41. In a city with an air-pollution problem, a bus has no combustion engine. It runs on energy drawn from a large, rapidly rotating flywheel under the floor of the bus. The flywheel is spun up to its maximum rotation rate of 4,000 rev/min by an electric motor at the bus terminal. Every time the bus speeds up, the flywheel slows down slightly. The bus is equipped with regenerative braking, so that the flywheel can speed up when the bus slows down. The flywheel is a uniform solid cylinder with mass 1,600 kg and radius 0.650 m. The bus body does work against air resistance and rolling resistance at the average rate of 18.0 hp as it travels with an average speed of 40.0 km/h. How far can the bus travel before the flywheel has to be spun up to speed again?

P10.41 The power output of the bus is $P = \frac{E}{t}$

where $E = \frac{1}{2} M \omega^2 - \frac{1}{2} I \omega^2$ is the stored energy and $\Delta t = \frac{\Delta x}{v}$ is the time it can roll. Then $\frac{1}{4} M R^2 \omega^2 = P \Delta t = \frac{P \Delta x}{v}$ and

$$\Delta x = \frac{M R^2 \omega^2 

\frac{v}{P} = \frac{1600 \text{ kg} (0.65 \text{ m})^2 \left(4000 \text{ rev/min}\right)^2 11 \text{ m/s}}{4 \left(18.716 \text{ W}\right)} = 24.5 \text{ km}$$
A cylinder of mass 10.0 kg rolls without slipping on a horizontal surface. At the instant its center of mass has a speed of 10.0 m/s, determine (a) the translational kinetic energy of its center of mass, (b) the rotational kinetic energy about its center of mass; and (c) its total energy.

P10.31

(a) 
\[ K_{cm} = \frac{1}{2} m v^2 = \frac{1}{2} (10.0 \text{ kg}) (10.0 \text{ m/s})^2 = 500 \text{ J} \]

(b) 
\[ K_{roll} = \frac{1}{2} I \omega^2 = \frac{1}{2} (I_{cm}) \left( \frac{v}{r} \right)^2 = \frac{1}{2} (10.0 \text{ kg}) (10.0 \text{ m/s})^2 = 250 \text{ J} \]

(c) 
\[ K_{total} = K_{cm} + K_{roll} = 750 \text{ J} \]
A metal can containing condensed mushroom soup has mass 215 g, height 10.8 cm and diameter 6.38 cm. It is placed at rest on its side at the top of a 3.00-m long incline that is at 25.0° to the horizontal, and is then released to roll straight down. Assuming mechanical energy conservation, calculate the moment of inertia of the can if it takes 1.50 s to reach the bottom of the incline. Which pieces of data, if any, are unnecessary for calculating the solution?

\[ \ddot{r} = \frac{\Delta x}{\Delta t} = \frac{2.00 \text{ m}}{1.50 \text{ s}} = 1.33 \text{ m/s}^2 \]

\[ v_e = 2.00 \text{ m/s} \]

\[ \omega = \frac{v_e}{r} = \frac{4.00 \text{ m/s}}{[3.00 \times 10^{-3} \text{ m}] / 2} = 8.00 \text{ rad/s} \]

We ignore internal friction and suppose the can rolls without slipping.

\[ \left( K_{\text{can}} + K_{\text{ms}} + V_{\text{g}} \right)_{\text{in}} = \left( K_{\text{can}} + K_{\text{ms}} + V_{\text{g}} \right)_{\text{out}} \]

\[ (2 + 0 + m g h) + \frac{1}{2} I \omega^2 + \frac{1}{2} m v_e^2 + 0 \]

\[ 0.215 \text{ kg} \left( 0.200 \text{ m/s} \right) \left[ (3.00 \text{ m}) \sin 25^{\circ} \right] = \frac{1}{2} (0.215 \text{ kg}) \left( 4.00 \text{ m/s} \right)^2 + \frac{1}{2} \left( 8.00 \times 10^{-3} \text{ kg m}^2 \text{ rad/s}^2 \right) \]

\[ 2.67 \text{ J} = 1.72 \text{ J} \left( 7.860 \text{ s}^2 \right) \]

\[ I = \frac{0.951 \text{ kg m}^2 \text{ s}^2}{7.860 \text{ s}^2} = 0.121 \times 10^{-3} \text{ kg m}^2 \]

The moment of inertia is unnecessary data.
A long uniform rod of length $L$ and mass $M$ is pivoted about a horizontal, frictionless pin through one end. The rod is released from rest in a vertical position, as shown in Figure P10.61. At the instant the rod is horizontal, find (a) its angular speed, (b) the magnitude of its angular acceleration, (c) the $x$ and $y$ components of the acceleration of its center of mass, and (d) the components of the reaction force at the pivot.

\[ \Delta \theta = 0 \quad \Rightarrow \quad K_0 + U_g = K_f + U_g \]

\[ \frac{1}{2} I \dot{\omega}^2 + \frac{1}{2} M g \left( \frac{L}{2} \right)^2 = 0 + M g \left( \frac{L}{2} \right) \]

Therefore,

\[ \omega = \sqrt{\frac{3g}{L}} \]

(b) \[ \sum r = 0 \text{, so that in the horizontal orientation.} \]

\[ \Sigma \tau = I \alpha \]

\[ M g \left( \frac{L}{2} \right) = \frac{M L^2}{3} \alpha \]

\[ \alpha = \frac{3g}{2L} \]

(c)

\[ a_y = a_y = -\omega_r \dot{\theta} = -\left( \frac{L}{2} \right) \ddot{\omega} = -\frac{3g}{2} \]

\[ a_x = -a_x = -\dot{\omega} - \alpha \left( \frac{L}{2} \right) = -\frac{3g}{4} \]

(d) Using Newton's second law, we have

\[ R_y = M \omega = \frac{3M g L}{2} \]