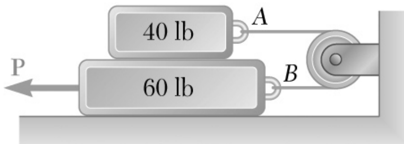
PROBLEM 8.11

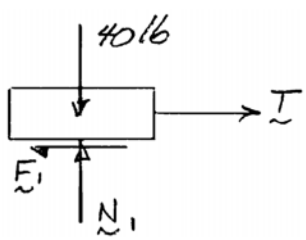


The coefficients of friction are $\mu_s = 0.40$ and $\mu_k = 0.30$ between all surfaces of contact. Determine the force **P** for which motion of the 60-lb block is impending if cable AB (a) is attached as shown, (b) is removed.

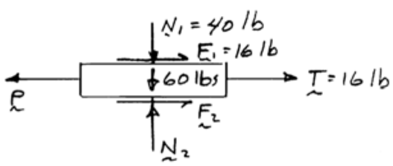
SOLUTION

FBDs

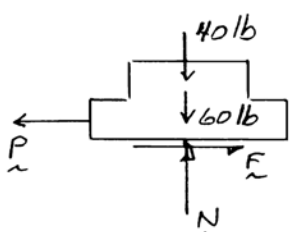
Top block:



Bottom block:



FBD blocks:



(a) Note: With the cable, motion must impend at both contact surfaces.

$$\uparrow \Sigma F_y = 0: \quad N_1 - 40 \text{ lb} = 0 \qquad N_1 = 40 \text{ lb}$$

Impending slip: $F_1 = \mu_s N_1 = 0.4(40 \text{ lb}) = 16 \text{ lb}$

$$\longrightarrow \Sigma F_x = 0: \quad T - F_1 = 0 \qquad T - 16 \text{ lb} = 0 \qquad T = 16 \text{ lb}$$

$$\uparrow \Sigma F_y = 0: \quad N_2 - 40 \text{ lb} - 60 \text{ lb} = 0 \qquad N_2 = 100 \text{ lb}$$

Impending slip: $F_2 = \mu_s N_2 = 0.4(100 \text{ lb}) = 40 \text{ lb}$

$$\longrightarrow \Sigma F_x = 0: \quad -P + 16 \text{ lb} + 16 \text{ lb} + 40 \text{ lb} = 0$$

$$\mathbf{P} = 72.0 \text{ lb} \longleftarrow \blacktriangleleft$$

(b) Without the cable, both blocks will stay together and motion will impend only at the floor.

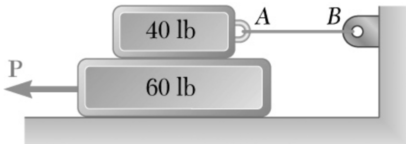
$$\uparrow \Sigma F_y = 0: \quad N - 40 \text{ lb} - 60 \text{ lb} = 0 \qquad N = 100 \text{ lb}$$

Impending slip: $F = \mu_s N = 0.4(100 \text{ lb}) = 40 \text{ lb}$

$$\longrightarrow \Sigma F_x = 0: \quad 40 \text{ lb} - P = 0$$

$$\mathbf{P} = 40.0 \text{ lb} \longleftarrow \blacktriangleleft$$

PROBLEM 8.12

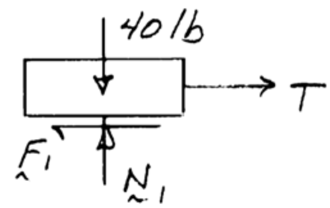


The coefficients of friction are $\mu_s = 0.40$ and $\mu_k = 0.30$ between all surfaces of contact. Determine the force **P** for which motion of the 60-lb block is impending if cable *AB* (*a*) is attached as shown, (*b*) is removed.

