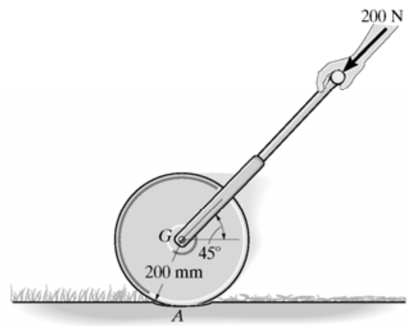
17-93

The lawn roller has a mass of 80 kg and a radius of gyration $k_G = 0.175$ m. If it is pushed forward with a force of 200 N when the handle is at 45°, determine its angular acceleration. The coefficients of static and kinetic friction between the ground and the roller are $\mu_s = 0.12$ and $\mu_k = 0.1$, respectively.




$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x; \qquad 200\cos 45° - F_A = 80a_G$

$+\uparrow \Sigma F_y = m(a_G)_y; \qquad N_A - 80(9.81) - 200\sin 45° = 0$

$\circlearrowleft + \Sigma M_G = I_G\,\alpha; \qquad F_A(0.2) = 80(0.175)^2\,\alpha$

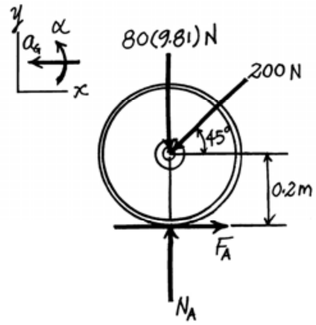
Assume no slipping: $a_G = 0.2\alpha$

$F_A = 61.32$ N

$N_A = 926.2$ N

$\alpha = 5.01 \text{ rad/s}^2$ **Ans.**

$(F_A)_{max} = \mu_s N_A = 0.12(926.2) = 111.1 \text{ N} > 61.32 \text{ N}$ **OK**

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17-98

$M = 75$ kg, $K_G = 0.38$ m, $\mu_k = 0.15$

$\nearrow \Sigma F = m a_G$

$T - mg\sin\theta - \mu_k N_A = -M a_G$ .. (1)

$\nwarrow \Sigma F = 0$

$N_A - mg\cos\theta = 0$

$N_A = 75 \times 9.81 \cos 30 = 637.18$ N

$\Sigma M_G = I_G\alpha$, $a_G = \alpha a$

$Ta - \mu_k N_A b = M k_G^2 \alpha$ .. (2)

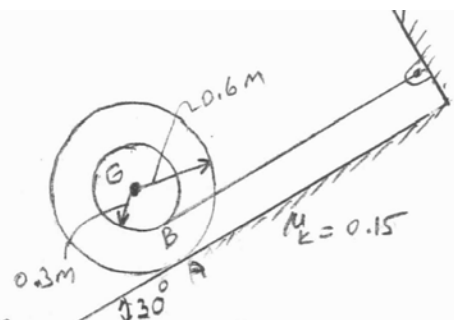
Substitute in (1) and (2):

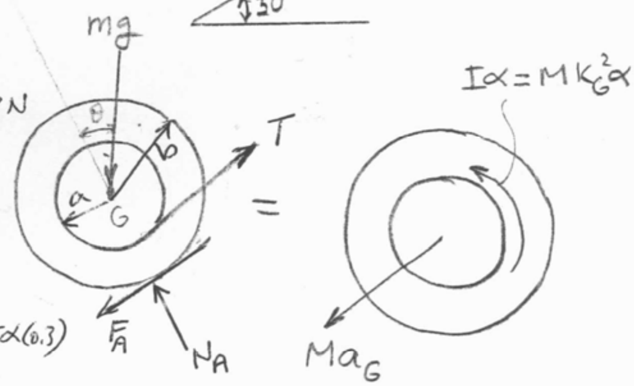
$T - 75(9.81)(\sin 30) - 0.15(637.18) = -75\alpha(0.3)$

$T(0.3) - 0.15(637.18)(0.6) = 75(0.38)^2\alpha$

solve to get: $T = 359$ N, $\alpha = 4.65 \text{ rad/s}^2$

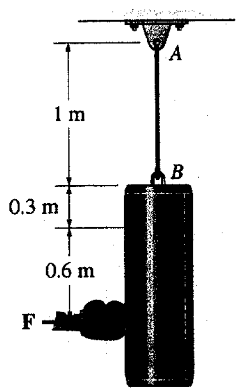
$a_G = 1.395 \text{ m/s}^2$,



17-105

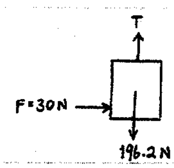
The 20-kg punching bag has a radius of gyration about its center of mass $G$ of $k_G = 0.4$ m. If it is initially at rest and is subjected to a horizontal force $F = 30$ N, determine the initial angular acceleration of the bag and the tension in the supporting cable $AB$.




