9.36 **IDENTIFY:** Treat each block as a point mass, so for each block $I = mr^2$, where r is the distance of the block from the axis. The total I for the object is the sum of the I for each of its pieces.

SET UP: In part (a) two blocks are a distance $L/2$ from the axis and the third block is on the axis. In part (b) two blocks are a distance $L/4$ from the axis and one is a distance $3L/4$ from the axis.

EXECUTE: **(a)** $I = 2m(L/2)^2 = \frac{1}{2}mL^2$.

(b) $I = 2m(L/4)^2 + m(3L/4)^2 = \dfrac{1}{16}mL^2(2+9) = \dfrac{11}{16}mL^2$.

EVALUATE: For the same object I is in general different for different axes.

9.39 **IDENTIFY** and **SET UP:** $I = \sum m_i r_i^2$ implies $I = I_{\text{rim}} + I_{\text{spokes}}$

EXECUTE: $I_{\text{rim}} = MR^2 = (1.40\text{ kg})(0.300\text{ m})^2 = 0.126\text{ kg}\cdot\text{m}^2$

Each spoke can be treated as a slender rod with the axis through one end, so

$I_{\text{spokes}} = 8\left(\frac{1}{3}ML^2\right) = \frac{8}{3}(0.280\text{ kg})(0.300\text{ m})^2 = 0.0672\text{ kg}\cdot\text{m}^2$

$I = I_{\text{rim}} + I_{\text{spokes}} = 0.126\text{ kg}\cdot\text{m}^2 + 0.0672\text{ kg}\cdot\text{m}^2 = 0.193\text{ kg}\cdot\text{m}^2$

EVALUATE: Our result is smaller than $m_{\text{tot}}R^2 = (3.64\text{ kg})(0.300\text{ m})^2 = 0.328\text{ kg}\cdot\text{m}^2$, since the mass of each spoke is distributed between $r = 0$ and $r = R$.

9.48 **IDENTIFY:** Repeat the calculation in Example 9.9, but with a different expression for I.

SET UP: For the solid cylinder in Example 9.9, $I = \frac{1}{2}MR^2$. For the thin-walled, hollow cylinder, $I = MR^2$.

EXECUTE: **(a)** With $I = MR^2$, the expression for v is $v = \sqrt{\dfrac{2gh}{1+M/m}}$.

(b) This expression is smaller than that for the solid cylinder; more of the cylinder's mass is concentrated at its edge, so for a given speed, the kinetic energy of the cylinder is larger. A larger fraction of the potential energy is converted to the kinetic energy of the cylinder, and so less is available for the falling mass.

EVALUATE: When M is much larger than m, v is very small. When M is much less than m, v becomes $v = \sqrt{2gh}$, the same as for a mass that falls freely from a height h.

9.52 **IDENTIFY:** The work the person does is the negative of the work done by gravity. $W_{\text{grav}} = U_{\text{grav,1}} - U_{\text{grav,2}}$.
$U_{\text{grav}} = Mgy_{\text{cm}}$.

SET UP: The center of mass of the ladder is at its center, 1.00 m from each end.
$y_{\text{cm,1}} = (1.00\text{ m})\sin 53.0° = 0.799\text{ m}$. $y_{\text{cm,2}} = 1.00\text{ m}$.

EXECUTE: $W_{\text{grav}} = (9.00\text{ kg})(9.80\text{ m/s}^2)(0.799\text{ m} - 1.00\text{ m}) = -17.7\text{ J}$. The work done by the person is 17.7 J.

EVALUATE: The gravity force is downward and the center of mass of the ladder moves upward, so gravity does negative work. The person pushes upward and does positive work.

9.55 **IDENTIFY:** Use Eq.(9.19) to relate I for the wood sphere about the desired axis to I for an axis along a diameter.

SET UP: For a thin-walled hollow sphere, axis along a diameter, $I = \frac{2}{3}MR^2$.

For a solid sphere with mass M and radius R, $I_{\text{cm}} = \frac{2}{5}MR^2$, for an axis along a diameter.

EXECUTE: Find d such that $I_P = I_{\text{cm}} + Md^2$ with $I_P = \frac{2}{3}MR^2$:

$\frac{2}{3}MR^2 = \frac{2}{5}MR^2 + Md^2$

The factors of M divide out and the equation becomes $\left(\frac{2}{3} - \frac{2}{5}\right)R^2 = d^2$

$d = \sqrt{(10-6)/15}R = 2R/\sqrt{15} = 0.516R$.

The axis is parallel to a diameter and is $0.516R$ from the center.

EVALUATE: $I_{\text{cm}}(\text{lead}) > I_{\text{cm}}(\text{wood})$ even though M and R are the same since for a hollow sphere all the mass is a distance R from the axis. Eq.(9.19) says $I_P > I_{\text{cm}}$, so there must be a d where $I_P(\text{wood}) = I_{\text{cm}}(\text{lead})$.

9.59 **IDENTIFY:** Use the equations in Table 9.2. I for the rod is the sum of I for each segment. The parallel-axis theorem says $I_{\text{p}} = I_{\text{cm}} + Md^2$.