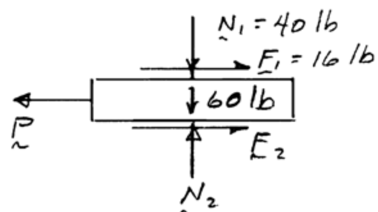
SOLUTION

FBDs

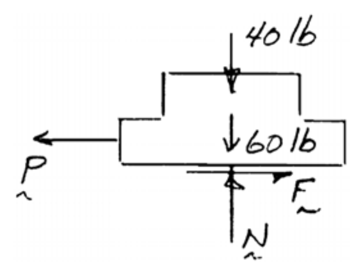
Top block:



Bottom block:



FBD blocks:



(*a*) With the cable, motion must impend at both surfaces.

$$\uparrow \Sigma F_y = 0: \quad N_1 - 40 \text{ lb} = 0 \qquad N_1 = 40 \text{ lb}$$

Impending slip: $F_1 = \mu_s N_1 = 0.4(40 \text{ lb}) = 16 \text{ lb}$

$$\uparrow \Sigma F_y = 0: \quad N_2 - 40 \text{ lb} - 60 \text{ lb} = 0 \qquad N_2 = 100 \text{ lb}$$

Impending slip: $F_2 = \mu N_2 = 0.4(100 \text{ lb}) = 40 \text{ lb}$

$$\longrightarrow \Sigma F_x = 0: \quad 16 \text{ lb} + 40 \text{ lb} - P = 0 \qquad P = 56 \text{ lb}$$

$\mathbf{P} = 56.0 \text{ lb} \longleftarrow$ ◀

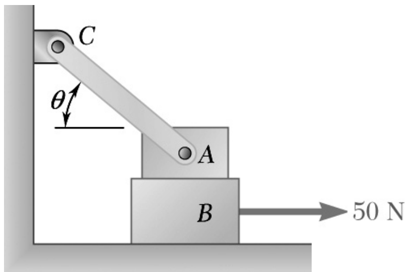
(*b*) Without the cable, both blocks stay together and motion will impend at the floor surface only.

$$\uparrow \Sigma F_y = 0: \quad N - 40 \text{ lb} - 60 \text{ lb} = 0 \qquad N = 100 \text{ lb}$$

Impending slip: $F = \mu_s N = 0.4(100 \text{ lb}) = 40 \text{ lb}$

$$\longrightarrow \Sigma F_x = 0: \quad -P + 40 \text{ lb} = 0 \qquad P = 40 \text{ lb}$$

$\mathbf{P} = 40.0 \text{ lb} \longleftarrow$ ◀

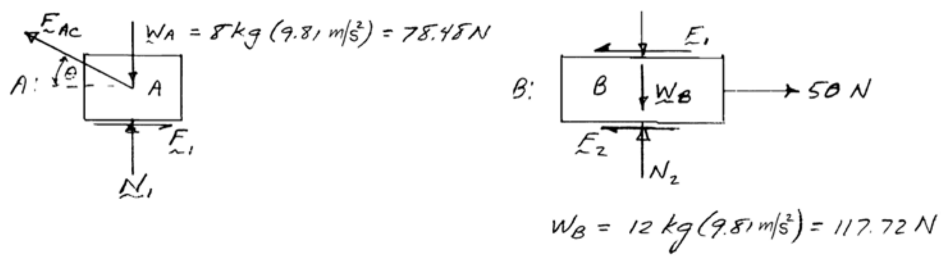


PROBLEM 8.13

The 8-kg block A is attached to link AC and rests on the 12-kg block B. Knowing that the coefficient of static friction is 0.20 between all surfaces of contact and neglecting the mass of the link, determine the value of θ for which motion of block B is impending.

SOLUTION

FBDs:



Motion must impend at both contact surfaces

Block A: $\uparrow \Sigma F_y = 0: \quad N_1 - W_A = 0 \qquad N_1 = W_A$

Block B: $\uparrow \Sigma F_y = 0: \quad N_2 - N_1 - W_B = 0$

$$N_2 = N_1 + W_B = W_A + W_B$$

Impending motion:

$$F_1 = \mu_s N_1 = \mu_s W_A$$

$$F_2 = \mu_s N_2 = \mu_s\left(N_1 + W_B\right)$$

Block B: $\longrightarrow \Sigma F_x = 0: \quad 50\text{ N} - F_1 - F_2 = 0$

or $\quad 50\text{ N} = \mu_s\left(N_1 + N_1 + W_B\right) = 0.2\left(2N_1 + 117.72\text{ N}\right)$

$$N_1 = 66.14\text{ N} \qquad F_1 = 0.2\left(66.14\text{ N}\right) = 13.228\text{ N}$$

