) \text{ m} \end{cases}$$



$$\begin{cases} \underline{R} = (0.8 + 0.6 + 5 \sin 30^\circ - 4 - 3) \underline{i} + 5 \cos 30^\circ \underline{j} \rightarrow \underline{R} = -3.10 \underline{i} + 4.33 \underline{j} \text{ kN} \\ \sum M_o = 0.6 \left(\frac{140}{1000} \right) + 0.8 \left(\frac{140 + 110}{1000} \right) + 3 \left(\frac{140}{1000} \right) + 4 \left(\frac{140 + 110}{1000} \right) = 1.704 \\ \therefore \sum M_o = 1.704 \text{ kN}\cdot\text{m CCW} \end{cases}$$

For A CCW M_o With Negative R_x , R is Placed Above O in Minus y.

$$\begin{cases} R_x y = M_o \rightarrow 3.10 |y| = 1.704 \rightarrow |y| = 0.550 \\ \therefore |y| = 550 \text{ mm ABOVE O or } (0, -550) \text{ (mm)} \end{cases}$$

$$\begin{aligned} \underline{2/87} \quad \underline{\underline{R}} &= \underline{\underline{\Sigma F}} = 400(\cos 45^\circ \underline{i} - \sin 45^\circ \underline{j}) + 500(\sin 15^\circ \underline{i} - \cos 15^\circ \underline{j}) \\ &= 412 \underline{i} - 766 \underline{j} \text{ N} \end{aligned}$$

$$\textcircled{2} \underline{M_o} = (500 - 400)(0.060) = 6 \text{ N}\cdot\text{m}$$

For the line of action of the standalone force:

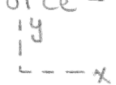
$$\underline{r} \times \underline{R} = \underline{M_o}$$

$$(x \underline{i} + y \underline{j}) \times (412 \underline{i} - 766 \underline{j}) = -6 \underline{k}$$

$$-766x - 412y = -6$$

$$\begin{cases} \text{For } x=0: & y = 0.01455 \text{ m or } \underline{y = 14.55 \text{ mm}} \\ \text{For } y=0: & x = 0.00783 \text{ m or } \underline{x = 7.83 \text{ mm}} \end{cases}$$

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2/88 For a zero force-couple system
at point O: 

$$\underline{R} = \Sigma \underline{F} = (-F_C \sin 30^\circ + F_D \sin 30^\circ) \underline{i} \\ + (50 - 10 - 100 - 50 + F_B \\ + F_C \cos 30^\circ + F_D \cos 30^\circ) \underline{j} = \underline{0}$$

$$\Rightarrow F_C = F_D = F$$

$$\Sigma M_O = -10(0.5) + 50(0.7) - 100(1.35) + F_B(2) \\ - 50(2.5) + 2F \cos 30^\circ (2.9) = 0$$

$$\underline{F = F_C = F_D = 6.42 \text{ N}}, \quad \underline{F_B = 98.9 \text{ N}}$$

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$$\begin{aligned} \underline{2/89} \quad \underline{\underline{F}} &= F \underline{\underline{n}} \\ &= 60 \left[\frac{40\underline{i} - 50\underline{j} + 110\underline{k}}{\sqrt{40^2 + 50^2 + 110^2}} \right] \\ &= \underline{18.86\underline{i} - 23.6\underline{j} + 51.9\underline{k} \text{ N}} \\ \cos \theta_y &= \frac{F_y}{F} = \frac{-23.6}{60}, \quad \underline{\theta_y = 113.1^\circ} \end{aligned}$$

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$$\begin{aligned} 2/90 \quad \underline{\underline{T}} &= T \underline{n}_{BA} \\ \underline{T} &= 12 \left[\frac{-35\mathbf{i} + 25\mathbf{j} + 60\mathbf{k}}{\sqrt{35^2 + 25^2 + 60^2}} \right] \\ &= \underline{\underline{-5.69\mathbf{i} + 4.06\mathbf{j} + 9.75\mathbf{k} \text{ kN}}} \end{aligned}$$

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$$\frac{2/91}{F_z} = 5 \cos 40^\circ = 3.83 \text{ kN}$$

$$F_h = 5 \sin 40^\circ = 3.21 \text{ kN}$$

$$F_x = -3.21 \sin 35^\circ = -1.843 \text{ kN}$$

$$F_y = 3.21 \cos 35^\circ = 2.63 \text{ kN}$$

$$\text{So } \underline{F} = -1.843 \underline{i} + 2.63 \underline{j} + 3.83 \underline{k} \text{ kN}$$

$$F_{OA} = \underline{F} \cdot \underline{n}_{OA}$$

$$= (-1.843 \underline{i} + 2.63 \underline{j} + 3.83 \underline{k}) \cdot (\cos 30^\circ \underline{i} + \sin 30^\circ \underline{j})$$

$$= -0.280 \text{ kN (as a scalar)}$$

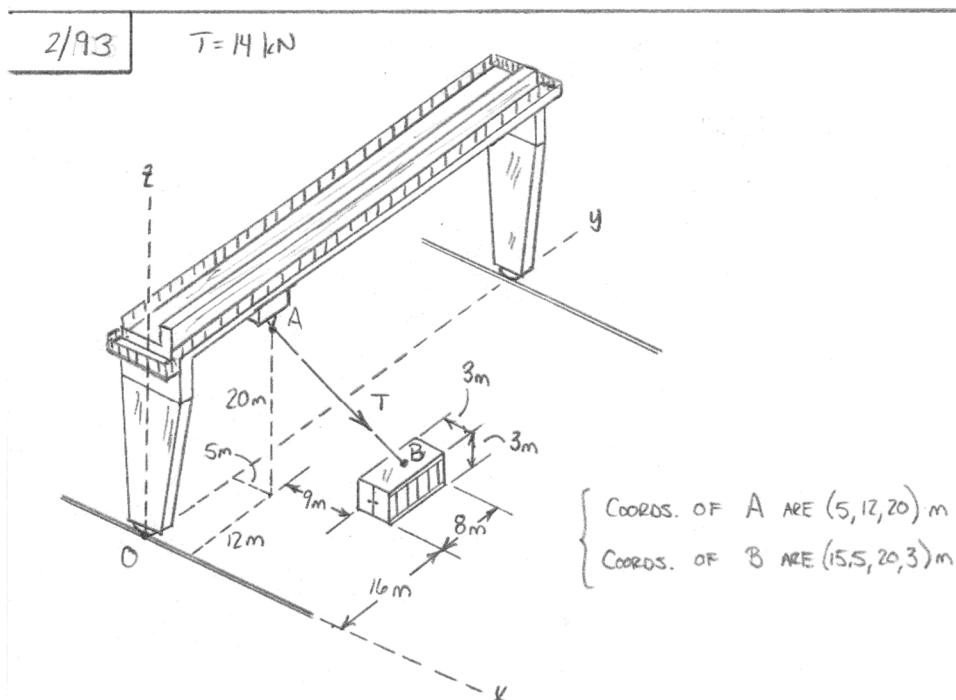
$$\underline{F}_{OA} = F_{OA} \underline{n}_{OA}$$

$$= -0.280 (\cos 30^\circ \underline{i} + \sin 30^\circ \underline{j})$$

$$= -0.243 \underline{i} - 0.140 \underline{j} \text{ kN}$$

$$\begin{aligned} \underline{2/92} \quad \underline{\underline{F = F_n = 300 \left[\frac{4\mathbf{i} - 8\mathbf{j} - 8\mathbf{k}}{\sqrt{4^2 + 8^2 + 8^2}} \right]}} \\ \underline{\underline{= 300 \left[\frac{1}{3}\mathbf{i} - \frac{2}{3}\mathbf{j} - \frac{2}{3}\mathbf{k} \right] \text{ lb}}} \\ \underline{\underline{F_x = 100 \text{ lb}, \quad F_y = -200 \text{ lb}, \quad F_z = -200 \text{ lb}}} \end{aligned}$$

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$$\hat{n}_{AB} = \frac{(15.5 - 5)\hat{i} + (20 - 12)\hat{j} + (3 - 20)\hat{k}}{[(15.5 - 5)^2 + (20 - 12)^2 + (3 - 20)^2]^{1/2}} \rightarrow \hat{n}_{AB} = 0.488\hat{i} + 0.372\hat{j} - 0.790\hat{k}$$

$$\begin{cases} T_x = T n_x = 14(0.488) \rightarrow T_x = 6.83 \text{ kN} \\ T_y = T n_y = 14(0.372) \rightarrow T_y = 5.20 \text{ kN} \\ T_z = T n_z = 14(-0.790) \rightarrow T_z = -11.06 \text{ kN} \end{cases}$$

$$\underline{2/94} \quad \underline{\underline{T = T_{n_{AB}} = 2.4 \left(\frac{2\mathbf{i} + \mathbf{j} - 5\mathbf{k}}{\sqrt{2^2 + 1^2 + 5^2}} \right)}}$$

$$= 0.876\mathbf{i} + 0.438\mathbf{j} - 2.19\mathbf{k} \text{ kN}$$

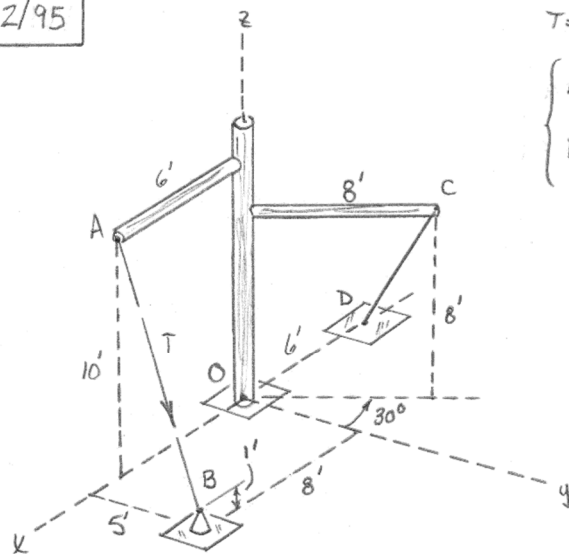
$$\text{Projection } T_{AC} = \underline{\underline{T \cdot n_{AC}}}$$

$$= (0.876\mathbf{i} + 0.438\mathbf{j} - 2.19\mathbf{k}) \cdot \left(\frac{2\mathbf{i} - 2\mathbf{j} - 5\mathbf{k}}{\sqrt{2^2 + 2^2 + 5^2}} \right)$$

$$= \underline{\underline{2.06 \text{ kN}}}$$

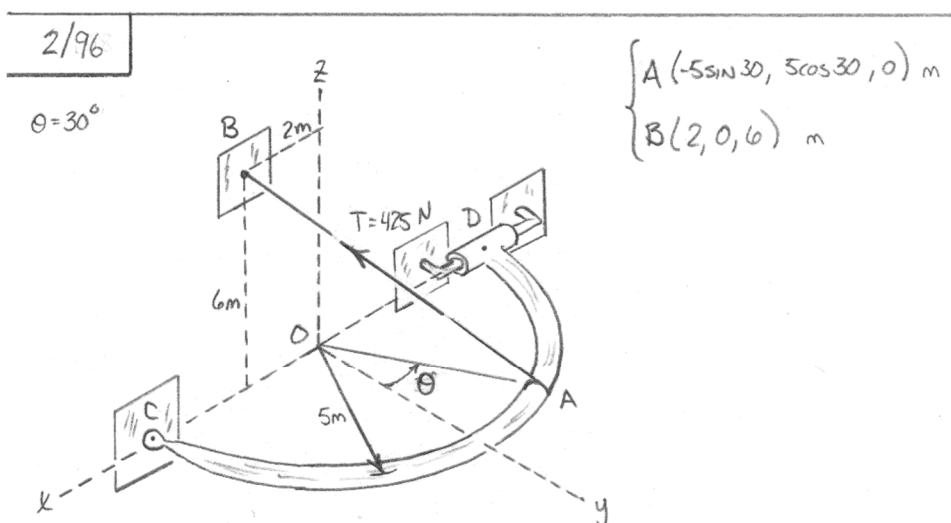
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$$\begin{cases} A(6, 0, 10) f_+ \\ B(8, 5, 1) f_+ \end{cases}$$



$$\underline{D}_{AB} = \frac{(8-6)\underline{i} + (5-0)\underline{j} + (1-10)\underline{k}}{[(8-6)^2 + 5^2 + (1-10)^2]^{1/2}} \rightarrow \underline{D}_{AB} = 0.1902\underline{i} + 0.472\underline{j} - 0.858\underline{k}$$

$$\begin{cases} \theta_x = \cos^{-1}(n_x) = \cos^{-1}(0.1907) \rightarrow \theta_x = 79.0^\circ \\ \theta_y = \cos^{-1}(n_y) = \cos^{-1}(0.477) \rightarrow \theta_y = 61.5^\circ \\ \theta_z = \cos^{-1}(n_z) = \cos^{-1}(-0.858) \rightarrow \theta_z = 149.1^\circ \end{cases}$$



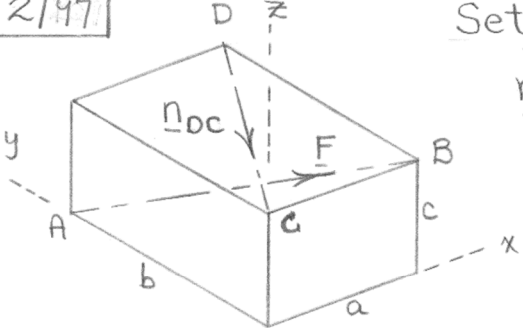
$$\underline{r}_{AB} = \frac{(2+5\sin 30)\underline{i} + (0-5\cos 30)\underline{j} + (6-0)\underline{k}}{[(2+5\sin 30)^2 + (5\cos 30)^2 + 6^2]^{1/2}}$$

$$\therefore \underline{r}_{AB} = 0.520\underline{i} - 0.5\underline{j} + 0.693\underline{k}$$

$$\underline{T}_A = T \underline{r}_{AB} = 425(0.520\underline{i} - 0.5\underline{j} + 0.693\underline{k}) \rightarrow \underline{T}_A = 221\underline{i} - 212\underline{j} + 294\underline{k} \text{ N}$$

$$\underline{T}_B = -\underline{T}_A \rightarrow \underline{T}_B = -221\underline{i} + 212\underline{j} - 294\underline{k} \text{ N}$$

