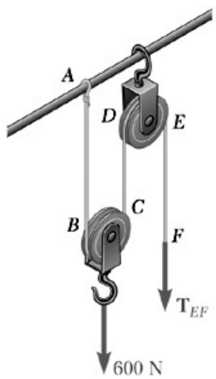
PROBLEM 8.81



The block and tackle shown are used to raise a 600-N load. Each of the 60-mm-diameter pulleys rotates on a 10-mm-diameter axle. Knowing that the coefficient of kinetic friction is 0.20, determine the tension in each portion of the rope as the load is slowly raised.

SOLUTION

Pulley FBD's:

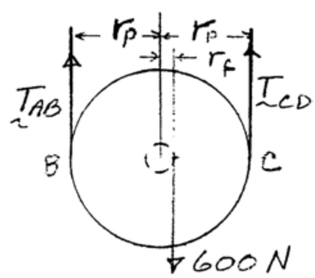
$$r_p = 30 \text{ mm}$$

$$r_f = r_{\text{axle}} \sin \phi_k = r_{\text{axle}} \sin\left(\tan^{-1} \mu_k\right)^*$$

$$= (5 \text{ mm})\sin\left(\tan^{-1} 0.2\right)$$

$$= 0.98058 \text{ mm}$$

Left:



Left:

$$\circlearrowleft \Sigma M_C = 0: \quad (r_p - r_f)(600 \text{ lb}) - 2r_p T_{AB} = 0$$

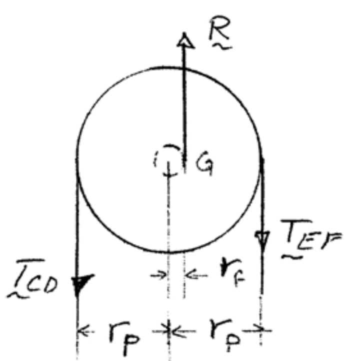
or $$T_{AB} = \frac{30 \text{ mm} - 0.98058 \text{ mm}}{2(30 \text{ mm})}(600 \text{ N}) = 290.19 \text{ N}$$

$$T_{AB} = 290 \text{ N} \blacktriangleleft$$

$$\uparrow \Sigma F_y = 0: \quad 290.19 \text{ N} - 600 \text{ N} + T_{CD} = 0$$

or $$T_{CD} = 309.81 \text{ N} \qquad T_{CD} = 310 \text{ N} \blacktriangleleft$$

Right:



Right:

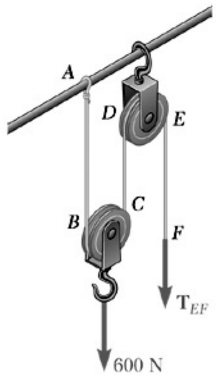
$$\circlearrowleft \Sigma M_G = 0: \quad (r_p + r_f)T_{CD} - (r_p - r_f)T_{EF} = 0$$

or $$T_{EF} = \frac{30 \text{ mm} + 0.98058 \text{ mm}}{30 \text{ mm} - 0.98058 \text{ mm}}(309.81 \text{ N}) = 330.75 \text{ N}$$

$$T_{EF} = 331 \text{ N} \blacktriangleleft$$

* See note before Problem 8.75.

PROBLEM 8.82

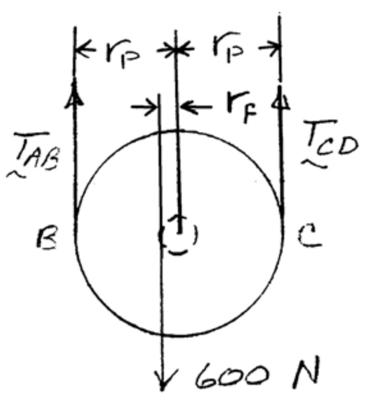


The block and tackle shown are used to lower a 600-N load. Each of the 60-mm-diameter pulleys rotates on a 10-mm-diameter axle. Knowing that the coefficient of kinetic friction is 0.20, determine the tension in each portion of the rope as the load is slowly lowered.