Block A: $\longrightarrow \Sigma F_x = 0: \quad 13.228\text{ N} - F_{AC}\cos\theta = 0$

or

$$F_{AC}\cos\theta = 13.228\text{ N} \tag{1}$$

$$\uparrow \Sigma F_y = 0: \quad 66.14\text{ N} - 78.48\text{ N} + F_{AC}\sin\theta = 0$$

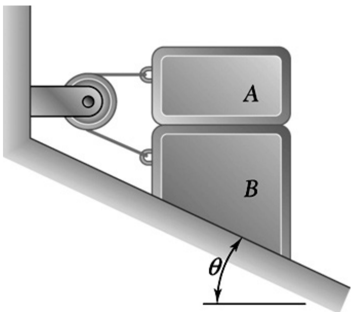
or

$$F_{AC}\sin\theta = 78.48\text{ N} - 66.14\text{ N} \tag{2}$$

Then, $\dfrac{\text{Eq. (2)}}{\text{Eq. (1)}}$

$$\tan\theta = \frac{78.48\text{ N} - 66.14\text{ N}}{13.228\text{ N}}$$

$\theta = 43.0° \blacktriangleleft$

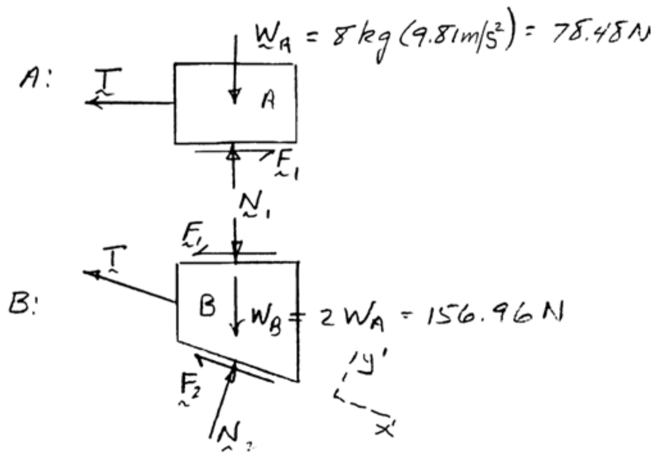


PROBLEM 8.14

The 8-kg block A and the 16-kg block B are at rest on an incline as shown. Knowing that the coefficient of static friction is 0.25 between all surfaces of contact, determine the value of θ for which motion is impending.

SOLUTION

FBDs:



Block A: $\quad \uparrow \Sigma F_y = 0: \quad N_1 - W_A = 0 \qquad N_1 = W_A$

Impending motion: $\quad F_1 = \mu_s N_1 = \mu_s W_A$

$\rightarrow \Sigma F_x = 0: \quad F_1 - T = 0 \qquad T = F_1 = \mu_s W_A$

Block B: $\quad \nearrow \Sigma F_{y'} = 0: \quad N_2 - (N_1 + W_B)\cos\theta - F_1 \sin\theta = 0$

$$N_2 = 3W_A \cos\theta + \mu_s W_A \sin\theta$$

$$= W_A(3\cos\theta + 0.25\sin\theta)$$

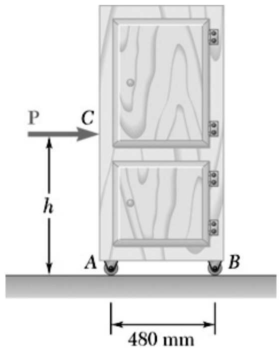
Impending motion: $\quad F_2 = \mu_s N_2 = 0.25 W_A(3\cos\theta + 0.25\sin\theta)$

$\searrow \Sigma F_{x'} = 0: \quad -T - F_2 - F_1\cos\theta + (N_1 + W_B)\sin\theta = 0$

$$\left[-0.25 - 0.25(3\cos\theta + 0.25\sin\theta) - 0.25\cos\theta + 3\sin\theta\right]W_A = 0$$