$\xrightarrow{+} \Sigma F_x = m(a_G)_x;$ $30 = 20(a_G)_x$

$+\uparrow \Sigma F_y = m(a_G)_y;$ $T - 196.2 = 20(a_G)_y$

$\circlearrowleft + \Sigma M_G = I_G \alpha;$ $30(0.6) = 20(0.4)^2 \alpha$



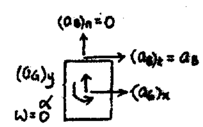

$\alpha = 5.62 \text{ rad/s}^2$ **Ans**

$(a_G)_x = 1.5 \text{ m/s}^2$

$\mathbf{a}_B = \mathbf{a}_G + \mathbf{a}_{B/G}$

$a_B \mathbf{i} = (a_G)_y \mathbf{j} + (a_G)_x \mathbf{i} - \alpha(0.3)\mathbf{i}$

$(+\uparrow)$ $(a_G)_y = 0$

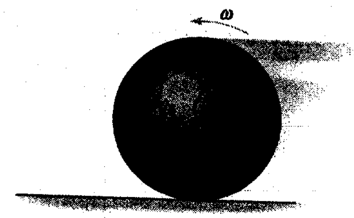



Thus,

$T = 196$ N **Ans**

17-107

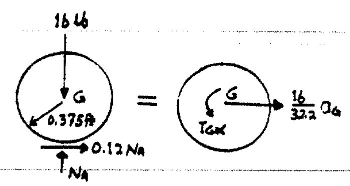
**The 16-lb bowling ball is cast horizontally onto a lane such that initially $\omega = 0$ and its mass center has a velocity $v = 8$ ft/s. If the coefficient of kinetic friction between the lane and the ball is $\mu_k = 0.12$, determine the distance the ball travels before it rolls without slipping. For the calculation, neglect the finger holes in the ball and assume the ball has a uniform density.**




$\xrightarrow{+} \Sigma F_x = m(a_G)_x; \quad 0.12N_A = \frac{16}{32.2}a_G$

$+\uparrow \Sigma F_y = m(a_G)_y; \quad N_A - 16 = 0$

$\circlearrowleft + \Sigma M_G = I_G\alpha; \quad 0.12N_A(0.375) = \left[\frac{2}{5}\left(\frac{16}{32.2}\right)(0.375)^2\right]\alpha$




