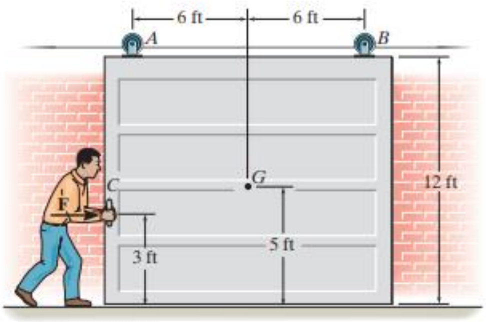
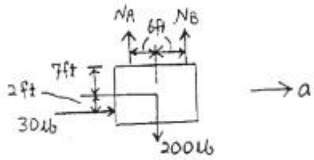
*17–24.

The door has a weight of 200 lb and a center of gravity at G. Determine how far the door moves in 2 s, starting from rest, if a man pushes on it at C with a horizontal force $F = 30$ lb. Also, find the vertical reactions at the rollers A and B.



SOLUTION



$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\qquad 30 = \left(\frac{200}{32.2}\right)a_G$

$a_G = 4.83 \text{ ft/s}^2$

$\circlearrowleft + \Sigma M_A = \Sigma(M_k)_A;\qquad N_B(12) - 200(6) + 30(9) = \left(\frac{200}{32.2}\right)(4.83)(7)$

$N_B = 95.0$ lb **Ans.**

$+\uparrow \Sigma F_y = m(a_G)_y;\qquad N_A + 95.0 - 200 = 0$

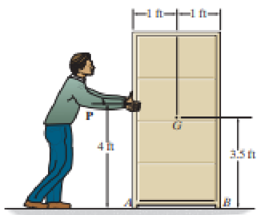
$N_A = 105$ lb **Ans.**

$(\xrightarrow{+})\qquad s = s_0 + v_0 t + \frac{1}{2}a_G t^2$

$s = 0 + 0 + \frac{1}{2}(4.83)(2)^2 = 9.66$ ft **Ans.**

17–43.

Determine the acceleration of the 150-lb cabinet and the normal reaction under the legs A and B if $P = 35$ lb. The coefficients of static and kinetic friction between the cabinet and the plane are $\mu_s = 0.2$ and $\mu_k = 0.15$, respectively. The cabinet's center of gravity is located at G.



SOLUTION

Equations of Equilibrium: The free-body diagram of the cabinet under the static condition is shown in Fig. *a*, where **P** is the unknown minimum force needed to move the cabinet. We will assume that the cabinet slides before it tips. Then, $F_A = \mu_s N_A = 0.2N_A$ and $F_B = \mu_s N_B = 0.2N_B$.

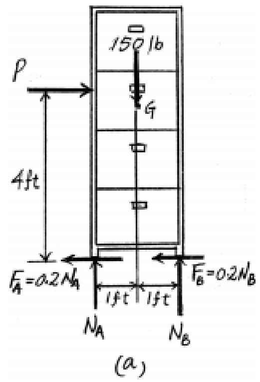
$$\xrightarrow{+} \Sigma F_x = 0; \qquad P - 0.2N_A - 0.2N_B = 0 \qquad (1)$$

$$+\uparrow \Sigma F_y = 0; \qquad N_A + N_B - 150 = 0 \qquad (2)$$

$$+\Sigma M_A = 0; \qquad N_B(2) - 150(1) - P(4) = 0 \qquad (3)$$

Solving Eqs. (1), (2), and (3) yields

$P = 30$ lb $\qquad N_A = 15$ lb $\qquad N_B = 135$ lb



Since $P < 35$ lb and $\mathbf{N}_A$ is positive, the cabinet will slide.