2/97



Set up x-y-z axes shown

$$\underline{n}_{DC} = \frac{\underline{DC}}{DC}$$

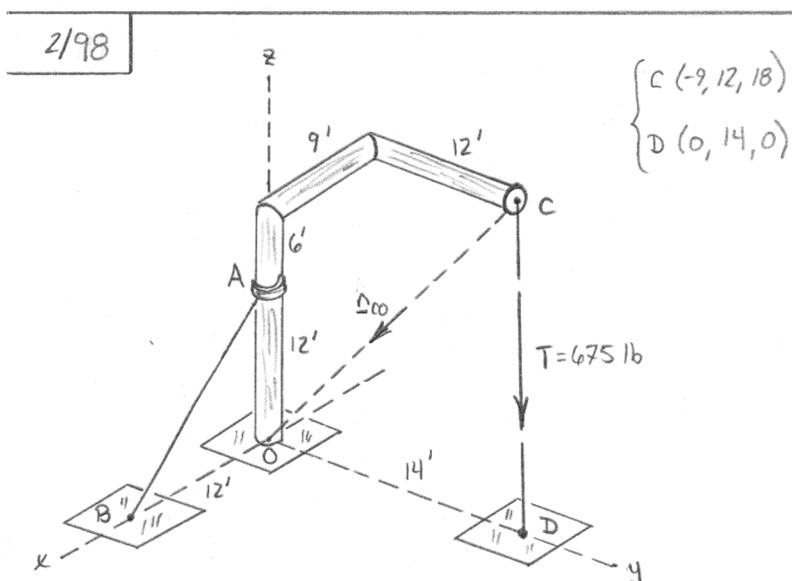
$$= \frac{-a\mathbf{i} - b\mathbf{j}}{\sqrt{a^2 + b^2}}$$

$$\underline{F} = F \underline{n}_{AB} = F \frac{\underline{AB}}{AB}$$

$$= F \frac{a\mathbf{i} - b\mathbf{j} + c\mathbf{k}}{\sqrt{a^2 + b^2 + c^2}}$$

$$F_{DC} = \underline{F} \cdot \underline{n}_{DC} = \frac{(b^2 - a^2) F}{\sqrt{(a^2 + b^2)} \sqrt{(a^2 + b^2 + c^2)}}$$

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$$\underline{n}_{CD} = \frac{(0+9)\underline{i} + (14-12)\underline{j} + (0-18)\underline{k}}{[9^2 + (14-12)^2 + (-18)^2]^{1/2}} \rightarrow \hat{n}_{CD} = 0.445\underline{i} + 0.0989\underline{j} - 0.890\underline{k}$$

$$\underline{T} = T \underline{n}_{CD} = 675(0.445\underline{i} + 0.0989\underline{j} - 0.890\underline{k}) \rightarrow \underline{T} = 300\underline{i} + 66.8\underline{j} - 601\underline{k} \text{ lb}$$

$$\underline{n}_{CO} = \frac{9\underline{i} - 12\underline{j} - 18\underline{k}}{\sqrt{9^2 + 12^2 + 18^2}} \rightarrow \underline{n}_{CO} = \frac{3}{\sqrt{61}}\underline{i} - \frac{4}{\sqrt{61}}\underline{j} - \frac{6}{\sqrt{61}}\underline{k}$$

$$T_{CO} = \underline{T} \cdot \underline{n}_{CO} = (300\underline{i} + 66.8\underline{j} - 601\underline{k}) \cdot \left(\frac{3}{\sqrt{61}}\underline{i} - \frac{4}{\sqrt{61}}\underline{j} - \frac{6}{\sqrt{61}}\underline{k} \right) \rightarrow \underline{T_{CO}} = 543 \text{ lb}$$

2/99 $T = 150 \text{ N}$ Coordinates of A are
 $(0.9 \cos 30^\circ, 0, 0.9 \sin 30^\circ)$
 or $(0.779, 0, 0.45) \text{ m}$
 $\overline{AB} = \sqrt{0.779^2 + 1.2^2 + (0.9 - 0.45)^2}$
 $= 1.50 \text{ m}$
 $l = -0.779/1.5, m = 1.2/1.5, n = \frac{0.45}{1.5}$
 $\underline{T} = \frac{100}{1.5}(-0.779\underline{i} + 1.2\underline{j} + 0.45\underline{k}) \text{ N}$
 $\underline{\lambda} = \text{unit vector along CD}$
 $\overline{CD} = \sqrt{0.9^2 + 1.2^2} = 1.5 \text{ m}$
 $l = 0.779/1.5, m = 1.2/1.5, n = 0.45/1.5$
 $\underline{\lambda} = \frac{1}{1.5}(0.779\underline{i} + 1.2\underline{j} + 0.45\underline{k})$
 $T_{CD} = \underline{T} \cdot \underline{\lambda} = \frac{100}{1.5}(-0.779\underline{i} + 1.2\underline{j} + 0.45\underline{k}) \cdot \frac{1}{1.5}(0.779\underline{i} + 1.2\underline{j} + 0.45\underline{k})$
 $= \frac{100}{2.25}(-0.779^2 + 1.2^2 + 0.45^2) = \frac{100}{2.25}(-0.6075 + 1.44 + 0.2025)$
 $= \frac{400}{9}(1.035) = \underline{46.0 \text{ N}}$

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$$\frac{2}{100} \quad \underline{F} = F_{n_{AB}} = 200 \left[\frac{-12\underline{i} + 24\underline{j} + 8\underline{k}}{\sqrt{12^2 + 24^2 + 8^2}} \right]$$

$$= -85.7\underline{i} + 171.4\underline{j} + 57.1\underline{k} \quad \text{lb}$$

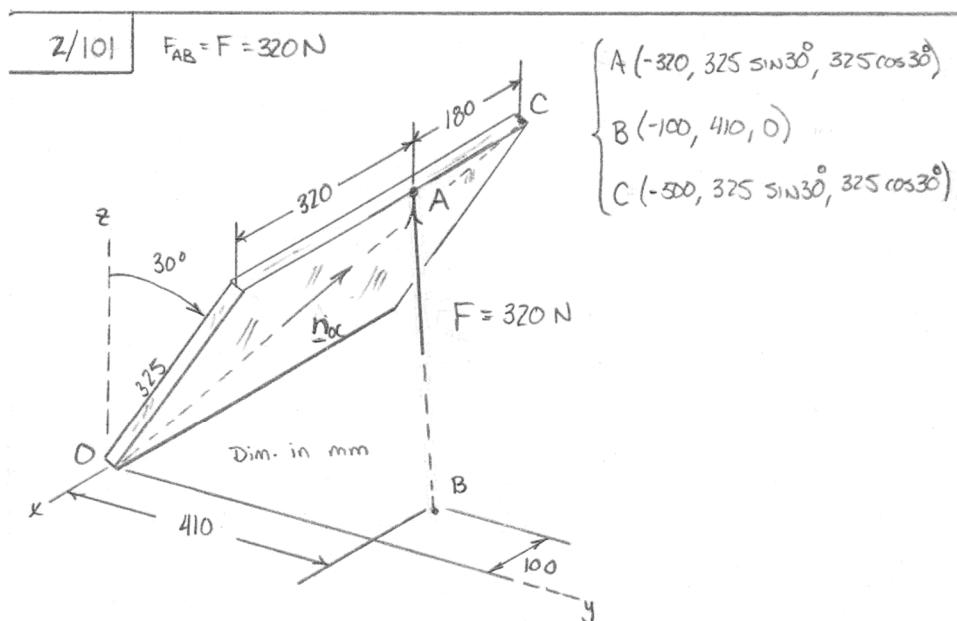
$$\underline{OC} = 12\underline{i} + 24\underline{j} \quad \text{in.}$$

The angle θ between $\underline{F}$ and $\underline{OC}$ is

$$\theta = \cos^{-1} \frac{\underline{F} \cdot \underline{OC}}{F(\underline{OC})} = \cos^{-1} \left[\frac{-85.7(12) + 171.4(24)}{200(\sqrt{12^2 + 24^2})} \right]$$

$$= \underline{54.9^\circ}$$

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$$\underline{n}_{BA} = \frac{(-320 + 100)\underline{i} + (325 \sin 30^\circ - 410)\underline{j} + 325 \cos 30^\circ \underline{k}}{[(-320 + 100)^2 + (325 \sin 30^\circ - 410)^2 + (325 \cos 30^\circ)^2]^{1/2}}$$

$$\therefore \underline{n}_{BA} = -0.506 \underline{i} - 0.569 \underline{j} + 0.648 \underline{k}$$

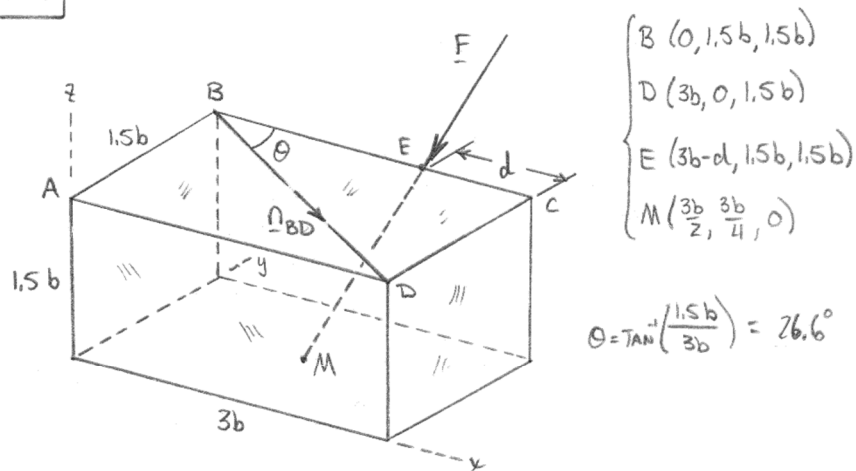
$$\underline{F} = F \underline{n}_{BA} = 320(-0.506 \underline{i} - 0.569 \underline{j} + 0.648 \underline{k}) \rightarrow \underline{F} = -162.0 \underline{i} - 182.2 \underline{j} + 207 \underline{k} \text{ N}$$

$$\underline{n}_{AC} = \frac{-500 \underline{i} + 325 \sin 30^\circ \underline{j} + 325 \cos 30^\circ \underline{k}}{\sqrt{500^2 + 325^2}} \rightarrow \underline{n}_{AC} = -0.838 \underline{i} + 0.272 \underline{j} + 0.472 \underline{k}$$

$$\underline{F}_{AC} = \underline{F} \cdot \underline{n}_{AC} = (-162.0 \underline{i} - 182.2 \underline{j} + 207 \underline{k}) \cdot (-0.838 \underline{i} + 0.272 \underline{j} + 0.472 \underline{k})$$

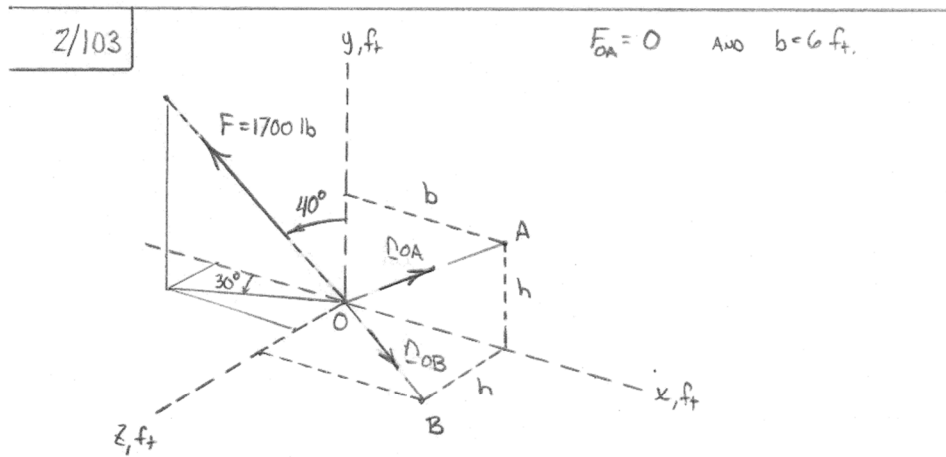
$$\therefore \underline{F}_{AC} = 184.0 \text{ N}$$

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$$\begin{aligned}
 \underline{n}_{BD} &= \cos \theta \underline{i} - \sin \theta \underline{j} \rightarrow \underline{n}_{BD} = 0.894 \underline{i} - 0.447 \underline{j} \\
 \underline{n}_{EM} &= \frac{(\frac{3b}{2} - 3b + d) \underline{i} + (\frac{3b}{4} - 1.5b) \underline{j} + (0 - 1.5b) \underline{k}}{[(\frac{3b}{2} - 3b + d)^2 + (\frac{3b}{4} - 1.5b)^2 + (-1.5b)^2]^{1/2}} \\
 \therefore \underline{n}_{EM} &= \frac{(4d - 6b) \underline{i} - 3b \underline{j} - 6b \underline{k}}{\sqrt{81b^2 - 48bd + 16d^2}} \quad \text{AND} \quad \underline{F} = F \underline{n}_{EM} \\
 F_{BD} &= \underline{F} \cdot \underline{n}_{BD} = F \left(\frac{(4d - 6b) \underline{i} - 3b \underline{j} - 6b \underline{k}}{\sqrt{81b^2 - 48bd + 16d^2}} \right) \cdot (0.894 \underline{i} - 0.447 \underline{j}) \\
 \therefore F_{BD} &= \frac{(8d - 9b) F}{\sqrt{5} \sqrt{81b^2 - 48bd + 16d^2}}
 \end{aligned}$$

$$\begin{cases}
 \text{If } d = \frac{b}{2} \dots \underline{F_{BD} = -0.286 F} \\
 \text{If } d = \frac{5b}{2} \dots \underline{F_{BD} = 0.630 F}
 \end{cases}$$



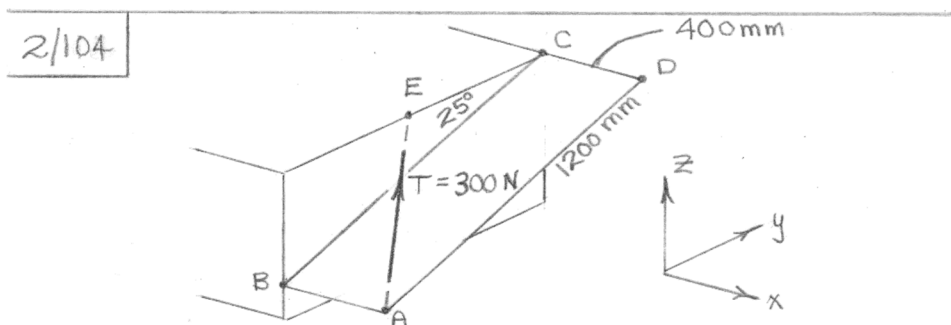
$$\begin{cases} F_x = -1700 \sin 40^\circ \cos 30^\circ = -946 \text{ lb} \\ F_y = 1700 \cos 40^\circ = 1302 \text{ lb} \\ F_z = 1700 \sin 40^\circ \sin 30^\circ = 546 \text{ lb} \end{cases} \quad \underline{F} = -946 \underline{i} + 1302 \underline{j} + 546 \underline{k} \text{ lb}$$

$$\underline{r}_{OA} = \frac{b \underline{i} + h \underline{j}}{\sqrt{b^2 + h^2}} \quad \text{so} \dots \quad \underline{F} \cdot \underline{r}_{OA} = (-946 \underline{i} + 1302 \underline{j} + 546 \underline{k}) \cdot \frac{b \underline{i} + h \underline{j}}{\sqrt{b^2 + h^2}}$$

$$F_{OA} = \underline{F} \cdot \underline{r}_{OA} = 0 = \frac{1302(h - 4.36)}{\sqrt{36 + h^2}} \quad \text{so} \dots \quad h = 4.36 \text{ ft}$$

$$\underline{r}_{OB} = \frac{b \underline{i} + h \underline{k}}{\sqrt{b^2 + h^2}} = 0.809 \underline{i} + 0.588 \underline{k}$$

$$F_{OB} = \underline{F} \cdot \underline{r}_{OB} = (-946 \underline{i} + 1302 \underline{j} + 546 \underline{k}) \cdot (0.809 \underline{i} + 0.588 \underline{k}) \rightarrow \underline{F_{OB}} = -444 \text{ lb}$$



$$\begin{aligned}\underline{T} &= T \underline{n}_{AE} = 300 \left[\frac{-400\underline{i} + 544\underline{j} + 507\underline{k}}{\sqrt{400^2 + 544^2 + 507^2}} \right] \\ &= 300 [-0.474\underline{i} + 0.644\underline{j} + 0.601\underline{k}] \text{ N}\end{aligned}$$

$$\underline{n}_{BC} = \cos 25^\circ \underline{j} + \sin 25^\circ \underline{k}$$

