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

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**2/1**

$$\begin{cases} F_x = 600 \cos 40^\circ = 460 \text{ N} \\ F_y = -600 \sin 40^\circ = -386 \text{ N} \end{cases}$$

$$\underline{F} = 460\underline{i} - 386\underline{j} \text{ N}$$

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**2/2**

$$\underline{F} = 400(-\cos 30^\circ \underline{i} + \sin 30^\circ \underline{j})$$

$$= -346\underline{i} + 200\underline{j} \text{ lb}$$

Scalar components:

$$F_x = -346 \text{ lb}$$

$$F_y = 200 \text{ lb}$$

Vector components:

$$\underline{F}_x = -346\underline{i} \text{ lb}$$

$$\underline{F}_y = 200\underline{j} \text{ lb}$$

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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.)

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**2/4**

$$\underline{F} = F\underline{n}_{AB} = 3000\left[\frac{15\underline{i} + 8\underline{j}}{\sqrt{15^2 + 8^2}}\right]$$

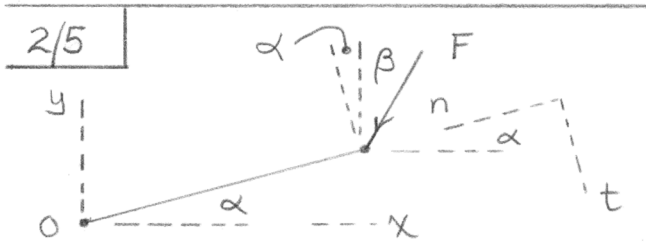
$$= 2650\underline{i} + 1412\underline{j} \text{ lb}$$

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

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2/5



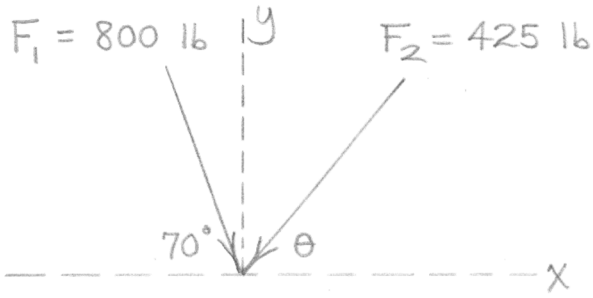

$$\begin{cases} F_x = -F\sin\beta \\ F_y = -F\cos\beta \end{cases}$$

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

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2/6




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

$$\theta = 49.9^\circ$$

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

$$= -1077 \text{ lb}$$

So $R = 1077$ lb

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2/7

$$\underline{R} = (500 + 350\cos 60^\circ)\,\underline{i} + 350 \sin 60^\circ\,\underline{j}$$

$$\underline{R} = 675\,\underline{i} + 303\,\underline{j}\ \text{N}$$

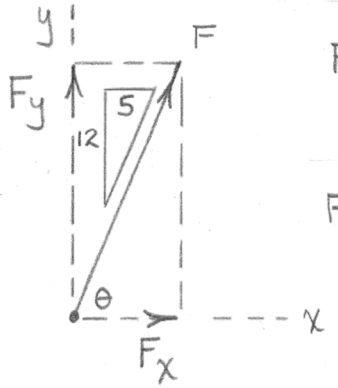
$$R = \sqrt{675^2 + 303^2} \longrightarrow R = 740\ \text{N}$$

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

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**2/8**




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

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

$F = 75.8$ lb

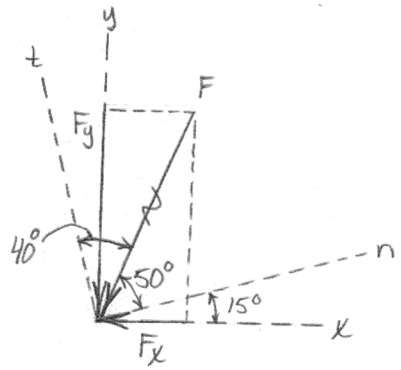
$F_x = F\cos\theta = 75.8\left(\frac{5}{13}\right)$

$= 29.2$ lb

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2/9

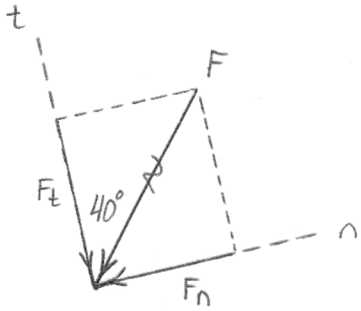



$$F_x = -F\cos 65^\circ = -13\cos 65^\circ$$

$$F_x = -5.49 \text{ kips}$$

$$F_y = -F\sin 65^\circ = -13\sin 65^\circ$$

$$F_y = -11.78 \text{ kips}$$




$$F_n = -F\sin 40^\circ = -13\sin 40^\circ$$

$$F_n = -8.36 \text{ kips}$$

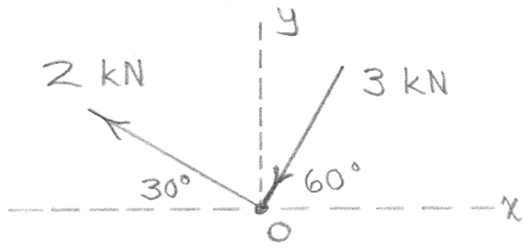
$$F_t = -F\cos 40^\circ = -13\cos 40^\circ$$

$$F_t = -9.96 \text{ kips}$$

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**2/10**




$$R_x = \Sigma F_x = -2\cos 30^\circ - 3\cos 60^\circ = -3.23 \text{ kN}$$

$$R_y = \Sigma F_y = 2\sin 30^\circ - 3\sin 60^\circ = -1.598 \text{ kN}$$

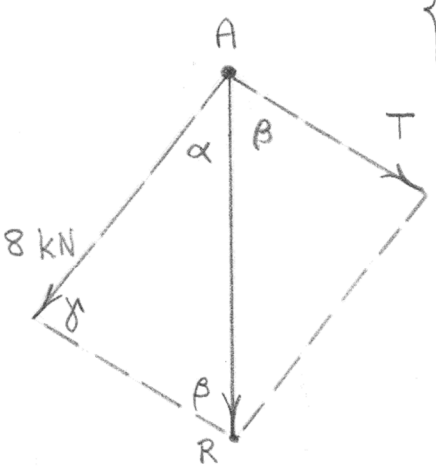
$$R = \sqrt{R_x^2 + R_y^2} = \underline{3.61 \text{ kN}}$$

$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right) = \tan^{-1}\left(\frac{-1.598}{-3.23}\right) = \underline{206^\circ}$$

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**2/11**




$$\alpha = \tan^{-1}\frac{40}{50} = 38.7^\circ$$

$$\beta = \tan^{-1}\frac{50}{30} = 59.0^\circ$$

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

$$= 82.3^\circ$$

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

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

$$\frac{\sin\beta}{8} = \frac{\sin\gamma}{R}, \qquad R = 9.25 \text{ kN}$$

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**2/12**

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

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

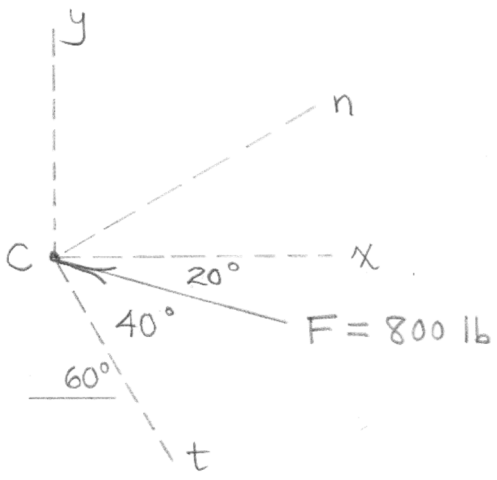
$$\Rightarrow \underline{R} = 600\underline{i} + 346\underline{j} \text{ N}$$

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

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2/13



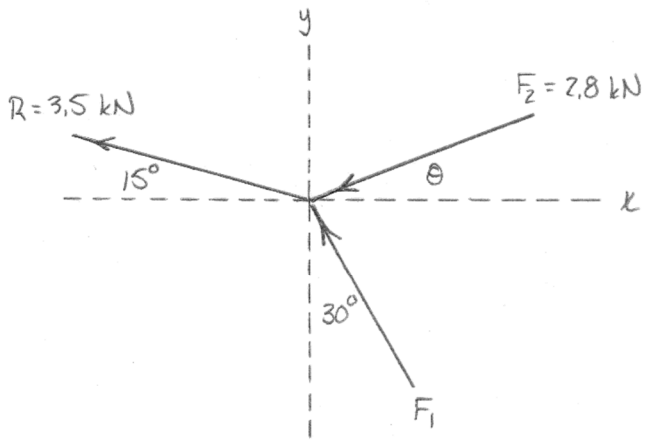

$$\begin{cases} F_x = -800 \cos 20^\circ = \underline{-752 \text{ lb}} \\ F_y = 800 \sin 20^\circ = \underline{274 \text{ lb}} \end{cases}$$

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

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2/14




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

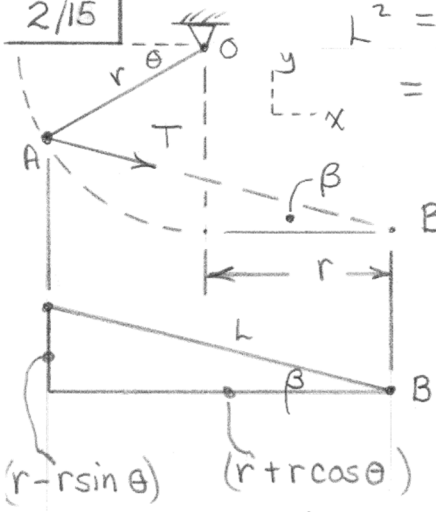
SOLVING (1) AND (2)...

$$\begin{cases} F_1 = 1.165 \text{ kN} \\ \theta = 2.11^\circ \end{cases} \quad \text{OR} \quad \begin{cases} F_1 = 3.78 \text{ kN} \\ \theta = 52.9^\circ \end{cases}$$

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**2/15**




$$L^2 = (r - r\sin\theta)^2 + (r + r\cos\theta)^2$$

$$= r^2 - 2r^2\sin\theta + r^2\sin^2\theta + r^2 + 2r^2\cos\theta + r^2\cos^2\theta$$

$$= r^2(3 + 2\cos\theta - 2\sin\theta)$$

So $\cos\beta = \dfrac{r(1+\cos\theta)}{r\sqrt{3+2\cos\theta-2\sin\theta}}$

$$= \frac{1+\cos\theta}{\sqrt{3+2\cos\theta-2\sin\theta}}$$

$$\sin\beta = \frac{1-\sin\theta}{\sqrt{3+2\cos\theta-2\sin\theta}}$$

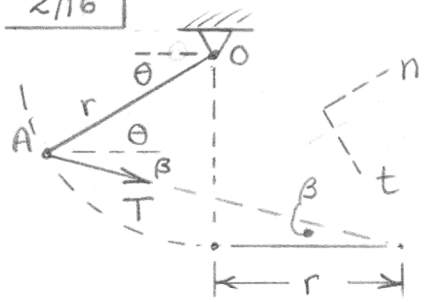
$$T_x = T\cos\beta = \frac{T(1+\cos\theta)}{\sqrt{3+2\cos\theta-2\sin\theta}}$$

$$T_y = -T\sin\beta = \frac{T(\sin\theta-1)}{\sqrt{3+2\cos\theta-2\sin\theta}}$$

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**2/116**




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 $T = 100$ N and $\theta = 35°$:

$\beta = 13.19°$

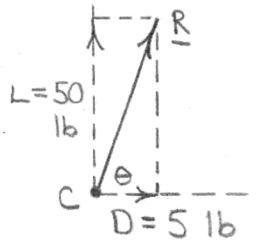
$$\begin{cases} T_n = 66.7 \text{ N} \\ T_t = 74.5 \text{ N} \end{cases}$$

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**2/17**

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




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

$$= \underline{50.2 \text{ lb}}$$

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

$$= \underline{84.3^\circ}$$

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**2/18** Using the coordinates of the problem figure:

$$R_x = \Sigma F_x = 200 \cos 35^\circ - 150 \sin 30^\circ$$
$$= 88.8 \text{ N}$$

$$R_y = \Sigma F_y = 200 \sin 35^\circ + 150 \cos 30^\circ$$
$$= 245 \text{ N}$$

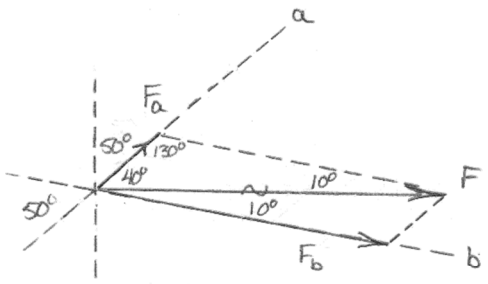
$$\therefore \underline{R} = 88.8\underline{i} + 245\underline{j} \text{ N}$$

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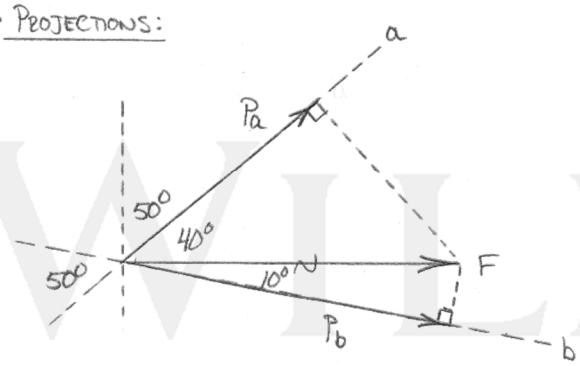
**2/19** $F = 2.5$ kN

• COMPONENTS:




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

• PROJECTIONS:

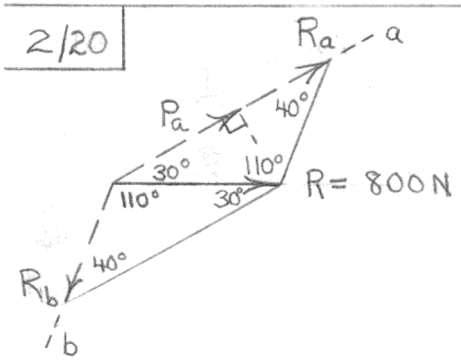



$$\begin{cases} P_a = F\cos 40^\circ = 2.5\cos 40^\circ \longrightarrow P_a = 1.915 \text{ kN} \\ P_b = F\cos 10^\circ = 2.5\cos 10^\circ \longrightarrow P_b = 2.46 \text{ kN} \end{cases}$$

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**2/20**




Law of sines:

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

$$R_a = 1170 \text{ N}$$

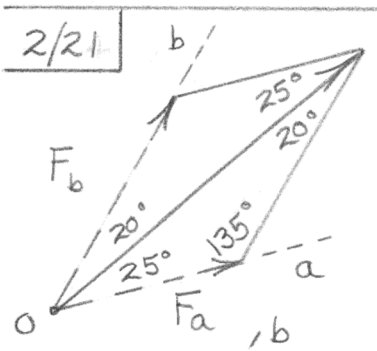
$$R_b = 622 \text{ N}$$

Projection $P_a = R\cos 30^\circ = 800 \cos 30^\circ = 693$ N

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**2/21**

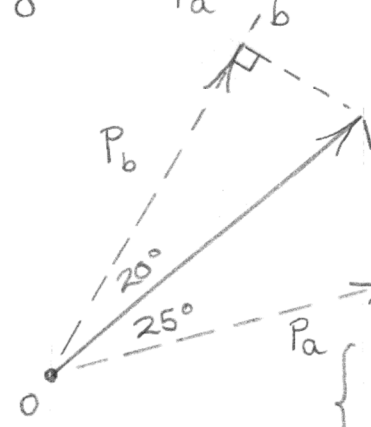



$F = 4$ kN

Components:

$$\frac{\sin 135^\circ}{4} = \frac{\sin 20^\circ}{F_a}, \quad F_a = 1.935 \text{ kN}$$

$$\frac{\sin 135^\circ}{4} = \frac{\sin 25^\circ}{F_b}, \quad F_b = 2.39 \text{ kN}$$




$F = 4$ kN

Projections:

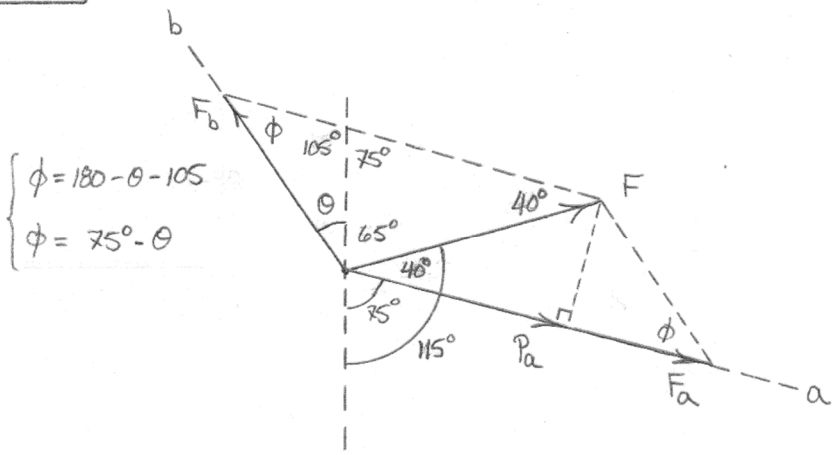
$$P_a = 4\cos 25^\circ = 3.63 \text{ kN}$$

$$P_b = 4\cos 20^\circ = 3.76 \text{ kN}$$

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2/22




$\phi = 180 - \theta - 105$

$\phi = 75° - \theta$

$P_a = F\cos 40° \rightarrow 325 = F\cos 40° \rightarrow \underline{F = 424\ \text{N}}$

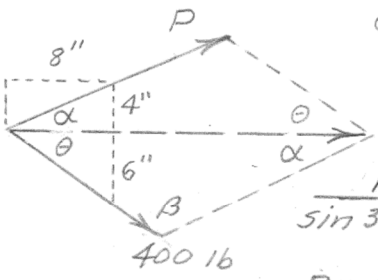
$$\frac{F}{\sin\phi} = \frac{F_b}{\sin 40°} \rightarrow \frac{424}{\sin(75°-\theta)} = \frac{325}{\sin 40°}$$

SOLVING THIS YIELDS ... $\underline{\theta = 17.95° \text{ OR } -48.0°}$

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**2/23**




$\alpha = \tan^{-1}\frac{4}{8} = 26.57°$

$\theta = \tan^{-1}\frac{16}{8} = 36.87°$

$\beta = 180 - (\alpha + \theta) = 116.57°$

$$\frac{P}{\sin 36.87°} = \frac{400}{\sin 26.57°}$$

$$P = 400\,\frac{0.6}{0.4472} = \underline{537 \text{ lb}}$$

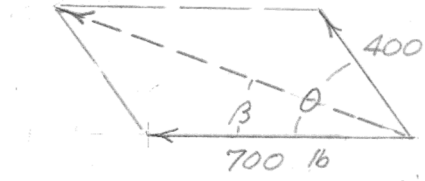
$$\frac{T}{\sin 116.56°} = \frac{400}{\sin 26.57°}, \quad T = 400\,\frac{0.8944}{0.4472} = \underline{800 \text{ lb}}$$

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**2/24** Law of cosines: $\overline{1000}^2 = \overline{400}^2 + \overline{700}^2 + 2(400)(700)\cos\theta$

$\cos\theta = 0.6250, \quad \theta = 51.3°$




Law of sines:

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

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

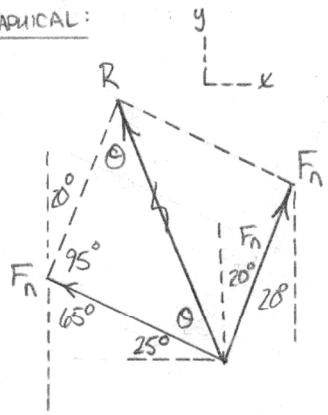
$$\beta = 18.19°$$

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## 2/25

• GRAPHICAL:




$$R = \sqrt{F_n^2 + F_n^2 - 2F_n^2 \cos 95^\circ}$$

$$R = \sqrt{2(5500)^2[1 - \cos 95^\circ]}$$

$$R = 8110 \text{ N}$$

$$\theta = \frac{180^\circ - 95^\circ}{2} \longrightarrow \theta = 42.5^\circ$$

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

• VECTORS:

$$\underline{R} = (F_n \sin 20^\circ - F_n \sin 65^\circ)\underline{i} + (F_n \cos 20^\circ + F_n \cos 65^\circ)\underline{j}$$

$$\underline{R} = 5500[(\sin 20^\circ - \sin 65^\circ)\underline{i} + (\cos 20^\circ + \cos 65^\circ)\underline{j}]$$

$$\underline{R} = -3100\underline{i} + 7490\underline{j} \text{ N}$$

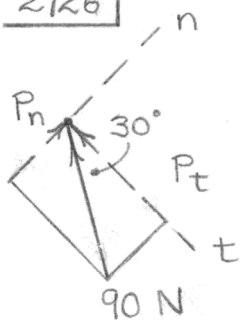
$$R = \sqrt{3100^2 + 7490^2} \longrightarrow R = 8110 \text{ N}$$