Equations of Motion: Since the cabinet is in motion, $F_A = \mu_k N_A = 0.15N_A$ and $F_B = \mu_k N_B = 0.15N_B$. Referring to the free-body diagram of the cabinet shown in Fig. *b*,

$$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \qquad 35 - 0.15N_A - 0.15N_B = \left(\frac{150}{32.2}\right)a \qquad (4)$$

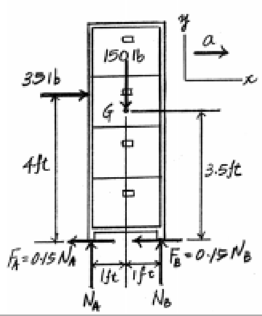
$$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \qquad N_A + N_B - 150 = 0 \qquad (5)$$

$$+\Sigma M_G = 0; \quad N_B(1) - 0.15N_B(3.5) - 0.15N_A(3.5) - N_A(1) - 35(0.5) = 0 \quad (6)$$

Solving Eqs. (4), (5), and (6) yields

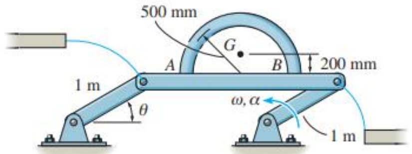
$a = 2.68 \text{ ft/s}^2$ **Ans.**

$N_A = 26.9$ lb $\qquad N_B = 123$ lb **Ans.**



17–53.

The arched pipe has a mass of 80 kg and rests on the surface of the platform. As it is hoisted from one level to the next, $\alpha = 0.25 \text{ rad/s}^2$ and $\omega = 0.5$ rad/s at the instant $\theta = 30°$. If it does not slip, determine the normal reactions of the arch on the platform at this instant.



SOLUTION

$$+\uparrow \Sigma F_y = m(a_G)_y; \qquad N_A + N_B - 80(9.81) = 20 \sin 60° - 20 \cos 60°$$

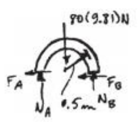
$$N_A + N_B = 792.12$$

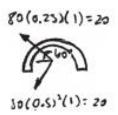
$$\circlearrowleft + \Sigma M_A = \Sigma(M_k)_A; \qquad N_B(1) - 80(9.81)(0.5) = 20 \cos 60°(0.2) + 20 \sin 60°(0.5)$$

$$- 20 \cos 60°(0.5) + 20 \sin 60°(0.2)$$

$N_B = 402$ N **Ans.**

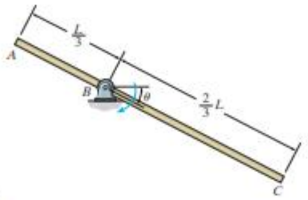
$N_A = 391$ N **Ans.**





17–59.

The uniform slender rod has a mass m. If it is released from rest when $\theta = 0^\circ$, determine the magnitude of the reactive force exerted on it by pin B when $\theta = 90^\circ$.



SOLUTION

Equations of Motion: Since the rod rotates about a fixed axis passing through point B, $(a_G)_t = \alpha r_G = \alpha\left(\frac{L}{6}\right)$ and $(a_G)_n = \omega^2 r_G = \omega^2\left(\frac{L}{6}\right)$. The mass moment of inertia of the rod about its G is $I_G = \frac{1}{12}mL^2$. Writing the moment equation of motion about point B,

$$+\Sigma M_B = \Sigma(M_k)_B; \quad -mg\cos\theta\left(\frac{L}{6}\right) = -m\left[\alpha\left(\frac{L}{6}\right)\right]\left(\frac{L}{6}\right) - \left(\frac{1}{12}mL^2\right)\alpha$$

$$\alpha = \frac{3g}{2L}\cos\theta$$

This equation can also be obtained by applying $\Sigma M_B = I_B\alpha$, where $I_B = \frac{1}{12}mL^2 + m\left(\frac{L}{6}\right)^2 = \frac{1}{9}mL^2$. Thus,

$$+\Sigma M_B = I_B\alpha; \quad -mg\cos\theta\left(\frac{L}{6}\right) = -\left(\frac{1}{9}mL^2\right)\alpha$$