Solving,

$N_A = 16$ lb; $\quad a_G = 3.864$ ft/s$^2$; $\quad \alpha = 25.76$ rad/s$^2$

When the ball rolls without slipping $v = \omega(0.375)$,

$(\circlearrowleft +) \quad \omega = \omega_0 + \alpha_c t$

$\frac{v}{0.375} = 0 + 25.76t$

$v = 9.660t$

$(\xleftarrow{+}) \quad v = v_0 + a_c t$

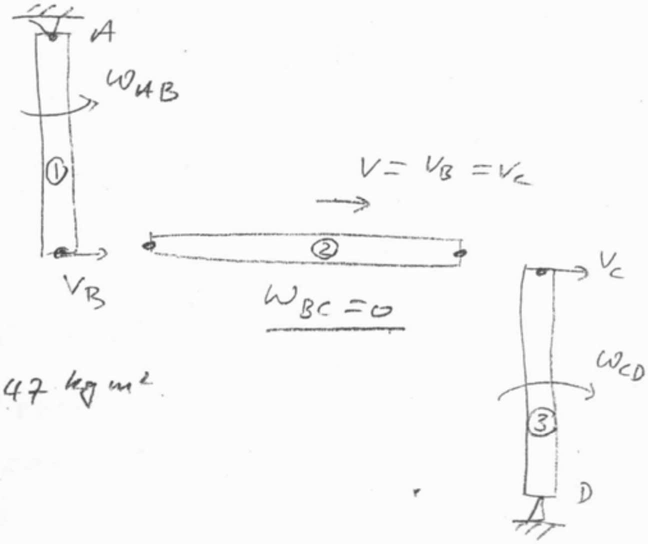
$9.660t = 8 - 3.864t$

$t = 0.592$ s

$(\xleftarrow{+}) \quad s = s_0 + v_0 t + \frac{1}{2}a_c t^2$

$s = 0 + 8(0.592) - \frac{1}{2}(3.864)(0.592)^2$

$s = 4.06$ ft **Ans**




$$V_C = V_B = \omega_{AB} r_{AB}$$
$$= (5)(0.5) = 2.5\ m/s^2$$

$$I_A = I_D = \frac{1}{3} m l^2$$
$$= \frac{1}{3}\left(\frac{50}{9.81}\right)(0.5)^2 = 0.4247\ kg\,m^2$$

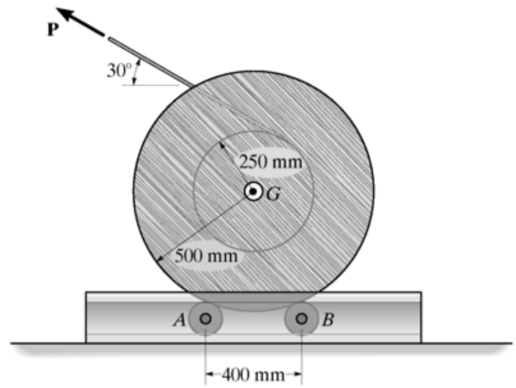
$$m_{BC} = \frac{100}{9.81} = 10.194\ kg$$

$$\omega_{CD} = \omega_{AB}$$

$$T = T_1 + T_2 + T_3$$
$$= \frac{1}{2} I_A \omega_{AB}^2 + \frac{1}{2} m_{BC} V^2 + \frac{1}{2} I_D \omega_{AD}^2$$
$$= 5.309 + 31.855 + 5.309$$
$$T = 42.473\ J$$

18-10

A force of $P = 20$ N is applied to the cable, which causes the 175-kg reel to turn without slipping on the two rollers $A$ and $B$ of the dispenser. Determine the angular velocity of the reel after it has rotated two revolutions starting from rest. Neglect the mass of the cable. Each roller can be considered as an 18-kg cylinder, having a radius of 0.1 m. The radius of gyration of the reel about its center axis is $k_G = 0.42$ m.



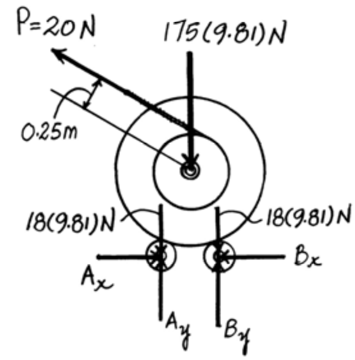

System:

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

$$[0 + 0 + 0] + 20(2)(2\pi)(0.250) = \frac{1}{2}\left[175(0.42^2)\right]\omega^2 + \frac{2}{2}\left[\frac{1}{2}(18)(0.1)^2\right]\omega_r^2$$

$$v = \omega_r\,(0.1) = \omega(0.5)$$

$$\omega_r = 5\omega$$

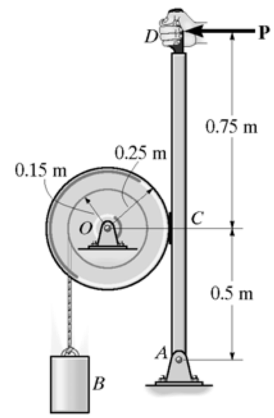



Solving:

$$\omega = 1.88 \text{ rad/s}$$ **Ans.**

18-17

The drum has a mass of 50 kg and a radius of gyration about the pin at $O$ of $k_O = 0.23$ m. If the 15-kg block is moving downward at 3 m/s, and a force of $P = 100$ N is applied to the brake arm, determine how far the block descends from the instant the brake is applied until it stops. Neglect the thickness of the handle. The coefficient of kinetic friction at the brake pad is $\mu_k = 0.5$.