Carry out $T_{BC} = \underline{T} \cdot \underline{n}_{BC}$ to obtain

$$\underline{T}_{BC} = 251 \text{ N}$$

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►2/105

$$F_x = F_{xy} \cos \theta, \quad F_y = F_{xy} \sin \theta$$

$$F_z = F \sin \beta, \quad F_{xy} = F \cos \beta$$

$$\tan \beta = \frac{R \cos \phi}{R \sin \phi - \frac{R}{2}} = \frac{2 \cos \phi}{2 \sin \phi - 1}$$

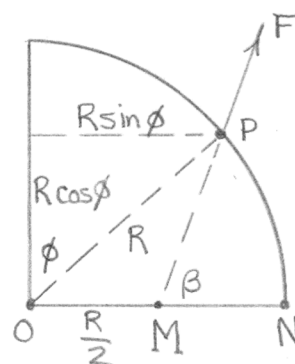
$$\text{So } \sin \beta = \frac{2 \cos \phi}{\sqrt{(2 \sin \phi - 1)^2 + (2 \cos \phi)^2}}$$

$$\cos \beta = \frac{2 \sin \phi - 1}{\sqrt{(2 \sin \phi - 1)^2 + (2 \cos \phi)^2}}$$

$$\text{Note that } \sqrt{(2 \sin \phi - 1)^2 + (2 \cos \phi)^2} = \sqrt{5 - 4 \sin \phi}$$

$$\text{So } \underline{F} = F [\cos \theta \cos \beta \underline{i} + \sin \theta \cos \beta \underline{j} + \sin \beta \underline{k}]$$

$$= \frac{F}{\sqrt{5 - 4 \sin \phi}} [(2 \sin \phi - 1)(\cos \theta \underline{i} + \sin \theta \underline{j}) + 2 \cos \phi \underline{k}]$$



2/106

$$\tan \gamma = \frac{c}{\sqrt{a^2+b^2}/2} = \frac{2c}{\sqrt{a^2+b^2}}$$

$$\gamma + 90^\circ + \beta = 180^\circ$$

$$\beta = 90^\circ - \gamma = 90^\circ - \tan^{-1} \frac{2c}{\sqrt{a^2+b^2}}$$

$$\tan \alpha = \frac{b}{a}$$

$$\begin{cases} \cos \alpha = \frac{a}{\sqrt{a^2+b^2}} \\ \sin \alpha = \frac{b}{\sqrt{a^2+b^2}} \end{cases}$$

$$\begin{cases} F_z = F \sin \beta \\ F_h = F \cos \beta \\ F_x = F_h \cos \alpha = F \cos \beta \cos \alpha \\ F_y = F_h \sin \alpha = F \cos \beta \sin \alpha \end{cases}$$

Now simplify $\sin \beta$ & $\cos \beta$ expressions:

$$\begin{aligned} \sin \beta &= \sin \left[90^\circ - \tan^{-1} \frac{2c}{\sqrt{a^2+b^2}} \right] \\ &= \sin 90^\circ \cos \left[\tan^{-1} \frac{2c}{\sqrt{a^2+b^2}} \right] - \cos 90^\circ \sin \left[\tan^{-1} \frac{2c}{\sqrt{a^2+b^2}} \right] \\ &= \frac{\sqrt{a^2+b^2}}{\sqrt{a^2+b^2+4c^2}} \quad (\text{Also see that } \sin \beta = \cos \gamma!) \end{aligned}$$

$$\cos \beta = \sin \gamma = \frac{c}{\sqrt{\frac{a^2+b^2}{4} + c^2}} = \frac{2c}{\sqrt{a^2+b^2+4c^2}}$$

Finally,

$$F_x = F \frac{2c}{\sqrt{a^2+b^2+4c^2}} \frac{a}{\sqrt{a^2+b^2}} = \frac{2acF}{\sqrt{a^2+b^2}\sqrt{a^2+b^2+4c^2}}$$

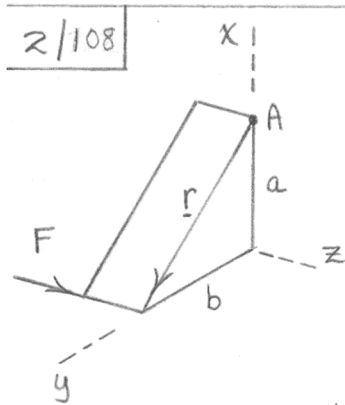
$$F_y = F \frac{2c}{\sqrt{a^2+b^2+4c^2}} \frac{b}{\sqrt{a^2+b^2}} = \frac{2bcF}{\sqrt{a^2+b^2}\sqrt{a^2+b^2+4c^2}}$$

$$F_z = F \sqrt{\frac{a^2+b^2}{a^2+b^2+4c^2}}$$

2/107

$$\begin{cases} \underline{M}_1 = \underline{-cF_1j} \\ \underline{M}_2 = \underline{cF_2j - bF_2k} = \underline{F_2(cj - bk)} \\ \underline{M}_3 = \underline{-bF_3k} \end{cases}$$

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$$\begin{aligned}\underline{M}_A &= \underline{r} \times \underline{F} \\ &= (-a\underline{i} + b\underline{j}) \times F\underline{k} \\ &= \underline{F(b\underline{i} + a\underline{j})}\end{aligned}$$

WILEY

$$\boxed{2/109} \quad \underline{\underline{M_o = F(-c\underline{i} + a\underline{k})}}$$

$$\underline{\underline{M_A = Fa\underline{k}}}$$

$$\begin{aligned} \underline{M_{oB}} &= (\underline{M_o} \cdot \underline{n_{oB}}) \underline{n_{oB}} \\ &= \left[F(-c\underline{i} + a\underline{k}) \cdot \frac{a\underline{i} + b\underline{j}}{\sqrt{a^2 + b^2}} \right] \frac{a\underline{i} + b\underline{j}}{\sqrt{a^2 + b^2}} \\ &= -\frac{Fac}{a^2 + b^2} (a\underline{i} + b\underline{j}) \end{aligned}$$

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$$\begin{aligned} 2/110 \quad \underline{M}_O &= \underline{r}_{OA} \times \underline{F} \\ &= (1.5\underline{j} + 0.75\underline{k}) \times 4(-\cos 30^\circ \underline{i} + \sin 30^\circ \underline{j}) \\ &= \underline{-1.5\underline{i} - 2.60\underline{j} + 5.20\underline{k} \text{ lb-in.}} \end{aligned}$$

WILEY

2/111

$$R = \Sigma F = 250 \text{ kips}$$

$$\underline{M} = -150(3)\underline{i} + (150-100)6\underline{j}$$

$$= -450\underline{i} + 300\underline{j} \text{ kip-in.}$$

$$\text{or } \underline{M} = (-0.450\underline{i} + 0.300\underline{j})10^6 \text{ lb-in.}$$

WILEY

$$\begin{aligned} 2/112 \quad \underline{M} &= \underline{r} \times \underline{F} \\ &= -0.5 \underline{i} \times 400 (\cos 15^\circ \underline{j} + \sin 15^\circ \underline{k}) \\ &= 51.8 \underline{j} - 193.2 \underline{k} \text{ N}\cdot\text{m} \end{aligned}$$

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$$2/113 \quad \overline{AB} = \sqrt{0.8^2 + 1.5^2 + 2^2} = 2.62 \text{ m}$$

$$\underline{T} = \frac{1.2}{2.62} (0.8\underline{i} + 1.5\underline{j} - 2\underline{k}) \text{ kN}$$

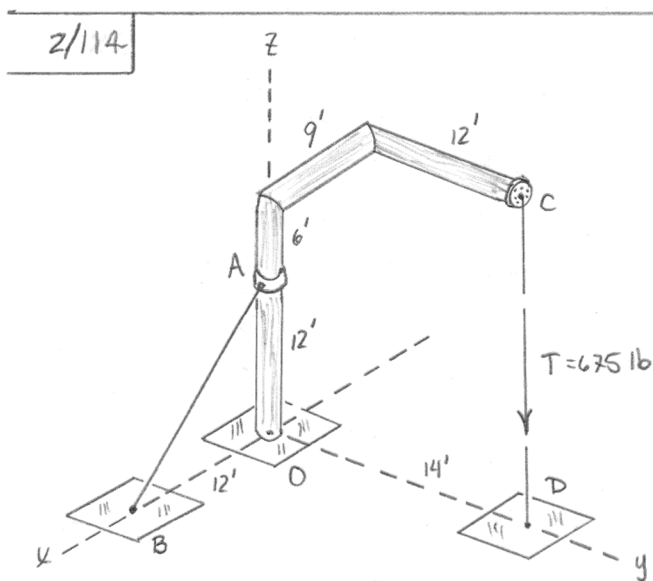
$$\text{Take } \underline{r} = \underline{OA} = 1.6\underline{i} + 2\underline{k} \text{ m}$$

$$\underline{M}_O = \underline{r} \times \underline{T} = \begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ 1.6 & 0 & 2 \\ 0.8 & 1.5 & -2 \end{vmatrix} \frac{1.2}{2.62}$$

$$\underline{M}_O = 0.457(-3\underline{i} + 4.8\underline{j} + 2.40\underline{k}) \text{ kN}\cdot\text{m}$$

$$M_O = |\underline{M}_O| = 0.457\sqrt{3^2 + 4.8^2 + 2.40^2} = \underline{2.81 \text{ kN}\cdot\text{m}}$$

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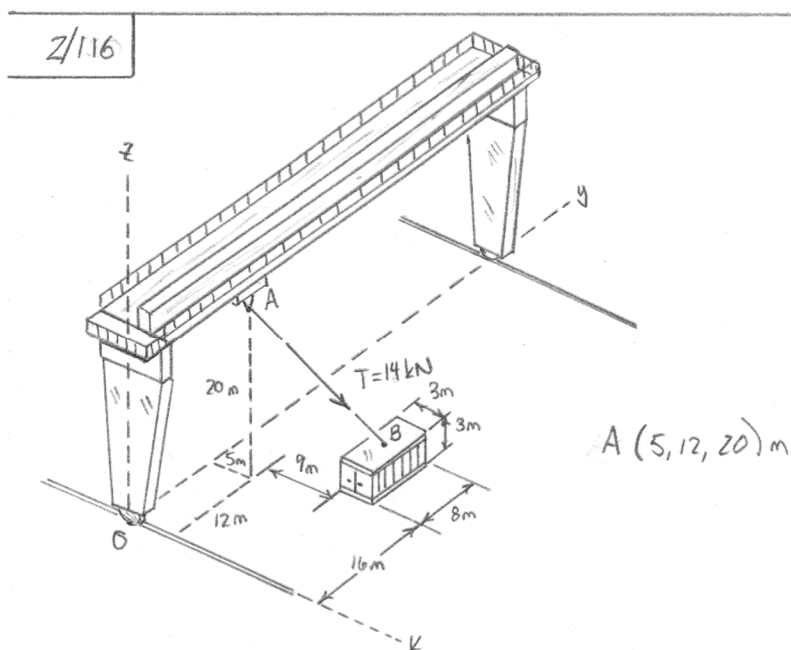


From 2/98... $\underline{T} = 300\underline{i} + 66.8\underline{j} - 601\underline{k}$ lb

$$\begin{cases} \underline{M}_O = \underline{r}_{OB} \times \underline{T} = 14\underline{j} \times (300\underline{i} + 66.8\underline{j} - 601\underline{k}) \\ \underline{M}_O = -8410\underline{i} - 4210\underline{k} \text{ lb-ft} \end{cases}$$

$$\begin{aligned} 2/115 \quad \underline{M} &= -150(0.250 + 0.250)\underline{i} + 150(0.150)\underline{j} \\ &= -75\underline{i} + 22.5\underline{j} \text{ N}\cdot\text{m} \end{aligned}$$

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From 2/93 ... $\underline{T} = \underline{R} = 6.83 \underline{i} + 5.20 \underline{j} - 11.06 \underline{k} \text{ kN}$

$$\begin{cases} \underline{M}_O = \underline{r}_{OA} \times \underline{T} = (5 \underline{i} + 12 \underline{j} + 20 \underline{k}) \times (6.83 \underline{i} + 5.20 \underline{j} - 11.06 \underline{k}) \\ \underline{M}_O = -237 \underline{i} + 191.9 \underline{j} - 55.9 \underline{k} \text{ kN}\cdot\text{m} \end{cases}$$

2/117

$$\begin{aligned} M_o &= (250 \sin 60^\circ)12 + (250 \cos 60^\circ) \sin 40^\circ (8 - 4.2) \\ &= 2900 \text{ lb-in.} \end{aligned}$$

WILEY

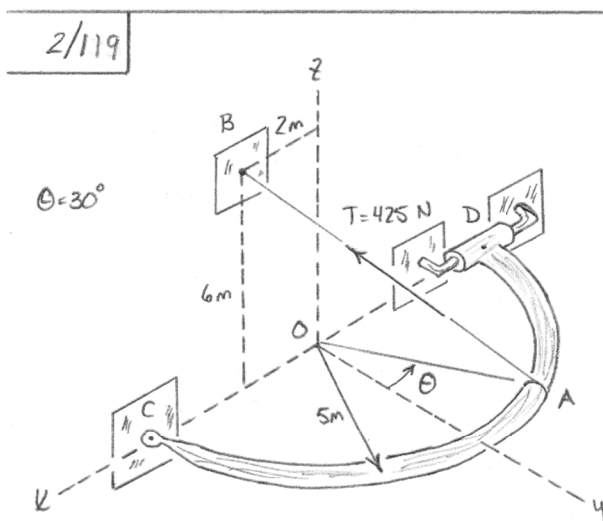
2/118

$$\underline{M}_O = \underline{r} \times \underline{F}$$

$$= (-6\underline{i} + 0.8\underline{j} + 1.2\underline{k}) \times (-400\underline{j})$$