$$\alpha = \frac{3g}{2L}\cos\theta$$

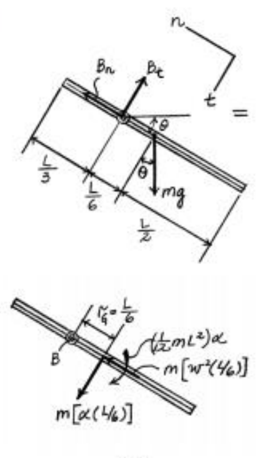
Using this result and writing the force equation of motion along the n and t axes,

$$\Sigma F_t = m(a_G)_t; \quad mg\cos\theta - B_t = m\left[\left(\frac{3g}{2L}\cos\theta\right)\left(\frac{L}{6}\right)\right]$$

$$B_t = \frac{3}{4}mg\cos\theta \qquad \textbf{(1)}$$

$$\Sigma F_n = m(a_G)_n; \quad B_n - mg\sin\theta = m\left[\omega^2\left(\frac{L}{6}\right)\right]$$

$$B_n = \frac{1}{6}m\omega^2 L + mg\sin\theta \qquad \textbf{(2)}$$



(a)

Kinematics: The angular velocity of the rod can be determined by integrating

$$\int \omega\, d\omega = \int \alpha\, d\theta$$

$$\int_0^\omega \omega\, d\omega = \int_0^\theta \frac{3g}{2L}\cos\theta\, d\theta$$

$$\omega = \sqrt{\frac{3g}{L}\sin\theta}$$

When $\theta = 90^\circ$, $\omega = \sqrt{\frac{3g}{L}}$. Substituting this result and $\theta = 90^\circ$ into Eqs. (1) and (2),

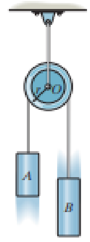
$$B_t = \frac{3}{4}mg\cos 90^\circ = 0$$

$$B_n = \frac{1}{6}m\left(\frac{3g}{L}\right)(L) + mg\sin 90^\circ = \frac{3}{2}mg$$

$$F_A = \sqrt{A_t^2 + A_n^2} = \sqrt{0^2 + \left(\frac{3}{2}mg\right)^2} = \frac{3}{2}mg \qquad \textbf{Ans.}$$

17–79.

The two blocks A and B have a mass of 5 kg and 10 kg, respectively. If the pulley can be treated as a disk of mass 3 kg and radius 0.15 m, determine the acceleration of block A. Neglect the mass of the cord and any slipping on the pulley.



SOLUTION

Kinematics: Since the pulley rotates about a fixed axis passes through point O, its angular acceleration is

$$\alpha = \frac{a}{r} = \frac{a}{0.15} = 6.6667a$$

The mass moment of inertia of the pulley about point O is

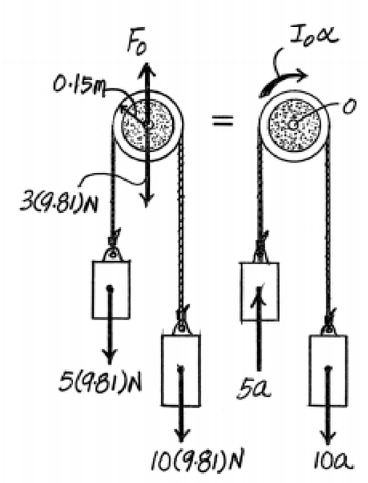
$$I_o = \frac{1}{2}Mr^2 = \frac{1}{2}(3)(0.15^2) = 0.03375\ \text{kg}\cdot\text{m}^2$$

Equation of Motion: Write the moment equation of motion about point O by referring to the free-body and kinetic diagram of the system shown in Fig. a,

$$\zeta + \Sigma M_o = \Sigma(M_k)_o; \qquad 5(9.81)(0.15) - 10(9.81)(0.15)$$

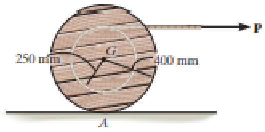
$$= -0.03375(6.6667a) - 5a(0.15) - 10a(0.15)$$

$$a = 2.973\ \text{m/s}^2 = 2.97\ \text{m/s}^2 \qquad \textbf{Ans.}$$

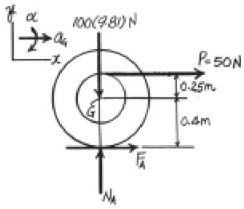


*17–96.