Brake arm:

$$\zeta + \Sigma M_A = 0; \qquad -N(0.5) + 100(1.25) = 0$$

$$N = 250 \text{ N}$$

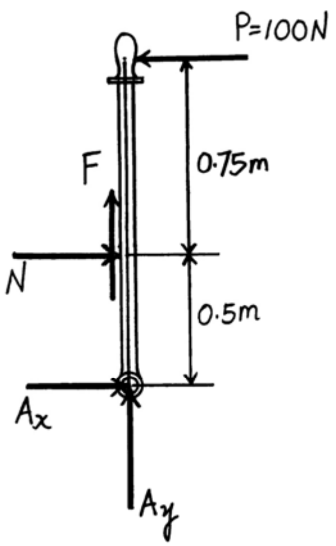
$$F = 0.5(250) = 125 \text{ N}$$

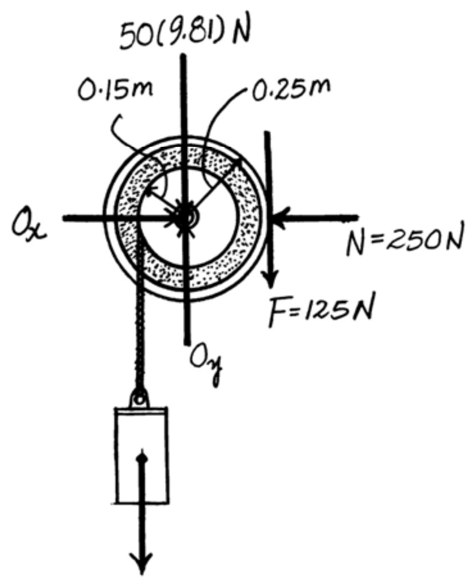
If block descends $s$, then $F$ acts through a distance $s' = s\left(\frac{0.25}{0.15}\right)$.

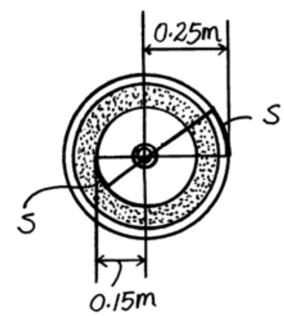
$$T_1 + \Sigma U_{1-2} = T_2$$

$$\frac{1}{2}\left[(50)(0.23)^2\right]\left(\frac{3}{0.15}\right)^2 + \frac{1}{2}(15)(3)^2 + 15(9.81)(s) - 125(s)\left(\frac{0.25}{0.15}\right) = 0$$

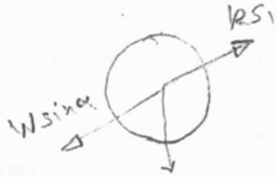
$$s = 9.75 \text{ m}$$ **Ans.**



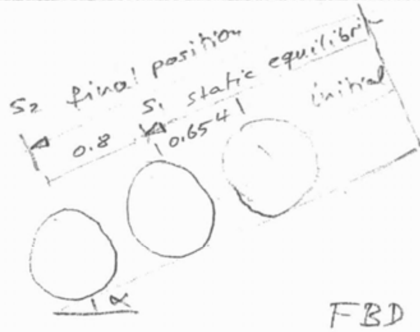
18-22



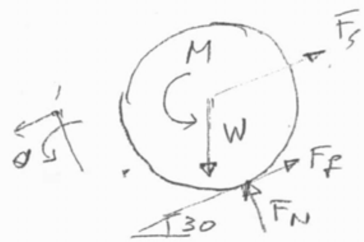

static equilibrium

$ks_1 = mg\sin\alpha$

$s_1 = \frac{mg\sin\alpha}{k} = 0.654\,m$




FBD




$I_G = \frac{1}{2}mr^2 = \frac{1}{2}(20)(0.2)^2 = 0.4\,kg\,m^2$

$s = \theta r$ without slipping

$\Rightarrow \theta = \frac{s}{r} = \frac{0.8}{0.2} = 4\ rad$

$v_G = \omega r_G = 0.2\omega$

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

$0 + mg\sin\alpha(0.8) - \frac{k}{2}(s_2^2 - s_1^2) + M\theta = \frac{1}{2}mv_G^2 + \frac{1}{2}I_G\omega^2$

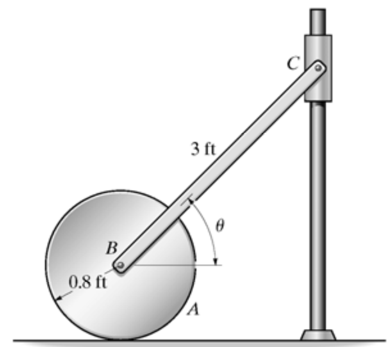
$20(9.81)\sin 30(0.8) - \frac{150}{2}[(0.8+0.654)^2 - (0.654)^2] + 30(4)$