SOLUTION

Pulley FBDs:

Left:



$$r_p = 30 \text{ mm}$$

$$r_f = r_{\text{axle}} \sin\phi_k = r_{\text{axle}} \sin\left(\tan^{-1}\mu_k\right)^*$$

$$= (5 \text{ mm})\sin\left(\tan^{-1} 0.2\right)$$

$$= 0.98058 \text{ mm}$$

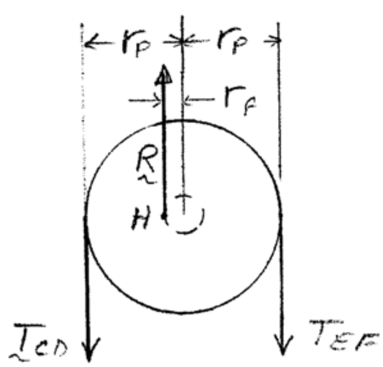
$$\circlearrowleft \Sigma M_C = 0: \quad (r_p + r_f)(600 \text{ N}) - 2r_p T_{AB} = 0$$

or $$T_{AB} = \frac{30 \text{ mm} + 0.98058 \text{ mm}}{2(30 \text{ mm})}(600 \text{ N}) = 309.81 \text{ N}$$

$$T_{AB} = 310 \text{ N} \blacktriangleleft$$

$$\uparrow \Sigma F_y = 0: \quad T_{AB} - 600 \text{ N} + T_{CD} = 0$$

Right:



or $$T_{CD} = 600 \text{ N} - 309.81 \text{ N} = 290.19 \text{ N}$$

$$T_{CD} = 290 \text{ N} \blacktriangleleft$$

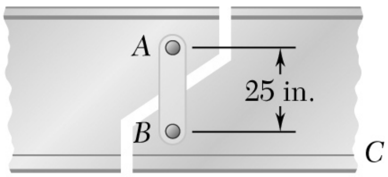
$$\circlearrowleft \Sigma M_H = 0: \quad (r_p - r_f)T_{CD} - (r_p + r_f)T_{EF} = 0$$

or $$T_{EF} = \frac{30 \text{ mm} - 0.98058 \text{ mm}}{30 \text{ mm} + 0.98058 \text{ mm}}(290.19 \text{ N})$$

$$T_{EF} = 272 \text{ N} \blacktriangleleft$$

* See note before Problem 8.75.

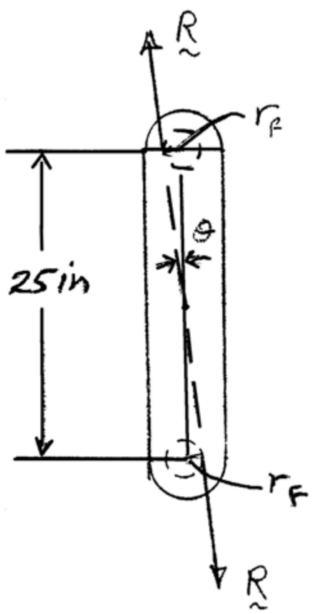
PROBLEM 8.83



The link arrangement shown is frequently used in highway bridge construction to allow for expansion due to changes in temperature. At each of the 3-in.-diameter pins *A* and *B* the coefficient of static friction is 0.20. Knowing that the vertical component of the force exerted by *BC* on the link is 50 kips, determine (*a*) the horizontal force which should be exerted on beam *BC* to just move the link, (*b*) the angle that the resulting force exerted by beam *BC* on the link will form with the vertical.

