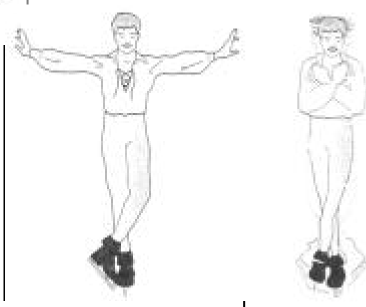
10.40 The Spinning Figure Skater. The outstretched hands and arms of a figure skater preparing for a spin can be considered a slender rod pivoting about an axis through its center (Fig. 10.48). When his hands and arms are brought in and wrapped around his body to execute the spin, the hands and arms can be considered a thin-walled hollow cylinder. His hands and arms have a combined mass 8.0 kg. When outstretched, they span 1.8 m; when wrapped, they form a cylinder of radius 25 cm. The moment of inertia about the rotation axis of the remainder of his body is constant and equal to 0.40 kg · m². If his original angular speed is 0.40 rev/s, what is his final angular speed?



10.40: The skater's initial moment of inertia is

$$I_1 = (0.400\ \text{kg}\cdot\text{m}^2) + \frac{1}{12}(8.00\ \text{kg})(1.80\ \text{m})^2 = 2.56\ \text{kg}\cdot\text{m}^2,$$

and her final moment of inertia is

$$I_2 = (0.400\ \text{kg}\cdot\text{m}^2) + (8.00\ \text{kg})(25\times 10^{-2}\ \text{m})^2 = 0.9\ \text{kg}\cdot\text{m}^2.$$

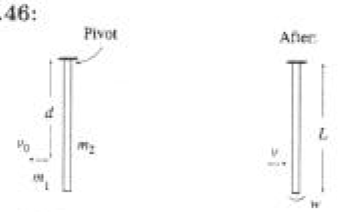
Then from Eq. (10.33),

$$\omega_2 = \omega_1 \frac{I_1}{I_2} = (0.40\ \text{rev/s})\frac{2.56\ \text{kg}\cdot\text{m}^2}{0.9\ \text{kg}\cdot\text{m}^2} = 1.14\ \text{rev/s}.$$

Note that conversion from rev/s to rad/s is not necessary.

10.46 A thin, uniform, metal bar, 2.00 m long and weighing 90.0 N, is hanging vertically from the ceiling by a frictionless pivot. Suddenly it is struck 1.50 m below the ceiling by a small 3.00-kg ball, initially traveling horizontally at 10.0 m/s. The ball rebounds in the opposite direction with a speed of 6.00 m/s. a) Find the angular speed of the bar just after the collision. b) During the collision, why is the angular momentum conserved, but not the linear momentum?

10.46:



(a) Conservation of angular momentum:

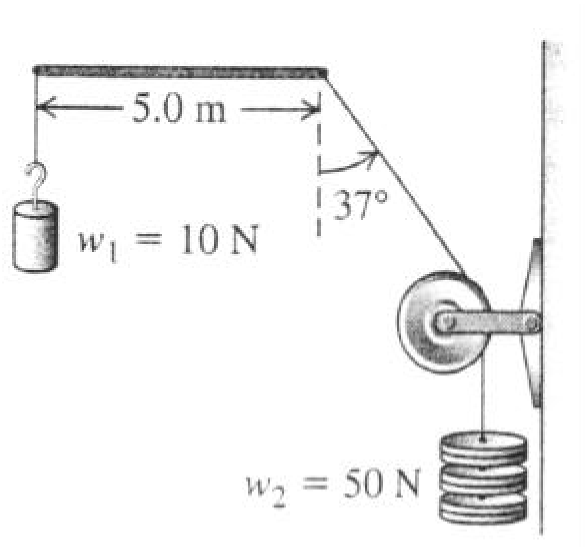
$$m_1 v_0 d = -m_1 v d + \tfrac{1}{3} m_2 L^2 \omega$$

$$(3.00\,\text{kg})(10.0\,\text{m/s})(1.50\,\text{m}) = -(3.00\,\text{kg})(6.00\,\text{m/s})(1.50\,\text{m}) + \frac{1}{3}\left(\frac{90.0\,\text{N}}{9.80\,\text{m/s}^2}\right)(2.00\,\text{m})^2\omega$$

$$\omega = 5.88\,\text{rad/s}$$

(b) There are no unbalanced torques about the pivot, so angular momentum is conserved. But the pivot exerts an unbalanced horizontal external force on the system, so the linear momentum is not conserved.

11.50 A single additional force is to be applied to the bar in Fig. 11.32 to maintain it in equilibrium in the position shown. You can ignore the weight of the bar. a) What are the horizontal and vertical components of the required force? b) What is the angle the force must make with the bar? c) What is the magnitude of the required force? d) Where should the force be applied?



11.50: a) The tension in the string is $w_2 = 50$ N, and the horizontal force on the bar must balance the horizontal component of the force that the string exerts on the bar, and is equal to $(50\text{ N})\sin 37° = 30$ N, to the left in the figure. The vertical force must be $(50\text{ N})\cos 37° + 10\text{ N} = 50$ N, up. b) $\arctan\left(\frac{50\text{ N}}{30\text{ N}}\right) = 59°$. c) $\sqrt{(30\text{ N})^2 + (50\text{ N})^2} = 58$ N. d) Taking torques about (and measuring the distance from) the left end, $(50\text{ N})x = (40\text{ N})(5.0\text{ m})$, so $x = 4.0$ m, where only the vertical components of the forces exert torques.