The spool has a mass of 100 kg and a radius of gyration of $k_G = 0.3$ m. If the coefficients of static and kinetic friction at A are $\mu_s = 0.2$ and $\mu_k = 0.15$, respectively, determine the angular acceleration of the spool if $P = 50$ N.



SOLUTION



$\xrightarrow{+} \Sigma F_x = m(a_G)_x;$ $\quad 50 + F_A = 100a_G$

$+\uparrow \Sigma F_y = m(a_G)_y;$ $\quad N_A - 100(9.81) = 0$

$\circlearrowright + \Sigma M_G = I_G\alpha;$ $\quad 50(0.25) - F_A(0.4) = [100(0.3)^2]\alpha$

Assume no slipping: $a_G = 0.4\alpha$

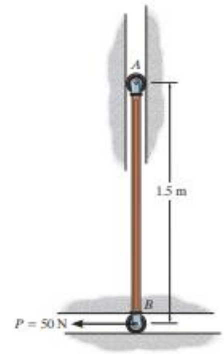
$\alpha = 1.30 \text{ rad/s}^2$ **Ans.**

$a_G = 0.520 \text{ m/s}^2 \quad N_A = 981 \text{ N} \quad F_A = 2.00 \text{ N}$

Since $(F_A)_{max} = 0.2(981) = 196.2 \text{ N} > 2.00 \text{ N}$ **OK**

*17–120.

The 30-kg slender rod AB rests in the position shown when the horizontal force $P = 50$ N is applied. Determine the initial angular acceleration of the rod. Neglect the mass of the rollers.



SOLUTION

Equations of Motion: Here, the mass moment of inertia of the rod about its mass center is $I_G = \frac{1}{12}ml^2 = \frac{1}{12}(30)(1.5^2) = 5.625\ \text{kg}\cdot\text{m}^2$. Writing the moment equations of motion about the intersection point A of the lines of action of $\mathbf{N}_A$ and $\mathbf{N}_B$ and using, Fig. a,

$$+\Sigma M_A = \Sigma(M_k)_A; \qquad -50(0.15) = 30(a_G)_x(0.75) - 5.625\alpha$$

$$5.625\alpha - 22.5(a_G)_x = 75 \tag{1}$$

Kinematics: Applying the relative acceleration equation to points A and G, Fig. b,

$$\mathbf{a}_G = \mathbf{a}_A + \alpha \times \mathbf{r}_{G/A} - \omega^2\mathbf{r}_{G/A}$$

$$(a_G)_x\mathbf{i} + (a_G)_y\mathbf{j} = -a_A\mathbf{j} + (-\alpha\mathbf{k}) \times (-0.75\mathbf{j}) - \mathbf{0}$$

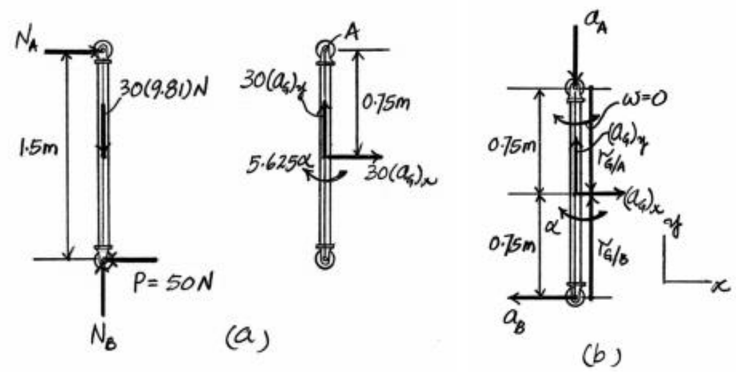
$$(a_G)_x\mathbf{i} + (a_G)_y\mathbf{j} = -0.75\alpha\mathbf{i} - a_A\mathbf{j}$$