SOLUTION

FBD link AB:



Note that *AB* is a two force member. For impending motion, the pin forces are tangent to the friction circles.

$$\theta = \sin^{-1}\frac{r_f}{25\text{ in.}}$$

where $$r_f = r_p \sin\phi_s = r_p \sin\left(\tan^{-1}\mu_s\right)^*$$

$$= (1.5\text{ in.})\sin\left(\tan^{-1}0.2\right) = 0.29417\text{ in.}$$

Then $$\theta = \sin^{-1}\frac{0.29417\text{ in.}}{12.5\text{ in.}} = 1.3485°$$

(*b*) $\theta = 1.349°$ ◀

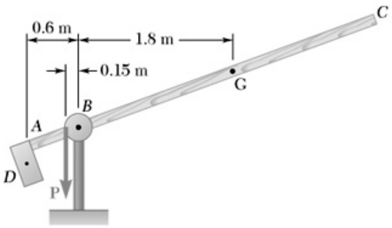
$$R_{\text{vert}} = R\cos\theta \qquad R_{\text{horiz}} = R\sin\theta$$

$$R_{\text{horiz}} = R_{\text{vert}}\tan\theta = (50\text{ kips})\tan 1.3485° = 1.177\text{ kips}$$

(*a*) $R_{\text{horiz}} = 1.177$ kips ◀

* See note before Problem 8.75.

PROBLEM 8.84

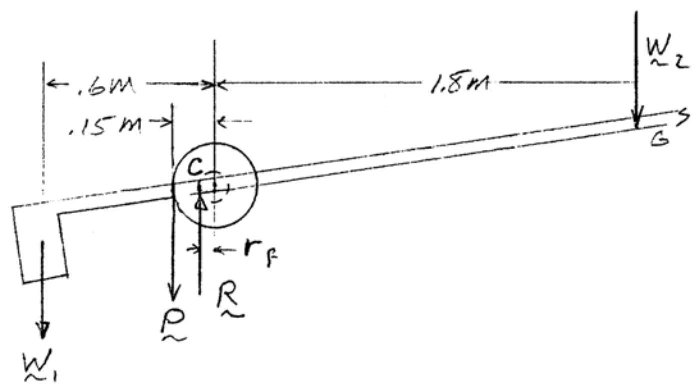


BEER • JOHNSTON Fig. P8-84 and P8-86
Vector Mechanics for Engineers: Statics & Dynamics, 7e
100% of size Fine Line Illustrations (516) 501-0400

A gate assembly consisting of a 24-kg gate *ABC* and a 66-kg counterweight *D* is attached to a 24-mm-diameter shaft *B* which fits loosely in a fixed bearing. Knowing that the coefficient of static friction is 0.20 between the shaft and the bearing, determine the magnitude of the force **P** for which counterclockwise rotation of the gate is impending.

SOLUTION

FBD gate:



$$W_1 = 66\text{ kg}\left(9.81\text{ m/s}^2\right) = 647.46\text{ N}$$

$$W_2 = 24\text{ kg}\left(9.81\text{ m/s}^2\right) = 235.44\text{ N}$$

$$r_f = r_s \sin\phi_s = r_s \sin\left(\tan^{-1}\mu_s\right)$$

$$= \left(0.012\text{ m}\right)\sin\left(\tan^{-1}0.2\right) = 0.0023534\text{ m}$$

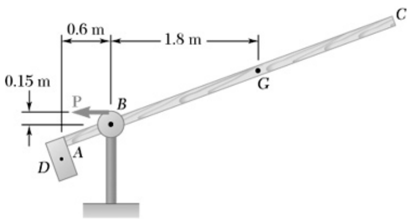
$$\circlearrowleft \Sigma M_C = 0: \quad \left(0.6\text{ m} - r_f\right)W_1 + \left(0.15\text{ m} - r_f\right)P - \left(1.8\text{ m} + r_f\right)W_2 = 0$$

$$P = \frac{\left(1.80235\text{ m}\right)\left(235.44\text{ N}\right) - \left(0.59765\text{ m}\right)\left(647.46\text{ N}\right)}{\left(0.14765\text{ m}\right)}$$

$$= 253.2\text{ N}$$

$$P = 253\text{ N} \blacktriangleleft$$

PROBLEM 8.85



BEER • JOHNSTON Fig. P8-85 and *P8-87*
Vector Mechanics for Engineers: Statics & Dynamics, 7e
100% of size Fine Line Illustrations (516) 501-0400