or $\quad 47\sin\theta - 16\cos\theta - 4 = 0$

Solving numerically $\qquad \theta = 23.4° ◀$

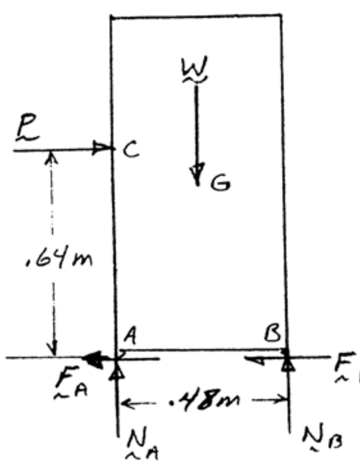


PROBLEM 8.15

A 48-kg cabinet is mounted on casters which can be locked to prevent their rotation. The coefficient of static friction between the floor and each caster is 0.30. Knowing that $h = 640$ mm, determine the magnitude of the force **P** required for impending motion of the cabinet to the right (*a*) if all casters are locked, (*b*) if the casters at *B* are locked and the casters at *A* are free to rotate, (*c*) if the casters at *A* are locked and the casters at *B* are free to rotate.

SOLUTION

FBD cabinet:



$$W = 48\text{ kg}\left(9.81\text{ m/s}^2\right)$$

$$= 470.88\text{ N}$$

$$\mu_s = 0.3$$

Note: For tipping, $N_A = F_A = 0$

$$\circlearrowleft \Sigma M_B = 0: \quad (0.24\text{ m})W - (0.64\text{ m})P_{\text{tip}} = 0 \qquad P_{\text{tip}} = 0.375W$$

(*a*) All casters locked: Impending slip: $F_A = \mu_s N_A,\ F_B = \mu_s N_B$

$$\uparrow \Sigma F_y = 0: \quad N_A + N_B - W = 0 \qquad N_A + N_B = W$$

So $F_A + F_B = \mu_s W$

$$\longrightarrow \Sigma F_x = 0: \quad P - F_A - F_B = 0 \qquad P = F_A + F_B = \mu_s W$$

$$\therefore \quad P = 0.3(470.88\text{ N}) \qquad \text{or} \qquad P = 141.3\text{ N} \blacktriangleleft$$

$$\left(P = 0.3W < P_{\text{tip}} \qquad \text{OK}\right)$$

(*b*) Casters at *A* free, so $F_A = 0$

Impending slip: $F_B = \mu_s N_B$

$$\longrightarrow \Sigma F_x = 0: \quad P - F_B = 0$$

$$P = F_B = \mu_s N_B \qquad N_B = \frac{P}{\mu_s}$$

$$\circlearrowleft \Sigma M_A = 0: \quad (0.64\text{ m})P + (0.24\text{ m})W - (0.48\text{ m})N_B = 0$$

$$8P + 3W - 6\frac{P}{0.3} = 0 \qquad P = 0.25W$$

$$\left(P = 0.25W < P_{\text{tip}} \qquad \text{OK}\right)$$

$$\therefore \quad P = 0.25(470.88\text{ N}) \qquad P = 117.7\text{ N} \blacktriangleleft$$

PROBLEM 8.15 CONTINUED

(*c*) Casters at *B* free, so $F_B = 0$

Impending slip: $F_A = \mu_s N_A$

$\xrightarrow{\quad} \Sigma F_x = 0$: $P - F_A = 0 \qquad P = F_A = \mu_s N_A$

$$N_A = \frac{P}{\mu_s} = \frac{P}{0.3}$$

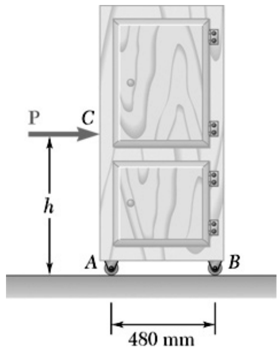
$\circlearrowright \Sigma M_B = 0$: $(0.24\text{ m})W - (0.64\text{ m})P - (0.48\text{ m})N_A = 0$

$$3W - 8P - 6\frac{P}{0.3} = 0 \qquad P = 0.10714W = 50.45\text{ N}$$

$$\left(P < P_{\text{tip}} \qquad \text{OK}\right)$$

$P = 50.5\text{ N}$ ◀

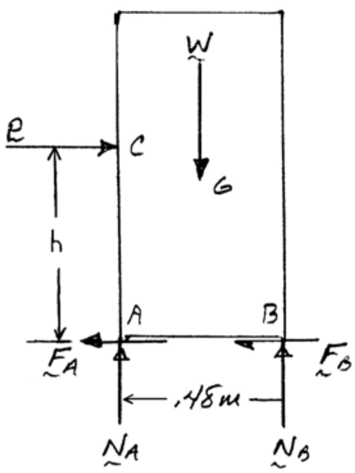
PROBLEM 8.16



A 48-kg cabinet is mounted on casters which can be locked to prevent their rotation. The coefficient of static friction between the floor and each caster is 0.30. Assuming that the casters at A and B are locked, determine (a) the force **P** required for impending motion of the cabinet to the right, (b) the largest allowable height h if the cabinet in not to tip over.