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

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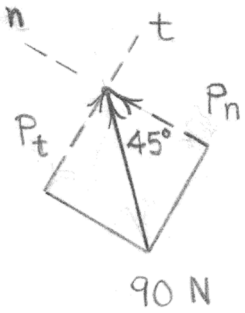
**2/26**




BC

$P_t = -90 \cos 30° = -77.9$ N

$P_n = 90 \sin 30° = 45.0$ N




AB

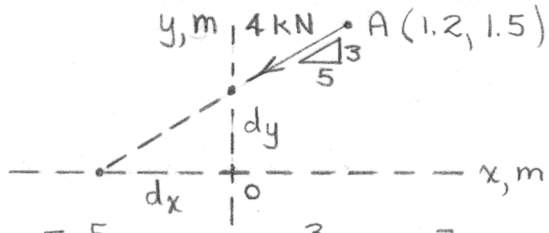
$P_t = 90 \sin 45° = 63.6$ N

$P_n = 90 \cos 45° = 63.6$ N

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**2/27**




$\curvearrowleft + \quad M_O = 4\left[\frac{5}{\sqrt{34}}(1.5) - \frac{3}{\sqrt{34}}(1.2)\right] = \underline{2.68 \text{ kN·m}}$

As a vector, $\underline{\mathbf{M}_O = 2.68\mathbf{k} \text{ kN·m}}$

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

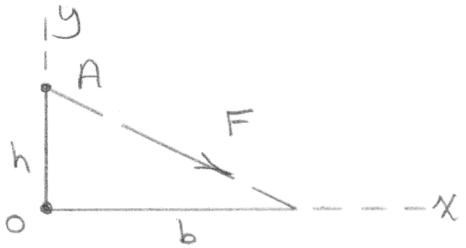
$\frac{d_y}{1.3} = \frac{3}{5}, \quad d_y = 0.78 \text{ m}$

Coordinates of intercepts (in m): $\underline{(-1.3, 0), (0, 0.78)}$

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**2/28**




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

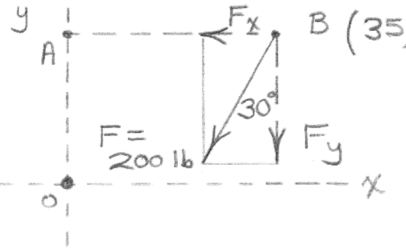
Acting at A:

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

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**2/29**




$|F_x| = 200 \sin 30°$
$= 100$ lb

$|F_y| = 200 \cos 30°$
$= 173.2$ lb

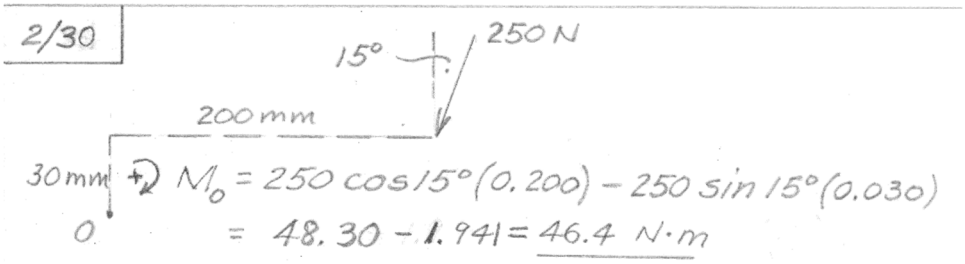
$+\circlearrowright M_A = 173.2(35) = 6060$ lb-in. $(505$ lb-ft$)$ CW

$+\circlearrowright M_O = 173.2(35) - 100(25)$
$= 3560$ lb-in. $(297$ lb-ft$)$ CW

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**2/30**



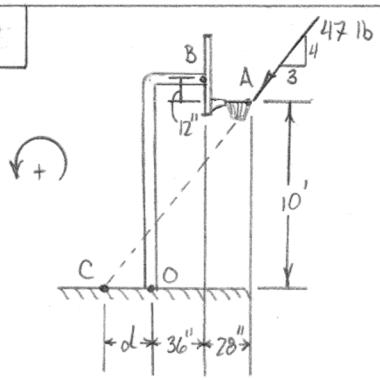

$$\curvearrowleft + M_O = 250\cos 15°(0.200) - 250\sin 15°(0.030)$$

$$= 48.30 - 1.941 = \underline{46.4\ \text{N·m}}$$

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2/31




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

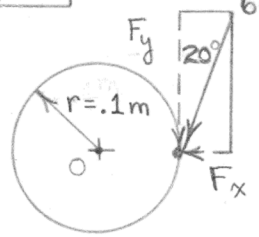
b) $M_B = -\frac{12}{12}\left(\frac{3}{5}47\right) - \frac{28}{12}\left(\frac{4}{5}47\right) = \underline{-115.9} \longrightarrow \underline{M_B = 115.9 \text{ lb-ft CW}}$

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

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2/32

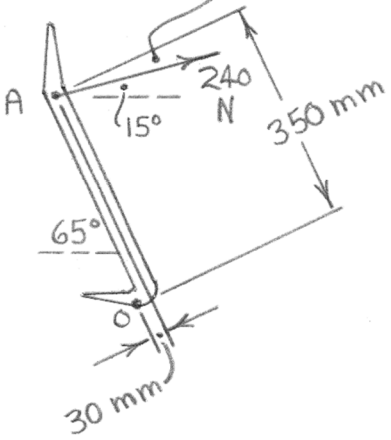



$$60\ \text{N} + \circlearrowleft M_O = r F_y$$
$$= (0.1)(60 \cos 20°)$$
$$= 5.64\ \text{N·m}$$

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**2/33**




$25° - 15° = 10°$

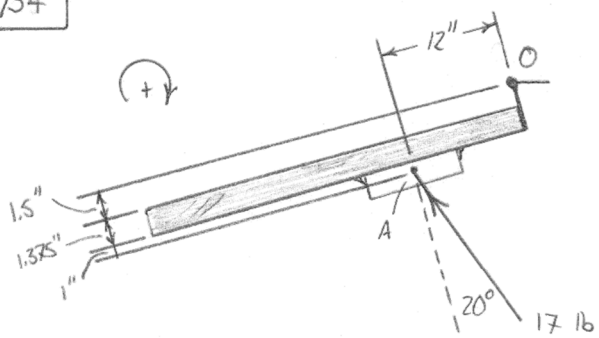
$+\circlearrowleft M_O = (240 \cos 10°)(0.350) + (240 \sin 10°)(0.030)$

$M_O = 84.0 \text{ N·m CW}$

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2/34



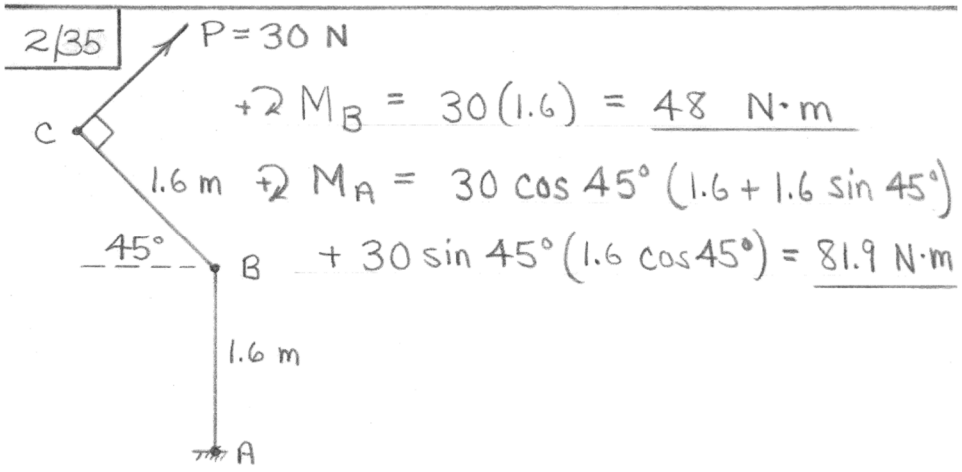

$$M_O = 12(17\cos 20^\circ) + (1 + 1.375 + 1.5)(17\sin 20^\circ)$$

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

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**2/35**



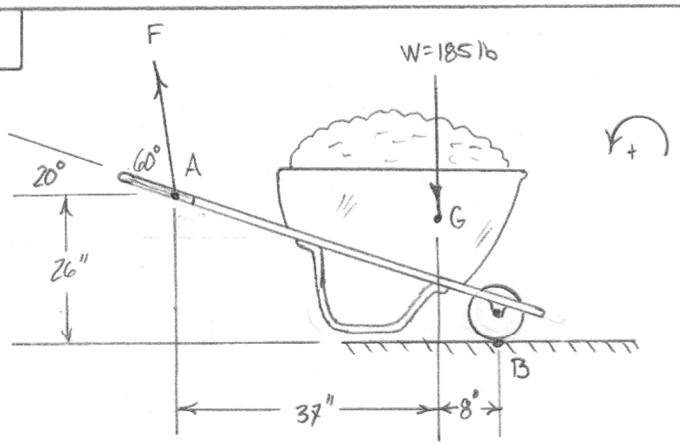

$+\circlearrowright M_B = 30(1.6) = 48 \text{ N·m}$

$+\circlearrowright M_A = 30\cos 45^\circ (1.6 + 1.6\sin 45^\circ) + 30\sin 45^\circ (1.6\cos 45^\circ) = 81.9 \text{ N·m}$

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2/36




$\Sigma M_B = 0$: $185(8) - F\sin(20°+60°)(37+8) + F\cos(20°+60°)(26) = 0$

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

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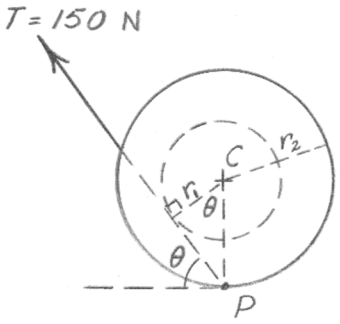
2/37

$\circlearrowleft M_C = Tr_1 = 150(0.125)$

$= \underline{18.75 \text{ N·m CW}}$

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

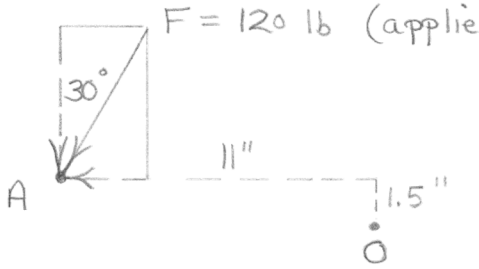
$\underline{\theta = 51.3^\circ}$




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**2/38**



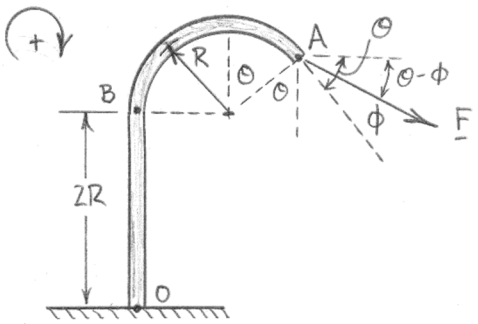

$$+\circlearrowleft M_O = 120\cos 30^\circ (11) + 120\sin 30^\circ (1.5)$$

$$= \underline{1233 \text{ lb-in.}} \text{ or } \underline{102.8 \text{ lb-ft CCW}}$$

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2/39




$$M_B = F\sin(\theta-\phi)(R+R\sin\theta) + F\cos(\theta-\phi)(R\cos\theta)$$

$$M_B = FR[\cos\phi + \sin(\theta-\phi)]$$

$$M_O = F\sin(\theta-\phi)(R+R\sin\theta) + F\cos(\theta-\phi)(2R+R\cos\theta)$$

$$M_O = FR[2\cos(\theta-\phi) + \cos\phi + \sin(\theta-\phi)]$$

IF $F = 750$ N, $R = 2.4$ m, $\theta = 30°$, AND $\phi = 15°$ ...

$$M_B = 2200 \text{ N·m CW}$$

$$M_O = 5680 \text{ N·m CW}$$

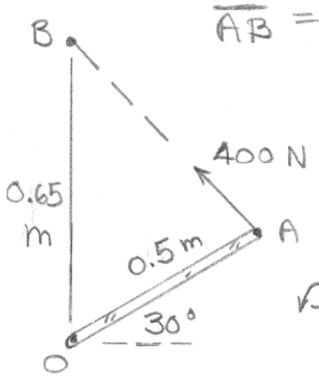
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**2/40**

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

$\overline{AB} = 0.589$ m




$\frac{\sin 60°}{\overline{AB}} = \frac{\sin \measuredangle OAB}{0.65}$

$\measuredangle OAB = 72.7°$

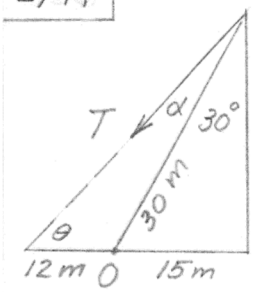
$+\circlearrowleft M_O = 0.5(400 \sin 72.7°)$

$= 191.0$ N·m CCW

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**2/41**




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

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

$$M_O = 72 \text{ kN·m}$$

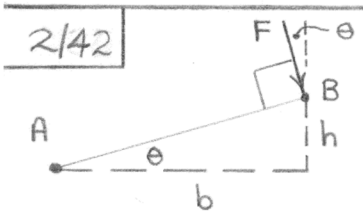
$$= T \sin 16.10^\circ (30) = 8.32T$$

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

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**2/42**



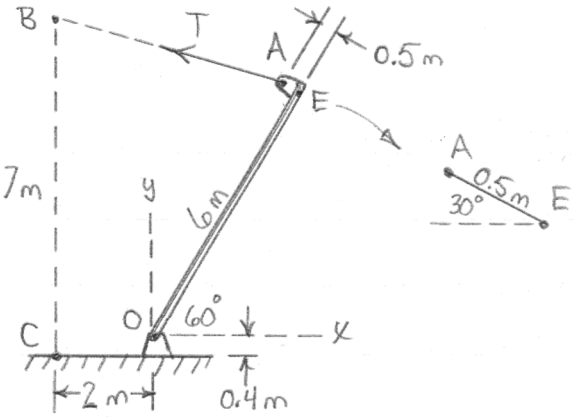

$M_A$ is maximum when F is perpendicular to AB.

Thus $\theta = \tan^{-1}(h/b)$

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**2/43** $T = 6.75$ kN




$$\underline{r}_{OA} = (6\cos 60^\circ - 0.5\cos 30^\circ)\underline{i} + (6\sin 60^\circ + 0.5\sin 30^\circ)\underline{j}$$

$$= 2.57\underline{i} + 5.45\underline{j} \text{ m}$$

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

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

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

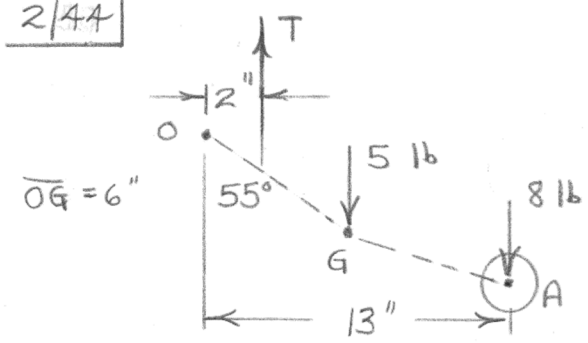
$$\underline{M}_O = \underline{r}_{OA} \times \underline{T} = (2.57\underline{i} + 5.45\underline{j}) \times (-6.54\underline{i} + 1.653\underline{j})$$

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

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**2/44**




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

$$+\circlearrowright M_O = 5(6 \sin 55°) + 8(13) = 128.6 \text{ lb-in.} \quad (CW)$$

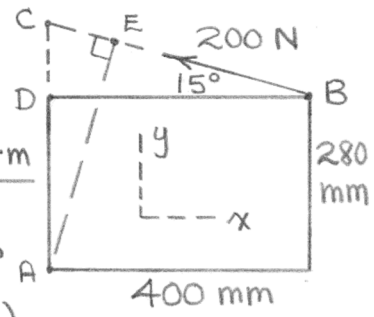
$$+\circlearrowright \Sigma M_O = 0: \quad -T(2) + 128.6 = 0$$

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

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**2/45**




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

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

(3) Apply force at C

$CD = 0.400 \tan 15° = 0.1072 \text{ m}$

$CA = 0.280 + 0.1072 = 0.387 \text{ m}$

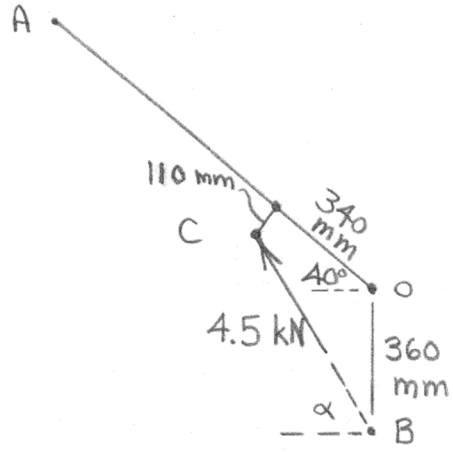
$M_A = (200 \cos 15°)(0.387) = \underline{74.8 \text{ N·m}}$

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

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**2/46**




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

$$= 56.2^\circ$$

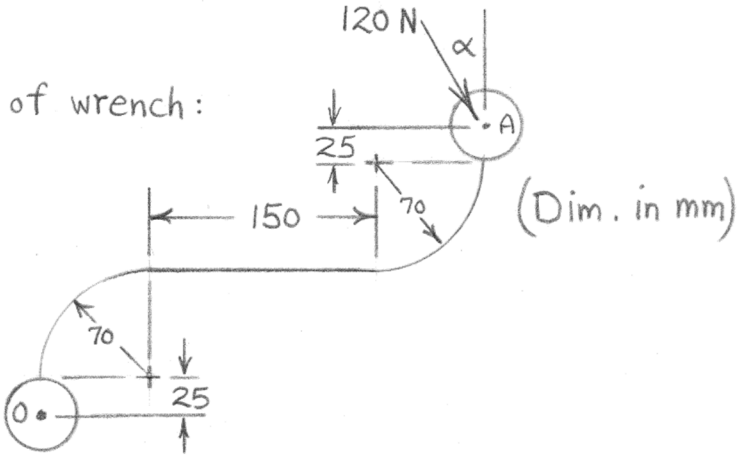
$$+\circlearrowright M_O = 4.5\,(0.360\cos 56.2^\circ) = \underline{0.902\ \text{kN}\cdot\text{m CW}}$$

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**2/47**

Elements of wrench:




$\alpha = 30°$:

$$+\circlearrowleft M_O = 120\cos 30°[70+150+70] + 120\sin 30°[25+70+70+25] = 41\,500 \text{ N·mm}$$

or $M_O = 41.5 \text{ N·m CW}$

For maximum $M_O$:

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

$$(M_O)_{max} = 120\sqrt{(25+70+25+70)^2 + (70+150+70)^2}$$

$$= 41\,600 \text{ N·mm} \quad \text{or} \quad 41.6 \text{ N·m CW}$$

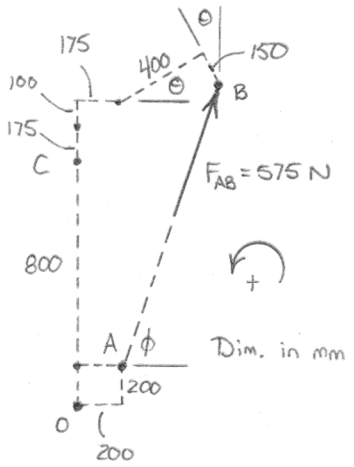
Engineering Mechanics Statics 9th edition Meriam Solutions Manual

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2/48

$\theta = 30^\circ$

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



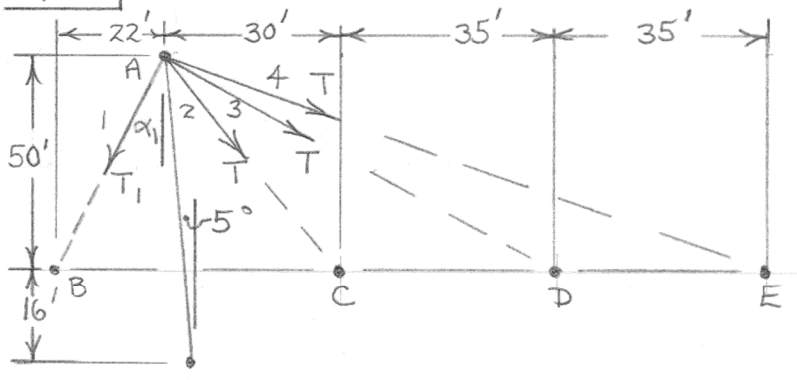

$$M_O = 575\sin\phi\,(0.200) - 575\cos\phi\,(0.200) \longrightarrow M_O = 71.1 \text{ N·m CCW}$$

$$M_C = 575\sin\phi\,(0.200) + 575\cos\phi\,(0.800) \longrightarrow M_C = 259 \text{ N·m CCW}$$