A gate assembly consisting of a 24-kg gate *ABC* and a 66-kg counterweight *D* is attached to a 24-mm-diameter shaft *B* which fits loosely in a fixed bearing. Knowing that the coefficient of static friction is 0.20 between the shaft and the bearing, determine the magnitude of the force **P** for which counterclockwise rotation of the gate is impending.

SOLUTION

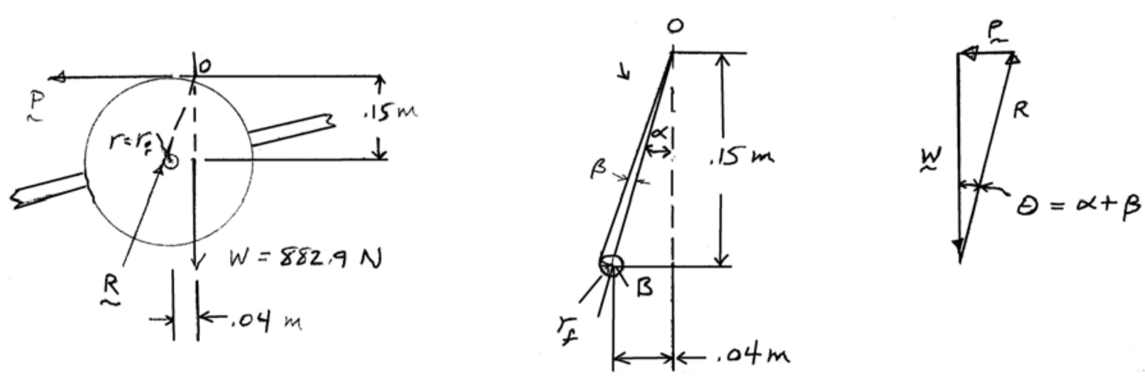
It is convenient to replace the $(66\text{ kg})g$ and $(24\text{ kg})g$ weights with a single combined weight of

$(90\text{ kg})(9.81\text{ m/s}^2) = 882.9\text{ N}$, located at a distance $x = \dfrac{(1.8\text{ m})(24\text{ kg}) - (0.6\text{ m})(24\text{ kg})}{90\text{ kg}} = 0.04\text{ m}$ to the right of *B*.

$$r_f = r_s \sin\phi_s = r_s \sin\left(\tan^{-1}\mu_s\right)^* = (0.012\text{ m})\sin\left(\tan^{-1}0.2\right)$$

$$= 0.0023534\text{ m}$$

FBD pulley + gate:



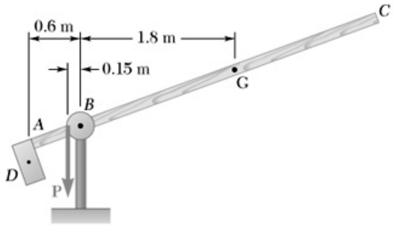
$$\alpha = \tan^{-1}\frac{0.04\text{ m}}{0.15\text{ m}} = 14.931° \qquad OB = \frac{0.15}{\cos\alpha} = 0.15524\text{ m}$$

$$\beta = \sin^{-1}\frac{r_f}{OB} = \sin^{-1}\frac{0.0023534\text{ m}}{0.15524\text{ m}} = 0.8686° \qquad \text{then} \qquad \theta = \alpha + \beta = 15.800°$$

$$P = W\tan\theta = 248.9\text{ N}$$

$P = 250\text{ N}$ ◀

* See note before Problem 8.75.