SOLUTION

FBD cabinet:



$$W = 48 \text{ kg}\left(9.81 \text{ m/s}^2\right)$$

$$= 470.88 \text{ N}$$

(a) $\uparrow \Sigma F_y = 0: \quad N_A + N_B - W = 0; \qquad N_A + N_B = W$

Impending slip: $\quad F_A = \mu_s N_A,\ F_B = \mu_s N_B$

So $\quad F_A + F_B = \mu_s W$

$\longrightarrow \Sigma F_x = 0: \quad P - F_A - F_B = 0 \qquad P = F_A + F_B = \mu_s W$

$$P = 0.3\left(470.88 \text{ N}\right) = 141.26 \text{ N}$$

$$\mathbf{P} = 141.3 \text{ N} \longrightarrow \blacktriangleleft$$

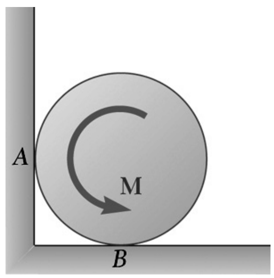
(b) For tipping, $\quad N_A = F_A = 0$

$\circlearrowleft \Sigma M_B = 0: \quad hP - \left(0.24 \text{ m}\right)W = 0$

$$h_{\max} = \left(0.24 \text{ m}\right)\frac{W}{P} = \left(0.24 \text{ m}\right)\frac{1}{\mu_s} = \frac{0.24 \text{ m}}{0.3}$$

$$h_{\max} = 0.800 \text{ m} \blacktriangleleft$$

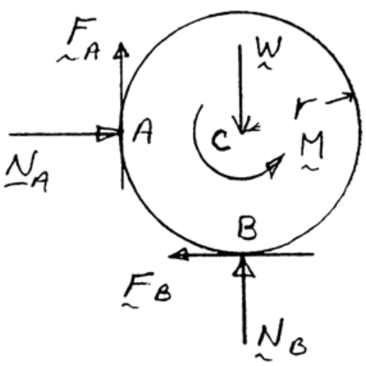
PROBLEM 8.17



The cylinder shown is of weight W and radius r, and the coefficient of static friction μ_s is the same at A and B. Determine the magnitude of the largest couple **M** which can be applied to the cylinder if it is not to rotate.

SOLUTION

FBD cylinder:



For maximum M, motion impends at both A and B

$$F_A = \mu_s N_{A,}\ F_B = \mu_s N_B$$

$$\xrightarrow{} \Sigma F_x = 0: \quad N_A - F_B = 0 \qquad \mathrm{N}_A = F_B = \mu_s N_B$$

$$F_A = \mu_s N_A = \mu_s^2 N_B$$

$$\uparrow \Sigma F_y = 0: \quad N_B + F_A - W = 0 \qquad N_B + \mu_s^2 N_B = W$$