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**2/49**




$\alpha_1 = \tan^{-1}\frac{22}{50} = 23.7°$; Similarly, $\alpha_2 = 31.0°$, $\alpha_3 = 52.4°$, $\alpha_4 = 63.4°$ (all relative to vertical)

$$\circlearrowleft \Sigma M_O = 0: \left[T_1 \sin(\alpha_1 + 5°) - T\sin(\alpha_2 - 5°) - T\sin(\alpha_3 - 5°) - T\sin(\alpha_4 - 5°)\right]\frac{50+16}{\cos 5°} = 0$$

$$T_1 = 4.21T$$

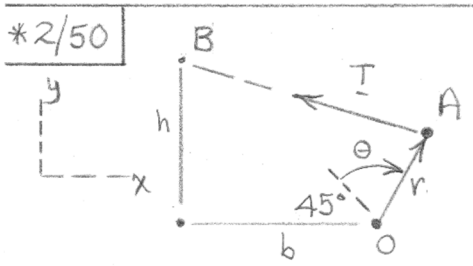
$$+\downarrow \Sigma F = P = T_1\cos(\alpha_1 + 5°) + T\left[\cos(\alpha_2 - 5°) + \cos(\alpha_3 - 5°) + \cos(\alpha_4 - 5°)\right]$$

$$\text{or } P = 5.79T \quad \text{(with } T_1 = 4.21T\text{)}$$

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***2/50**




$$\underline{M}_O = \underline{r}_{OA} \times \underline{T}$$

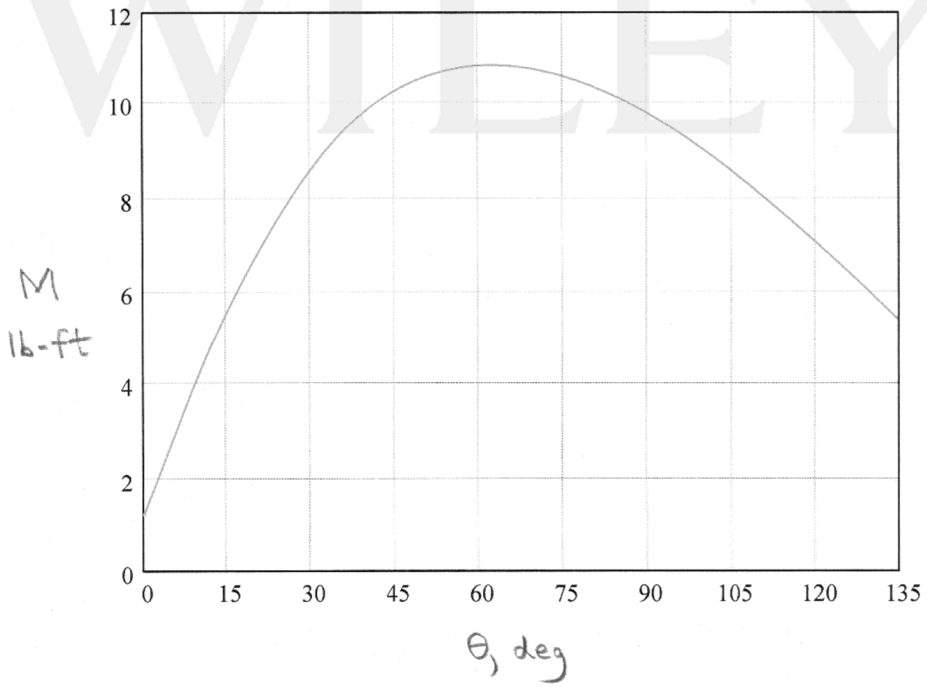
$$\underline{r}_{OA} = r\left[-\cos(\theta+45^\circ)\,\underline{i} + \sin(\theta+45^\circ)\,\underline{j}\right]$$

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

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

With $r = \frac{13}{12}$ ft, $h = \frac{21}{12}$ ft, $b = \frac{24}{12}$ ft, and $T = 10$ lb, vary $\theta$ and take the z-comp. of $\underline{M}_O$ to obtain the following plot.

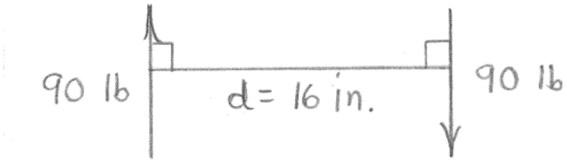
Note that $M_{max} = 10.83$ lb-ft at $\theta = 62.1^\circ$




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**2/51** $\circlearrowright + \quad M = M_O = M_A = Fd = 90(16) = 1440$ lb-in. CW




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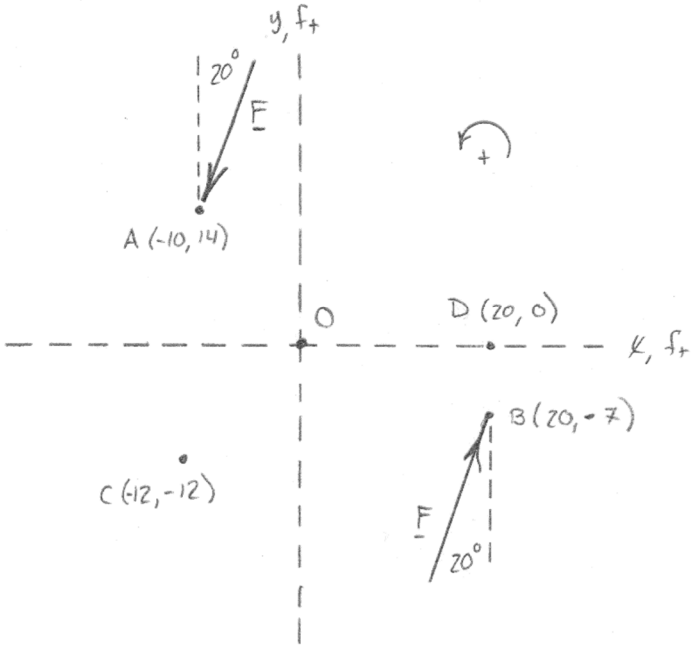
2/52 $+\circlearrowright M = Fd = 80(1.4) = 112$ lb-in. CW

(or 9.33 lb-ft CW)

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**2/53** $F = 65$ lb




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

$M_O = 2300$ lb-ft CCW

b) By inspection... $M_C = 2300$ lb-ft CCW

c) By inspection... $M_D = 2300$ lb-ft CCW

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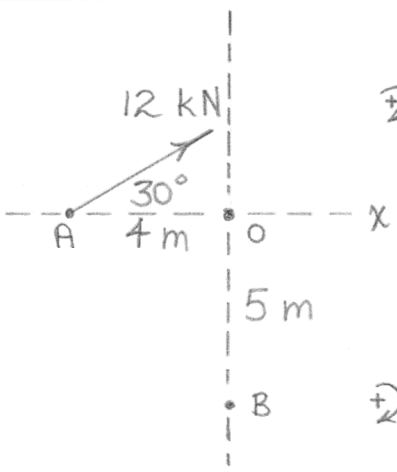
2/54 $\underline{R} = 6\underline{j}$ kN @ $x = \frac{400}{6000} = 0.0667$ m

or $x = 66.7$ mm

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**2/55**




At O:

$F = 12\ \text{kN}\ \angle 30°$

$\circlearrowleft + \sum M_O = (12 \sin 30°)(4)$

$= 24\ \text{kN·m CW}$

At B:

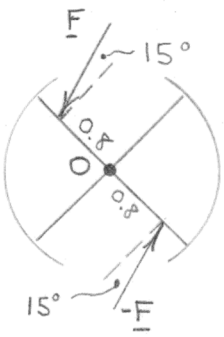
$F = 12\ \text{kN}\ \angle 30°$

$\circlearrowleft + \sum M_B = (12 \sin 30°)(4) + (12 \cos 30°)(5) = 76.0\ \text{kN·m CW}$

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2/56




$$\curvearrowleft + M_O = \Sigma Fd$$

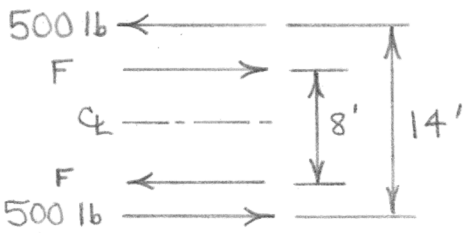
$$25 = 2F(\cos 15^\circ)(0.8)$$

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

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**2/57**



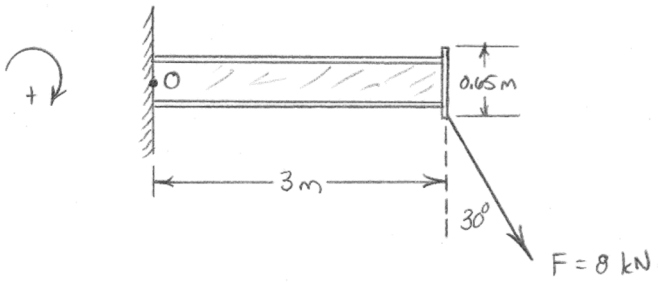

$\circlearrowleft + \sum M = 500(14) - F(8) = 0$

$F = 875 \text{ lb}$

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2/58



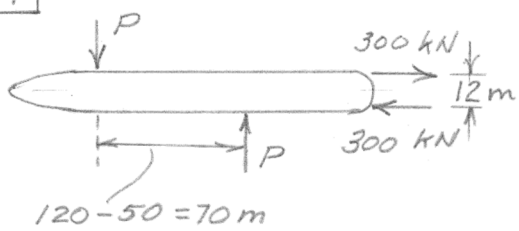

$F = 8$ kN @ 60° CW BELOW HORIZONTAL

$M_O = 8\cos 30^\circ (3) - 8 \sin 30^\circ \left(\frac{0.165}{2}\right) \longrightarrow M_O = 19.48$ kN·m CW

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2/59



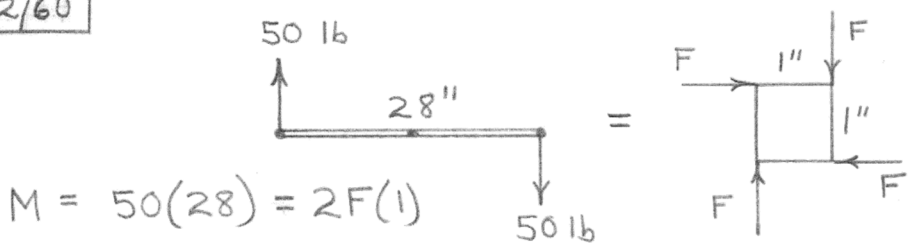

$70P = 300(12)$

$P = 51.4 \text{ kN}$

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2/60



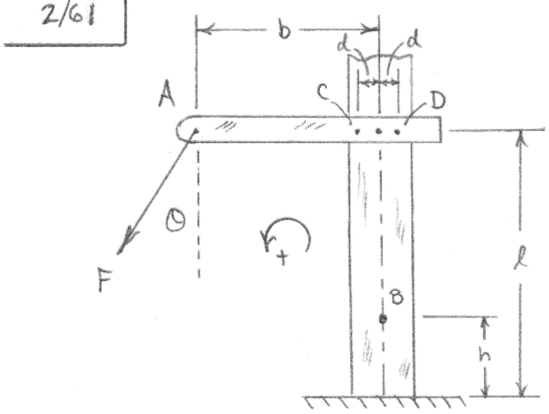

$M = 50(28) = 2F(1)$

$F = 700$ lb

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**2/61**




$F = 425\ N$
$\theta = 30°$
$b = 1.9\ m$
$d = 0.2\ m$
$h = 0.8\ m$
$l = 2.75\ m$

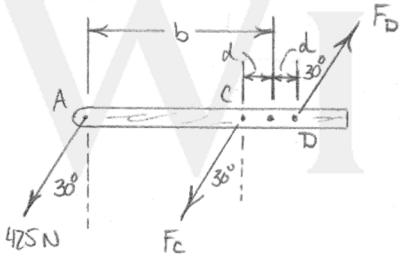
a) FORCE-COUPLE AT B:

$F = 425\ N$ @ $120°$ CW BELOW HORIZONTAL

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

$$\therefore M_B = 1114\ N\cdot m\ CCW$$

b) FORCES AT C AND D:




$$\Sigma F_{+\swarrow}: \quad F_C - F_D = 425$$

$$\Sigma M_A = 0: \quad F_d\cos 30°(b+d) - F_C\cos 30°(b-d) = 0$$

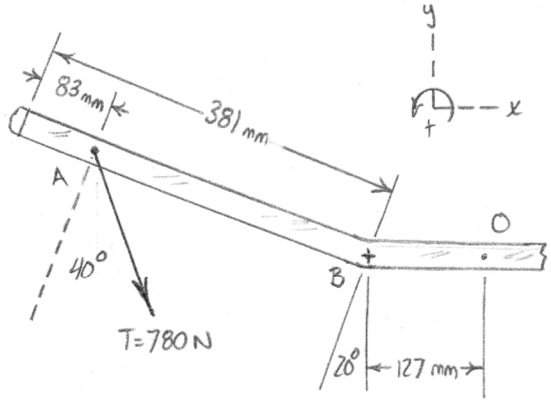
SOLVING...

$F_C = 2230\ N$ @ $120°$ CW BELOW HORIZONTAL

$F_D = 1806\ N$ @ $60°$ CCW ABOVE HORIZONTAL

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2/62




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

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

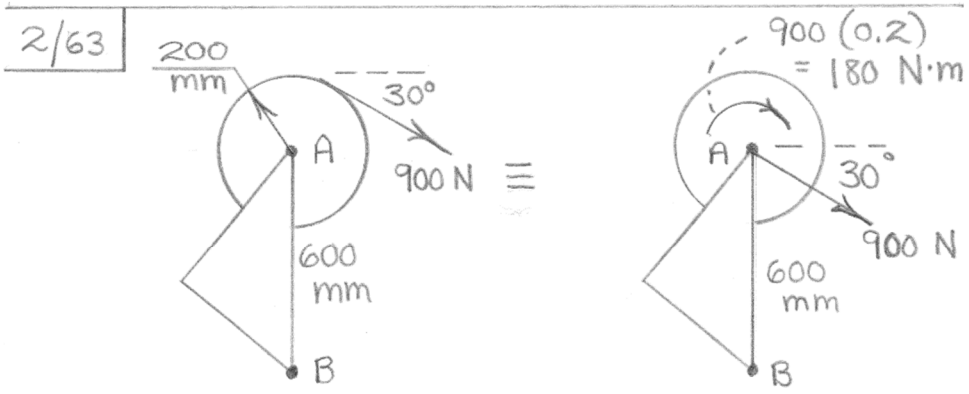
$$\underline{M}_O = \underline{M}_B + T \cos 20^\circ (\overline{OB}) = \left(178.1 + 780 \cos 20^\circ \left(\frac{127}{1000}\right)\right) \underline{k}$$

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

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**2/63**

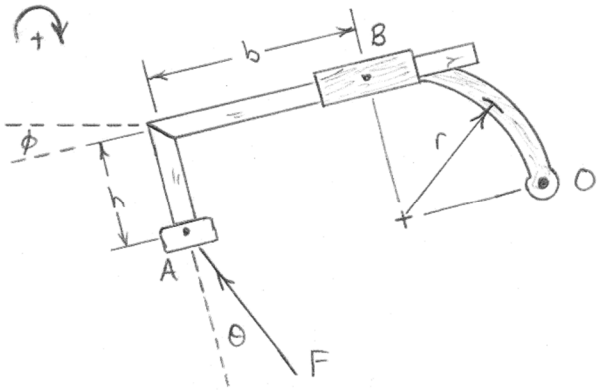



$$+\circlearrowleft M_B = 180 + 900 \cos 30^\circ (0.6) = \underline{648 \text{ N·m CW}}$$

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**2/64** $b = 450\text{ mm}$, $h = 215\text{ mm}$, $r = 325\text{ mm}$, $F = 520\text{ N}$, $\theta = 15^\circ$, $\phi = 10^\circ$




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

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

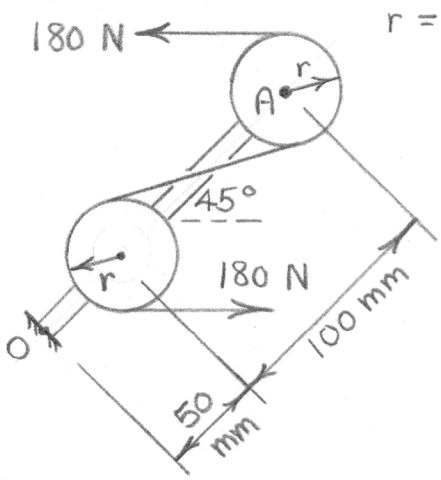
$$= 520\cos 15^\circ\left(\frac{450+325}{1000}\right) - 520\sin 15^\circ\left(\frac{325-215}{1000}\right)$$

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

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2/65




The system at O is a couple.

$$\curvearrowleft M = Fd = 180(100 \sin 45^\circ + 25 + 25)$$

$$= 21\,700 \text{ N·mm or } \underline{21.7 \text{ N·m CCW}}$$

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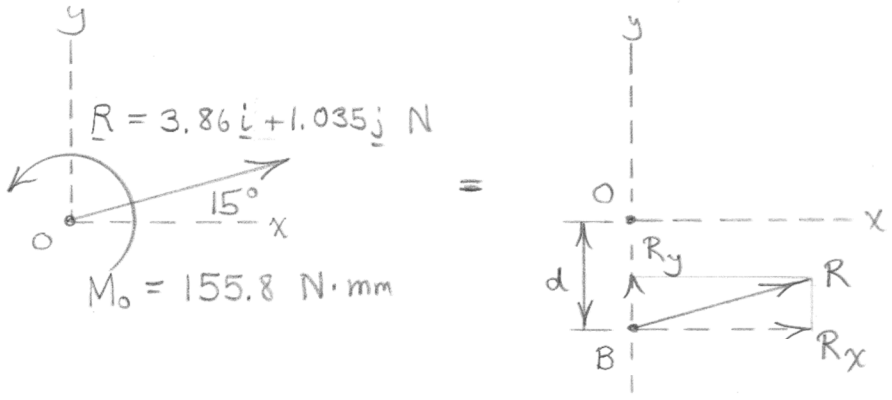
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**2/66** At O:

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

$$\curvearrowleft + M_O = 300 - 4\cos 15^\circ (40) + 4\sin 15^\circ (10)$$

$$= 155.8 \text{ N·mm} \quad \text{CCW}$$




Condition: $R_x d = M_O$

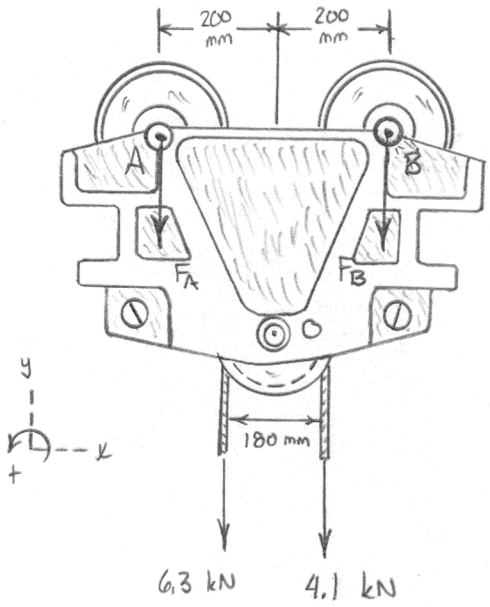
$$3.86\, d = 155.8, \quad d = 40.3 \text{ mm}$$

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

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2/67




$F_A$ & $F_B$ ARE DOWN AT A & B.

$$\begin{cases} \Sigma F_y: & F_A + F_B = 6.3 + 4.1 \\ \Sigma M_O: & 200\,F_A - 200\,F_B = 90(6.3) - 90(4.1) \end{cases}$$

SOLVING...