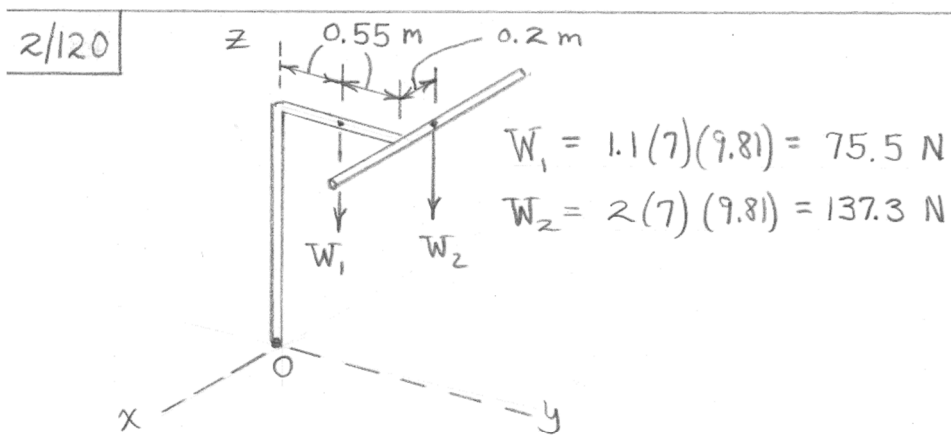
$$= \underline{480\underline{i} + 2400\underline{k} \text{ N}\cdot\text{m}}$$

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From 2/108 ... $\underline{T} = 221 \underline{i} - 212 \underline{j} + 294 \underline{k} \text{ N}$

$$M_{O_x} = r \cos \theta T_z = 5 \cos 30^\circ (294) \rightarrow \underline{M_{O_x} = 1275 \text{ N}\cdot\text{m}}$$



$$\begin{cases} M_{Ox} = -75.5(0.55) - 137.3(1.1) = -192.6 \text{ N}\cdot\text{m} \\ M_{Oy} = -137.3(0.2) = -27.5 \text{ N}\cdot\text{m} \\ M_{Oz} = 0 \end{cases}$$

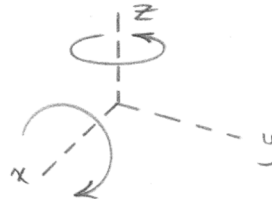
$$\therefore \underline{M_O} = -192.6\mathbf{i} - 27.5\mathbf{j} \text{ N}\cdot\text{m}$$

$$\underline{M_O} = 194.6 \text{ N}\cdot\text{m}$$

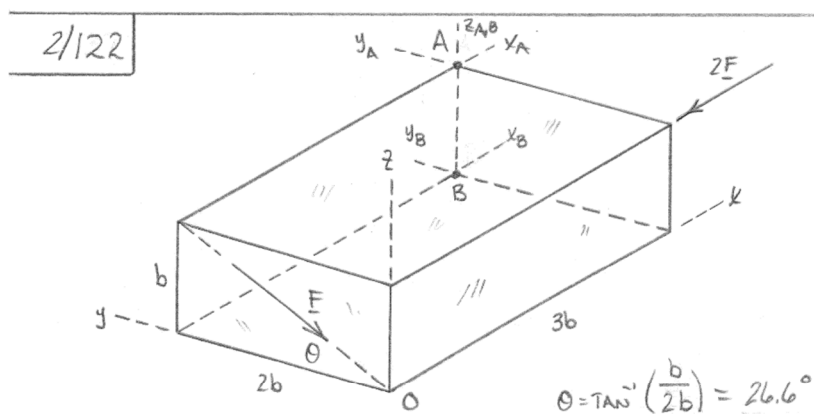
2/121

$$\underline{M} = 1.2(40)\underline{k} - 1.2(50)\underline{i}$$
$$= -60\underline{i} + 48\underline{k} \quad \text{lb-in.}$$

The spacecraft will begin to rotate about its
x- and z axes.



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• Force $\underline{F}$

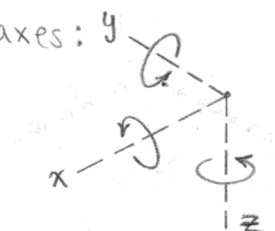
$$\begin{cases} \underline{M}_A = F \cos \theta (3b) \underline{k} - F \sin \theta (3b) \underline{j} \rightarrow \underline{M}_A = \frac{Fb}{\sqrt{5}} (-3\underline{j} + 6\underline{k}) \\ \underline{M}_B = F \cos \theta (3b) \underline{k} - F \sin \theta (3b) \underline{j} + F \sin \theta (2b) \underline{i} \\ \therefore \underline{M}_B = \frac{Fb}{\sqrt{5}} (2\underline{i} - 3\underline{j} + 6\underline{k}) \end{cases}$$

• Force $2\underline{F}$

$$\begin{cases} \underline{M}_A = -2F(2b) \underline{k} \rightarrow \underline{M}_A = -4Fb \underline{k} \\ \underline{M}_B = -2F(2b) \underline{k} - 2F(b) \underline{j} \rightarrow \underline{M}_B = -2Fb (\underline{j} + 2\underline{k}) \end{cases}$$

$$\begin{aligned} \underline{2/123} \quad \underline{\underline{M}} &= (1700)(2)\underline{i} - (1700)(30)\underline{j} - (1700)(30)\underline{k} \\ &= 3400\underline{i} - 51000\underline{j} - 51000\underline{k} \text{ N}\cdot\text{m} \end{aligned}$$

The orbiter would acquire rotational motion about all three axes:



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$$\begin{aligned}\underline{M}_o &= 0\underline{i} - (200)(0.2 + 0.125 \sin 20^\circ)\underline{j} \\ &\quad - 200(0.125 \cos 20^\circ - 0.070)\underline{k} \\ &= -48.6\underline{j} - 9.49\underline{k} \text{ N}\cdot\text{m}\end{aligned}$$

There would be no z-component of $\underline{M}_o$ if
 $d \cos 20^\circ - 70 = 0$, $d = 74.5 \text{ mm}$

WILEY

2/125

$$\underline{T} = T \left[\frac{-0.35\mathbf{i} - 0.45\cos 20^\circ \mathbf{j} + (0.4 + 0.45\sin 20^\circ)\mathbf{k}}{\sqrt{(0.35)^2 + (0.45\cos 20^\circ)^2 + (0.4 + 0.45\sin 20^\circ)^2}} \right]$$

$$= 143.4 [-0.449\mathbf{i} - 0.542\mathbf{j} + 0.710\mathbf{k}] \text{ N}$$

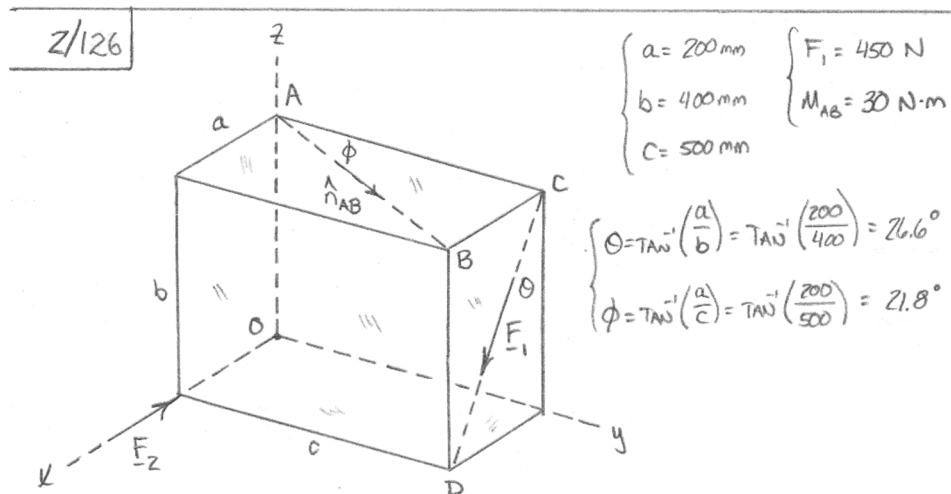
Moment of this force about the x -axis is

$$M_{O_x} = (0.710)(143.4)(0.45\cos 20^\circ) - 0.542(143.4)(0.45\sin 20^\circ) = \underline{31.1 \text{ N}\cdot\text{m}}$$

The moment of the weight W of the 15-kg plate about the x -axis is

$$(M_{O_x})_W = -15(9.81) \frac{0.45\cos 20^\circ}{2} = \underline{-31.1 \text{ N}\cdot\text{m}}$$

The moment of $\underline{T}$ about the line OB is zero, because $\underline{T}$ intersects OB .



$$\underline{F}_1 = 450 (\sin \theta \underline{i} - \cos \theta \underline{k}) \rightarrow \underline{F}_1 = 201 \underline{i} - 402 \underline{k} \text{ N}$$

$$\underline{n}_{AB} = \sin \phi \underline{i} + \cos \phi \underline{j} \rightarrow \underline{n}_{AB} = 0.371 \underline{i} + 0.928 \underline{j}$$

$$\underline{M}_A = b \underline{F}_2 \underline{j} - c \underline{F}_1 \underline{i} - c \underline{F}_{1x} \underline{k} = 0.4 \underline{F}_2 \underline{j} - 0.5 (402) \underline{i} - 0.5 (201) \underline{k}$$

$$\underline{M}_A = -201 \underline{i} + 0.4 \underline{F}_2 \underline{j} - 100.6 \underline{k} \text{ N}\cdot\text{m}$$

$$M_{AB} = \underline{M}_A \cdot \underline{n}_{AB} \rightarrow 30 = (-201 \underline{i} + 0.4 \underline{F}_2 \underline{j} - 100.6 \underline{k}) \cdot (0.371 \underline{i} + 0.928 \underline{j})$$

$$30 = 0.371 F_2 - 74.7 \rightarrow \underline{F_2 = 282 \text{ N}}$$

2/127 Using the coordinates of the figure:

$$\underline{M}_A = \underline{r} \times \underline{F}, \quad \underline{F} = -1.8 \underline{k} \text{ lb}$$

$$\underline{r} = [(2+1) \cos 30^\circ] \underline{i} + 3 \underline{j} + [(2+1) \sin 30^\circ] \underline{k} \text{ in.}$$

$$\therefore \underline{M}_A = -5.40 \underline{i} + 4.68 \underline{j} \text{ lb-in.}$$

$$\underline{M}_{AB} = (\underline{M}_A \cdot \underline{n}_{AB}) \underline{n}_{AB}, \quad \underline{n}_{AB} = \cos 30^\circ \underline{i} + \sin 30^\circ \underline{k}$$

$$\therefore \underline{M}_{AB} = -4.05 \underline{i} - 2.34 \underline{k} \text{ lb-in.}$$

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$$\begin{aligned} \underline{2/128} \quad \text{Moment of couple is } 240(\underline{j} \cos 30^\circ - \underline{k} \sin 30^\circ) \\ = 207.8 \underline{j} - 120 \underline{k} \text{ N}\cdot\text{m} \end{aligned}$$

Moment of force is

$$\begin{aligned} 1200 \cos 30^\circ (-0.250 \underline{i} + 0.200 \underline{k}) + 1200 \sin 30^\circ (0.200 \underline{j}) \\ = -259.8 \underline{i} + 120 \underline{j} + 207.8 \underline{k} \text{ N}\cdot\text{m} \end{aligned}$$

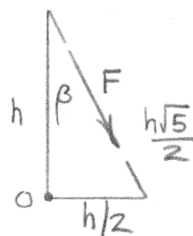
Thus total moment is

$$\underline{M}_O = -259.8 \underline{i} + 327.8 \underline{j} + 87.8 \underline{k} \text{ N}\cdot\text{m}$$

$$\text{or } \underline{M}_O = -260 \underline{i} + 328 \underline{j} + 88 \underline{k} \text{ N}\cdot\text{m}$$

WILEY

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$$F_z = -F \cos \beta = -F \frac{1}{\sqrt{5}/2} = -\frac{2F}{\sqrt{5}}$$

$$F_{hor} = F \sin \beta = F/\sqrt{5}$$

$$F_x = F_{hor} \cos \theta = \frac{F}{\sqrt{5}} \cos \theta$$

$$F_y = F_{hor} \sin \theta = \frac{F}{\sqrt{5}} \sin \theta$$

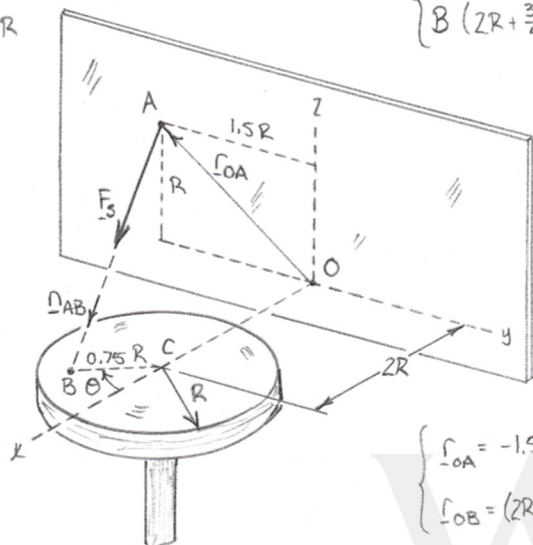
$$\text{So } \underline{F} = \frac{F}{\sqrt{5}} [\cos \theta \underline{i} + \sin \theta \underline{j} - 2\underline{k}]$$

$$\begin{aligned} \underline{M}_O &= \underline{r} \times \underline{F} = h\underline{k} \times \frac{F}{\sqrt{5}} [\cos \theta \underline{i} + \sin \theta \underline{j} - 2\underline{k}] \\ &= \frac{Fh}{\sqrt{5}} (\cos \theta \underline{j} - \sin \theta \underline{i}) \end{aligned}$$

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$$L_0 = 1.5R$$



$$\begin{cases} A(0, -1.5R, R) \\ B(2R + \frac{3}{4}R \cos \theta, -\frac{3}{4}R \sin \theta, 0) \end{cases}$$

$$\begin{cases} F_s = k\delta \\ \text{AND } \delta = d - L_0 \end{cases}$$

$$\begin{cases} \mathbf{r}_{OA} = -1.5R\mathbf{j} + R\mathbf{k} \\ \mathbf{r}_{OB} = (2R + \frac{3}{4}R \cos \theta)\mathbf{i} - \frac{3}{4}R \sin \theta\mathbf{j} \end{cases}$$

$$\mathbf{d}_{AB} = \frac{(8 + 3\cos \theta)\mathbf{i} + (4 - 3\sin \theta)\mathbf{j} - 4\mathbf{k}}{\sqrt{125 + 48\cos \theta - 36\sin \theta}}$$

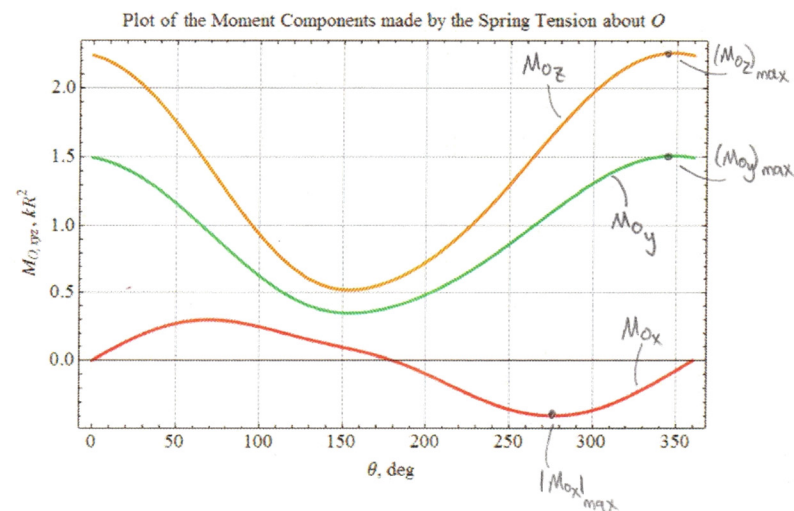
$$d = |\mathbf{r}_{OB} - \mathbf{r}_{OA}| = \frac{R}{4} \sqrt{125 + 48\cos \theta - 36\sin \theta}$$

$$\delta = d - L_0 = \frac{R}{4} (\sqrt{125 + 48\cos \theta - 36\sin \theta} - 6)$$