or

$$N_B = \frac{W}{1 + \mu_s^2}$$

and

$$F_B = \frac{\mu_s W}{1 + \mu_s^2}$$

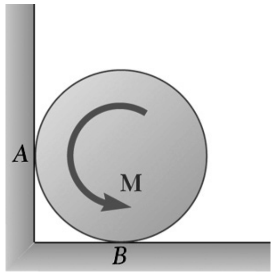
$$F_A = \frac{\mu_s^2 W}{1 + \mu^2}$$

$$\circlearrowleft \Sigma M_C = 0: \quad M - r\left(F_A + F_B\right) = 0$$

$$M = r\left(\mu_s + \mu_s^2\right)\frac{W}{1 + \mu_s^2}$$

$$M_{\max} = Wr\mu_s \frac{1 + \mu_s}{1 + \mu_s^2} \blacktriangleleft$$

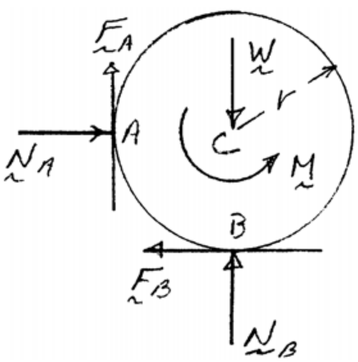
PROBLEM 8.18



The cylinder shown is of weight W and radius r. Express in terms of W and r the magnitude of the largest couple **M** which can be applied to the cylinder if it is not to rotate assuming that the coefficient of static friction is (*a*) zero at A and 0.36 at B, (*b*) 0.30 at A and 0.36 at B.

SOLUTION

FBD cylinder:



For maximum M, motion impends at both A and B

$$F_A = \mu_A N_A; \qquad F_B = \mu_B N_B$$

$$\longrightarrow \Sigma F_x = 0: \quad N_A - F_B = 0 \qquad N_A = F_B = \mu_B N_B$$

$$F_A = \mu_A N_A = \mu_A \mu_B N_B$$

$$\uparrow \Sigma F_y = 0: \quad N_B + F_A - W = 0 \qquad N_B\left(1 + \mu_A \mu_B\right) = W$$

or
$$N_B = \frac{1}{1 + \mu_A \mu_B} W$$

and
$$F_B = \mu_B N_B = \frac{\mu_B}{1 + \mu_A \mu_B} W$$

$$F_A = \mu_A \mu_B N_B = \frac{\mu_A \mu_B}{1 + \mu_A \mu_B} W$$

$$\circlearrowleft \Sigma M_C = 0: \quad M - r\left(F_A + F_B\right) = 0 \qquad M = Wr\mu_B \frac{1 + \mu_A}{1 + \mu_A \mu_B}$$

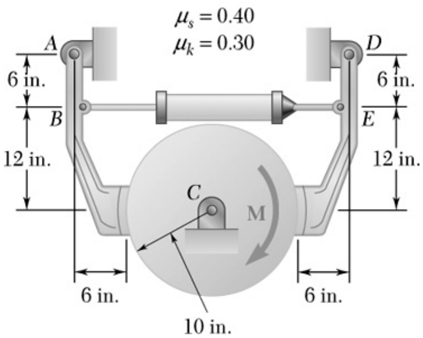
(*a*) For $\mu_A = 0$ and $\mu_B = 0.36$

$M = 0.360Wr$ ◀

(*b*) For $\mu_A = 0.30$ and $\mu_B = 0.36$

$M = 0.422Wr$ ◀

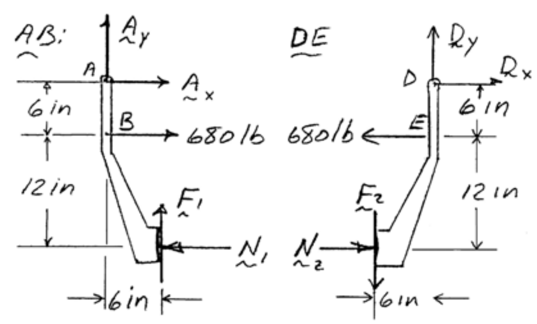
PROBLEM 8.19



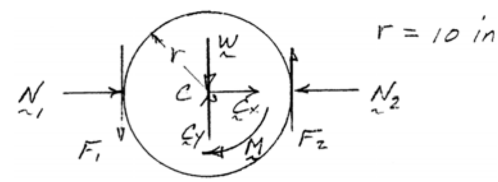
The hydraulic cylinder shown exerts a force of 680 lb directed to the right on point *B* and to the left on point *E*. Determine the magnitude of the couple **M** required to rotate the drum clockwise at a constant speed.