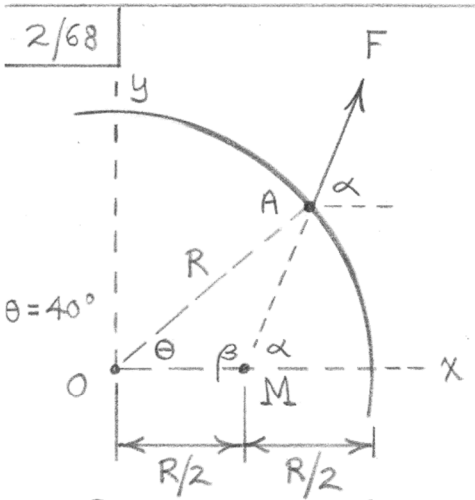
$$\begin{cases} F_A = 5.70 \text{ kN} \\ F_B = 4.70 \text{ kN} \end{cases}$$

(BOTH DOWN AS SHOWN)

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**2/68**




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

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

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

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

$$\curvearrowleft M_O = (F\sin\alpha)\frac{R}{2} = (F\sin 67.5^\circ)\frac{R}{2}$$

$$= 0.462FR$$

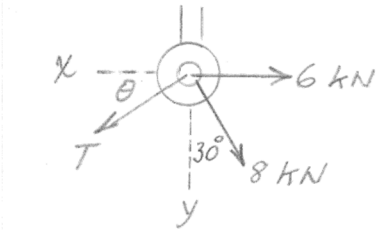
So the force-couple system for $\theta = 40^\circ$ is

$$\begin{cases} F \ \angle 67.5^\circ \\ M_O = 0.462FR \quad \text{CCW} \end{cases}$$

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**2/69**




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

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

So $T\sin\theta = 8.07$

$T\cos\theta = 10$

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

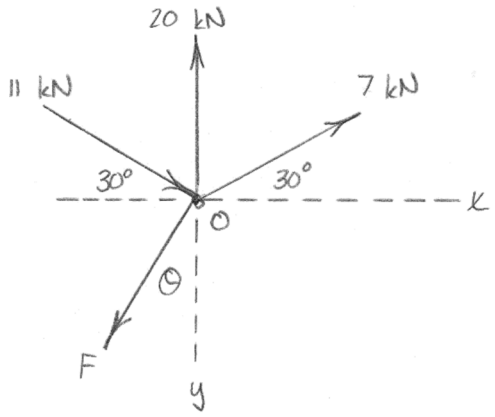
$\theta = 38.9°$

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

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**2/70** $R = 9$ kN, RIGHTWARD



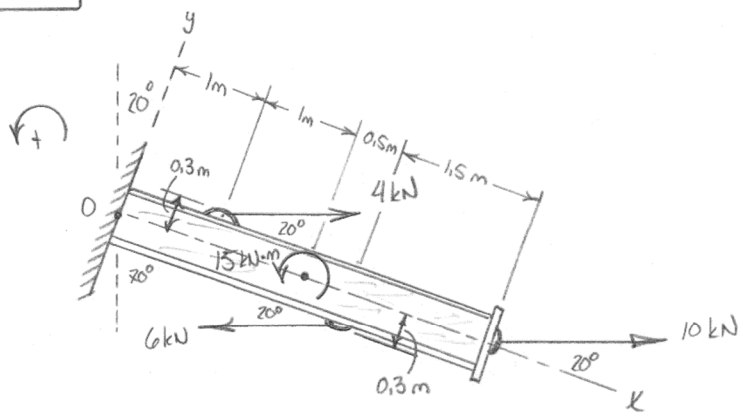

$$\begin{cases} R_x = 9 = 11\cos 30^\circ + 7\cos 30^\circ - F\sin\theta \\ R_y = 0 = 11\sin 30^\circ - 7\sin 30^\circ + F\cos\theta - 20 \end{cases}$$

SOLVING... $F = 19.17$ kN AND $\theta = 20.1^\circ$

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2/71




$$\begin{cases} R = 10 + 4 - 6 \longrightarrow R = 8\ \text{kN} \\ \underline{R} = 8\cos 20^\circ \underline{i} + 8\sin 20^\circ \underline{j} \longrightarrow \underline{R} = 7.52\,\underline{i} + 2.74\,\underline{j}\ \text{kN} \end{cases}$$

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

$$\therefore \underline{M_O = 22.1\ \text{kN·m CCW}}$$

• LINE-OF-ACTION:

$$\underline{r} \times \underline{R} = \underline{M}_O \longrightarrow (x\,\underline{i} + y\,\underline{j}) \times (7.52\,\underline{i} + 2.74\,\underline{j}) = 22.1\,\underline{k}$$

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

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

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2/72 (a) $\underline{R} = -2F\underline{j}$, $\underline{M}_O = \underline{0}$

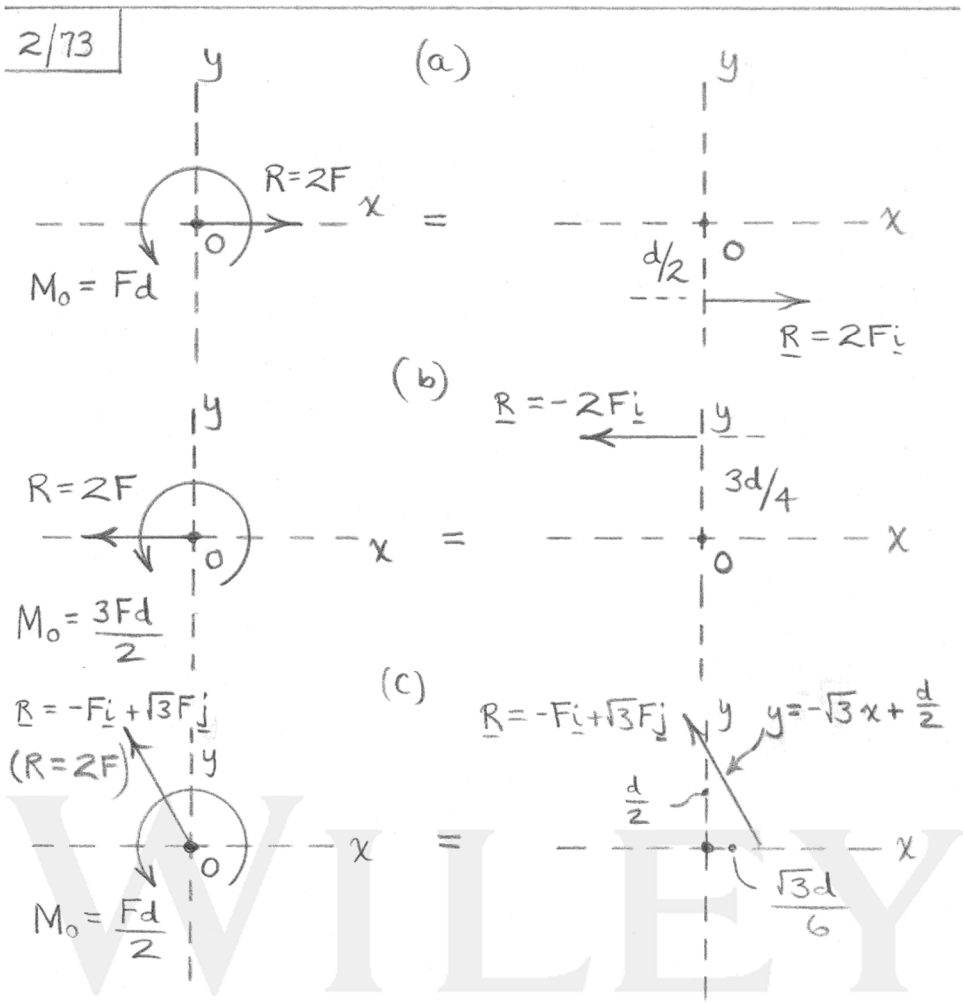
(b) $\underline{R} = \underline{0}$, $\underline{M}_O = Fd\underline{k}$ $(+\underline{k}$ is out$)$

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

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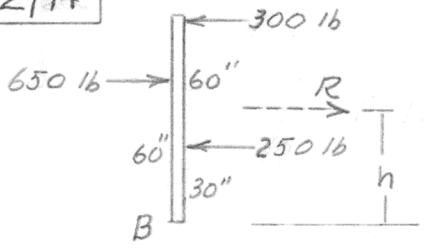
2/73




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**2/174**




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

$= 100 \text{ lb}$

$Rh = \Sigma M_B;$

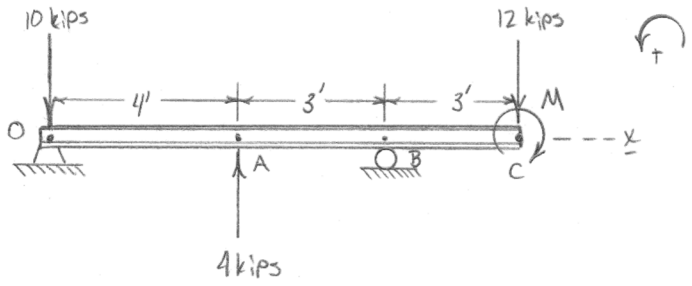
$100h = 650(60) - 300(90) - 250(30)$

$h = 45 \text{ in.}$

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2/75




$R = 18$ kips DOWN

$\Sigma M_B = 0: \quad 7(10) - 4(3) - 12(3) - M = 0 \longrightarrow M = 22$ kip-ft CW

$M_O = 4(4) - 12(10) - 22 = -126$ so... $M_O = 126$ kip-ft CW

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**2/76** $M_O = 0$, so

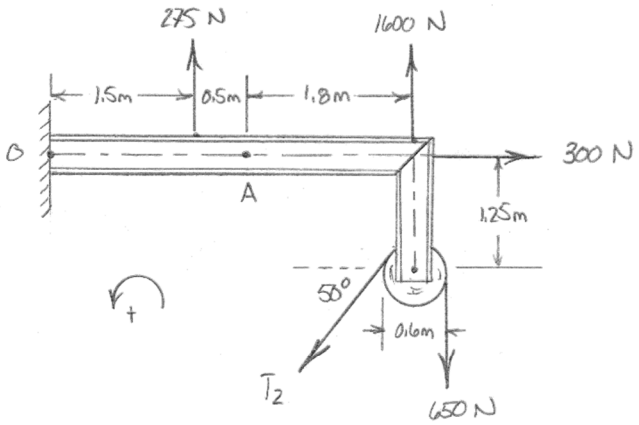
$$\circlearrowleft_+ M - 400(0.150\cos 30^\circ) - 320(0.300) = 0$$

$$M = 148.0 \text{ N·m}$$

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2/77




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

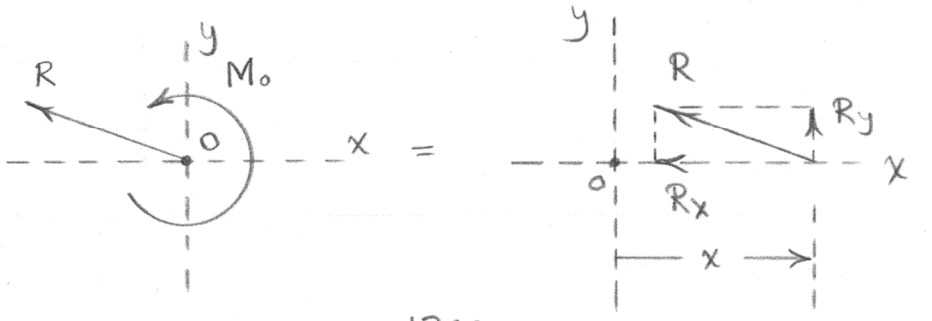
$T_2 = 732$ N

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

$\curvearrowleft + M_O = -40(10) + 60(20) + 50(10) = 1300$ lb-in.

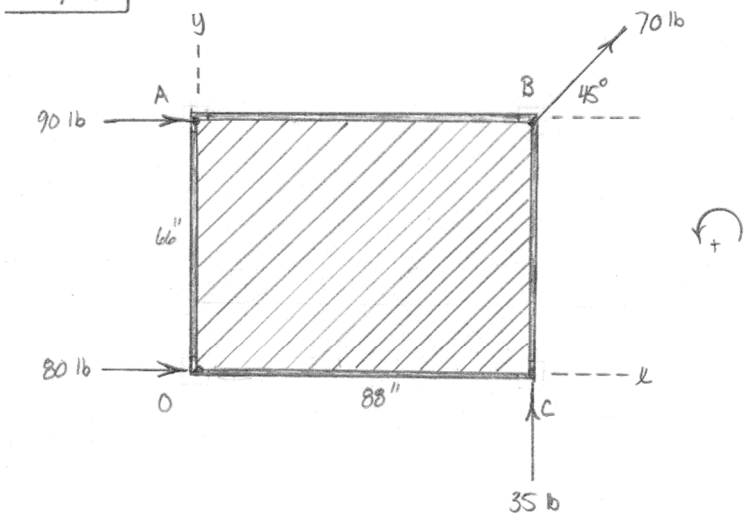



$R_y x = M_O$, $x = \frac{1300}{20} = \underline{65 \text{ in. (off pipe)}}$

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2/79




$$\underline{R} = (90 + 80 + 70\cos 45^\circ)\,\underline{i} + (35 + 70\sin 45^\circ)\,\underline{j}$$

$$\underline{R} = 219\,\underline{i} + 84.5\,\underline{j}\ \text{lb}$$

$$M_O = -90(66) + 35(88) + 70\sin 45^\circ(88) - 70\cos 45^\circ(66) = -1771$$

$$M_O = 1771\ \text{lb-in. CW}$$

To produce a CW moment about O with $R_x$ positive, $R_x$ is placed above O.

$$R_x y = M_O \rightarrow 219y = 1771 \rightarrow y = 8.07\ \text{in. above O}$$

To produce a CW moment about O with $R_y$ positive, $R_y$ is placed left of O.

$$R_y x = M_O \rightarrow 84.5x = 1771 \rightarrow x = 21.0\ \text{in. left of O}$$

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**2/80** $\Sigma M_O = 0$ since $\underline{R}$ passes through O.

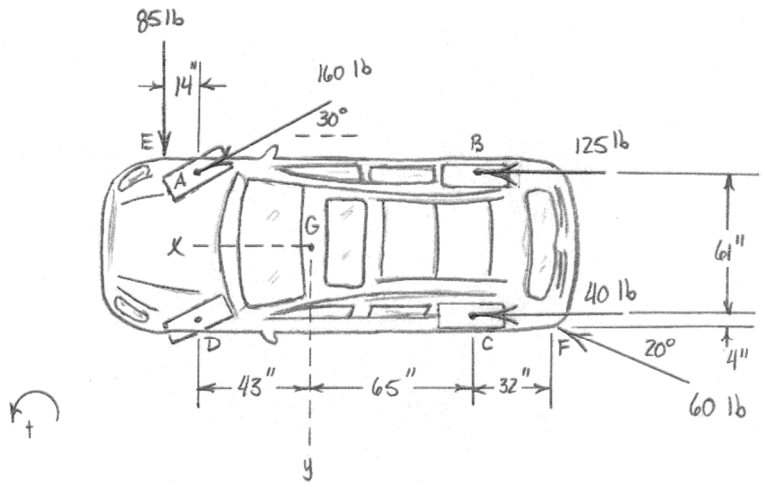
$40(8) + 60(4) - 5P\cos 20^\circ = 0, \quad P = 119.2 \text{ lb}$

Moment of 40-lb & 60-lb forces unaffected by $\theta$ so result for P is not dependent on $\theta$.

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2/81




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

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

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

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

For CCW $M_G$ with positive $R_x$, R is placed above G, in negative y.

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

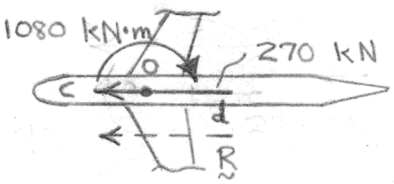
For CCW $M_G$ with positive $R_y$, R is placed left of G, in positive x.

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

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**2/82** Force – Couple system at point O:

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



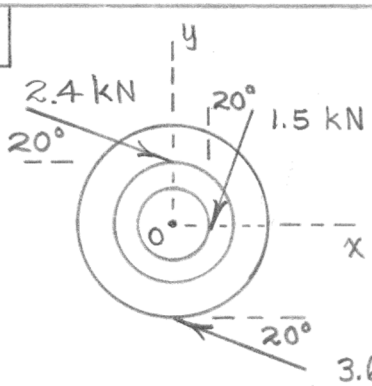

$$d = \frac{M_O}{R} = \frac{1080}{270}$$

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

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**2/83**




$r_1 = 0.120$ m
$r_2 = 0.200$ m
$r_3 = 0.300$ m

$$\underline{R} = \Sigma \underline{F} = 2.4(c20°\underline{i} - s20°\underline{j}) + 1.5(-s20°\underline{i} - c20°\underline{j}) + 3.6(-c20°\underline{i} + s20°\underline{j}) = -1.641\underline{i} - 0.999\underline{j} \text{ kN}$$

$$\circlearrowleft M_O = (2.4(0.2) + 1.5(0.12) + 3.6(0.3))\cos 20° = 1.635 \text{ kN·m}$$

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

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

Axis intercepts: $x = 1.637$ m, $y = -0.997$ m

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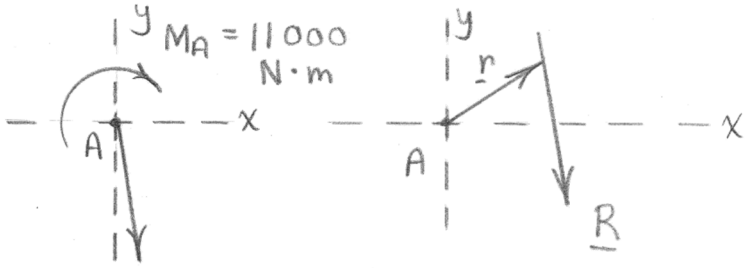
**2/84** Equivalent force-couple system at A:

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

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

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

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




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

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

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

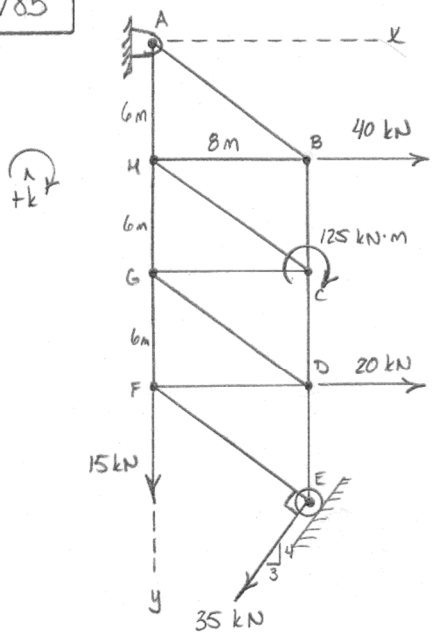
$$= (-2200x - 346y)\underline{k}$$

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

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**2/85**




$$\underline{R} = \left(40 + 20 - \tfrac{3}{5}35\right)\underline{i} + \left(15 + \tfrac{4}{5}35\right)\underline{j}$$

$$\underline{R} = 39\underline{i} + 43\underline{j} \text{ kN}$$

$$\underline{M}_A = \left[-40(6) - 20(18) + 125 + 35(10) + \tfrac{3}{5}35(18)\right]\underline{k} \longrightarrow \underline{M}_A = 253\,\underline{k} \text{ kN·m}$$

$$\underline{r} \times \underline{R} = \underline{M}_A \longrightarrow (x\underline{i} + y\underline{j}) \times (39\underline{i} - 43\underline{j}) = 253\underline{k}$$

$$\underline{k}: \quad 43x - 39y = 253 \longrightarrow \underline{y = 1.103x - 6.49 \text{ (m)}}$$

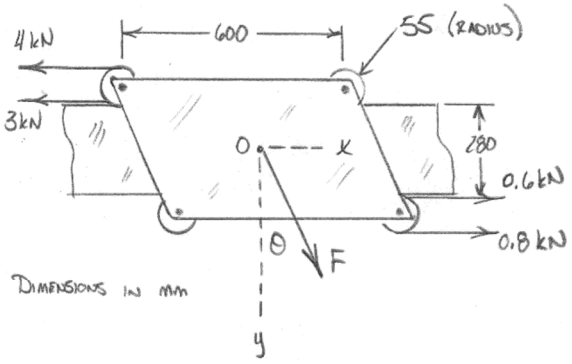
$$\underline{x\text{-Axis:}} \quad y = 0 = 1.103x - 6.49 \longrightarrow \underline{x = 5.88 \text{ m} \quad \text{so} \quad (5.88, 0) \text{ m}}$$

$$\underline{y\text{-Axis:}} \quad x = 0 \longrightarrow \underline{y = -6.49 \text{ m} \quad \text{so} \quad (0, -6.49) \text{ m}}$$

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**2/86** $F = 5$ kN, $\Theta = 30^\circ$




$$\underline{R} = (0.8 + 0.6 + 5\sin 30^\circ - 4 - 3)\,\underline{i} + 5\cos 30^\circ\,\underline{j} \longrightarrow \underline{R} = -3.10\,\underline{i} + 4.33\,\underline{j} \text{ kN}$$

$$\Sigma M_O = 0.6\left(\frac{140}{1000}\right) + 0.8\left(\frac{140+110}{1000}\right) + 3\left(\frac{140}{1000}\right) + 4\left(\frac{140+110}{1000}\right) =$$

$$\therefore \Sigma M_O = 1.704 \text{ kN·m CCW}$$

FOR A CCW $M_O$ WITH NEGATIVE $R_x$, $R$ IS PLACED ABOVE O IN MINUS y.

$$R_x y = M_O \longrightarrow 3.10|y| = 1.704 \longrightarrow |y| = 0.550$$

$$\therefore |y| = 550 \text{ mm ABOVE O OR } (0, -550) \text{ (mm)}$$

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**2/87**

$$\underline{R} = \Sigma \underline{F} = 400(\cos 45^\circ \underline{i} - \sin 45^\circ \underline{j}) + 500(\sin 15^\circ \underline{i} - \cos 15^\circ \underline{j})$$

$$= 412\underline{i} - 766\underline{j} \text{ N}$$

$$+\circlearrowleft M_O = (500 - 400)(0.060) = 6 \text{ N} \cdot \text{m}$$

For the line of action of the standalone force:

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

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

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

For $x = 0$: $y = 0.01455$ m or $y = 14.55$ mm

For $y = 0$: $x = 0.00783$ m or $x = 7.83$ mm

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




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

$$\Rightarrow F_C = F_D = F$$

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

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

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**2/89**

$$\underline{F} = F\underline{n}$$

$$= 60\left[\frac{40\underline{i} - 50\underline{j} + 110\underline{k}}{\sqrt{40^2 + 50^2 + 110^2}}\right]$$

$$= \underline{18.86\underline{i} - 23.6\underline{j} + 51.9\underline{k}\ \text{N}}$$

$$\cos\theta_y = \frac{F_y}{F} = \frac{-23.6}{60}, \quad \underline{\theta_y = 113.1^\circ}$$