BEER • JOHNSTON Fig. P8-84 and P8-86
Vector Mechanics for Engineers: Statics & Dynamics, 7e
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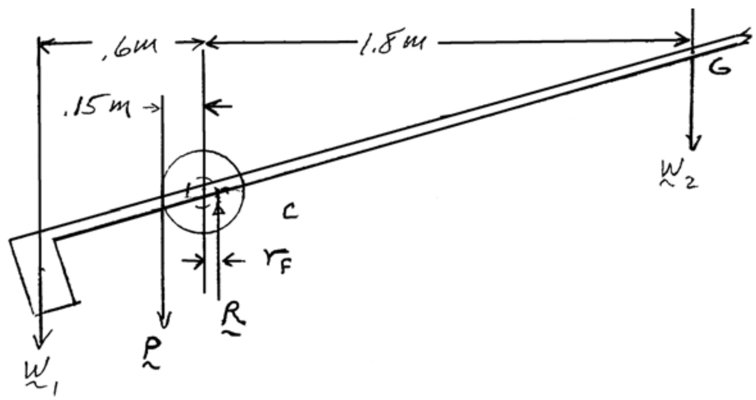
PROBLEM 8.86

A gate assembly consisting of a 24-kg gate *ABC* and a 66-kg counterweight *D* is attached to a 24-mm-diameter shaft *B* which fits loosely in a fixed bearing. Knowing that the coefficient of static friction is 0.20 between the shaft and the bearing, determine the magnitude of the force **P** for which clockwise rotation of the gate is impending.

SOLUTION

FBD gate:



$$W_1 = 66\text{ kg}\left(9.81\text{ m/s}^2\right) = 647.46\text{ N}$$

$$W_2 = 24\text{ kg}\left(9.81\text{ m/s}^2\right) = 235.44\text{ N}$$

$$r_f = r_s \sin\phi_s = r_s \sin\left(\tan^{-1}\mu_s\right)^*$$

$$= \left(0.012\text{ m}\right)\sin\left(\tan^{-1}0.2\right) = 0.0023534\text{ m}$$

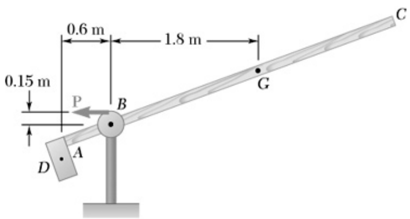
$$\circlearrowleft \Sigma M_C = 0: \quad \left(0.6\text{ m} + r_f\right)W_1 + \left(0.15\text{ m} + r_f\right)P - \left(1.8\text{ m} - r_f\right)W_2 = 0$$

$$P = \frac{\left(1.79765\text{ m}\right)\left(235.44\text{ N}\right) - \left(0.60235\text{ m}\right)\left(647.46\text{ N}\right)}{0.15235\text{ m}}$$

$$= 218.19\text{ N}$$

$$P = 218\text{ N} \blacktriangleleft$$

* See note before Problem 8.75.



BEER • JOHNSTON Fig. P8-85 and *P8-87*
Vector Mechanics for Engineers: Statics & Dynamics, 7e
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PROBLEM 8.87

A gate assembly consisting of a 24-kg gate *ABC* and a 66-kg counterweight *D* is attached to a 24-mm-diameter shaft *B* which fits loosely in a fixed bearing. Knowing that the coefficient of static friction is 0.20 between the shaft and the bearing, determine the magnitude of the force **P** for which clockwise rotation of the gate is impending.