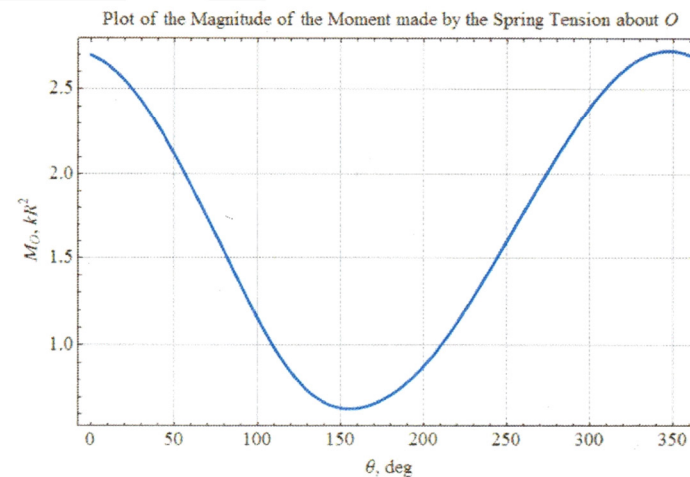
$$\mathbf{F}_s = k\delta \mathbf{d}_{AB}$$

$$\mathbf{M}_O = \mathbf{r}_{OA} \times \mathbf{F}_s \quad \text{AND} \quad \mathbf{r}_{OA} = -1.5R\mathbf{j} + R\mathbf{k}$$

CARRY OUT THE CROSS PRODUCT AND PLOT THE MOMENT COMPONENTS.



$$\begin{cases} |M_{Ox}|_{\max} = 0.398 kR^2 \text{ AT } \theta = 277^\circ \\ |M_{Oy}|_{\max} = 1.509 kR^2 \text{ AT } \theta = 348^\circ \\ |M_{Oz}|_{\max} = 2.26 kR^2 \text{ AT } \theta = 348^\circ \end{cases}$$



$$|M_O|_{\max} = 2.72 kR^2 \text{ AT } \theta = 347^\circ$$

$$\begin{aligned} 2/131 \quad & \begin{cases} R_x = \sum F_x = -7 \text{ kN} \\ R_y = \sum F_y = 4 - F_3 \cos \theta = -5 \text{ kN} \quad (1) \\ R_z = \sum F_z = F_3 \sin \theta = 6 \text{ kN} \quad (2) \end{cases} \end{aligned}$$

$$(1): F_3 \cos \theta = 9$$

$$(2): F_3 \sin \theta = 6$$

$$\text{Divide Eq. (2) by Eq. 1: } \tan \theta = \frac{2}{3}$$

$$\theta = 33.7^\circ$$

$$\text{Then } \underline{F_3 = 10.82 \text{ kN}}$$

$$R = \sqrt{7^2 + 5^2 + 6^2} = \underline{10.49 \text{ kN}}$$

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$$\begin{aligned} 2/132 \quad R &= \Sigma F = 160 + 200 + 80 + 160 = \underline{600 \text{ N} \downarrow} \\ \underline{M_o} &= (-200 - 160)(0.6) \underline{i} + (80 + 160)(0.9) \underline{j} \\ &= \underline{-216 \underline{i} + 216 \underline{j} \text{ N}\cdot\text{m}} \\ \underline{R} \cdot \underline{M_o} &= -600 \underline{k} \cdot (-216 \underline{i} + 216 \underline{j}) = 0, \quad \underline{R \perp M_o} \end{aligned}$$

WILEY

$$\begin{aligned}
 \underline{R} &= -2F\underline{k} + F\underline{k} + F(\cos 30^\circ \underline{k} + \sin 30^\circ \underline{j}) \\
 &= \frac{F}{2}\underline{j} + F\left(\frac{\sqrt{3}}{2} - 1\right)\underline{k} = F\left(\frac{1}{2}\underline{j} + \left(\frac{\sqrt{3}}{2} - 1\right)\underline{k}\right) \\
 \underline{M}_0 &= 2Fb\underline{j} + Fb\underline{i} + \frac{F}{2}(2b)\underline{k} + \frac{\sqrt{3}}{2}Fb\underline{i} - \frac{\sqrt{3}}{2}F(2b)\underline{j} \\
 &= Fb\left[\left(1 + \frac{\sqrt{3}}{2}\right)\underline{i} + (2 - \sqrt{3})\underline{j} + \underline{k}\right] \\
 \underline{R} \cdot \underline{M}_0 &= \left[\frac{1}{2}(2 - \sqrt{3}) + \left(\frac{\sqrt{3}}{2} - 1\right)(1)\right]F^2b = 0, \text{ so} \\
 \underline{R} &\perp \underline{M}_0.
 \end{aligned}$$

WILEY

$$2/134 \quad \underline{R} = \Sigma \underline{F} = -8 \underline{i} \text{ kN}$$

$$\begin{aligned} \underline{M}_G &= 50(10) \underline{k} + 8(6) \underline{j} + 8(40) \underline{k} \\ &= 48 \underline{j} + 820 \underline{k} \text{ kN}\cdot\text{m} \end{aligned}$$

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$$\underline{2/135} \quad R = \sum F_z = 70 + 30 - 80 - 60 - 50 = -90 \text{ lb}$$

$$-R|y = \sum M_x: -90y = 30(12) + 70(12) - 60(6) - 50(12)$$

$$\underline{y = -2.67 \text{ in.}}$$

$$|R|x = \sum M_y: 90x = 80(10) - 30(10) - 50(8)$$

$$\underline{x = 1.111 \text{ in.}}$$

WILEY

$$\begin{aligned} 2/136 \quad & \text{The two 160-N forces constitute a} \\ & \text{couple } 160(0.250)\underline{j} = 40\underline{j} \text{ N}\cdot\text{m} \\ \underline{R} = \Sigma \underline{F} = & 120\underline{i} - 180\underline{j} - 100\underline{k} \text{ N} \\ \underline{M} = \Sigma \underline{M}_A = & [120(0.25) + 100(0.3) + 40]\underline{j} + 50\underline{k} \text{ N}\cdot\text{m} \\ & = 100\underline{j} + 50\underline{k} \text{ N}\cdot\text{m} \end{aligned}$$

WILEY

$$\begin{aligned} \underline{2/137} \quad \underline{\underline{R}} &= \underline{\underline{\Sigma F}} = 600(\sin 30^\circ \underline{j} + \cos 30^\circ \underline{k}) \\ &\quad + 800(-\sin 45^\circ \underline{j} + \cos 45^\circ \underline{k}) \\ &= \underline{\underline{-266 \underline{j} + 1085 \underline{k} \text{ N}}} \end{aligned}$$

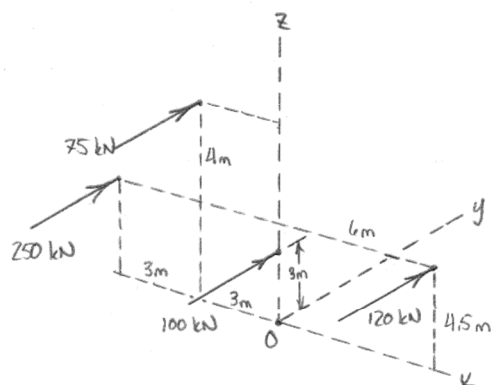
$$\begin{aligned} \underline{\underline{M_o}} &= -0.080 \underline{i} \times 600(\sin 30^\circ \underline{j} + \cos 30^\circ \underline{k}) \\ &\quad + 0.160 \underline{i} \times 800(-\sin 45^\circ \underline{j} + \cos 45^\circ \underline{k}) \\ &= \underline{\underline{-48.9 \underline{j} - 114.5 \underline{k} \text{ N}\cdot\text{m}}} \end{aligned}$$

$\underline{R}$ is not perpendicular to $\underline{M_o}$, because

$$\underline{R} \cdot \underline{M_o} \neq 0.$$

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$$\underline{r} = x \underline{i} + z \underline{k}$$

$$\underline{R} = (75 + 250 + 100 + 120) \underline{j} \rightarrow \underline{R} = 545 \underline{j} \text{ kN}$$

$$\underline{M}_O = [-120(4.5) + 100(3) + 250(4.5) + 75(0.5)] \underline{i} + [120(6) - 75(3) - 250(0)] \underline{k}$$

$$\underline{M}_O = -2600 \underline{i} - 1010 \underline{k} \text{ kN}\cdot\text{m}$$

$$\underline{r} \times \underline{R} = \underline{M}_O \rightarrow (x \underline{i} + z \underline{k}) \times 545 \underline{j} = -2600 \underline{i} - 1010 \underline{k}$$

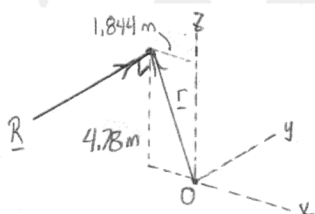
$$\begin{cases} \underline{i}: -545 z = -2600 \\ \underline{k}: 545 x = -1010 \end{cases}$$

Solving...

$$x = -1.844 \text{ m}$$

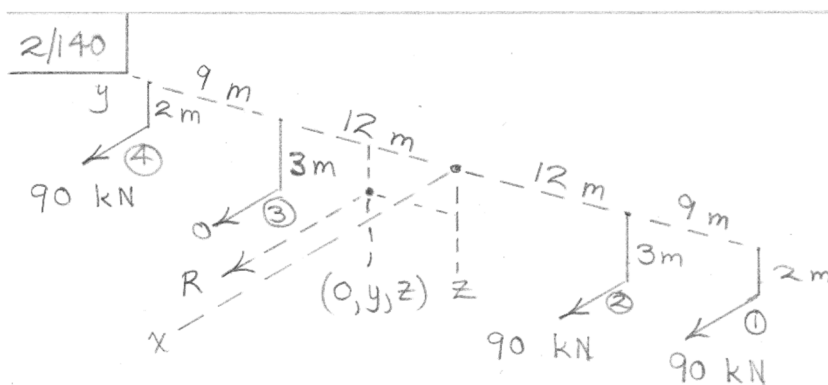
$$z = 4.78 \text{ m}$$

$$\underline{P} = (-1.844, 0, 4.78) \text{ m}$$



$$\begin{aligned}
 \underline{2/139} \quad \underline{\underline{R}} &= (200 + 800)\underline{i} + 1200(\cos 10^\circ \underline{j} - \sin 10^\circ \underline{i}) \\
 &= \underline{792 \underline{i} + 1182 \underline{j} \text{ N}} \\
 \underline{M_o} &= [(200 - 800)(0.1) + (1200 \cos 10^\circ)(0.075)] \underline{k} \\
 &\quad + [- (200 + 800)(0.220 + 0.330) + 1200 \sin 10^\circ (0.220)] \underline{j} \\
 &\quad + [1200 \cos 10^\circ (0.220)] \underline{i} \\
 &= \underline{260 \underline{i} - 504 \underline{j} + 28.6 \underline{k} \text{ N}\cdot\text{m}}
 \end{aligned}$$

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$$R = \Sigma F = 3(90) = 270 \text{ kN}$$

$$\Sigma M_z = -R_y : 90(21) + 90(12) - 90(21) = -270y$$

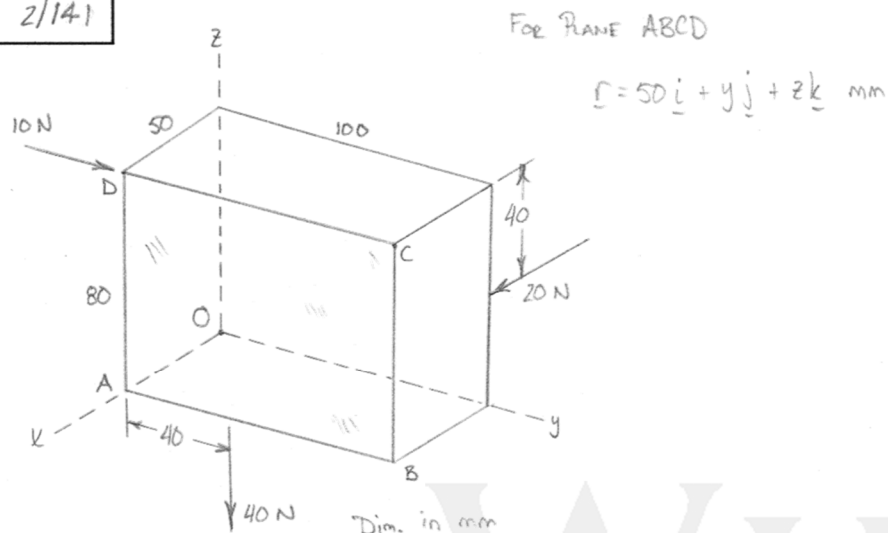
$$y = -4 \text{ m}$$

$$\Sigma M_y = R_z : 2(90)(2) + 90(3) = 270z$$

$$z = 2.33 \text{ m}$$

WILEY

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$$\underline{R} = 20\underline{i} + 10\underline{j} - 40\underline{k}$$

$$\underline{d} = \frac{\underline{R}}{R} = \frac{1}{\sqrt{21}}(2\underline{i} + \underline{j} - 4\underline{k})$$

$$\underline{M}_O = [-10(0.08) - 40(0.04)]\underline{i} + [20(0.04) + 40(0.05)]\underline{j} + [10(0.05) - 20(0.1)]\underline{k}$$

$$\underline{M}_O = -2.4\underline{i} + 2.8\underline{j} - 1.5\underline{k} \text{ N}\cdot\text{m}$$

$$\underline{M} = \underline{M}_O \cdot \underline{d} = (-2.4\underline{i} + 2.8\underline{j} - 1.5\underline{k}) \cdot \left[\frac{1}{\sqrt{21}}(2\underline{i} + \underline{j} - 4\underline{k}) \right] \rightarrow \underline{M} = 0.873 \text{ N}\cdot\text{m} (+)$$

$$\underline{M} = M \underline{d} = 0.873 \left(\frac{2}{\sqrt{21}}\underline{i} + \frac{1}{\sqrt{21}}\underline{j} - \frac{4}{\sqrt{21}}\underline{k} \right) \rightarrow \underline{M} = 0.381\underline{i} + 0.1905\underline{j} - 0.762\underline{k} \text{ N}\cdot\text{m}$$