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2/90

$$\underline{T} = T\underline{n}_{BA}$$

$$\underline{T} = 12\left[\frac{-35\underline{i} + 25\underline{j} + 60\underline{k}}{\sqrt{35^2 + 25^2 + 60^2}}\right]$$

$$= -5.69\underline{i} + 4.06\underline{j} + 9.75\underline{k} \quad \text{kN}$$

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

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

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

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

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)

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

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

$= -0.243\underline{i} - 0.1401\underline{j} \text{ kN}$

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**2/92**

$$\underline{F} = F\underline{n} = 300\left[\frac{4\underline{i} - 8\underline{j} - 8\underline{k}}{\sqrt{4^2 + 8^2 + 8^2}}\right]$$

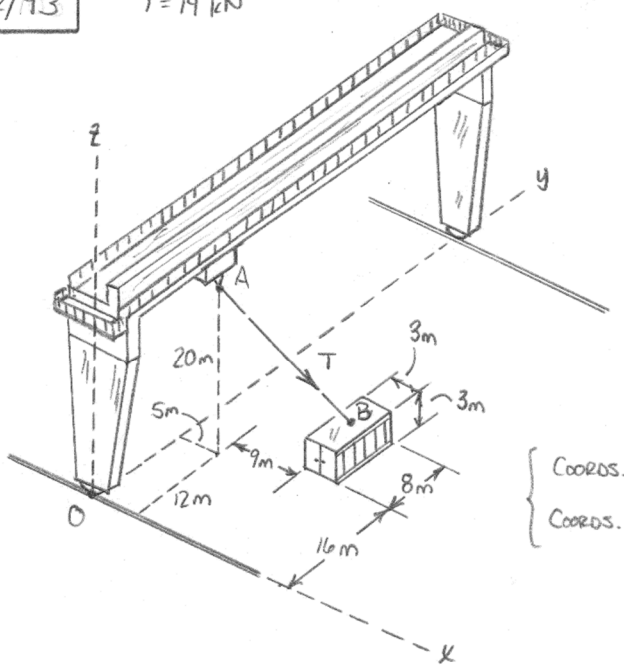
$$= 300\left[\frac{1}{3}\underline{i} - \frac{2}{3}\underline{j} - \frac{2}{3}\underline{k}\right] \text{ lb}$$

$F_x = 100$ lb, $F_y = -200$ lb, $F_z = -200$ lb

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**2/93** $T = 14$ kN




Coords. of A are $(5, 12, 20)$ m

Coords. of B are $(15.5, 20, 3)$ m

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

$T_x = T n_x = 14(0.488) \rightarrow T_x = 6.83$ kN

$T_y = T n_y = 14(0.372) \rightarrow T_y = 5.20$ kN

$T_z = T n_z = 14(-0.790) \rightarrow T_z = -11.06$ kN

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

$= 0.876\,\underline{i} + 0.438\,\underline{j} - 2.19\,\underline{k}$ kN

Projection $T_{AC} = \underline{T} \cdot \underline{n}_{AC}$

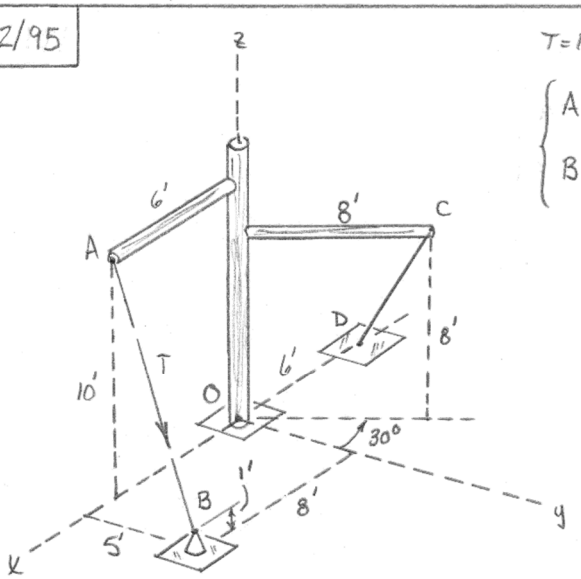
$= (0.876\,\underline{i} + 0.438\,\underline{j} - 2.19\,\underline{k}) \cdot \left(\frac{2\underline{i} - 2\underline{j} - 5\underline{k}}{\sqrt{2^2 + 2^2 + 5^2}}\right)$

$= 2.06$ kN

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**2/95**




$T = 1750\ \text{lb}$

$A(6, 0, 10)$ ft

$B(8, 5, 1)$ ft

$$\underline{\Omega}_{AB} = \frac{(8-6)\underline{i} + (5-0)\underline{j} + (1-10)\underline{k}}{[(8-6)^2 + 5^2 + (1-10)^2]^{1/2}} \rightarrow \underline{\Omega}_{AB} = 0.1907\underline{i} + 0.477\underline{j} - 0.858\underline{k}$$

$$\theta_x = \cos^{-1}(n_x) = \cos^{-1}(0.1907) \rightarrow \theta_x = 79.0°$$

$$\theta_y = \cos^{-1}(n_y) = \cos^{-1}(0.477) \rightarrow \theta_y = 61.5°$$

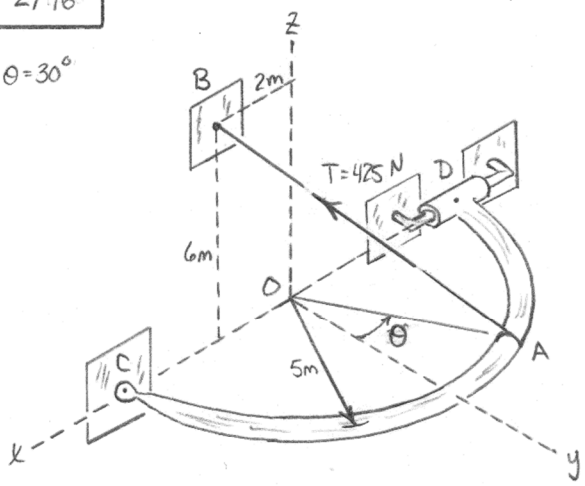
$$\theta_z = \cos^{-1}(n_z) = \cos^{-1}(-0.858) \rightarrow \theta_z = 149.1°$$

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**2/96**

$\theta = 30^\circ$




$\begin{cases} A(-5\sin 30,\ 5\cos 30,\ 0)\ m \\ B(2, 0, 6)\ m \end{cases}$

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

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

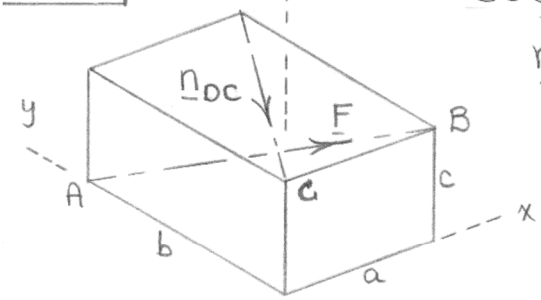
$$\underline{T}_A = T\Omega_{AB} = 425(0.520\hat{i} - 0.5\hat{j} + 0.693\hat{k}) \longrightarrow \underline{T}_A = 221\underline{i} - 212\underline{j} + 294\underline{k}\ \text{N}$$

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

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**2/97**




Set up x-y-z axes shown

$$\underline{n}_{DC} = \frac{\underline{DC}}{\overline{DC}} = \frac{-a\underline{i} - b\underline{j}}{\sqrt{a^2+b^2}}$$

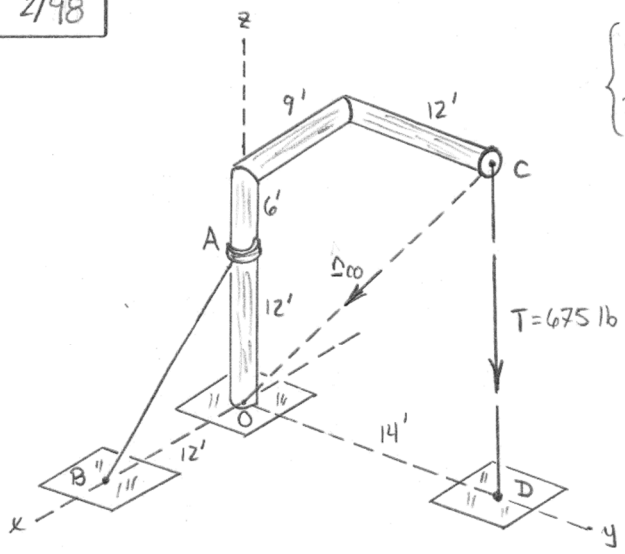
$$\underline{F} = F\underline{n}_{AB} = F\frac{\underline{AB}}{\overline{AB}} = F\frac{a\underline{i} - b\underline{j} + c\underline{k}}{\sqrt{a^2+b^2+c^2}}$$

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

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**2/98**




C (-9, 12, 18)

D (0, 14, 0)

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

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

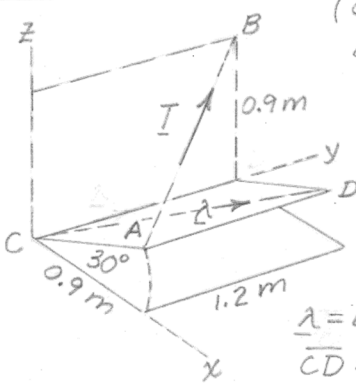
$$\underline{n}_{CO} = \frac{9\underline{i} - 12\underline{j} - 18\underline{k}}{\sqrt{9^2 + 12^2 + 18^2}} \rightarrow \underline{n}_{CO} = \frac{3}{\sqrt{61}}\underline{i} - \frac{4}{\sqrt{61}}\underline{j} - \frac{6}{\sqrt{61}}\underline{k}$$

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

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**2/99** $T = 150$ N




Coordinates of A are
$(0.9\cos 30°,\ 0,\ 0.9\sin 30°)$
or $(0.779, 0, 0.45)$ m

$\overline{AB} = \sqrt{0.779^2 + 1.2^2 + (0.9-0.45)^2}$

$= 1.50$ m

$l = -0.779/1.5,\ m = 1.2/1.5,\ n = \frac{0.45}{1.5}$

$\underline{T} = \frac{100}{1.5}(-0.779\underline{i} + 1.2\underline{j} + 0.45\underline{k})$ N

$\underline{\lambda}$ = unit vector along CD

$\overline{CD} = \sqrt{0.9^2 + 1.2^2} = 1.5$ m

$l = 0.779/1.5,\ m = 1.2/1.5,\ n = 0.45/1.5$

$\underline{\lambda} = \frac{1}{1.5}(0.779\underline{i} + 1.2\underline{j} + 0.45\underline{k})$

$$\underline{T}_{CD} = \underline{T}\cdot\underline{\lambda} = \frac{100}{1.5}(-0.779\underline{i} + 1.2\underline{j} + 0.45\underline{k})\cdot\frac{1}{1.5}(0.779\underline{i} + 1.2\underline{j} + 0.45\underline{k})$$

$$= \frac{100}{2.25}(-0.779^2 + 1.2^2 + 0.45^2) = \frac{100}{2.25}(-0.6075 + 1.44 + 0.2025)$$

$$= \frac{400}{9}(1.035) = \underline{46.0\ \text{N}}$$

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**2/100**

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

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

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

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

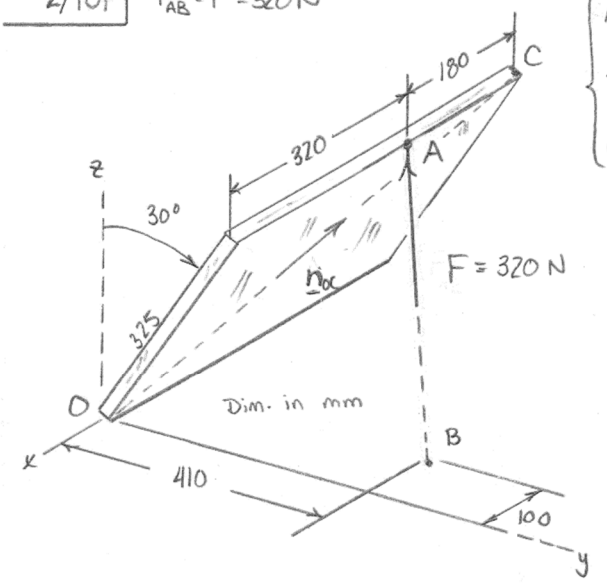
$$\theta = \cos^{-1}\frac{\underline{F}\cdot\underline{OC}}{F(\overline{OC})} = \cos^{-1}\left[\frac{-85.7(12) + 171.4(24)}{200\left(\sqrt{12^2+24^2}\right)}\right]$$

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

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**2/101** $F_{AB} = F = 320\ N$




$A\,(-320,\ 325\sin30^\circ,\ 325\cos30^\circ)$

$B\,(-100,\ 410,\ 0)$

$C\,(-500,\ 325\sin30^\circ,\ 325\cos30^\circ)$

$$\underline{n}_{BA} = \frac{(-320+100)\underline{i} + (325\sin30^\circ - 410)\underline{j} + 325\cos30^\circ\,\underline{k}}{\left[(-320+100)^2 + (325\sin30^\circ - 410)^2 + (325\cos30^\circ)^2\right]^{1/2}}$$

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

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

$$\underline{n}_{OC} = \frac{-500\underline{i} + 325\sin30^\circ\underline{j} + 325\cos30^\circ\underline{k}}{\sqrt{500^2 + 325^2}} \longrightarrow \underline{n}_{OC} = -0.838\underline{i} + 0.272\underline{j} + 0.472\underline{k}$$

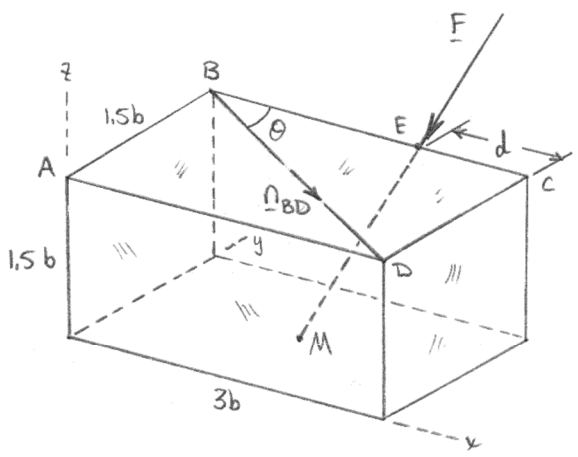
$$F_{OC} = \underline{F}\cdot\underline{n}_{OC} = (-162.0\underline{i} - 182.2\underline{j} + 207\underline{k})\cdot(-0.838\underline{i} + 0.272\underline{j} + 0.472\underline{k})$$

$$\therefore \quad F_{OC} = 184.0\ N$$

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**2/102**




$B\ (0, 1.5b, 1.5b)$

$D\ (3b, 0, 1.5b)$

$E\ (3b-d, 1.5b, 1.5b)$

$M\left(\frac{3b}{2}, \frac{3b}{4}, 0\right)$

$\theta = \tan^{-1}\left(\frac{1.5b}{3b}\right) = 26.6°$

$$\underline{n}_{BD} = \cos\theta\,\underline{i} - \sin\theta\,\underline{j} \longrightarrow \underline{n}_{BD} = 0.894\,\underline{i} - 0.447\,\underline{j}$$

$$\underline{n}_{EM} = \frac{\left(\frac{3b}{2} - 3b + d\right)\underline{i} + \left(\frac{3b}{4} - 1.5b\right)\underline{j} + (0 - 1.5b)\underline{k}}{\left[\left(\frac{3b}{2} - 3b + d\right)^2 + \left(\frac{3b}{4} - 1.5b\right)^2 + (-1.5b)^2\right]^{1/2}}$$

$$\therefore \underline{n}_{EM} = \frac{(4d - 6b)\underline{i} - 3b\,\underline{j} - 6b\,\underline{k}}{\sqrt{81b^2 - 48bd + 16d^2}} \quad \text{AND} \quad \underline{F} = F\,\underline{n}_{EM}$$

$$F_{BD} = \underline{F} \cdot \underline{n}_{BD} = F\left(\frac{(4d - 6b)\underline{i} - 3b\,\underline{j} - 6b\,\underline{k}}{\sqrt{81b^2 - 48bd + 16d^2}}\right) \cdot \left(0.894\,\underline{i} - 0.447\,\underline{j}\right)$$

$$\therefore F_{BD} = \frac{(8d - 9b)F}{\sqrt{5}\sqrt{81b^2 - 48bd + 16d^2}}$$

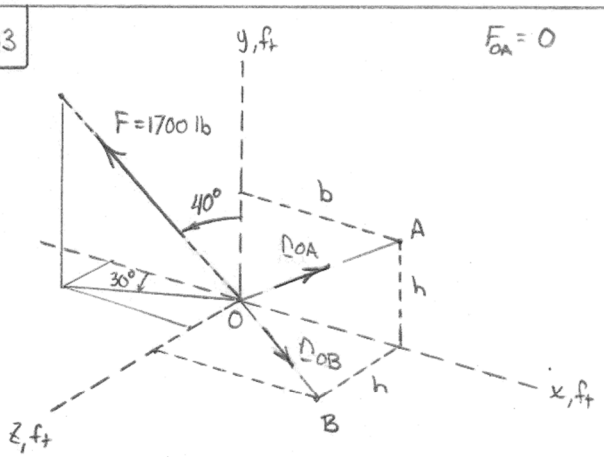
IF $d = \frac{b}{2}$ ... $F_{BD} = -0.286\,F$

IF $d = \frac{5b}{2}$ ... $F_{BD} = 0.630\,F$

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**2/103** $F_{OA} = 0$ AND $b = 6$ ft.




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

$$\underline{n}_{OA} = \frac{b\underline{i} + h\underline{j}}{\sqrt{b^2 + h^2}} \quad \text{so...} \quad \underline{F} \cdot \underline{n}_{OA} = (-946\underline{i} + 1302\underline{j} + 546\underline{k}) \cdot \frac{6\underline{i} + h\underline{j}}{\sqrt{6^2 + h^2}}$$

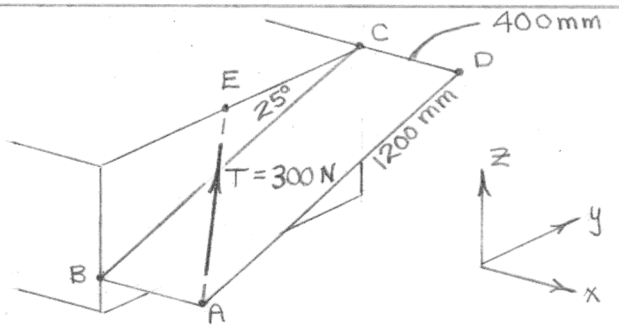
$$F_{OA} = \underline{F} \cdot \underline{n}_{OA} = 0 = \frac{1302\,(h - 4.36)}{\sqrt{36 + h^2}} \quad \text{so...} \quad h = 4.36 \text{ ft}$$

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

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

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**2/104**




$$\underline{T} = T\underline{n}_{AE} = 300\left[\frac{-400\underline{i} + 544\underline{j} + 507\underline{k}}{\sqrt{400^2 + 544^2 + 507^2}}\right]$$

$$= 300\left[-0.474\underline{i} + 0.644\underline{j} + 0.601\underline{k}\right] \text{ N}$$

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

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

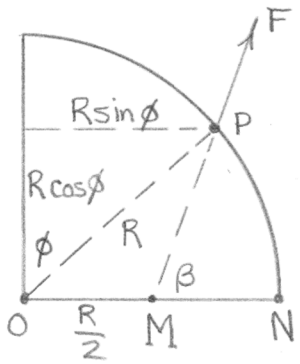
$$T_{BC} = 251 \text{ N}$$

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**▶2/105** $F_x = F_{xy}\cos\theta$, $F_y = F_{xy}\sin\theta$

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




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

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

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

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

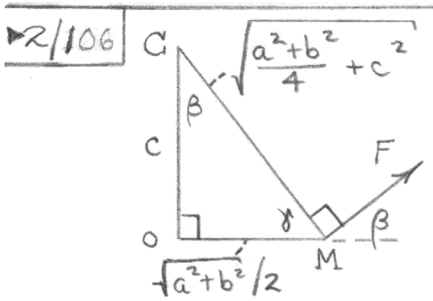
$$\text{So } \underline{F} = F\left[\cos\theta\cos\beta\,\underline{i} + \sin\theta\cos\beta\,\underline{j} + \sin\beta\,\underline{k}\right]$$

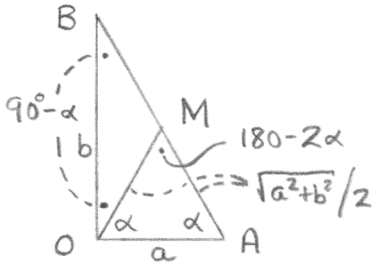
$$= \frac{F}{\sqrt{5-4\sin\phi}}\left[(2\sin\phi-1)(\cos\theta\,\underline{i} + \sin\theta\,\underline{j}) + 2\cos\phi\,\underline{k}\right]$$

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**2/106**



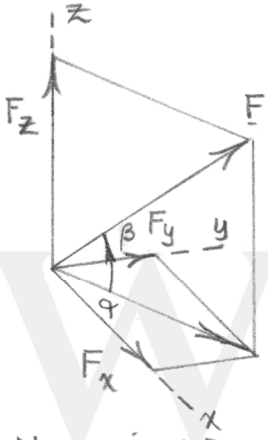

$$\tan\gamma = \frac{c}{\sqrt{a^2+b^2}/2} = \frac{2c}{\sqrt{a^2+b^2}}$$

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

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

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

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




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

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

$$\sin\beta = \sin\left[90^\circ - \tan^{-1}\frac{2c}{\sqrt{a^2+b^2}}\right]$$

$$= \sin 90^\circ\cos\left[\tan^{-1}\frac{2c}{\sqrt{a^2+b^2}}\right] - \cos 90^\circ\sin\left[\tan^{-1}\frac{2c}{\sqrt{a^2+b^2}}\right]$$

$$= \frac{\sqrt{a^2+b^2}}{\sqrt{a^2+b^2+4c^2}}$$ (Also see that $\sin\beta = \cos\gamma$!)