Equating the $\mathbf{i}$ components,

$$(a_G)_x = -0.75\alpha \tag{2}$$

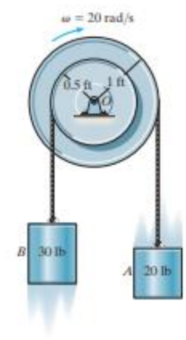
Substituting Eq. (2) into Eq. (1),

$$\alpha = 3.333\ \text{rad/s}^2 = 3.33\ \text{rad/s}^2 \qquad \textbf{Ans.}$$



*18–8.

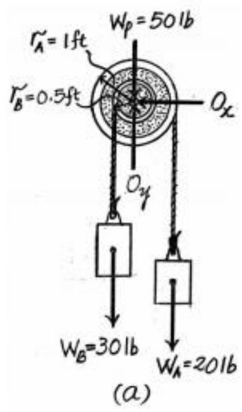
The double pulley consists of two parts that are attached to one another. It has a weight of 50 lb and a centroidal radius of gyration of $k_O = 0.6$ ft and is turning with an angular velocity of 20 rad/s clockwise. Determine the angular velocity of the pulley at the instant the 20-lb weight moves 2 ft downward.



SOLUTION

Kinetic Energy and Work: Since the pulley rotates about a fixed axis, $v_A = \omega r_A = \omega(1)$ and $v_B = \omega r_B = \omega(0.5)$. The mass moment of inertia of the pulley about point O is $I_O = mk_O{}^2 = \left(\frac{50}{32.2}\right)(0.6^2) = 0.5590\ \text{slug}\cdot\text{ft}^2$. Thus, the kinetic energy of the system is

$$
\begin{aligned}
T &= \frac{1}{2}I_O\omega^2 + \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B{}^2 \\
&= \frac{1}{2}(0.5590)\omega^2 + \frac{1}{2}\left(\frac{20}{32.2}\right)[\omega(1)]^2 + \frac{1}{2}\left(\frac{30}{32.2}\right)[\omega(0.5)]^2 \\
&= 0.7065\omega^2
\end{aligned}
$$



Thus, $T_1 = 0.7065(20^2) = 282.61\ \text{ft}\cdot\text{lb}$. Referring to the FBD of the system shown in Fig. a, we notice that $\mathbf{O}_x$, $\mathbf{O}_y$, and $\mathbf{W}_p$ do no work while $\mathbf{W}_A$ does positive work and $\mathbf{W}_B$ does negative work. When A moves 2 ft downward, the pulley rotates

$$
\theta = \frac{S_A}{r_A} = \frac{S_B}{r_B}
$$

$$
\frac{2}{1} = \frac{S_B}{0.5}
$$

$$
S_B = 2(0.5) = 1\ \text{ft}\uparrow
$$

Thus, the work of $\mathbf{W}_A$ and $\mathbf{W}_B$ are

$$
U_{W_A} = W_A S_A = 20(2) = 40\ \text{ft}\cdot\text{lb}
$$

$$
U_{W_B} = -W_B S_B = -30(1) = -30\ \text{ft}\cdot\text{lb}
$$

Principle of Work and Energy:

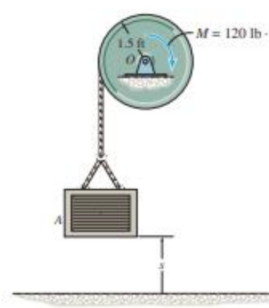
$$
T_1 + U_{1\text{-}2} = T_2
$$

$$
282.61 + [40 + (-30)] = 0.7065\,\omega^2
$$

$$
\omega = 20.4\ \text{rad/s} \qquad \textbf{Ans.}
$$

18–29.