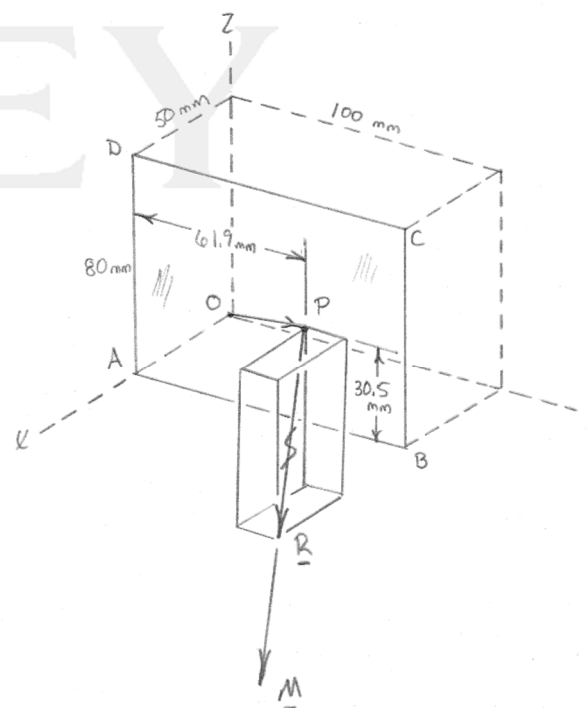
$$\underline{r} \times \underline{R} + \underline{M} = \underline{M}_O \rightarrow \left(\frac{50}{1000}\underline{i} + \frac{y}{1000}\underline{j} + \frac{z}{1000}\underline{k} \right) \times (20\underline{i} + 10\underline{j} - 40\underline{k}) + 0.381\underline{i} + 0.1905\underline{j} - 0.762\underline{k} = -2.4\underline{i} + 2.8\underline{j} - 1.5\underline{k}$$

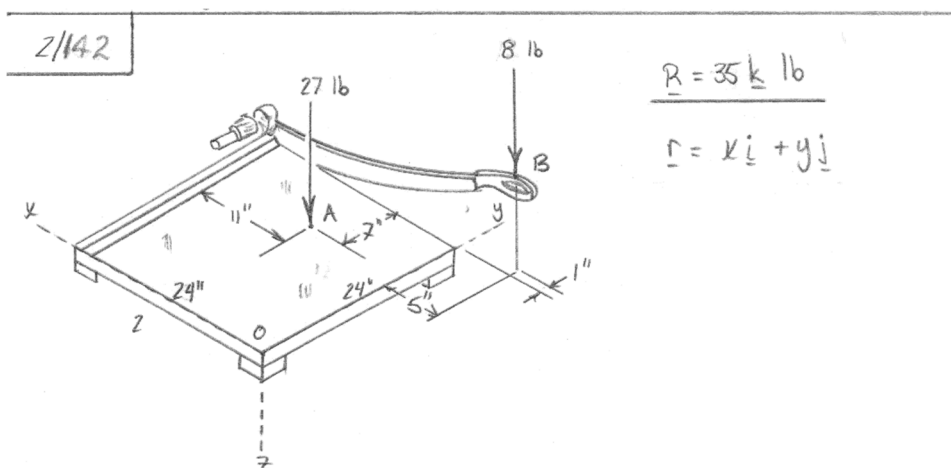
$$\begin{cases} \underline{i}: -0.04y - 0.01z + 0.381 = -2.4 \\ \underline{j}: 0.02z + 2.19 = 2.8 \\ \underline{k}: -0.02y - 0.262 = -1.5 \end{cases}$$

Solving...

$$\begin{cases} y = 61.9 \text{ mm} \\ z = 30.5 \text{ mm} \end{cases}$$

$$\underline{P} = (50, 61.9, 30.5) \text{ mm}$$

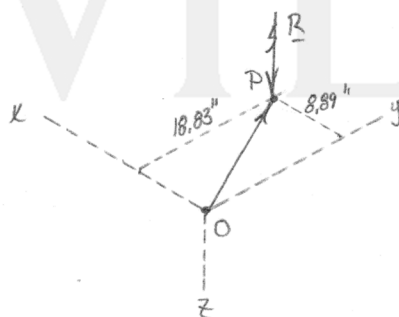




$$\underline{M}_O = [27(24-7) + 8(24+1)] \underline{i} + [8(5) - 27(24-11)] \underline{j} \rightarrow \underline{M}_O = 659 \underline{i} - 311 \underline{j} \text{ lb-in.}$$

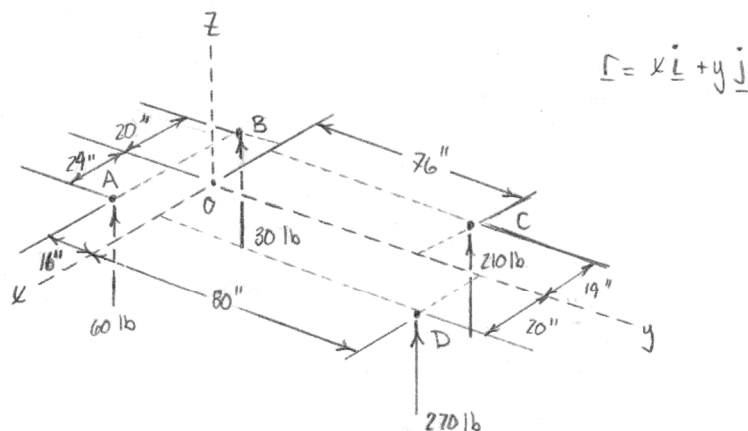
$$\underline{r} \times \underline{R} = \underline{M}_O \rightarrow (x \underline{i} + y \underline{j}) \times 35 \underline{k} = 659 \underline{i} - 311 \underline{j}$$

$$\begin{cases} \underline{i}: 35y = 659 \\ \underline{j}: -35x = -311 \end{cases} \rightarrow \underline{x} = 8.89 \text{ in.} \quad \& \quad \underline{y} = 18.83 \text{ in.}$$



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$$\underline{R} = (60 + 30 + 210 + 270) \underline{k} \rightarrow \underline{R} = 570 \underline{k} \text{ lb}$$



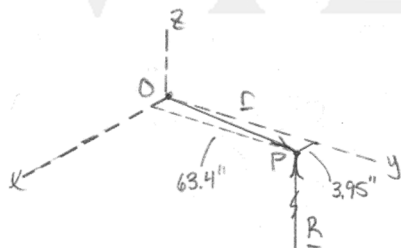
$$\underline{r} = x \underline{i} + y \underline{j}$$

$$\underline{M}_O = [270(80) + 210(76) - 60(16) - 30(16)] \underline{i} + [210(19) + 30(20) - 270(20) - 60(24)] \underline{j}$$

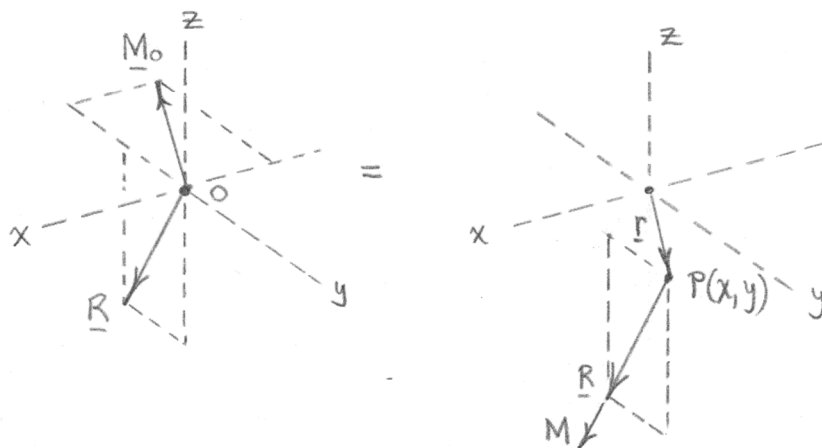
$$\underline{M}_O = 36,120 \underline{i} - 2250 \underline{j} \text{ lb-in.}$$

$$\underline{r} \times \underline{R} = \underline{M}_O \rightarrow (x \underline{i} + y \underline{j}) \times 570 \underline{k} = 36,120 \underline{i} - 2250 \underline{j}$$

$$\begin{cases} \underline{i}: 570 y = 36,120 \\ \underline{j}: -570 x = -2250 \end{cases} \rightarrow \underline{x} = 3.95 \text{ in.} \quad \& \quad \underline{y} = 63.4 \text{ in.}$$



$$\frac{2}{144} \left\{ \begin{aligned} \underline{R} &= -20\underline{j} - 40\underline{k} \text{ lb} \quad (= 44.7(-0.447\underline{j} - 0.894\underline{k})) \\ \underline{M}_O &= -40(1.4)\underline{i} - 40(8)\underline{j} \\ &= -56\underline{i} - 320\underline{j} \text{ lb-in.} \end{aligned} \right.$$



$$\underline{M}_O: -56\underline{i} - 320\underline{j} = \underline{r} \times \underline{R} + \underline{M} = (x\underline{i} + y\underline{j}) \times (-20\underline{j} - 40\underline{k}) + M(-0.447\underline{j} - 0.894\underline{k})$$

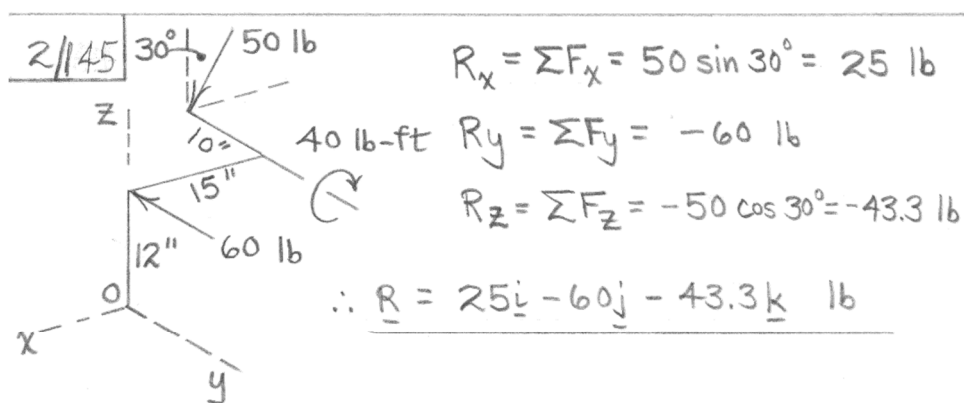
Equate coefficients:

$$\begin{cases} \underline{i}: -56 = -40y \\ \underline{j}: -320 = 40x - 0.447M \\ \underline{k}: 0 = -20x - 0.894M \end{cases}$$

Solution:

$$x = -6.4 \text{ in.}$$

$$y = 1.4 \text{ in.}$$

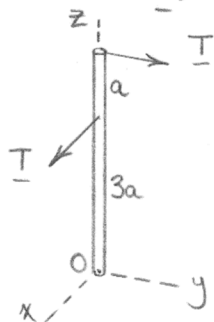


$$\begin{aligned}
 \underline{M}_O &= 12(60)\underline{i} + 50 \sin 30^\circ (12)\underline{j} + 50 \sin 30^\circ (10)\underline{k} \\
 &\quad + 50 \cos 30^\circ (10)\underline{i} - 50 \cos 30^\circ (15)\underline{j} - 40(12)\underline{j} \\
 &= \underline{1153\underline{i} - 830\underline{j} + 250\underline{k} \text{ lb-in.}}
 \end{aligned}$$

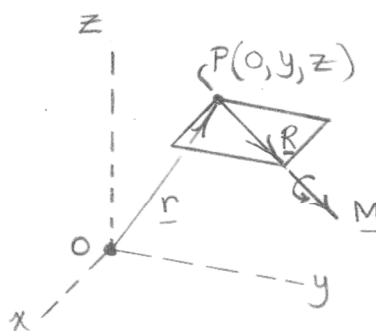
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$$2/146 \quad \underline{R} = \Sigma \underline{F} = T \underline{i} + T \underline{j} = \sqrt{2}T \left[\frac{1}{\sqrt{2}} \underline{i} + \frac{1}{\sqrt{2}} \underline{j} \right]$$

$$\Sigma \underline{M}_O = 3aT \underline{j} - 4aT \underline{i}$$



=



$$\Sigma \underline{M}_O = \underline{r} \times \underline{R} + \underline{M}$$

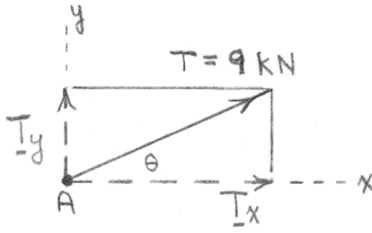
$$3aT \underline{j} - 4aT \underline{i} = (y \underline{j} + z \underline{k}) \times (T \underline{i} + T \underline{j}) + M \left(\frac{1}{\sqrt{2}} \underline{i} + \frac{1}{\sqrt{2}} \underline{j} \right)$$

$$\Rightarrow \begin{cases} -4aT = -zT + \frac{M}{\sqrt{2}} \\ 3aT = zT + \frac{M}{\sqrt{2}} \\ 0 = -yT \end{cases}$$

$$\text{So } \begin{cases} y = 0 \\ z = \frac{7}{2}a \\ M = -\frac{\sqrt{2}}{2}aT \end{cases}$$

$$\text{So } \underline{M} = -\frac{\sqrt{2}}{2}aT \left(\frac{1}{\sqrt{2}} \underline{i} + \frac{1}{\sqrt{2}} \underline{j} \right) \\ = \underline{\underline{-\frac{aT}{2} (\underline{i} + \underline{j})}} \quad (\text{a negative wrench})$$

2/147



$\theta = \tan^{-1} \frac{6}{10} = 31.0^\circ$

$T_x = T \cos \theta = 9 \cos 31.0^\circ$
 $= 7.72 \text{ kN}$

$T_y = T \sin \theta = 9 \sin 31.0^\circ$
 $= 4.63 \text{ kN}$

$\underline{T = 7.72 \underline{i} + 4.63 \underline{j} \text{ kN}}$

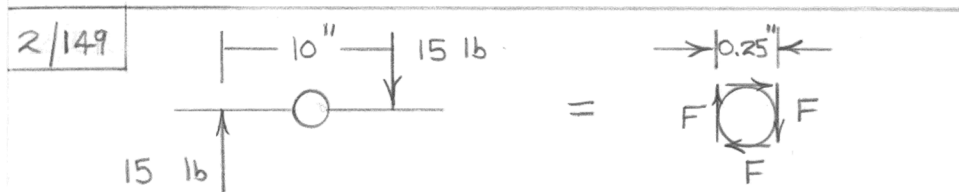
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$$\begin{cases} \underline{M}_1 = -c \underline{F}_1 \underline{i} \\ \underline{M}_2 = c \underline{F}_2 \underline{i} - a \underline{F}_2 \underline{k} = \underline{F}_2 (c \underline{i} - a \underline{k}) \\ \underline{M}_3 = -a \underline{F}_3 \underline{k} \end{cases}$$

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15 lb

10"

15 lb

=

0.25"