$= \frac{1}{2}(I_G + mr_G^2)\,\omega^2$ $\qquad r_G = 0.2$

$\hookrightarrow \omega = 10.96\ rad/s$

18-53

The system consists of a 20-lb disk $A$, 4-lb slender rod $BC$, and a 1-lb smooth collar $C$. If the disk rolls without slipping, determine the velocity of the collar at the instant $\theta = 30°$. The system is released from rest when $\theta = 45°$.




$$v_B = 0.8\omega_A$$

$$\omega_{BC} = \frac{v_B}{1.5} = \frac{v_C}{2.598} = \frac{v_G}{1.5}$$

Thus,

$$v_B = v_G = 1.5\omega_{BC} \qquad v_C = 2.598\omega_{BC}$$

$$\omega_A = 1.875\,\omega_{BC}$$

$$T_1 + V_1 = T_2 + V_2$$

$$0 + 4(1.5\sin 45°) + 1(3\sin 45°)$$

$$= \frac{1}{2}\left[\frac{1}{2}\left(\frac{20}{32.2}\right)(0.8)^2\right](1.875\omega_{BC})^2 + \frac{1}{2}\left(\frac{20}{32.2}\right)(1.5\,\omega_{BC})^2$$

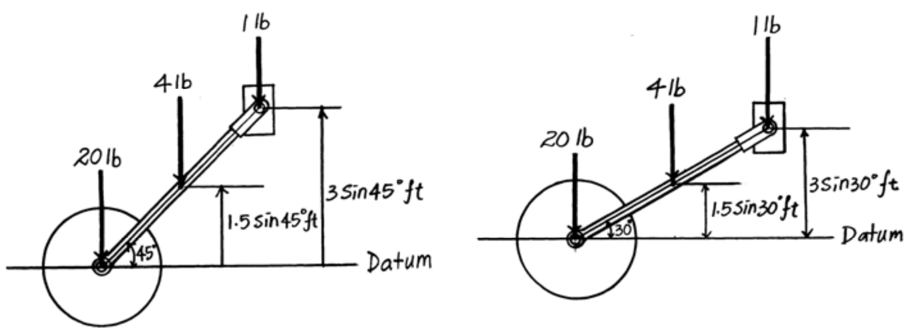
$$+\frac{1}{2}\left[\frac{1}{12}\left(\frac{4}{32.2}\right)(3)^2\right]\omega_{BC}^2 + \frac{1}{2}\left(\frac{4}{32.2}\right)(1.5\omega_{BC})^2$$

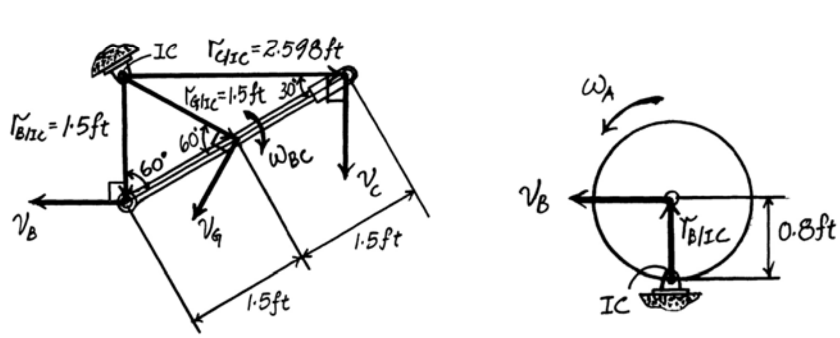
$$+\frac{1}{2}\left(\frac{1}{32.2}\right)(2.598\omega_{BC})^2 + 4(1.5\sin 30°) + 1(3\sin 30°)$$

$$\omega_{BC} = 1.180 \text{ rad/s}$$

Thus,

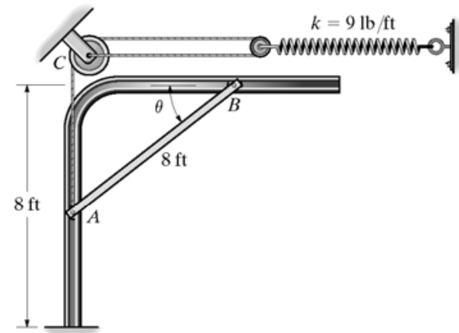
$$v_C = 2.598(1.180) = 3.07 \text{ ft/s}$$ **Ans.**