SOLUTION

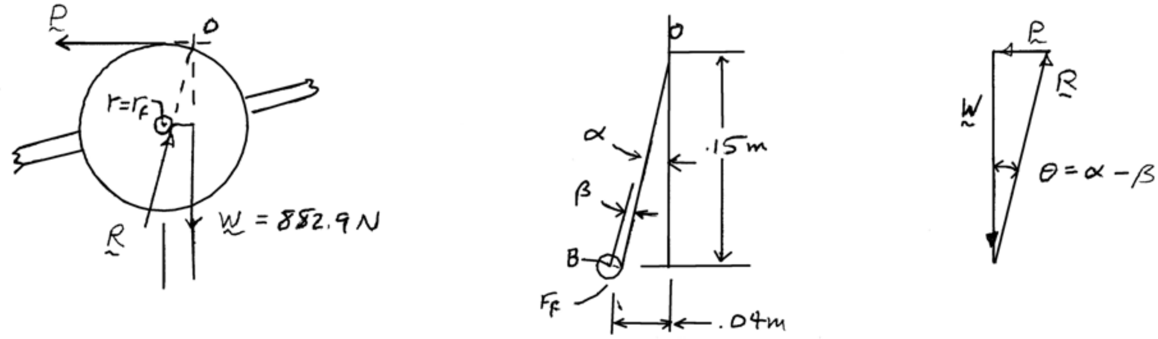
It is convenient to replace the $(66\text{ kg})g$ and $(24\text{ kg})g$ weights with a single weight of

$(90\text{ kg})(9.81\text{ N/kg}) = 882.9\text{ N}$, located at a distance $x = \dfrac{(1.8\text{ m})(24\text{ kg}) - (0.15\text{ m})(66\text{ kg})}{90\text{ kg}} = 0.04\text{ m}$ to the right of *B*.

FBD pulley + gate:

$$r_f = r_s \sin\phi_s = r_s \sin\left(\tan^{-1}\mu_s\right)^{*} = (0.012\text{ m})\sin\left(\tan^{-1}0.2\right)$$

$$r_f = 0.0023534\text{ m}$$



$$\alpha = \tan^{-1}\frac{0.04\text{ m}}{0.15\text{ m}} = 14.931° \qquad OB = \frac{0.15\text{ m}}{\cos\alpha} = 0.15524\text{ m}$$

$$\beta = \sin^{-1}\frac{r_f}{OB} = \sin^{-1}\frac{0.0023534\text{ m}}{0.15524\text{ m}} = 0.8686° \qquad \text{then} \qquad \theta = \alpha - \beta = 14.062°$$

$$P = W\tan\theta = 221.1\text{ N}$$

$P = 221\text{ N}$ ◀

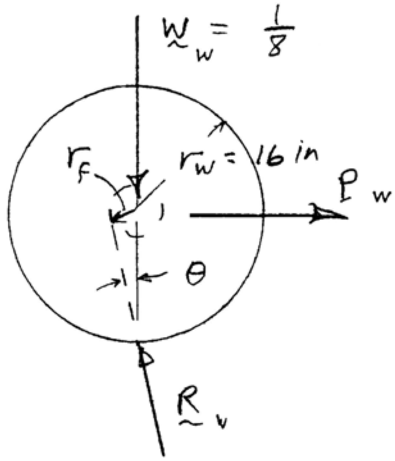
* See note before Problem 8.75.

PROBLEM 8.88

A loaded railroad car has a weight of 35 tons and is supported by eight 32-in.-diameter wheels with 5-in.-diameter axles. Knowing that the coefficients of friction are $\mu_s = 0.020$ and $\mu_k = 0.015$, determine the horizontal force required (*a*) for impending motion of the car, (*b*) to keep the car moving at a constant speed. Neglect rolling resistance between the wheels and the track.

SOLUTION

FBD wheel:



$$W_w = \frac{1}{8}W_c = \frac{1}{8}(35\text{ ton}) = \frac{1}{8}(70{,}000)\text{lb}$$