F

F

F

F

$$M = Fd = 15(10) = 2F(0.25), \underline{F = 300 \text{ lb}}$$

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2/150

Dim. in inches

$$M_o = Fd$$

$$= 1.2(4 + 10 \cos 15^\circ - 2 \sin 15^\circ)$$

$$= 15.77 \text{ lb-in. } (\checkmark)$$

$$M_{ow} = W d_w$$

$$= 9(2 + 2 \cos 15^\circ - 4 \sin 15^\circ)$$

$$= 26.1 \text{ lb-in. } (2)$$

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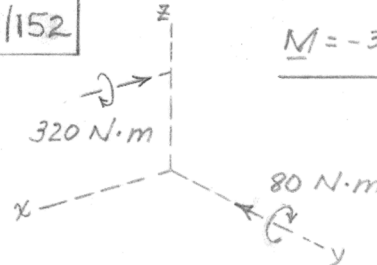
$$\underline{2/15/} \quad \underline{\underline{P = P\left(\frac{4}{5}\underline{i} + \frac{3}{5}\underline{j}\right) ; \quad \underline{r}_{AB} = b(-\underline{i} + \underline{j} + \underline{k})}}$$

Carry out $\underline{M}_A = \underline{r}_{AB} \times \underline{P}$ to obtain

$$\underline{M}_A = \frac{Pb}{5}(-3\underline{i} + 4\underline{j} - 7\underline{k})$$

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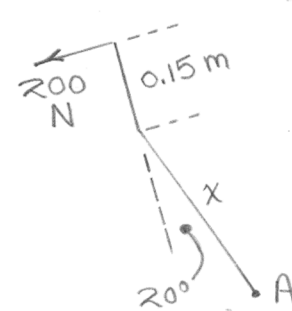
$\underline{M} = -320\underline{i} - 80\underline{j} \text{ N}\cdot\text{m}$

$$\cos \theta_x = \frac{M_x}{|\underline{M}|} = \frac{-320}{\sqrt{320^2 + 80^2}} = -0.970$$

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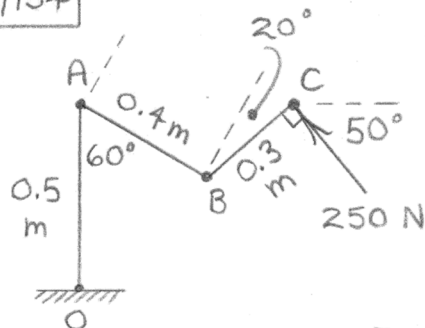
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$$M_A = Fd : 80 = 200(0.15 + x \cos 20^\circ)$$
$$x = 0.266 \text{ m or } \underline{266 \text{ mm}}$$



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$$\begin{aligned}
 \curvearrowright M_O &= 250 \cos 50^\circ [0.5 - 0.4 \cos 60^\circ + 0.3 \sin 40^\circ] \\
 &\quad + 250 \sin 50^\circ [0.4 \sin 60^\circ + 0.3 \cos 40^\circ] \\
 &= \underline{189.6 \text{ N}\cdot\text{m} \text{ CCW}}
 \end{aligned}$$

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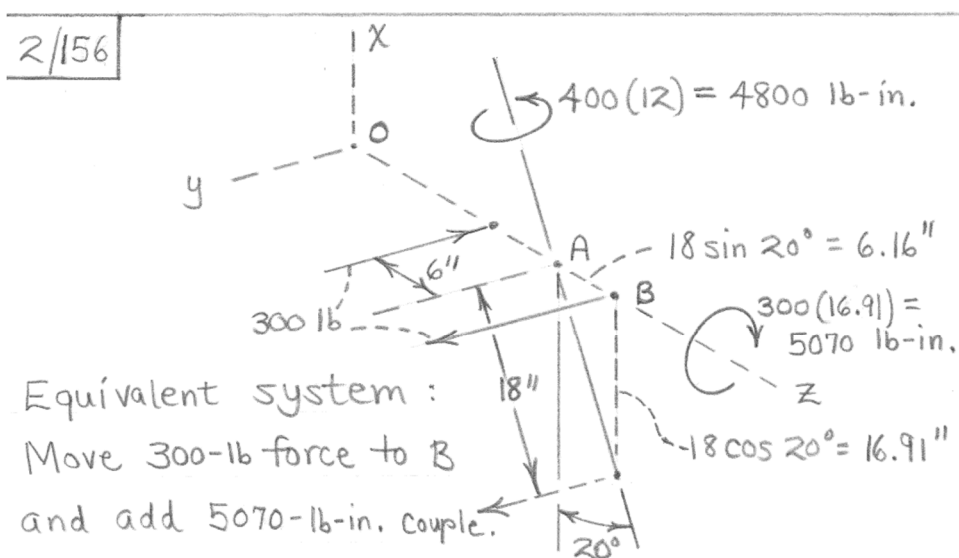
$$\begin{aligned} \underline{2/155} \quad \underline{\underline{R}} &= 800 \left[-\sin 30^\circ \cos 20^\circ \underline{i} + \sin 30^\circ \sin 20^\circ \underline{j} \right. \\ &\quad \left. + \cos 30^\circ \underline{k} \right] \\ &= \underline{-376 \underline{i} + 136.8 \underline{j} + 693 \underline{k} \quad \text{N}} \end{aligned}$$

$$\underline{M}_O = \underline{r}_{OB} \times \underline{F}$$

$$\underline{r}_{OB} = [300 \sin 20^\circ \underline{i} + 300 \cos 20^\circ \underline{j} + 250 \underline{k}] \text{ mm}$$

$$\underline{M}_O = 161.1 \underline{i} - 165.1 \underline{j} + 120 \underline{k} \quad \text{N}\cdot\text{m}$$

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The components of the resultant couple are

$$M_x = -300(6 + 6.16) + 4800 \cos 20^\circ = 864 \text{ lb-in.}$$

$$M_y = 0$$

$$M_z = -4800 \sin 20^\circ - 5070 = -6720 \text{ lb-in.}$$

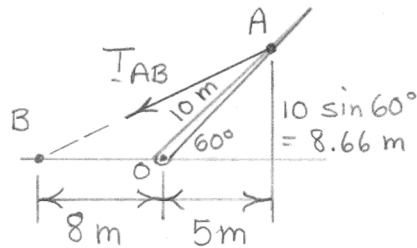
$$\underline{M} = 864\mathbf{i} - 6720\mathbf{k} \text{ lb-in.}$$

$$M = \sqrt{864^2 + 6720^2} = 6770 \text{ lb-in.}$$

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$$\overline{AB}^2 = 8^2 + 10^2 - 2(8)(10) \cos 120^\circ$$

$$\overline{AB} = 15.62 \text{ m}$$



$$\begin{aligned} (a) \quad \underline{T}_{AB} &= 3 \left[-\frac{13}{15.62} \cos 35^\circ \underline{i} - \frac{13}{15.62} \sin 35^\circ \underline{j} \right. \\ &\quad \left. - \frac{8.66}{15.62} \underline{k} \right] \\ &= -2.05 \underline{i} - 1.432 \underline{j} - 1.663 \underline{k} \text{ kN} \end{aligned}$$

(b) Carry out $\underline{r}_{OB} \times \underline{T}_{AB}$, where $\underline{r}_{OB} = 8(-\cos 35^\circ \underline{i} - \sin 35^\circ \underline{j}) \text{ m}$ to obtain

$$\underline{M}_O = 7.63 \underline{i} - 10.90 \underline{j} \text{ kN} \cdot \text{m}$$

$$\therefore M_{Ox} = 7.63 \text{ kN} \cdot \text{m}, M_{Oy} = -10.90 \text{ kN} \cdot \text{m}, M_{Oz} = 0$$

$$(c) \quad T_{AO} = T_{AB} \cdot \underline{n}_{AO}$$

$$\text{With } \underline{n}_{AO} = -\cos 60^\circ \cos 35^\circ \underline{i} - \cos 60^\circ \sin 35^\circ \underline{j} - \sin 60^\circ \underline{k},$$

$$\text{we obtain } T_{AO} = 2.69 \text{ kN}$$

$$\begin{aligned}
 2/158 \quad \underline{R} = \underline{\Sigma F} &= 500 \cos 45^\circ (\underline{i}) + 400 \underline{j} - (600 + 500 \sin 45^\circ) \underline{k} \\
 &= 354 \underline{i} + 400 \underline{j} - 954 \underline{k} \quad \text{lb} \\
 R &= \sqrt{354^2 + 400^2 + 954^2} = \underline{1093 \text{ lb}} \\
 \underline{M} &= [500 \cos 45^\circ (3) - 600(3) - 400(10)] \underline{i} \\
 &\quad + [500 \cos 45^\circ (6) + 500 \sin 45^\circ (7) + 600(6)] \underline{j} \\
 &\quad + [500 \sin 45^\circ (3) + 400(3)] \underline{k} \\
 &= -4739 \underline{i} + 8196 \underline{j} + 2261 \underline{k} \quad \text{lb-ft} \\
 M &= \sqrt{4739^2 + 8196^2 + 2261^2} = \underline{9730 \text{ lb-ft}}
 \end{aligned}$$

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$$\Sigma F_x = 0 : -360 - 240 \sin \theta + T \sin 30^\circ + 400 \cos 30^\circ = 0 \quad (1)$$

$$\Sigma F_y = 600 : 240 \cos \theta + T \cos 30^\circ + 400 \sin 30^\circ = 600 \quad (2)$$

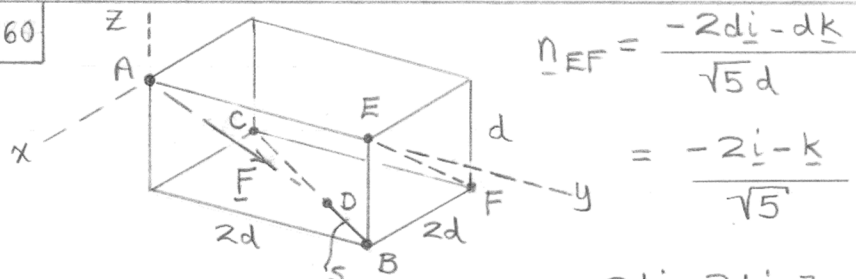
Numerical solution of Eqs. (1) & (2):

$$\theta = 21.7^\circ, \quad T = 204 \text{ lb}$$

(We could eliminate T between Eqs. (1) & (2),
but the resulting equation is still transcendental.)

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$$\underline{n}_{EF} = \frac{-2d\underline{i} - d\underline{k}}{\sqrt{5}d}$$

$$= \frac{-2\underline{i} - \underline{k}}{\sqrt{5}}$$

$$\underline{AD} = \underline{AB} + \underline{BD} = 2d\underline{j} - d\underline{k} + s \left[\frac{-2d\underline{i} - 2d\underline{j}}{\sqrt{8}d} \right]$$

$$= -\frac{s}{\sqrt{2}}\underline{i} + \left(2d - \frac{s}{\sqrt{2}}\right)\underline{j} - d\underline{k}$$

$$|\underline{AD}| = \sqrt{\frac{s^2}{2} + \left(2d - \frac{s}{\sqrt{2}}\right)^2 + d^2} = \sqrt{s^2 + 5d^2 - 2\sqrt{2}ds}$$

$$\underline{F} = F \frac{\underline{AD}}{|\underline{AD}|} = F \frac{-\frac{s}{\sqrt{2}}\underline{i} + \left(2d - \frac{s}{\sqrt{2}}\right)\underline{j} - d\underline{k}}{\sqrt{s^2 + 5d^2 - 2\sqrt{2}ds}}$$

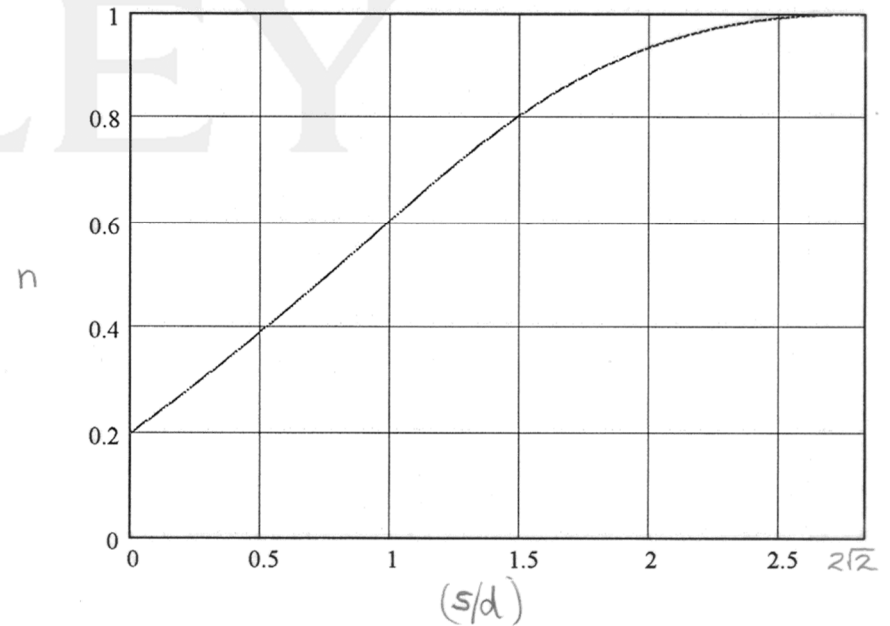
Carry out $\underline{F} \cdot \underline{n}_{EF}$ to obtain the projection

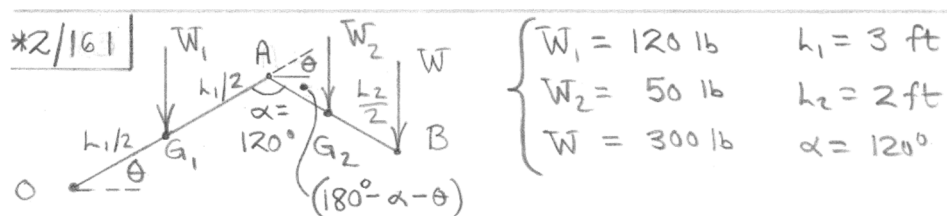
$$\underline{F} \cdot \underline{n}_{EF} = \frac{F(s\sqrt{2} + d)}{\sqrt{5} \sqrt{s^2 + 5d^2 - 2\sqrt{2}ds}}$$

The nondimensionalized fraction n of the magnitude F projected is then

$$n = \frac{\underline{F} \cdot \underline{n}_{EF}}{F} = \frac{\sqrt{2} \frac{s}{d} + 1}{\sqrt{5} \sqrt{\left(\frac{s}{d}\right)^2 + 5 - 2\sqrt{2} \frac{s}{d}}}$$

We let $\frac{s}{d}$ vary from 0 to $2\sqrt{2}$ as D moves from B to C . Resulting plot:





$$+2 M_o = W_1 \frac{l_1}{2} \cos \theta + W_2 \left(l_1 \cos \theta + \frac{l_2}{2} \cos (180^\circ - \alpha - \theta) \right) + W \left(l_1 \cos \theta + l_2 \cos (180^\circ - \alpha - \theta) \right)$$

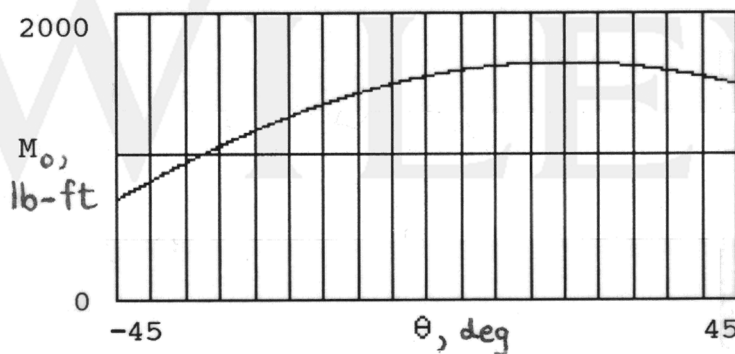
With the above numbers:

$$M_o = 1230 \cos \theta + 650 \cos (60^\circ - \theta) \quad (\text{in lb-ft})$$