18-63

The motion of the uniform 80-lb garage door is guided at its ends by the track. If it is released from rest at $\theta = 0°$, determine the door's angular velocity at the instant $\theta = 30°$. The spring is originally stretched 1 ft when the door is held open, $\theta = 0°$. Assume the door can be treated as a thin plate, and there is a spring and pulley system on each of the two sides of the door.




$$v_G = 4\omega$$

$$s_A + 2s_s = l$$

$$\Delta s_A = -2\Delta s_s$$

$$4 \text{ ft} = -2\Delta s_s$$

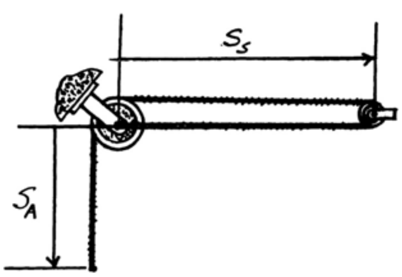
$$\Delta s_s = -2 \text{ ft}$$

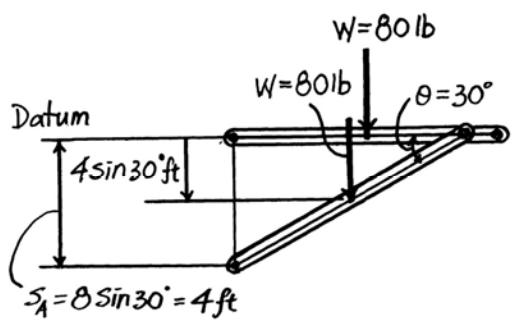
$$T_1 + V_1 = T_2 + V_2$$

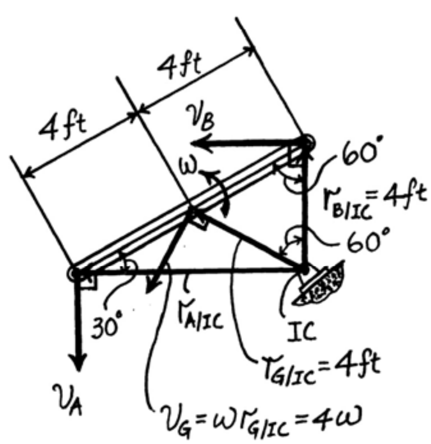
$$0 + 2\left[\frac{1}{2}(9)(1)^2\right] = \frac{1}{2}\left(\frac{80}{32.2}\right)(4\omega)^2 + \frac{1}{2}\left[\frac{1}{12}\left(\frac{80}{32.2}\right)(8)^2\right]\omega^2 - 80(4\sin 30°)$$

$$+ 2\left[\frac{1}{2}(9)(2+1)^2\right]$$

$\omega = 1.82$ rad/s **Ans.**

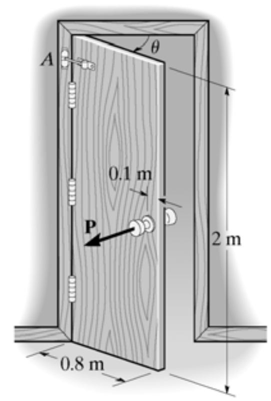


18-extra

The uniform door has a mass of 20 kg and can be treated as a thin plate having the dimensions shown. If it is connected to a torsional spring at $A$, which has a stiffness of $k = 80\ \text{N}\cdot\text{m/rad}$, determine the required initial twist of the spring in radians so that the door has an angular velocity of 12 rad/s when it closes at $\theta = 0°$ after being opened at $\theta = 90°$ and released from rest. *Hint:* For a torsional spring $M = k\theta$, when $k$ is the stiffness and $\theta$ is the angle of twist.




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

$$0 + \int_{\theta_O}^{\theta_O+\frac{\pi}{2}} 80\theta\, d\theta = \frac{1}{2}\left[\frac{1}{3}(20)(0.8)^2\right](12)^2$$

$$40\left[\left(\theta_O + \tfrac{\pi}{2}\right)^2 - \theta_0^2\right] = 307.2$$

$$\theta_O = 1.66\ \text{rad}$$ **Ans.**