SET UP: The bent rod and axes a and b are shown in Figure 9.59. Each segment has length $L/2$ and mass $M/2$.

EXECUTE: **(a)** For each segment the moment of inertia is for a rod with mass $M/2$, length $L/2$ and the axis through one end. For one segment, $I_s = \frac{1}{3}\left(\frac{M}{2}\right)\left(\frac{L}{2}\right)^2 = \frac{1}{24}ML^2$. For the rod, $I_a = 2I_s = \frac{1}{12}ML^2$.

(b) The center of mass of each segment is at the center of the segment, a distance of $L/4$ from each end. For each segment, $I_{cm} = \frac{1}{12}\left(\frac{M}{2}\right)\left(\frac{L}{2}\right)^2 = \frac{1}{96}ML^2$. Axis *b* is a distance $L/4$ from the cm of each segment, so for each segment the parallel axis theorem gives *I* for axis *b* to be $I_s = \frac{1}{96}ML^2 + \frac{M}{2}\left(\frac{L}{4}\right)^2 = \frac{1}{24}ML^2$ and $I_b = 2I_s = \frac{1}{12}ML^2$.

EVALUATE: *I* for these two axes are the same.

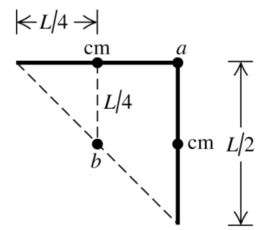


Figure 9.59

9.77 **IDENTIFY:** $K = \frac{1}{2}I\omega^2$. $a_{rad} = r\omega^2$. $m = \rho V$.

SET UP: For a disk with the axis at the center, $I = \frac{1}{2}mR^2$. $V = t\pi R^2$, where $t = 0.100$ m is the thickness of the flywheel. $\rho = 7800\ \text{kg/m}^3$ is the density of the iron.

EXECUTE: **(a)** $\omega = 90.0\ \text{rpm} = 9.425\ \text{rad/s}$. $I = \frac{2K}{\omega^2} = \frac{2(10.0\times10^6\ \text{J})}{(9.425\ \text{rad/s})^2} = 2.252\times10^5\ \text{kg}\cdot\text{m}^2$.

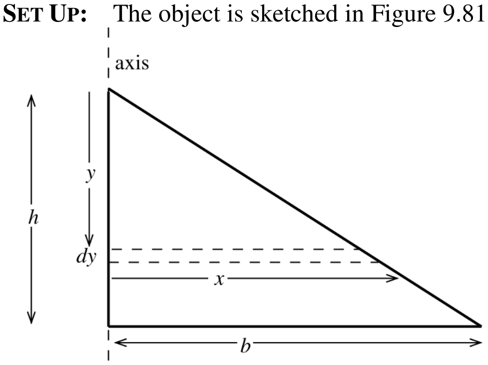
$m = \rho V = \rho\pi R^2 t$. $I = \frac{1}{2}mR^2 = \frac{1}{2}\rho\pi t R^4$. This gives $R = (2I/\rho\pi t)^{1/4} = 3.68\ \text{m}$ and the diameter is 7.36 m.

(b) $a_{rad} = R\omega^2 = 327\ \text{m/s}^2$

EVALUATE: In $K = \frac{1}{2}I\omega^2$, ω must be in rad/s. a_{rad} is about 33*g*; the flywheel material must have large cohesive strength to prevent the flywheel from flying apart.

9.81 **IDENTIFY:** Use Eq.(9.20) to calculate *I*. Then use $K = \frac{1}{2}I\omega^2$ to calculate *K*.

(a) SET UP: The object is sketched in Figure 9.81.



Consider a small strip of width *dy* and a distance *y* below the top of the triangle.
The length of the strip is $x = (y/h)b$.

Figure 9.81

EXECUTE: The strip has area $x\,dy$ and the area of the sign is $\frac{1}{2}bh$, so the mass of the strip is

$$dm = M\left(\frac{x\,dy}{\frac{1}{2}bh}\right) = M\left(\frac{yb}{h}\right)\left(\frac{2\,dy}{bh}\right) = \left(\frac{2M}{h^2}\right)y\,dy$$

$$dI = \tfrac{1}{3}(dm)x^2 = \left(\frac{2Mb^2}{3h^4}\right)y^3\,dy$$

$$I = \int_0^h dI = \frac{2Mb^2}{3h^4} \int_0^h y^3 \ dy = \frac{2Mb^2}{3h^4}\left(\frac{1}{h} y^4 \Big|_0^h \right) = \frac{1}{6} Mb^2$$

(b) $I = \frac{1}{6} Mb^2 = 2.304 \ \text{kg} \cdot \text{m}^2$

$\omega = 2.00 \ \text{rev/s} = 4.00\pi \ \text{rad/s}$

$K = \frac{1}{2} I\omega^2 = 182 \ \text{J}$

EVALUATE: From Table (9.2), if the sign were rectangular, with length b, then $I = \frac{1}{3} Mb^2$. Our result is one-half this, since mass is closer to the axis for the triangular than for the rectangular shape.