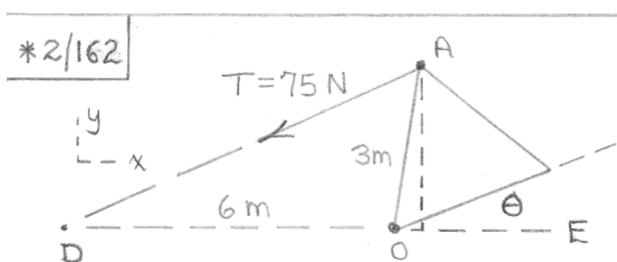
(see plot below)

For $(M_o)_{\max}$: $\frac{dM_o}{d\theta} = -1230 \sin \theta + 650 \sin (60^\circ - \theta) = 0$

Numerical solution: $\theta = 19.90^\circ$, $(M_o)_{\max} = 1654 \text{ lb-ft}$



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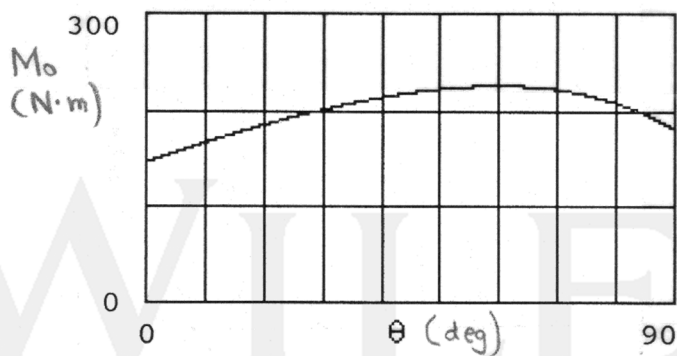


Angle $\angle AOE = \theta + 60^\circ$
 Use $\underline{M}_O = \underline{r}_{OD} \times \underline{T}$
 $\underline{r}_{OD} = -6\hat{i} \text{ m}$

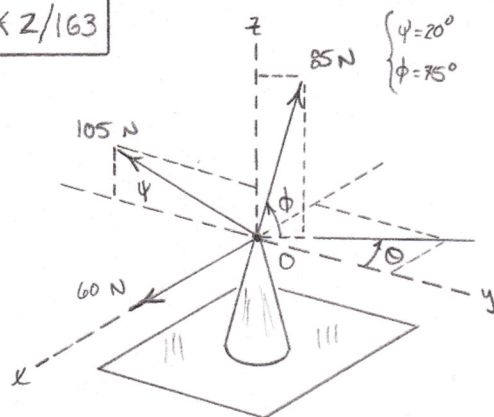
$$\underline{T} = T \underline{n}_{AD} = 75 \left[\frac{-(6 + 3 \cos(\theta + 60^\circ))\hat{i} - 3 \sin(\theta + 60^\circ)\hat{j}}{\sqrt{[6 + 3 \cos(\theta + 60^\circ)]^2 + [3 \sin(\theta + 60^\circ)]^2}} \right] \text{ N}$$

$$\underline{M}_O = \underline{r}_{OD} \times \underline{T} = \frac{1350 \sin(\theta + 60^\circ) \text{ k}}{\sqrt{45 + 36 \cos(\theta + 60^\circ)}} \text{ N}\cdot\text{m}$$

M_O is a max @ $\theta = 60^\circ$: $M_O = 225 \text{ N}\cdot\text{m}$



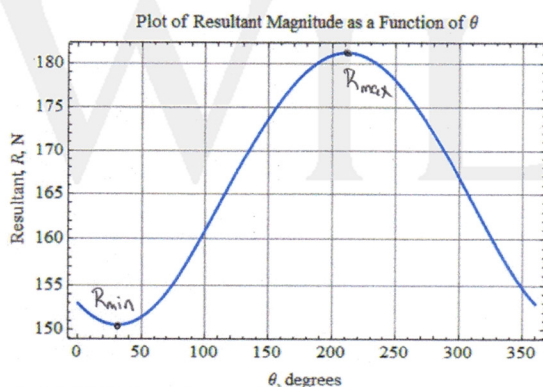
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$$\begin{aligned} \underline{R} &= (60 - 85 \cos 75^\circ \sin \theta) \underline{i} + (85 \cos 75^\circ \cos \theta - 105 \cos 20^\circ) \underline{j} + (85 \sin 75^\circ + 105 \sin 20^\circ) \underline{k} \\ \underline{R} &= (60 - 22.0 \sin \theta) \underline{i} + (22.0 \cos \theta - 98.7) \underline{j} + 118.0 \underline{k} \text{ N} \end{aligned}$$

$$R = \sqrt{\underline{R} \cdot \underline{R}} \rightarrow R = [(60 - 22.0 \sin \theta)^2 + (22.0 \cos \theta - 98.7)^2 + 118.0^2]^{1/2}$$

Plotting R ... For $\theta_{\max}$, SET $\frac{dR}{d\theta} = 0$



$$R_{\min} = 150.6 \text{ N}$$

$$\theta_{\min} = 31.3^\circ$$

$$R_{\max} = 181.2 \text{ N}$$

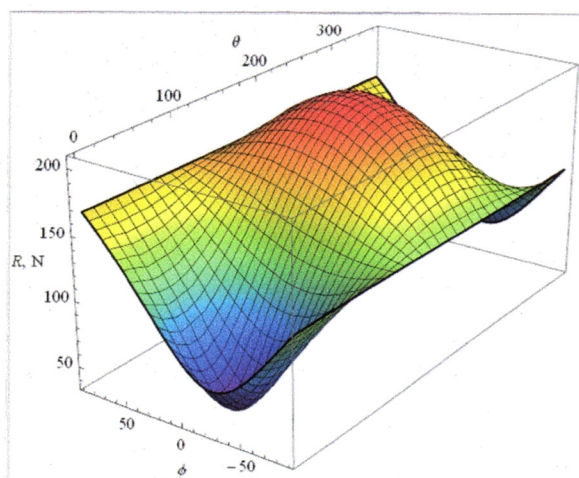
$$\theta_{\max} = 211^\circ$$

* 2/164

FROM 2/163...

$$\underline{R} = (60 - 85 \cos \phi \sin \theta) \underline{i} + (85 \cos \phi \cos \theta - 105 \cos 2\theta) \underline{j} + (85 \sin \phi + 105 \sin 2\theta) \underline{k}$$

$$R = \sqrt{\underline{R} \cdot \underline{R}} \quad \text{AND WE PLOT FOR } 0 \leq \theta \leq 360^\circ \text{ AND } -90^\circ \leq \phi \leq 90^\circ$$



$$R_{\min} = 35.9 \text{ N}$$

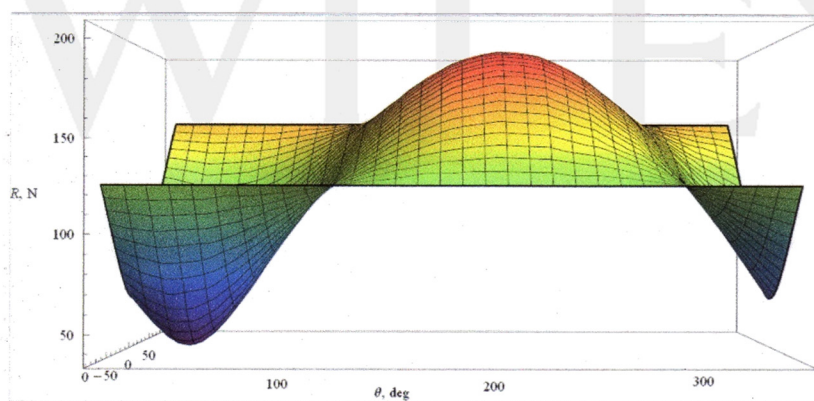
$$\theta_{\min} = 31.3^\circ$$

$$\phi_{\min} = -17.27^\circ$$

$$R_{\max} = 206 \text{ N}$$

$$\theta_{\max} = 211^\circ$$

$$\phi_{\max} = 17.27^\circ$$



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$$\underline{I} = T \underline{n}_{AB}$$



$$\underline{I} = T \left[\frac{(d + 40 \cos \beta) \underline{i} + 40(1 - \sin \beta) \underline{j}}{\sqrt{(d + 40 \cos \beta)^2 + 40^2(1 - \sin \beta)^2}} \right]$$

$$\underline{r}_{OB} = (d \underline{i} + 40 \underline{j}) \quad (\beta = \theta + \frac{\pi}{4})$$

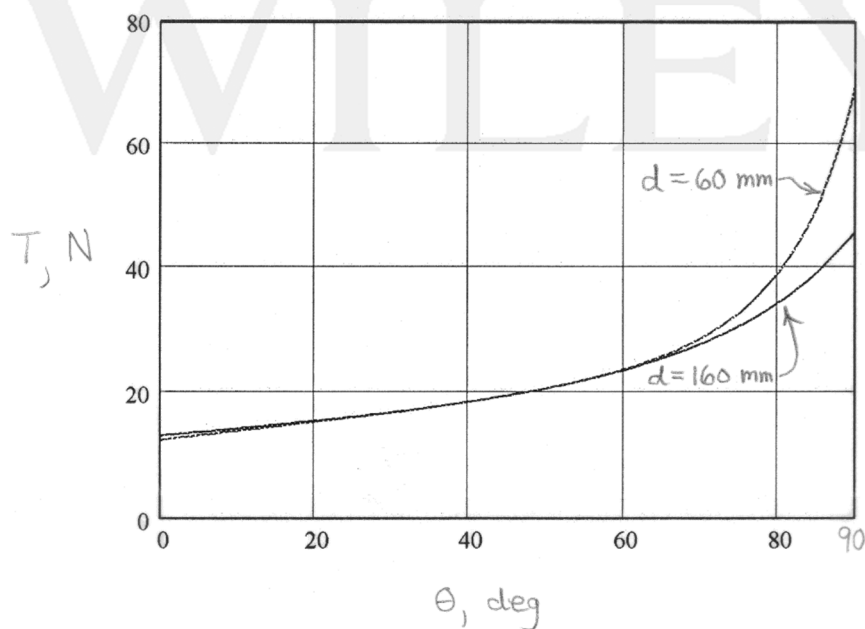
$$\sum \underline{M}_O = \underline{0}: \quad \underline{r}_{OB} \times \underline{I} + K \beta \underline{k} = \underline{0}$$

Carry out the cross product, consider the z-component, and solve for T to obtain

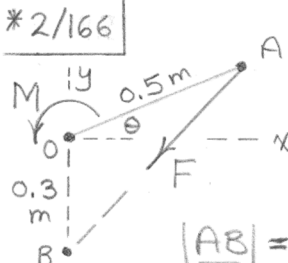
$$T = \frac{12.5(\theta + \frac{\pi}{4}) \sqrt{d^2 + 80d \cos(\theta + \frac{\pi}{4}) - 3200 \sin(\theta + \frac{\pi}{4}) + 3200}}{\left[d \sin(\theta + \frac{\pi}{4}) + 40 \cos(\theta + \frac{\pi}{4}) \right]}$$

(T in N, θ in radians)

Plot of T versus θ for $d = 60$ mm and
for $d = 160$ mm:



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$$\underline{F} = F \underline{n}_{AB} = F \frac{\underline{AB}}{|\underline{AB}|}$$

$$\underline{AB} = -0.5 \cos \theta \underline{i} - (0.5 \sin \theta + 0.3) \underline{j} \text{ m}$$

$$|\underline{AB}| = \sqrt{(0.5 \cos \theta)^2 + (0.5 \sin \theta + 0.3)^2}$$

$$= \sqrt{0.34 + 0.3 \sin \theta} \text{ m}$$

$$F = k\delta = 600 \left[\sqrt{0.34 + 0.3 \sin \theta} - 0.65 \right] \text{ N}$$

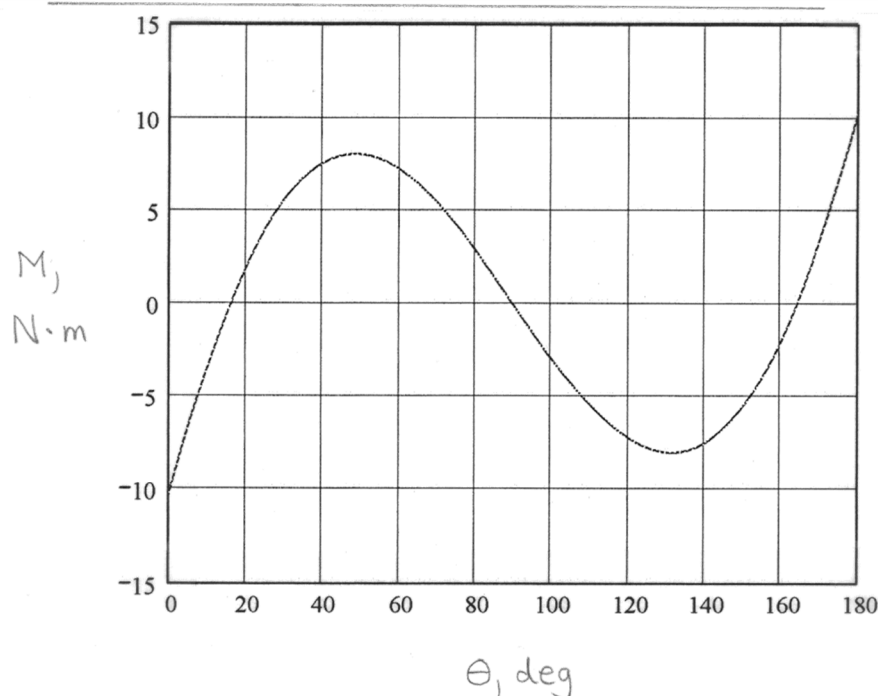
So

$$\underline{F} = \frac{600 \left[\sqrt{0.34 + 0.3 \sin \theta} - 0.65 \right]}{\sqrt{0.34 + 0.3 \sin \theta}} \left[-0.5 \cos \theta \underline{i} - (0.5 \sin \theta + 0.3) \underline{j} \right]$$

Now form $\underline{r}_{OB} \times \underline{F}$, where $\underline{r}_{OB} = -0.3 \underline{j} \text{ m}$,
to obtain $\frac{90 \cos \theta (\sqrt{0.34 + 0.3 \sin \theta} - 0.65)}{\sqrt{0.34 + 0.3 \sin \theta}} \underline{k}$

With the above moment plus $M \underline{k}$ summing to zero, we obtain the scalar

$$M = \frac{90 \cos \theta \left[\sqrt{0.34 + 0.3 \sin \theta} - 0.65 \right]}{\sqrt{0.34 + 0.3 \sin \theta}} \text{ (N}\cdot\text{m)}$$



(Note: $M(0) = -10.33 \text{ N}\cdot\text{m}$
 $M(180^\circ) = 10.33 \text{ N}\cdot\text{m}$)