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

Finally,

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

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

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

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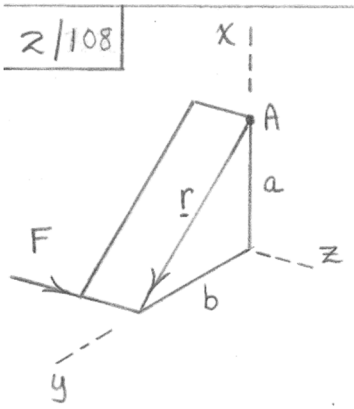
2/107

$$\begin{cases} \underline{M}_1 = -cF_1\underline{j} \\ \underline{M}_2 = cF_2\underline{j} - bF_2\underline{k} = F_2(c\underline{j} - b\underline{k}) \\ \underline{M}_3 = -bF_3\underline{k} \end{cases}$$

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**2/108**




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

$$= (-a\underline{i} + b\underline{j}) \times F\underline{k}$$

$$= \underline{F(b\underline{i} + a\underline{j})}$$

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**2/109**

$$\underline{M}_O = F(-c\underline{i} + a\underline{k})$$

$$\underline{M}_A = Fa\underline{k}$$

$$\underline{M}_{OB} = (\underline{M}_O \cdot \underline{n}_{OB})\underline{n}_{OB}$$

$$= \left[F(-c\underline{i} + a\underline{k}) \cdot \frac{a\underline{i} + b\underline{j}}{\sqrt{a^2+b^2}}\right] \frac{a\underline{i} + b\underline{j}}{\sqrt{a^2+b^2}}$$

$$= -\frac{Fac}{a^2+b^2}(a\underline{i} + b\underline{j})$$

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**2/110**

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

$$= (1.5\underline{j} + 0.75\underline{k}) \times 4(-\cos 30^\circ \underline{i} + \sin 30^\circ \underline{j})$$

$$= \underline{-1.5\underline{i} - 2.60\underline{j} + 5.20\underline{k} \text{ lb-in.}}$$

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**2/111**

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

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

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

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

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**2/112** $\underline{M} = \underline{r} \times \underline{F}$

$= -0.5\underline{i} \times 400\left(\cos 15^\circ \underline{j} + \sin 15^\circ \underline{k}\right)$

$= \underline{51.8\underline{j} - 193.2\underline{k}}$ N·m

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

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

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

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

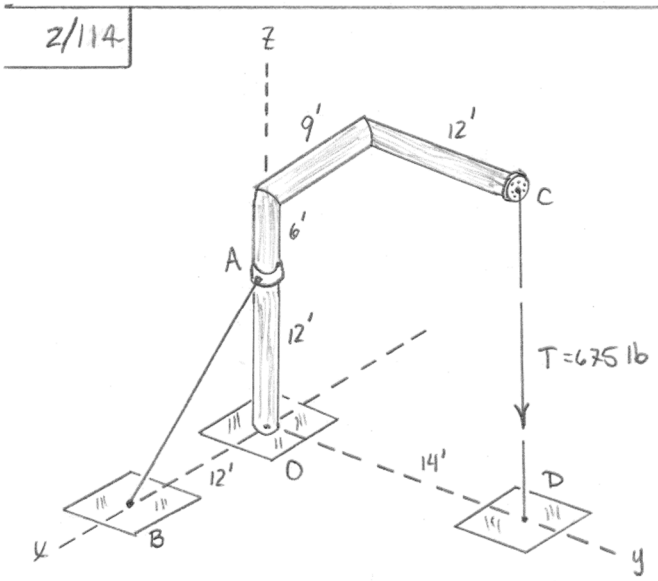
$$\underline{M}_O = 0.457(-3\underline{i} + 4.8\underline{j} + 2.40\underline{k}) \text{ kN·m}$$

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

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2/114




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

$$\underline{M}_O = \underline{r}_{OD} \times \underline{T} = 14\underline{j} \times (300\underline{i} + 66.8\underline{j} - 601\underline{k})$$

$$\underline{M}_O = -8410\underline{i} - 4210\underline{k} \text{ lb-ft}$$

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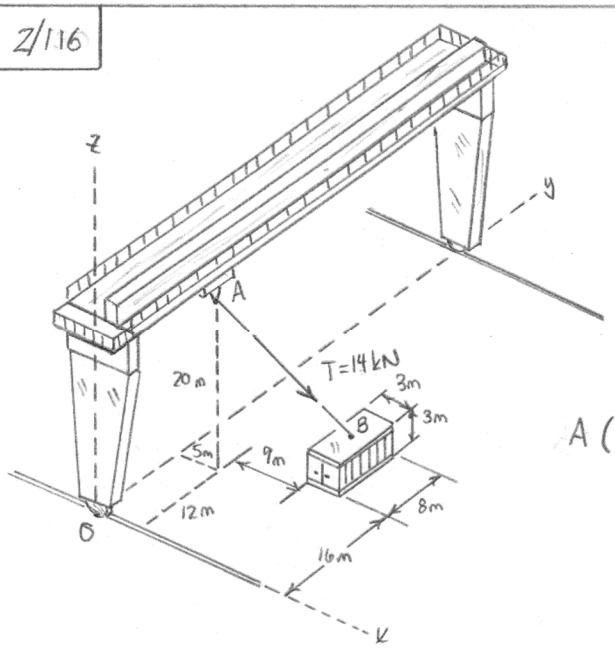
2/115 $\underline{M} = -150(0.250+0.250)\underline{i} + 150(0.150)\underline{j}$

$= -75\underline{i} + 22.5\underline{j}$ N·m

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2/116




A (5, 12, 20) m

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

$$\underline{M}_O = \underline{r}_{OA} \times \underline{T} = (5\underline{i} + 12\underline{j} + 20\underline{k}) \times (6.83\,\underline{i} + 5.20\,\underline{j} - 11.06\,\underline{k})$$

$$\underline{M}_O = -237\,\underline{i} + 191.9\,\underline{j} - 55.9\,\underline{k} \text{ kN·m}$$

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**2/117**

$$M_O = (250 \sin 60^\circ)12 + (250 \cos 60^\circ) \sin 40^\circ (8 - 4.2)$$

$$= 2900 \text{ lb-in.} \quad \curvearrowleft$$

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2/118 $\underline{M}_O = \underline{r} \times \underline{F}$

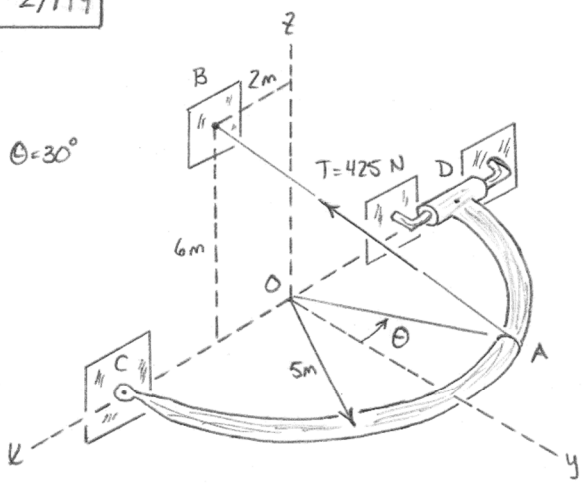
$= (-6\underline{i} + 0.8\underline{j} + 1.2\underline{k}) \times (-400\underline{j})$

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

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2/119



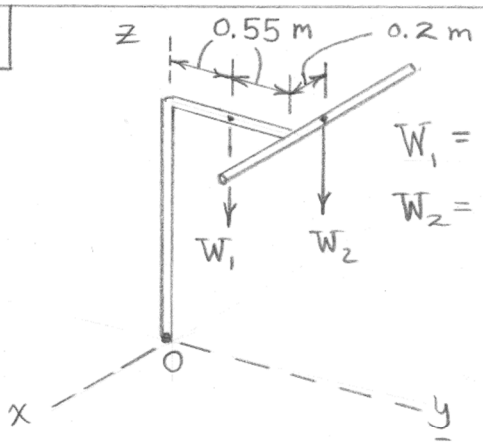

From 2/108 ... $\underline{T} = 221\underline{i} - 212\underline{j} + 294\underline{k}$ N

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

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**2/120**




$W_1 = 1.1(7)(9.81) = 75.5$ N

$W_2 = 2(7)(9.81) = 137.3$ N

$$\begin{cases} M_{O_x} = -75.5(0.55) - 137.3(1.1) = -192.6 \text{ N·m} \\ M_{O_y} = -137.3(0.2) = -27.5 \text{ N·m} \\ M_{O_z} = 0 \end{cases}$$

$\therefore \underline{M}_O = -192.6\,\underline{i} - 27.5\,\underline{j}$ N·m

$M_O = 194.6$ N·m

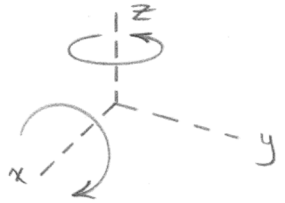
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2/121 $\underline{M} = 1.2(40)\underline{k} - 1.2(50)\underline{i}$

$= -60\underline{i} + 48\underline{k}$ lb-in.

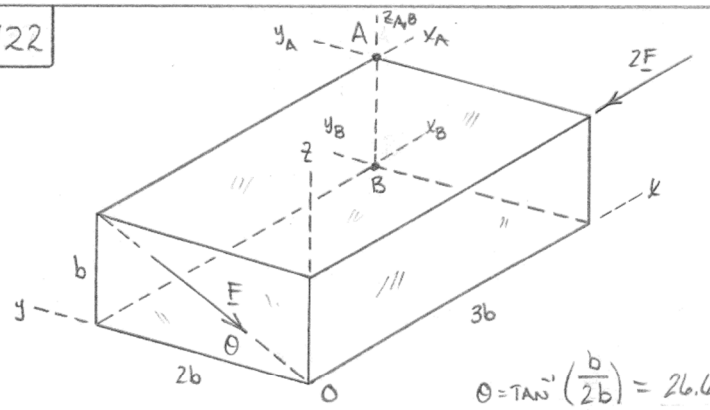
The spacecraft will begin to rotate about its x- and z axes.




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**2/122**




$\theta = \tan^{-1}\left(\frac{b}{2b}\right) = 26.6°$

· Force $\underline{F}$

$$\underline{M}_A = F\cos\theta(3b)\underline{k} - F\sin\theta(3b)\underline{j} \longrightarrow \underline{M}_A = \frac{Fb}{\sqrt{5}}(-3\underline{j} + 6\underline{k})$$

$$\underline{M}_B = F\cos\theta(3b)\underline{k} - F\sin\theta(3b)\underline{j} + F\sin\theta(2b)\underline{i}$$

$$\therefore \underline{M}_B = \frac{Fb}{\sqrt{5}}(2\underline{i} - 3\underline{j} + 6\underline{k})$$

· Force $2\underline{F}$

$$\underline{M}_A = -2F(2b)\underline{k} \longrightarrow \underline{M}_A = -4Fb\,\underline{k}$$

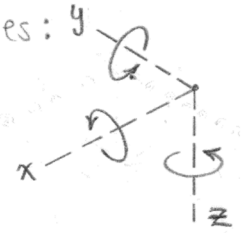
$$\underline{M}_B = -2F(2b)\underline{k} - 2F(b)\underline{j} \longrightarrow \underline{M}_B = -2Fb(\underline{j} + 2\underline{k})$$

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**2/123** $\underline{M} = (1700)(2)\underline{i} - (1700)(30)\underline{j} - (1700)(30)\underline{k}$

$= \underline{3400\,\underline{i} - 51\,000\,\underline{j} - 51\,000\,\underline{k}\ \text{N·m}}$

The orbiter would acquire rotational motion about all three axes:




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**2/124**

$$\underline{M}_O = 0\underline{i} - (200)(0.2 + 0.125\sin 20^\circ)\underline{j}$$
$$-200\,(0.125\cos 20^\circ - 0.070)\underline{k}$$
$$= -48.6\underline{j} - 9.49\underline{k} \ \text{N·m}$$

There would be no z-component of $\underline{M}_O$ if

$$d\cos 20^\circ - 70 = 0, \quad d = 74.5 \ \text{mm}$$

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**2/125**

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

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

Moment of this force about the $x$-axis is

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

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

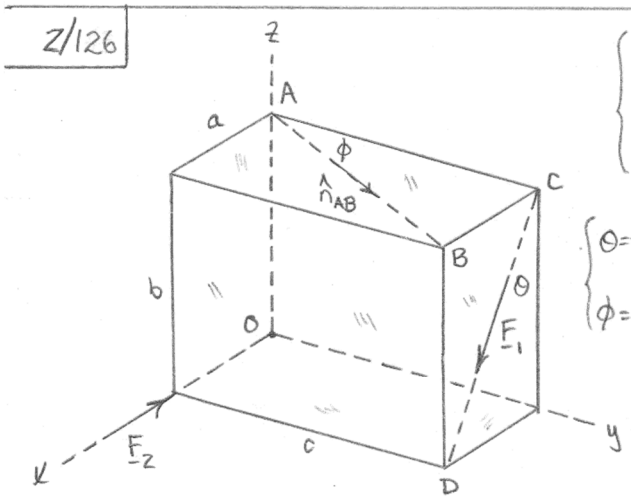
$$(M_{O_x})_W = -15(9.81)\frac{0.45\cos 20^\circ}{2} = \underline{-31.1 \text{ N·m}}$$

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

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**2/126**




$a = 200\ mm$ $\quad F_1 = 450\ N$

$b = 400\ mm$ $\quad M_{AB} = 30\ N\cdot m$

$c = 500\ mm$

$\theta = \tan^{-1}\left(\frac{a}{b}\right) = \tan^{-1}\left(\frac{200}{400}\right) = 26.6°$

$\phi = \tan^{-1}\left(\frac{a}{c}\right) = \tan^{-1}\left(\frac{200}{500}\right) = 21.8°$

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

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

$\underline{M}_A = bF_z\,\underline{j} - cF_{1_z}\,\underline{i} - cF_{1_x}\,\underline{k} = 0.4F_z\,\underline{j} - 0.5(402)\,\underline{i} - 0.5(201)\,\underline{k}$

$\underline{M}_A = -201\,\underline{i} + 0.4F_z\,\underline{j} - 100.6\,\underline{k}\ N\cdot m$

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

$30 = 0.371F_z - 74.7 \longrightarrow \underline{F_z = 282\ N}$

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**2/127** Using the coordinates of the figure:

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

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

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

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

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

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**2/128** Moment of couple is $240(\underline{j}\cos 30° - \underline{k}\sin 30°)$

$= 207.8\underline{j} - 120\underline{k}$ N·m

Moment of force is

$1200\cos 30°(-0.250\underline{i} + 0.200\underline{k}) + 1200\sin 30°(0.200\underline{j})$

$= -259.8\underline{i} + 120\underline{j} + 207.8\underline{k}$ N·m

Thus total moment is

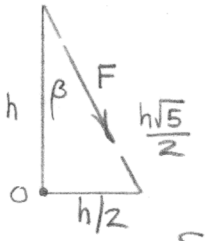
$\underline{M}_O = -259.8\underline{i} + 327.8\underline{j} + 87.8\underline{k}$ N·m

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

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**2/129**




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

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

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

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

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

$$\underline{M}_O = \underline{r}\times\underline{F} = h\underline{k}\times\frac{F}{\sqrt{5}}\left[\cos\theta\,\underline{i} + \sin\theta\,\underline{j} - 2\underline{k}\right]$$

$$= \frac{Fh}{\sqrt{5}}\left(\cos\theta\,\underline{j} - \sin\theta\,\underline{i}\right)$$

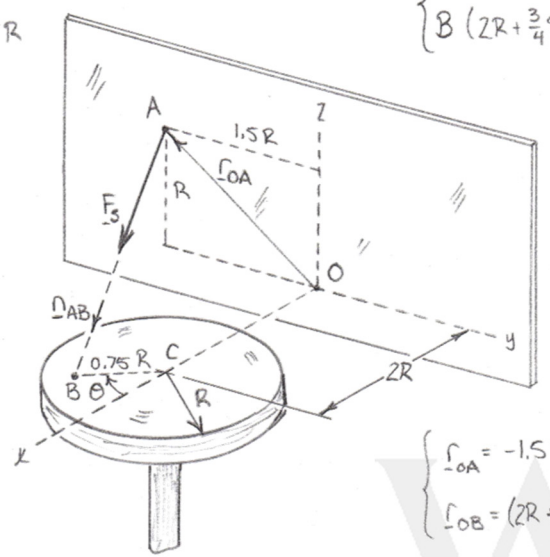
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***2/130**

$L_0 = 1.5R$

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




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

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

$$\underline{\Omega}_{AB} = \frac{(8 + 3\cos\theta)\,\underline{i} + (6 - 3\sin\theta)\,\underline{j} - 4\,\underline{k}}{\sqrt{125 + 48\cos\theta - 36\sin\theta}}$$

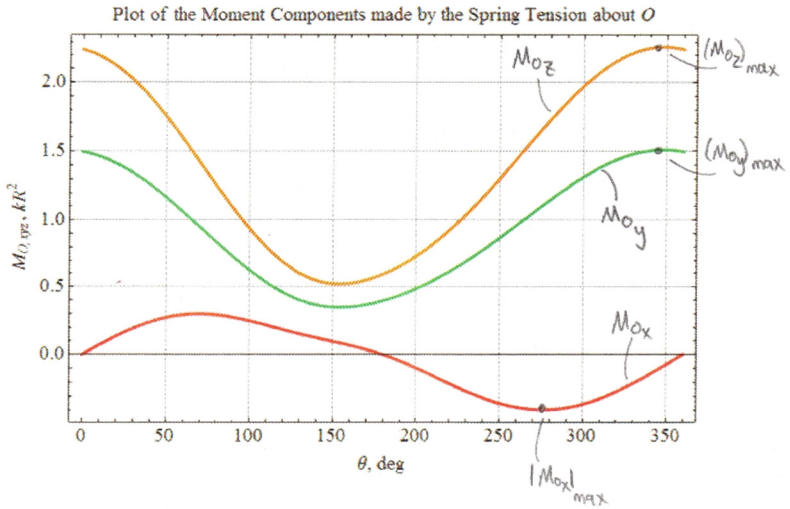
$$d = |\underline{r}_{OB} - \underline{r}_{OA}| = \frac{R}{4}\sqrt{125 + 48\cos\theta - 36\sin\theta}$$

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

$$\underline{F}_s = k\delta\,\underline{\Omega}_{AB}$$

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

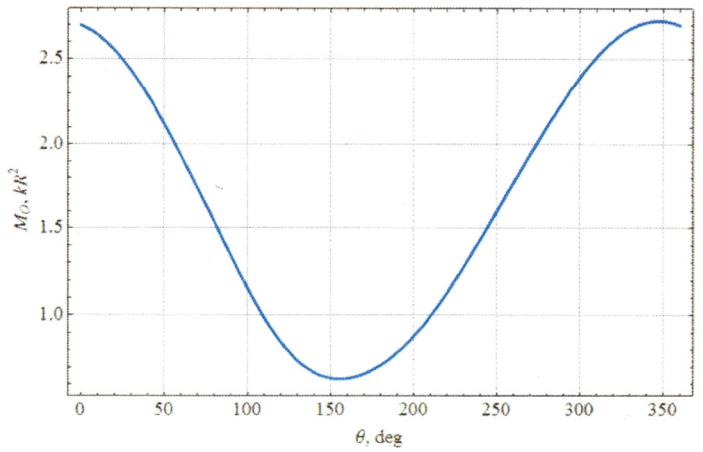
CARRY OUT THE CROSS PRODUCT AND PLOT THE MOMENT COMPONENTS.




$$|M_{Ox}|_{max} = 0.398\ kR^2 \quad \text{AT} \quad \theta = 277^\circ$$

$$|M_{Oy}|_{max} = 1.509\ kR^2 \quad \text{AT} \quad \theta = 348^\circ$$

$$|M_{Oz}|_{max} = 2.26\ kR^2 \quad \text{AT} \quad \theta = 348^\circ$$




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

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**2/131**

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

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

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

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

$$\theta = 33.7^\circ$$

Then $F_3 = 10.82 \text{ kN}$

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

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**2/132** $R = \Sigma F = 160 + 200 + 80 + 160 = 600\ \text{N} \downarrow$

$$\underline{M}_O = (-200-160)(0.6)\underline{i} + (80+160)(0.9)\underline{j}$$

$$= -216\underline{i} + 216\underline{j}\ \text{N}\cdot\text{m}$$

$$\underline{R}\cdot\underline{M}_O = -600\underline{k}\cdot(-216\underline{i} + 216\underline{j}) = 0, \quad \underline{R} \perp \underline{M}_O$$

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**2/133**

$$\underline{R} = -2F\underline{k} + F\underline{k} + F(\cos 30^\circ \underline{k} + \sin 30^\circ \underline{j})$$

$$= \frac{F}{2}\underline{j} + F\left(\frac{\sqrt{3}}{2} - 1\right)\underline{k} = \underline{F\left(\frac{1}{2}\underline{j} + \left(\frac{\sqrt{3}}{2} - 1\right)\underline{k}\right)}$$

$$\underline{M}_o = 2Fb\underline{j} + Fb\underline{i} + \frac{F}{2}(2b)\underline{k} + \frac{\sqrt{3}}{2}Fb\underline{i} - \frac{\sqrt{3}}{2}F(2b)\underline{j}$$

$$= \underline{Fb\left[\left(1 + \frac{\sqrt{3}}{2}\right)\underline{i} + (2 - \sqrt{3})\underline{j} + \underline{k}\right]}$$

$$\underline{R} \cdot \underline{M}_o = \left[\frac{1}{2}(2 - \sqrt{3}) + \left(\frac{\sqrt{3}}{2} - 1\right)(1)\right]F^2 b = 0, \text{ so}$$

$\underline{R} \perp \underline{M}_o$.