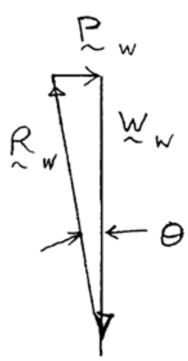
$$r_f = r_a \sin\phi = r_a \sin\left(\tan^{-1}\mu\right)^*$$

$$\theta = \sin^{-1}\frac{r_f}{r_w} = \sin^{-1}\left[\frac{(2.5\text{ in.})\sin\left(\tan^{-1}\mu\right)}{16\text{ in.}}\right]$$

$$= \sin^{-1}\left[0.15625\sin\left(\tan^{-1}\mu\right)\right]$$

(*a*) For impending motion use $\mu_s = 0.02$: then $\theta_s = 0.179014°$

(*b*) For steady motion use $\mu_k = 0.15$: then $\theta_k = 0.134272°$



$$P_w = W_w \tan\theta \qquad P_c = W_c \tan\theta = 8W_w \tan\theta$$

(*a*) $$P_c = (70{,}000\text{ lb})\tan(0.179014°)$$

$$P_c = 219\text{ lb} \blacktriangleleft$$

(*b*) $$P_c = (70{,}000\text{ lb})\tan(0.134272°)$$

$$P_c = 164.0\text{ lb} \blacktriangleleft$$

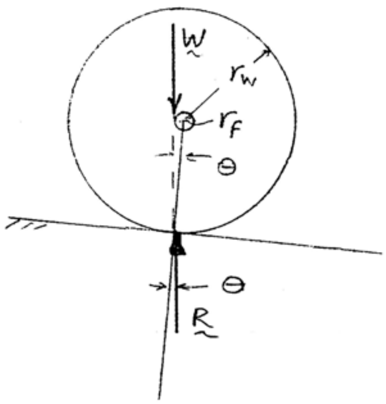
* See note before Problem 8.75.

PROBLEM 8.89

A scooter is designed to roll down a 2 percent slope at a constant speed. Assuming that the coefficient of kinetic friction between the 1-in.-diameter axles and the bearing is 0.10, determine the required diameter of the wheels. Neglect the rolling resistance between the wheels and the ground.

SOLUTION

FBD wheel:



Note: The wheel is a two-force member in equilibrium, so **R** and **W** must be collinear and tangent to friction circle.

$$2\% \text{ slope} \Rightarrow \tan\theta = 0.02$$

Also $$\sin\theta = \frac{r_f}{r_w}\sin\left(\tan^{-1}0.02\right) = 0.019996$$

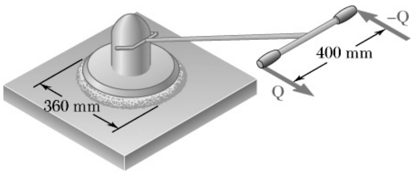
But $$r_f = r_a \sin\phi_k = r_a \sin\left(\tan^{-1}\mu_k\right)^*$$

$$= (1\text{ in.})\sin\left(\tan^{-1}0.1\right) = 0.099504\text{ in.}$$

Then $$r_w = \frac{r_f}{\sin\theta} = \frac{0.099504}{0.019996} = 4.976\text{ in.}$$

and $$d_w = 2r_w$$ $$d_w = 9.95\text{ in.} \blacktriangleleft$$

* See note before Problem 8.75.



PROBLEM 8.90

A 25-kg electric floor polisher is operated on a surface for which the coefficient of kinetic friction is 0.25. Assuming that the normal force per unit area between the disk and the floor is uniformly distributed, determine the magnitude Q of the horizontal forces required to prevent motion of the machine.

SOLUTION

Couple exerted on handle $$M_H = dQ = (0.4\text{ m})Q$$

Couple exerted on floor $$M_F = \frac{2}{3}\mu_k PR \qquad \text{(Equation 8.9)}$$

where $$\mu_k = 0.25, \quad P = (25\text{ kg})\left(9.81\text{ m/s}^2\right) = 245.25\text{ N}, \quad R = 0.18\text{ m}$$

For equilibrium $$M_H = M_F,$$

so $$Q = \frac{\frac{2}{3}(0.25)(245.25\text{ N})(0.18\text{ m})}{0.4\text{ m}}$$

$$Q = 18.39\text{ N} \blacktriangleleft$$