SOLUTION

FBDs



Drum:



Rotating drum ⇒ slip at both sides; constant speed ⇒ equilibrium

$$\therefore \quad F_1 = \mu_k N_1 = 0.3 N_1; \qquad F_2 = \mu_k N_2 = 0.3 N_2$$

AB: $\quad \circlearrowleft \Sigma M_A = 0: \quad (6 \text{ in.})(680 \text{ lb}) + (6 \text{ in.})(F_1) - (18 \text{ in.})N_1 = 0$

$$F_1\left(\frac{18 \text{ in.}}{0.3} - 6 \text{ in.}\right) = (6 \text{ in.})(680 \text{ lb}) \qquad \text{or} \qquad F_1 = 75.555 \text{ lb}$$

DE: $\quad \circlearrowleft \Sigma M_D = 0: \quad (6 \text{ in.})F_2 + (18 \text{ in.})N_2 - (6 \text{ in.})(680 \text{ lb}) = 0$

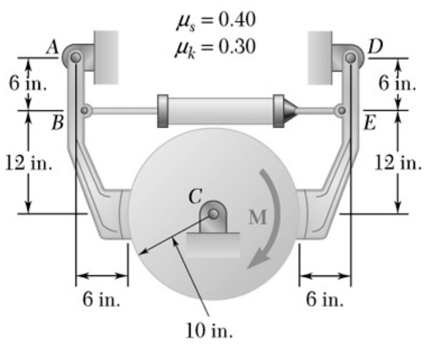
$$F_2\left(6 \text{ in.} + \frac{18 \text{ in.}}{0.3}\right) = (6 \text{ in.})(680 \text{ lb}) \qquad \text{or} \qquad F_2 = 61.818 \text{ lb}$$

Drum: $\quad \circlearrowleft \Sigma M_C = 0: \quad r(F_1 + F_2) - M = 0$

$$M = (10 \text{ in.})(75.555 + 61.818) \text{lb}$$

$M = 1374 \text{ lb·in.}$ ◀

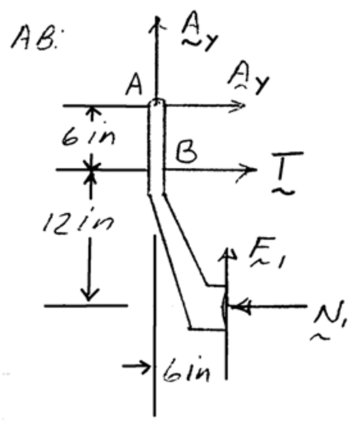
PROBLEM 8.20

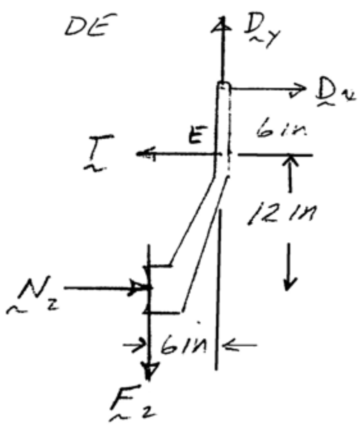


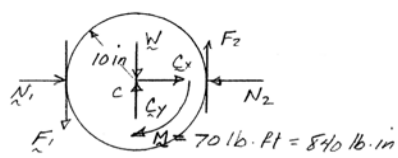
A couple **M** of magnitude 70 lb·ft is applied to the drum as shown. Determine the smallest force which must be exerted by the hydraulic cylinder on joints *B* and *E* if the drum is not to rotate.

SOLUTION

FBDs **DE:** **Drum:**







For minimum *T*, slip impends at both sides, so

$$F_1 = \mu_s N_1 = 0.4N_1 \qquad F_2 = \mu_s N_2 = 0.4N_2$$

AB: $\circlearrowleft \Sigma M_A = 0$: $(6\text{ in.})T + (6\text{ in.})F_1 - (18\text{ in.})N_1 = 0$

$$F_1\left(\frac{18\text{ in.}}{0.4} - 6\text{ in.}\right) = (6\text{ in.})T \quad \text{or} \quad F_1 = \frac{T}{6.5}$$

DE: $\circlearrowleft \Sigma M_D = 0$: $(6\text{ in.})F_2 + (18\text{ in.})N_2 - (6\text{ in.})T = 0$

$$F_2\left(6\text{ in.} + \frac{18\text{ in.}}{0.4}\right) = (6\text{ in.})T \quad \text{or} \quad F_2 = \frac{T}{8.5}$$

Drum: $\circlearrowleft \Sigma M_C = 0$: $(10\text{ in.})(F_1 + F_2) - 840\text{ lb}\cdot\text{in.} = 0$

$$T\left(\frac{1}{6.5} + \frac{1}{8.5}\right) = 84\text{ lb}$$

$T = 309$ lb ◀