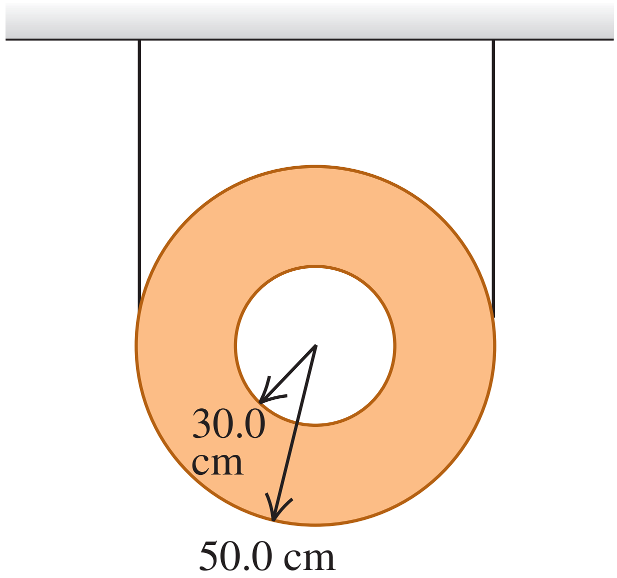
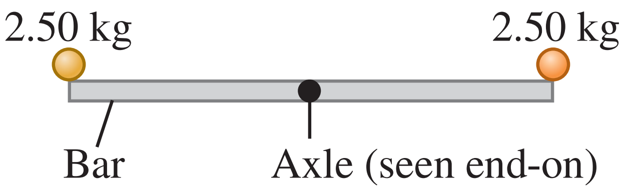
62 ••• A uniform hollow disk has two pieces of thin, light wire wrapped around its outer rim and is supported from the ceiling (Fig. P62). Suddenly one of the wires breaks, and the remaining wire does not slip as the disk rolls down. Use energy conservation to find the speed of the center of this disk after it has fallen a distance of 2.20 m.

Figure **P62**



63 ••• A thin, uniform, 3.80-kg bar, 80.0 cm long, has very small 2.50-kg balls glued on at either end (Fig. P63). It is supported horizontally by a thin, horizontal, frictionless axle passing through its center and perpendicular to the bar. Suddenly the right-hand ball becomes detached and falls off, but the other ball remains glued to the bar. (a) Find the angular acceleration of the bar just after the ball falls off. (b) Will the angular acceleration remain constant as the bar continues to swing? If not, will it increase or decrease? (c) Find the angular velocity of the bar just as it swings through its vertical position.

Figure **P63**



64 ••• While exploring a castle, Exena the Exterminator is spotted by a dragon that chases her down a hallway. Exena runs into a room and attempts to swing the heavy door shut before the dragon gets her. The door is initially perpendicular to the wall, so it must be turned through 90° to close. The door is 3.00 m tall and 1.25 m wide, and it weighs 750 N. You can ignore the friction at the hinges. If Exena applies a force of 220 N at the edge of the door and perpendicular to it, how much time does it take her to close the door?

10.62. **IDENTIFY:** The kinetic energy of the disk is $K=\frac{1}{2}Mv_{cm}^2+\frac{1}{2}I\omega^2$. As it falls its gravitational potential energy decreases and its kinetic energy increases. The only work done on the disk is the work done by gravity, so $K_1+U_1=K_2+U_2$.

SET UP: $I_{cm}=\frac{1}{2}M(R_2^2+R_1^2)$, where $R_1=0.300$ m and $R_2=0.500$ m. $v_{cm}=R_2\omega$. Take $y_1=0$, so $y_2=-2.20$ m.

EXECUTE: $K_1+U_1=K_2+U_2$. $K_1=0$, $U_1=0$. $K_2=-U_2$. $\frac{1}{2}Mv_{cm}^2+\frac{1}{2}I_{cm}\omega^2=-Mgy_2$.

$\frac{1}{2}I_{cm}\omega^2=\frac{1}{4}M(1+[R_1/R_2]^2)v_{cm}^2=0.340Mv_{cm}^2$. Then $0.840Mv_{cm}^2=-Mgy_2$ and

$$v_{cm}=\sqrt{\frac{-gy_2}{0.840}}=\sqrt{\frac{-(9.80\ \text{m/s}^2)(-2.20\ \text{m})}{0.840}}=5.07\ \text{m/s}.$$

EVALUATE: A point mass in free fall acquires a speed of 6.57 m/s after falling 2.20 m. The disk has a value of v_{cm} that is less than this, because some of the original gravitational potential energy has been converted to rotational kinetic energy.