A motor supplies a constant torque or twist of $M = 120 \text{ lb}\cdot\text{ft}$ to the drum. If the drum has a weight of 30 lb and a radius of gyration of $k_O = 0.8$ ft, determine the speed of the 15-lb crate A after it rises $s = 4$ ft starting from rest. Neglect the mass of the cord.



SOLUTION

Free Body Diagram: The weight of the crate does *negative* work since it acts in the opposite direction to that of its displacement s_w. Also, the couple moment **M** does positive work as it acts in the same direction of its angular displacement θ. The reactions O_x, O_y and the weight of the drum do no work since point O does not displace.

Kinematic: Since the drum rotates about point O, the angular velocity of the drum and the speed of the crate can be related by $\omega_D = \frac{v_A}{r_D} = \frac{v_A}{1.5} = 0.6667\, v_A$. When the crate rises $s = 4$ ft, the angular displacement of the drum is given by $\theta = \frac{s}{r_D} = \frac{4}{1.5} = 2.667$ rad.

Principle of Work and Energy: The mass moment of inertia of the drum about point O is $I_O = mk_O^2 = \left(\frac{30}{32.2}\right)(0.8^2) = 0.5963 \text{ slug}\cdot\text{ft}^2$. Applying Eq. 18–13, we have

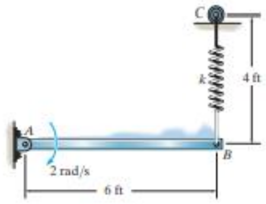
$$T_1 + \sum U_{1-2} = T_2$$

$$0 + M\theta - W_C s_C = \frac{1}{2} I_O \omega^2 + \frac{1}{2} m_C v_C^2$$

$$0 + 120(2.667) - 15(4) = \frac{1}{2}(0.5963)(0.6667 v_A)^2 + \frac{1}{2}\left(\frac{15}{32.2}\right)v_A^2$$

$$v_A = 26.7 \text{ ft/s} \qquad \textbf{Ans.}$$

At the instant shown, the 50-lb bar rotates clockwise at 2 rad/s. The spring attached to its end always remains vertical due to the roller guide at C. If the spring has an unstretched length of 2 ft and a stiffness of $k = 6$ lb/ft, determine the angular velocity of the bar the instant it has rotated 30° clockwise.



SOLUTION

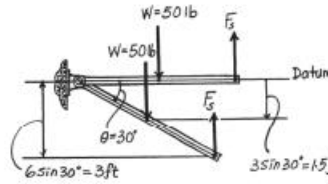
Datum through A.

$$T_1 + V_1 = T_2 + V_2$$

$$\frac{1}{2}\left[\frac{1}{3}\left(\frac{50}{32.2}\right)(6)^2\right](2)^2 + \frac{1}{2}(6)(4-2)^2 = \frac{1}{2}\left[\frac{1}{3}\left(\frac{50}{32.2}\right)(6)^2\right]\omega^2$$

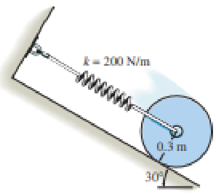
$$+ \frac{1}{2}(6)(7-2)^2 - 50(1.5)$$

$$\omega = 2.30 \text{ rad/s} \qquad \textbf{Ans.}$$



18–47.

At the instant the spring becomes undeformed, the center of the 40-kg disk has a speed of 4 m/s. From this point determine the distance d the disk moves down the plane before momentarily stopping. The disk rolls without slipping.



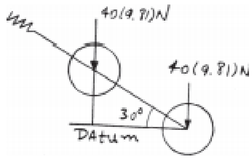
SOLUTION

Datum at lowest point.

$$T_1 + V_1 = T_2 + V_2$$

$$\frac{1}{2}\left[\frac{1}{2}(40)(0.3)^2\right]\left(\frac{4}{0.3}\right)^2 + \frac{1}{2}(40)(4)^2 + 40(9.81)d\sin 30^\circ = 0 + \frac{1}{2}(200)d^2$$

$$100d^2 - 196.2d - 480 = 0$$



Solving for the positive root

$$d = 3.38 \text{ m}$$ **Ans.**