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

$\underline{M}_G = 50(10)\underline{k} + 8(6)\underline{j} + 8(40)\underline{k}$

$= 48\underline{j} + 820\underline{k}$ kN·m

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

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

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

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

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

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**2/136** The two 160-N forces constitute a couple $160(0.250)\underline{j} = 40\underline{j}$ N·m

$\underline{R} = \Sigma \underline{F} = 120\underline{i} - 180\underline{j} - 100\underline{k}$ N

$\underline{M} = \Sigma \underline{M}_A = [120(0.25) + 100(0.3) + 40]\underline{j} + 50\underline{k}$ N·m

$= 100\underline{j} + 50\underline{k}$ N·m

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**2/137**

$$\underline{R} = \Sigma \underline{F} = 600(\sin 30^\circ \underline{j} + \cos 30^\circ \underline{k}) + 800(-\sin 45^\circ \underline{j} + \cos 45^\circ \underline{k})$$

$$= \underline{-266\underline{j} + 1085\underline{k}} \ \text{N}$$

$$\underline{M}_O = -0.080\underline{i} \times 600(\sin 30^\circ \underline{j} + \cos 30^\circ \underline{k}) + 0.160\underline{i} \times 800(-\sin 45^\circ \underline{j} + \cos 45^\circ \underline{k})$$

$$= \underline{-48.9\underline{j} - 114.5\underline{k}} \ \text{N·m}$$

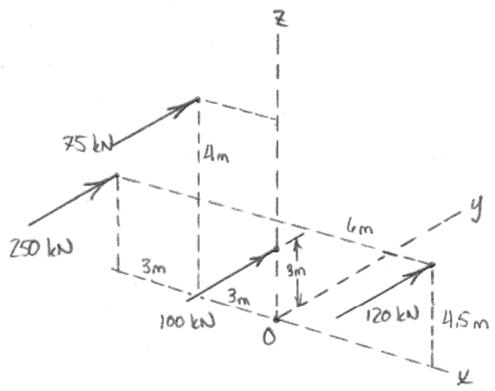
$\underline{R}$ is not perpendicular to $\underline{M}_O$, because

$\underline{R} \cdot \underline{M}_O \neq 0$.

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2/138




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

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

$\underline{M}_O = -[120(4.5) + 100(3) + 250(4.5) + 75(8.5)]\,\underline{i} + [120(6) - 75(3) - 250(6)]\,\underline{k}$

$\underline{M}_O = -2600\,\underline{i} - 1010\,\underline{k}$ kN·m

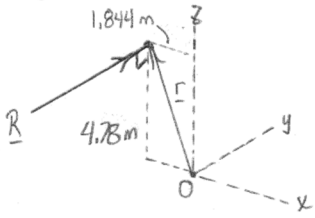
$\underline{r} \times \underline{R} = \underline{M}_O \longrightarrow (x\underline{i} + z\underline{k}) \times 545\,\underline{j} = -2600\,\underline{i} - 1010\,\underline{k}$

$\underline{i}$: $-545z = -2600$

$\underline{k}$: $545x = -1010$

Solving... $x = -1.844$ m $\quad z = 4.78$ m

$P = (-1.844, 0, 4.78)$ m




Engineering Mechanics Statics 9th edition Meriam Solutions Manual

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**2/139**

$$\underline{R} = (200 + 800)\underline{i} + 1200(\cos 10^\circ \underline{j} - \sin 10^\circ \underline{i})$$

$$= \underline{792\,\underline{i} + 1182\,\underline{j}\ \text{N}}$$

$$\underline{M}_O = [(200-800)(0.1) + (1200\cos 10^\circ)(0.075)]\underline{k}$$

$$+ [-(200+800)(0.220+0.330) + 1200\sin 10^\circ (0.220)]\underline{j}$$

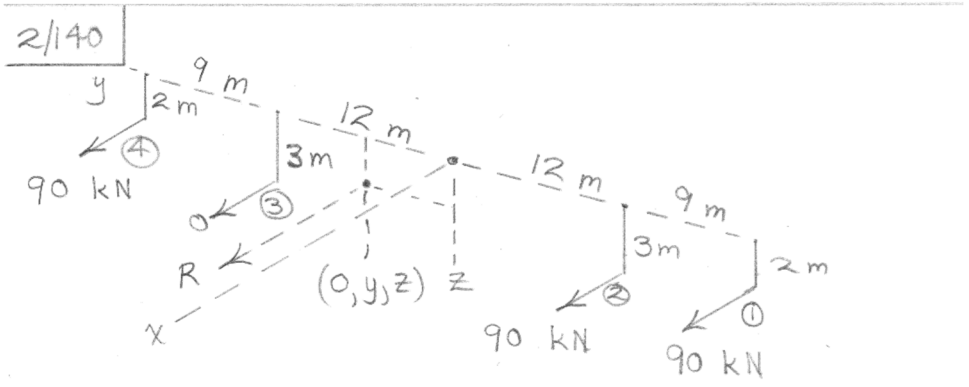
$$+ [1200\cos 10^\circ (0.220)]\underline{i}$$

$$= \underline{260\,\underline{i} - 504\,\underline{j} + 28.6\,\underline{k}\ \text{N}\cdot\text{m}}$$

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2/140




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

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

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

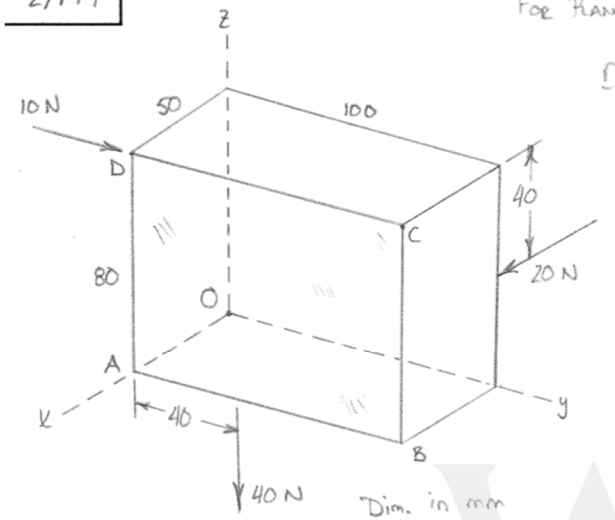
$$\Sigma M_y = Rz : 2(90)(2) + 90(3) = 270z$$

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

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**2/141**




For plane ABCD

$\underline{r} = 50\,\underline{i} + y\,\underline{j} + z\,\underline{k}$ mm

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

$\underline{n} = \dfrac{\underline{R}}{R} = \dfrac{1}{\sqrt{21}}(2\,\underline{i} + \underline{j} - 4\,\underline{k})$

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

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

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

$\underline{M} = M\,\underline{n} = 0.873\left(\dfrac{2}{\sqrt{21}}\,\underline{i} + \dfrac{1}{\sqrt{21}}\,\underline{j} - \dfrac{4}{\sqrt{21}}\,\underline{k}\right) \rightarrow \underline{M} = 0.381\,\underline{i} + 0.1905\,\underline{j} - 0.762\,\underline{k}$ N·m

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

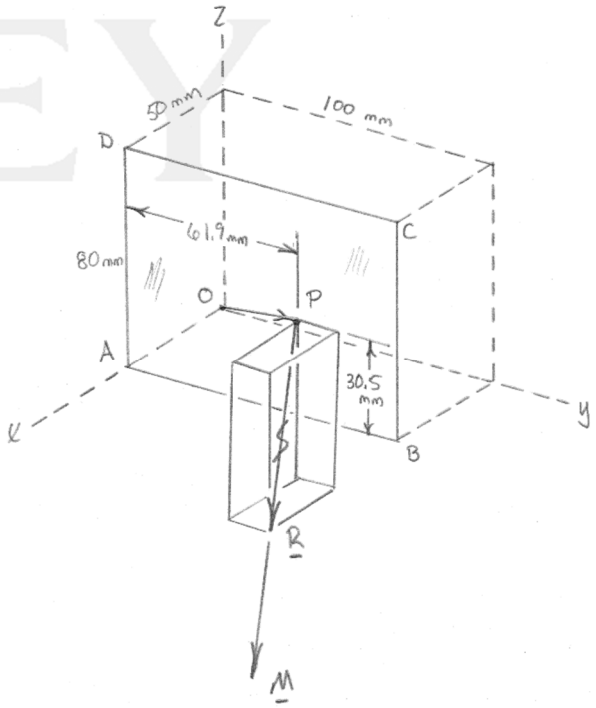
$\ldots\ 0.762\,\underline{k} = -2.4\,\underline{i} + 2.8\,\underline{j} - 1.5\,\underline{k}$

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

Solving...

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

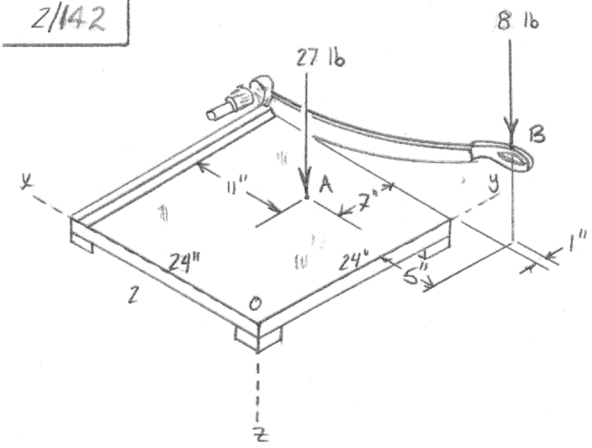
$P = (50, 61.9, 30.5)$ mm




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**2/142**



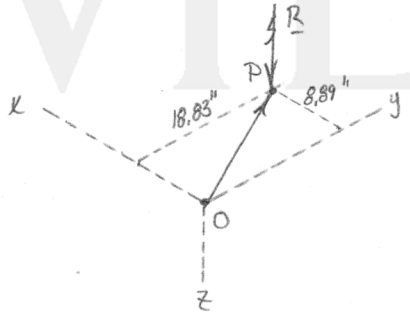

$\underline{R} = 35\underline{k}$ lb

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

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

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

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

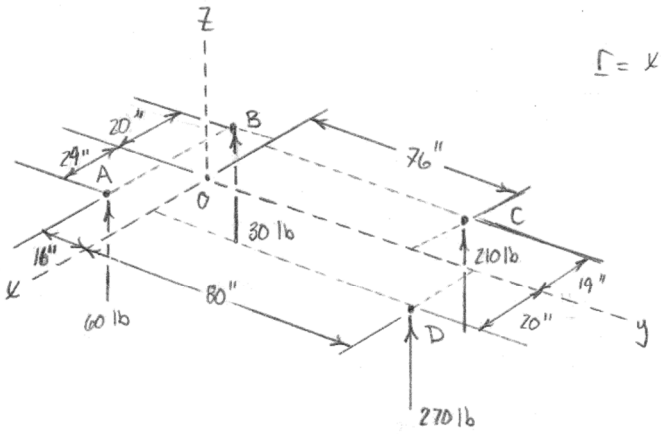



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**2/143**

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



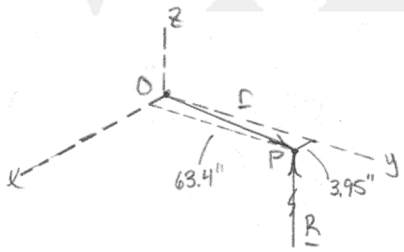

$$\underline{r} = x\underline{i} + y\underline{j}$$

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

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

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

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




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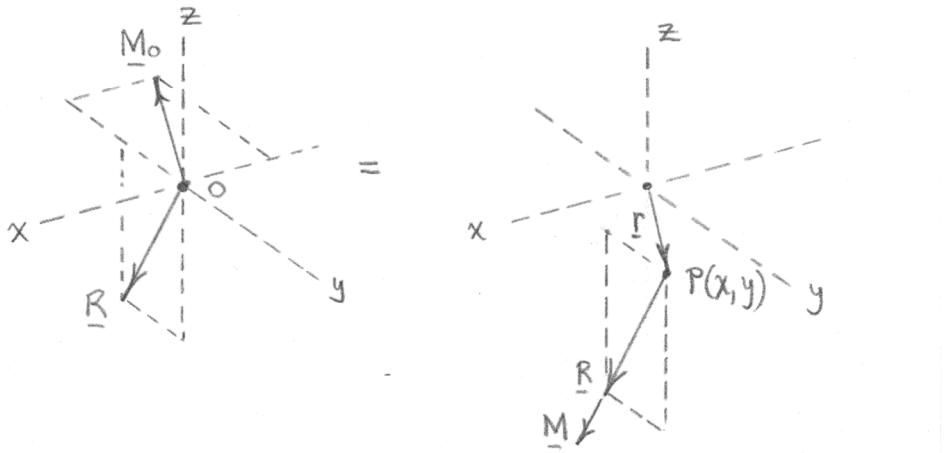
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**2/144**

$$\underline{R} = -20\underline{j} - 40\underline{k} \text{ lb} \quad (= 44.7(-0.447\underline{j} - 0.894\underline{k}))$$

$$\underline{M}_O = -40(1.4)\underline{i} - 40(8)\underline{j}$$

$$= -56\underline{i} - 320\underline{j} \text{ lb-in.}$$




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

Equate coefficients:

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

Solution:

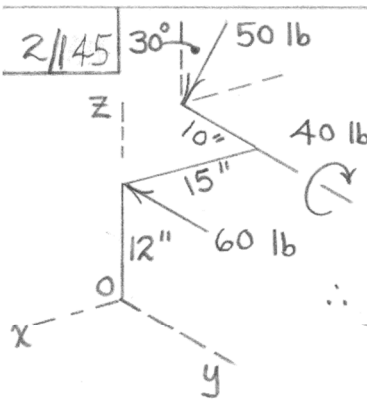
$x = -6.4$ in.

$y = 1.4$ in.

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**2/145**




$R_x = \Sigma F_x = 50 \sin 30^\circ = 25$ lb

$R_y = \Sigma F_y = -60$ lb

$R_z = \Sigma F_z = -50 \cos 30^\circ = -43.3$ lb

$\therefore \underline{R} = 25\underline{i} - 60\underline{j} - 43.3\underline{k}$ lb

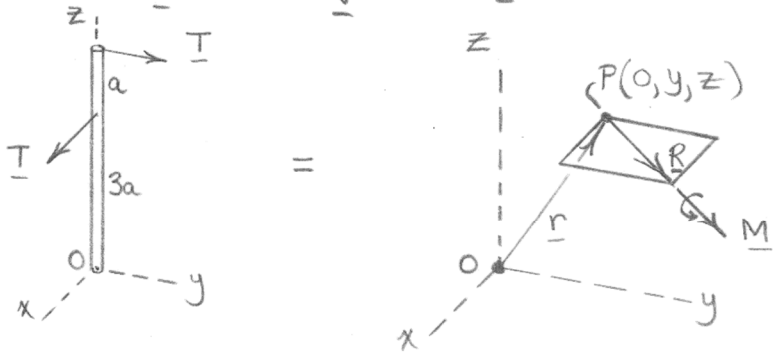
$$\underline{M}_O = 12(60)\underline{i} + 50 \sin 30^\circ (12)\underline{j} + 50 \sin 30^\circ (10)\underline{k}$$
$$+ 50 \cos 30^\circ (10)\underline{i} - 50 \cos 30^\circ (15)\underline{j} - 40(12)\underline{j}$$
$$= 1153\underline{i} - 830\underline{j} + 250\underline{k} \text{ lb-in.}$$

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

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




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

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

$$\Rightarrow \begin{cases} -4aT = -zT + \frac{M}{\sqrt{2}} \\ 3aT = zT + \frac{M}{\sqrt{2}} \\ 0 = -yT \end{cases} \quad \text{So} \quad \begin{cases} y = 0 \\ z = \frac{7}{2}a \\ M = -\frac{\sqrt{2}}{2}aT \end{cases}$$

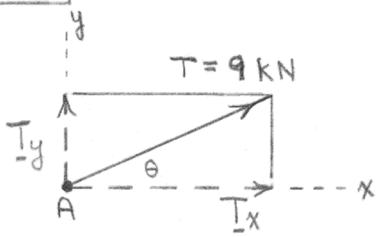
So $\underline{M} = -\frac{\sqrt{2}}{2}aT\left(\frac{1}{\sqrt{2}}\underline{i} + \frac{1}{\sqrt{2}}\underline{j}\right)$

$= \underline{\frac{-aT}{2}(\underline{i} + \underline{j})}$ (a negative wrench)

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**2|147**




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

$T_x = T\cos\theta = 9\cos 31.0°$

$= 7.72$ kN

$T_y = T\sin\theta = 9\sin 31.0°$

$= 4.63$ kN

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

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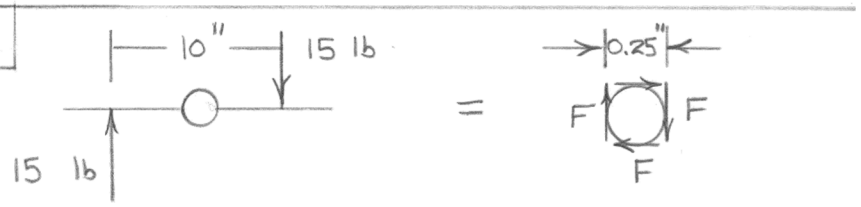
2/148

$$\begin{cases} \underline{M}_1 = -cF_1\underline{i} \\ \underline{M}_2 = cF_2\underline{i} - aF_2\underline{k} = F_2(c\underline{i} - a\underline{k}) \\ \underline{M}_3 = -aF_3\underline{k} \end{cases}$$

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**2/149**

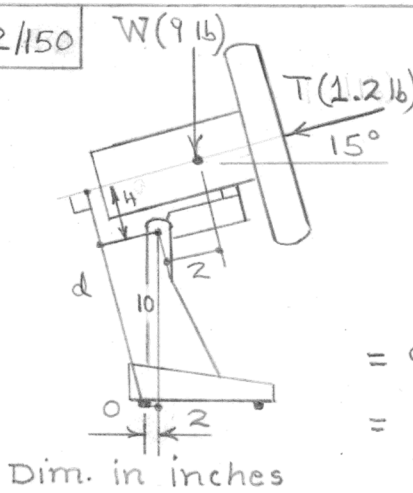



$M = Fd = 15(10) = 2F(0.25)$, $F = 300$ lb

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**2/150**




$$M_O = Fd$$
$$= 1.2(4 + 10\cos 15^\circ - 2\sin 15^\circ)$$
$$= 15.77 \text{ lb-in.} \quad (\curvearrowleft)$$

$$M_{O_W} = W d_W$$
$$= 9(2 + 2\cos 15^\circ - 4\sin 15^\circ)$$
$$= 26.1 \text{ lb-in.} \quad (\curvearrowright)$$

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**2/151** $\underline{P} = P\left(\frac{4}{5}\underline{i} + \frac{3}{5}\underline{j}\right)$ ; $\underline{r}_{AB} = b\left(-\underline{i} + \underline{j} + \underline{k}\right)$

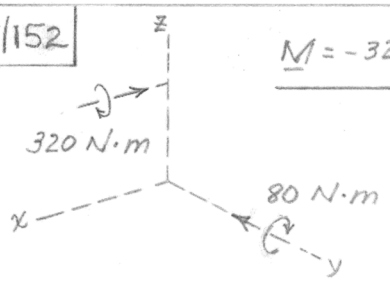
Carry out $\underline{M}_A = \underline{r}_{AB} \times \underline{P}$ to obtain

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

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**2/152**




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

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

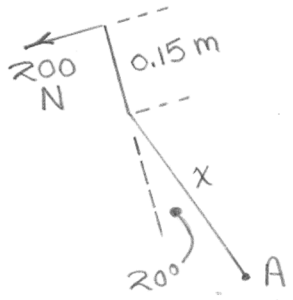
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**2/153**