10.63. **IDENTIFY:** Use $\sum\tau_z=I\alpha_z$ to find the angular acceleration just after the ball falls off and use conservation of energy to find the angular velocity of the bar as it swings through the vertical position.

SET UP: The axis of rotation is at the axle. For this axis the bar has $I=\frac{1}{12}m_{bar}L^2$, where $m_{bar}=3.80$ kg and $L=0.800$ m. Energy conservation gives $K_1+U_1=K_2+U_2$. The gravitational potential energy of the bar doesn't change. Let $y_1=0$, so $y_2=-L/2$.

EXECUTE: **(a)** $\tau_z=m_{ball}g(L/2)$ and $I=I_{ball}+I_{bar}=\frac{1}{12}m_{bar}L^2+m_{ball}(L/2)^2$. $\sum\tau_z=I\alpha_z$ gives

$$\alpha_z=\frac{m_{ball}g(L/2)}{\frac{1}{12}m_{bar}L^2+m_{ball}(L/2)^2}=\frac{2g}{L}\left(\frac{m_{ball}}{m_{ball}+m_{bar}/3}\right)\ \text{and}$$

$$\alpha_z=\frac{2(9.80\ \text{m/s}^2)}{0.800\ \text{m}}\left(\frac{2.50\ \text{kg}}{2.50\ \text{kg}+[3.80\ \text{kg}]/3}\right)=16.3\ \text{rad/s}^2.$$

(b) As the bar rotates, the moment arm for the weight of the ball decreases and the angular acceleration of the bar decreases.

(c) $K_1+U_1=K_2+U_2$. $0=K_2+U_2$. $\frac{1}{2}(I_{bar}+I_{ball})\omega^2=-m_{ball}g(-L/2)$.

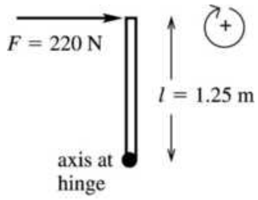
$$\omega=\sqrt{\frac{m_{ball}gL}{m_{ball}L^2/4+m_{bar}L^2/12}}=\sqrt{\frac{g}{L}\left(\frac{4m_{ball}}{m_{ball}+m_{bar}/3}\right)}=\sqrt{\frac{9.80\ \text{m/s}^2}{0.800\ \text{m}}\left(\frac{4[2.50\ \text{kg}]}{2.50\ \text{kg}+[3.80\ \text{kg}]/3}\right)}$$

$\omega=5.70$ rad/s.

EVALUATE: As the bar swings through the vertical, the linear speed of the ball that is still attached to the bar is $v=(0.400\ \text{m})(5.70\ \text{rad/s})=2.28$ m/s. A point mass in free-fall acquires a speed of 2.80 m/s after falling 0.400 m; the ball on the bar acquires a speed less than this.

10.64. **IDENTIFY:** Use $\sum\tau_z=I\alpha_z$ to find α_z, and then use the constant α_z kinematic equations to solve for *t*.

SET UP: The door is sketched in Figure 10.64.



EXECUTE:

$\sum\tau_z=Fl=(220\ \text{N})(1.25\ \text{m})=275\ \text{N}\cdot\text{m}$

From Table 9.2(d), $I=\frac{1}{3}Ml^2$

$I=\frac{1}{3}(750\ \text{N}/9.80\ \text{m/s}^2)(1.25\ \text{m})^2=$

$39.9\ \text{kg}\cdot\text{m}^2$

Figure 10.64

$$\sum\tau_z=I\alpha_z\ \text{so}\ \alpha_z=\frac{\sum\tau_z}{I}=\frac{275\ \text{N}\cdot\text{m}}{39.9\ \text{kg}\cdot\text{m}^2}=6.89\ \text{rad/s}^2$$

SET UP: $\alpha_z=6.89\ \text{rad/s}^2$; $\theta-\theta_0=90°(\pi\ \text{rad}/180°)=\pi/2$ rad; $\omega_{0z}=0$ (door initially at rest); $t=?$

$\theta-\theta_0=\omega_{0z}t+\frac{1}{2}\alpha_zt^2$

EXECUTE: $$t=\sqrt{\frac{2(\theta-\theta_0)}{\alpha_z}}=\sqrt{\frac{2(\pi/2\ \text{rad})}{6.89\ \text{rad/s}^2}}=0.675\ \text{s}$$

EVALUATE: The forces and the motion are connected through the angular acceleration.