$M_A = Fd$ : $80 = 200(0.15 + x\cos 20°)$

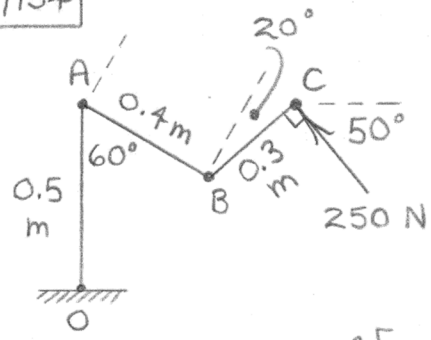
$x = 0.266\text{ m}$ or $\underline{266\text{ mm}}$




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2/154




$$\curvearrowleft M_O = 250\cos 50^\circ\left[0.5 - 0.4\cos 60^\circ + 0.3\sin 40^\circ\right]$$
$$+ 250\sin 50^\circ\left[0.4\sin 60^\circ + 0.3\cos 40^\circ\right]$$
$$= \underline{189.6 \text{ N·m CCW}}$$

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**2/155**

$$\underline{R} = 800\left[-\sin 30^\circ \cos 20^\circ \underline{i} + \sin 30^\circ \sin 20^\circ \underline{j} + \cos 30^\circ \underline{k}\right]$$

$$= \underline{-376\underline{i} + 136.8\underline{j} + 693\underline{k}} \quad \text{N}$$

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

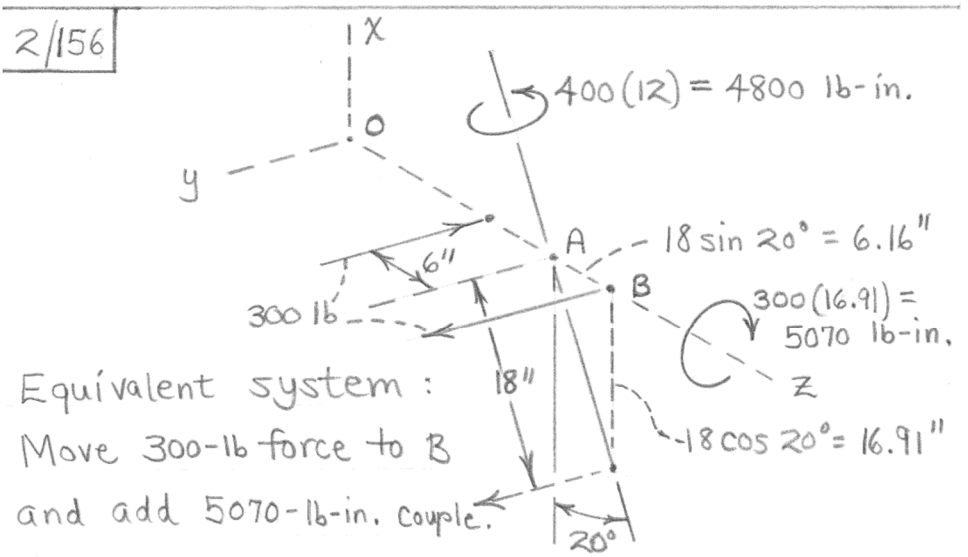
$$\underline{r}_{OB} = \left[300 \sin 20^\circ \underline{i} + 300 \cos 20^\circ \underline{j} + 250\underline{k}\right] \text{mm}$$

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

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**2/156**




Equivalent system:
Move 300-lb force to B
and add 5070-lb-in. couple.

The components of the resultant couple are

$M_X = -300(6+6.16) + 4800 \cos 20° = 864$ lb-in.

$M_Y = 0$

$M_Z = -4800 \sin 20° - 5070 = -6720$ lb-in.

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

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

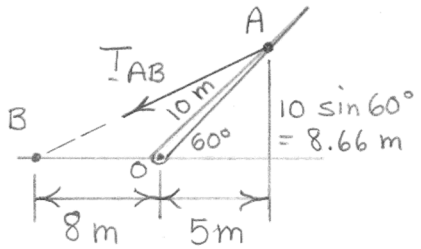
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**2/157**

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

$\overline{AB} = 15.62$ m




(a) $\underline{T}_{AB} = 3\left[-\frac{13}{15.62}\cos 35°\,\underline{i} - \frac{13}{15.62}\sin 35°\,\underline{j} - \frac{8.66}{15.62}\underline{k}\right]$

$= -2.05\underline{i} - 1.432\underline{j} - 1.663\underline{k}$ kN

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

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

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

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

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

we obtain $T_{AO} = 2.69$ kN

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**2/158**

$$\underline{R} = \Sigma \underline{F} = 500 \cos 45^\circ (\underline{i}) + 400 \underline{j} - (600 + 500 \sin 45^\circ) \underline{k}$$

$$= 354 \underline{i} + 400 \underline{j} - 954 \underline{k} \text{ lb}$$

$$R = \sqrt{354^2 + 400^2 + 954^2} = 1093 \text{ lb}$$

$$\underline{M} = [500 \cos 45^\circ (3) - 600 (3) - 400 (10)] \underline{i}$$
$$+ [500 \cos 45^\circ (6) + 500 \sin 45^\circ (7) + 600 (6)] \underline{j}$$
$$+ [500 \sin 45^\circ (3) + 400 (3)] \underline{k}$$

$$= -4739 \underline{i} + 8196 \underline{j} + 2261 \underline{k} \text{ lb-ft}$$

$$M = \sqrt{4739^2 + 8196^2 + 2261^2} = 9730 \text{ lb-ft}$$

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***2/159**

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

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

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

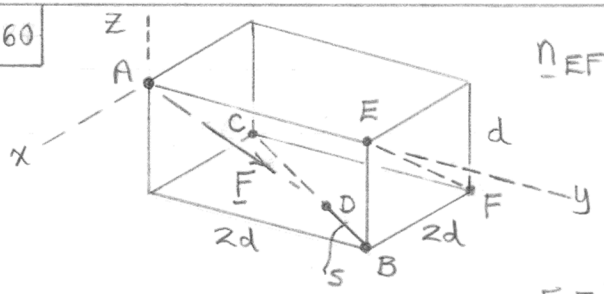
$$\theta = 21.7^\circ, \quad T = 204 \text{ lb}$$

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

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***2/160**




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

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

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

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

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

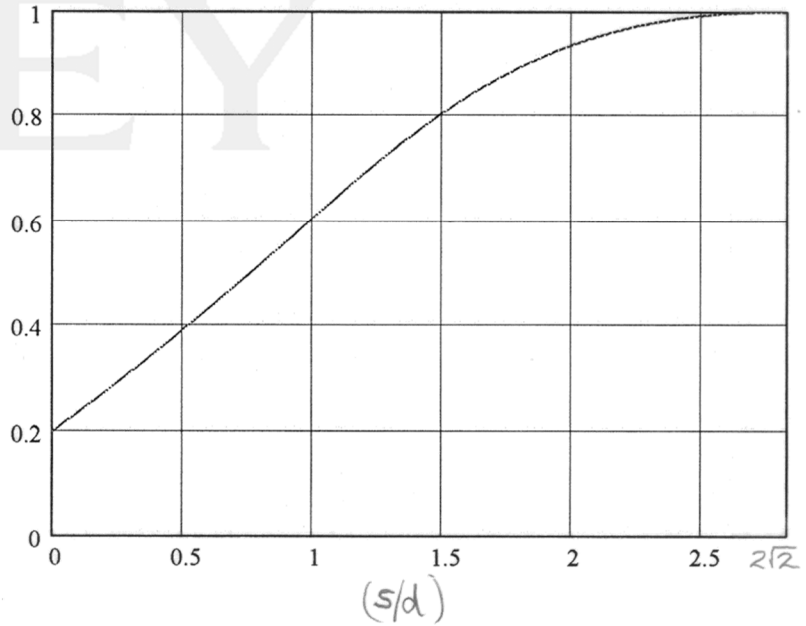
Carry out $\underline{F}\cdot\underline{n}_{EF}$ to obtain the projection

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

The nondimensionalized fraction n of the magnitude F projected is then

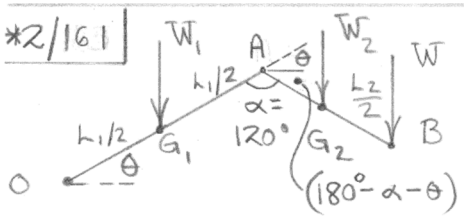
$$n = \frac{\underline{F}\cdot\underline{n}_{EF}}{F} = \frac{\sqrt{2}\,\frac{s}{d} + 1}{\sqrt{5}\sqrt{\left(\frac{s}{d}\right)^2 + 5 - 2\sqrt{2}\,\frac{s}{d}}}$$

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



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***2/161**




$$\begin{cases} W_1 = 120 \text{ lb} & h_1 = 3 \text{ ft} \\ W_2 = 50 \text{ lb} & h_2 = 2 \text{ ft} \\ W = 300 \text{ lb} & \alpha = 120^\circ \end{cases}$$

$$+\circlearrowleft M_O = W_1 \frac{h_1}{2}\cos\theta + W_2\left(h_1\cos\theta + \frac{L_2}{2}\cos(180^\circ - \alpha - \theta)\right) + W\left(h_1\cos\theta + h_2\cos(180^\circ - \alpha - \theta)\right)$$

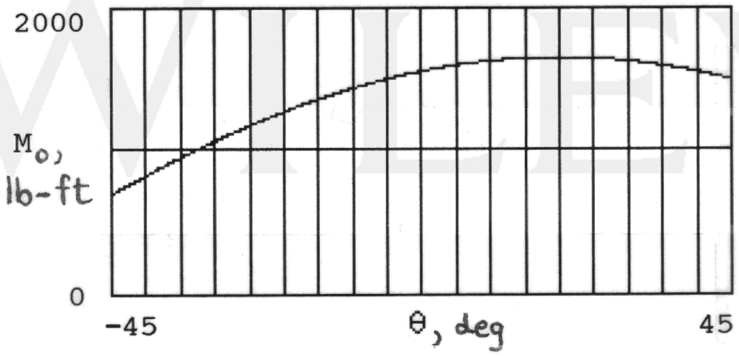
With the above numbers:

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

(see plot below)

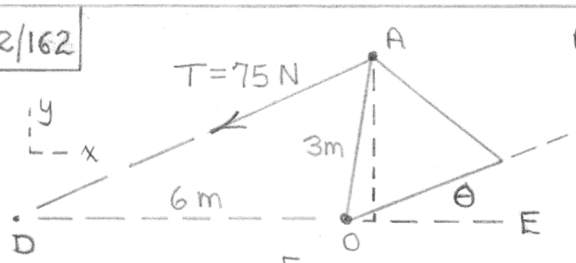
For $(M_O)_{max}$: $\frac{dM_O}{d\theta} = -1230\sin\theta + 650\sin(60^\circ - \theta) = 0$

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



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***2/162**




Angle $AOE = \theta + 60^\circ$

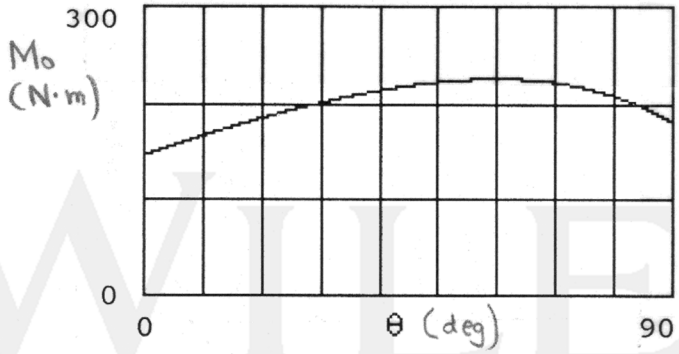
Use $\underline{M}_O = \underline{r}_{OD} \times \underline{T}$

$\underline{r}_{OD} = -6\underline{i}$ m

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

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

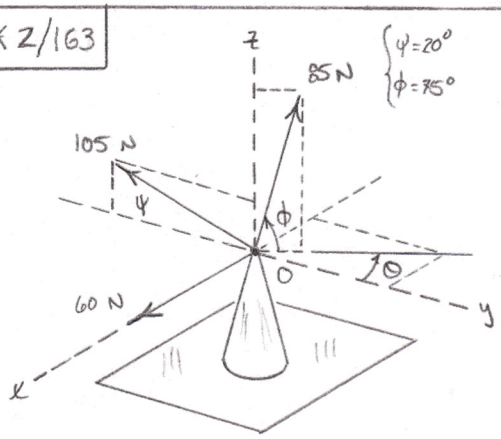
$M_O$ is a max @ $\theta = 60^\circ$ : $M_O = 225$ N·m




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## *2/163




$\psi = 20°$

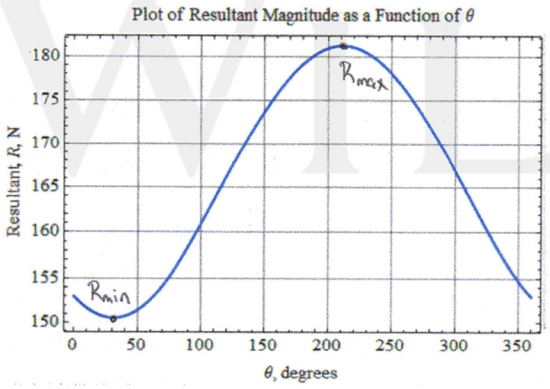
$\phi = 75°$

$$\underline{R} = (60 - 85\cos 75°\sin\theta)\hat{i} + (85\cos 75°\cos\theta - 105\cos 20°)\hat{j} + (85\sin 75° + 105\sin 20°)\hat{k}$$

$$\underline{R} = (60 - 22.0\sin\theta)\underline{i} + (22.0\cos\theta - 98.7)\underline{j} + 118.0\underline{k} \text{ N}$$

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

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




$R_{min} = 150.6$ N

$\theta_{min} = 31.3°$

$R_{max} = 181.2$ N

$\theta_{max} = 211°$

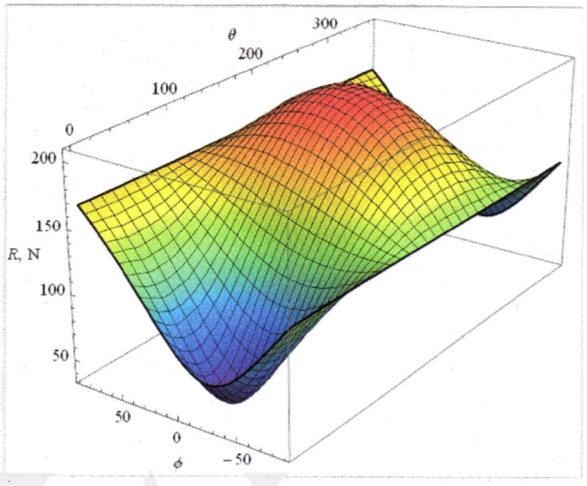
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* 2/164

FROM 2/163...

$$\underline{R} = (60 - 85\cos\phi\sin\theta)\underline{i} + (85\cos\phi\cos\theta - 105\cos 20)\underline{j} + (85\sin\phi + 105\sin 20)\underline{k}$$

$R = \sqrt{\underline{R}\cdot\underline{R}}$ AND WE PLOT FOR $0 \le \theta \le 360°$ AND $-90° \le \phi \le 90°$




$R_{min} = 35.9$ N

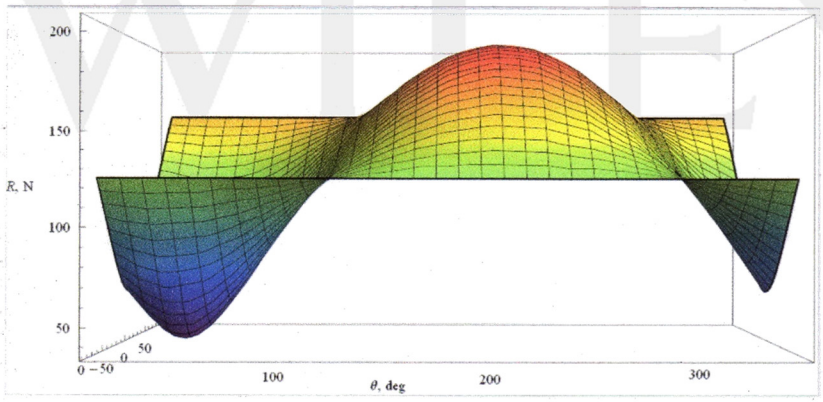
$\theta_{min} = 31.3°$

$\phi_{min} = -17.27°$

$R_{max} = 206$ N

$\theta_{max} = 211°$

$\phi_{max} = 17.27°$




Engineering Mechanics Statics 9th edition Meriam Solutions Manual

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***2/165** $\underline{T} = T\underline{n}_{AB}$




$$\underline{T} = T\left[\frac{(d+40\cos\beta)\underline{i} + 40(1-\sin\beta)\underline{j}}{\sqrt{(d+40\cos\beta)^2 + 40^2(1-\sin\beta)^2}}\right] \qquad \left(\beta = \theta + \frac{\pi}{4}\right)$$

$$\underline{r}_{OB} = (d\underline{i} + 40\underline{j})$$

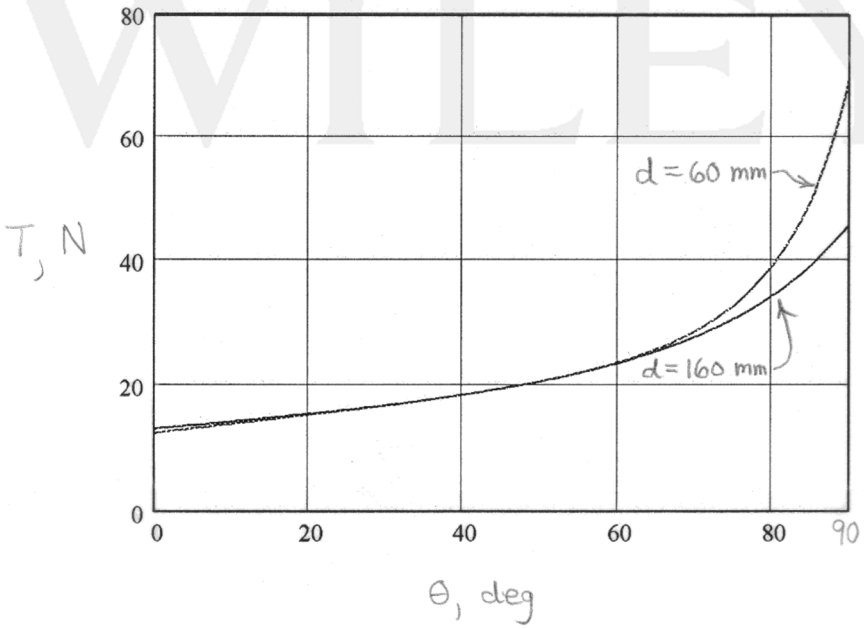
$$\Sigma \underline{M}_O = \underline{0}: \quad \underline{r}_{OB} \times \underline{T} + K\beta\underline{k} = \underline{0}$$

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

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

(T in N, θ in radians)

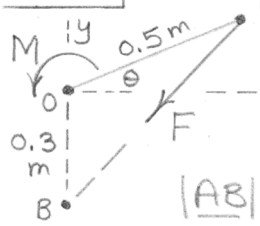
Plot of T versus θ for $d = 60$ mm and for $d = 160$ mm:




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***2/166**




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

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

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

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

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

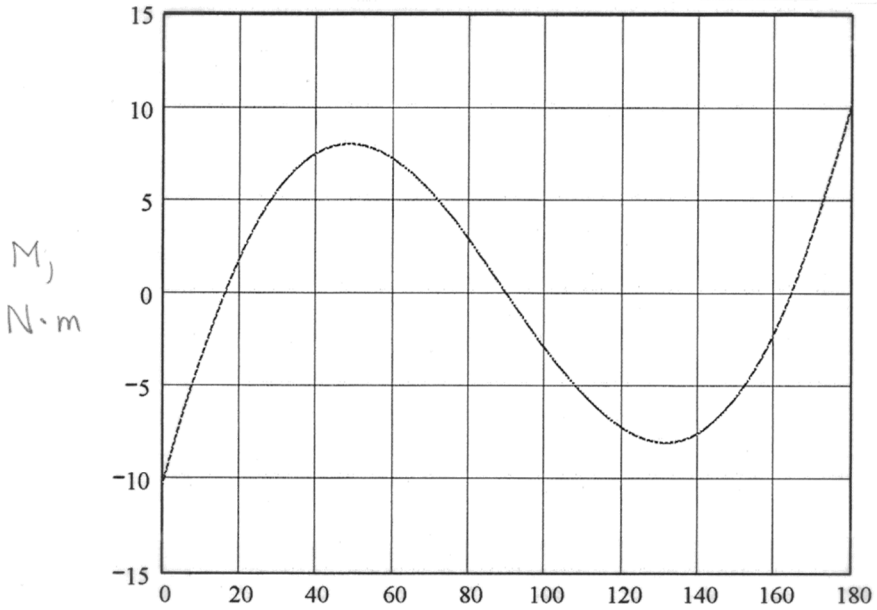
So

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

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

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: $M(0) = -10.33$ N·m
$M(180°) = 10.33$ N·m)

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