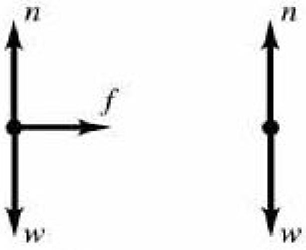
4.28. **IDENTIFY:** The surface of block B can exert both a friction force and a normal force on block A. The friction force is directed so as to oppose relative motion between blocks B and A. Gravity exerts a downward force w on block A.

SET UP: The pull is a force on B not on A.

EXECUTE: **(a)** If the table is frictionless there is a net horizontal force on the combined object of the two blocks, and block B accelerates in the direction of the pull. The friction force that B exerts on A is to the right, to try to prevent A from slipping relative to B as B accelerates to the right. The free-body diagram is sketched in Figure 4.28a. f is the friction force that B exerts on A and n is the normal force that B exerts on A.

(b) The pull and the friction force exerted on B by the table cancel and the net force on the system of two blocks is zero. The blocks move with the same constant speed and B exerts no friction force on A. The free-body diagram is sketched in Figure 4.28b.

EVALUATE: If in part (b) the pull force is decreased, block B will slow down, with an acceleration directed to the left. In this case the friction force on A would be to the left, to prevent relative motion between the two blocks by giving A an acceleration equal to that of B.



(a) (b)

9.47. **IDENTIFY:** Apply conservation of energy to the system of stone plus pulley. $v = r\omega$ relates the motion of the stone to the rotation of the pulley.

SET UP: For a uniform solid disk, $I = \frac{1}{2}MR^2$. Let point 1 be when the stone is at its initial position and point 2 be when it has descended the desired distance. Let $+y$ be upward and take $y = 0$ at the initial position of the stone, so $y_1 = 0$ and $y_2 = -h$, where h is the distance the stone descends.

EXECUTE: **(a)** $K_p = \frac{1}{2}I_p\omega^2$. $I_p = \frac{1}{2}M_pR^2 = \frac{1}{2}(2.50\text{ kg})(0.200\text{ m})^2 = 0.0500\text{ kg}\cdot\text{m}^2$.

$\omega = \sqrt{\dfrac{2K_p}{I_p}} = \sqrt{\dfrac{2(4.50\text{ J})}{0.0500\text{ kg}\cdot\text{m}^2}} = 13.4\text{ rad/s}$. The stone has speed $v = R\omega = (0.200\text{ m})(13.4\text{ rad/s}) = 2.68\text{ m/s}$.

The stone has kinetic energy $K_s = \frac{1}{2}mv^2 = \frac{1}{2}(1.50\text{ kg})(2.68\text{ m/s})^2 = 5.39\text{ J}$. $K_1 + U_1 = K_2 + U_2$ gives

$0 = K_2 + U_2$. $0 = 4.50\text{ J} + 5.39\text{ J} + mg(-h)$. $h = \dfrac{9.89\text{ J}}{(1.50\text{ kg})(9.80\text{ m/s}^2)} = 0.673\text{ m}$.

(b) $K_{tot} = K_p + K_s = 9.89\text{ J}$. $\dfrac{K_p}{K_{tot}} = \dfrac{4.50\text{ J}}{9.89\text{ J}} = 45.5\%$.

EVALUATE: The gravitational potential energy of the pulley doesn't change as it rotates. The tension in the wire does positive work on the pulley and negative work of the same magnitude on the stone, so no net work on the system.

EXECUTE: **(a)** Yes, angular momentum is conserved. The moment arm for the tension in the cord is zero so this force exerts no torque and there is no net torque on the block.

(b) $L_1 = L_2$ so $I_1\omega_1 = I_2\omega_2$. Block treated as a point mass, so $I = mr^2$, where r is the distance of the block from the hole.

$$mr_1^2\omega_1 = mr_2^2\omega_2$$

$$\omega_2 = \left(\frac{r_1}{r_2}\right)^2 \omega_1 = \left(\frac{0.300\text{ m}}{0.150\text{ m}}\right)^2 (1.75\text{ rad/s}) = 7.00\text{ rad/s}$$

(c) $K_1 = \frac{1}{2}I_1\omega_1^2 = \frac{1}{2}mr_1^2\omega_1^2 = \frac{1}{2}mv_1^2$

$$v_1 = r_1\omega_1 = (0.300\text{ m})(1.75\text{ rad/s}) = 0.525\text{ m/s}$$

$$K_1 = \tfrac{1}{2}mv_1^2 = \tfrac{1}{2}(0.0250\text{ kg})(0.525\text{ m/s})^2 = 0.00345\text{ J}$$

$$K_2 = \tfrac{1}{2}mv_2^2$$

$$v_2 = r_2\omega_2 = (0.150\text{ m})(7.00\text{ rad/s}) = 1.05\text{ m/s}$$

$$K_2 = \tfrac{1}{2}mv_2^2 = \tfrac{1}{2}(0.0250\text{ kg})(1.05\text{ m/s})^2 = 0.01378\text{ J}$$

$$\Delta K = K_2 - K_1 = 0.01378\text{ J} - 0.00345\text{ J} = 0.0103\text{ J}$$

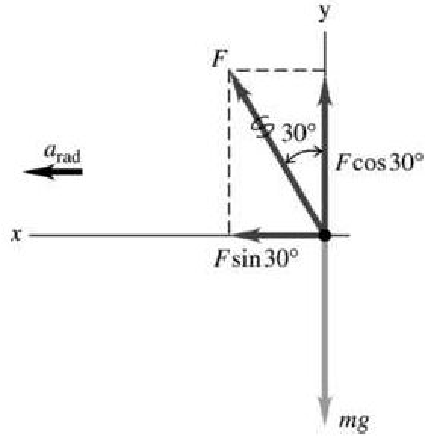
(d) $W_{\text{tot}} = \Delta K$

But $W_{\text{tot}} = W$, the work done by the tension in the cord, so $W = 0.0103$ J.

EVALUATE: Smaller r means smaller I. $L = I\omega$ is constant so ω increases and K increases. The work done by the tension is positive since it is directed inward and the block moves inward, toward the hole.

5.46. **IDENTIFY:** The acceleration of the person is $a_{rad} = v^2/R$, directed horizontally to the left in the figure in the problem. The time for one revolution is the period $T = \frac{2\pi R}{v}$. Apply $\Sigma\vec{F} = m\vec{a}$ to the person.

SET UP: The person moves in a circle of radius $R = 3.00\text{ m} + (5.00\text{ m})\sin 30.0° = 5.50\text{ m}$. The free-body diagram is given in Figure 5.46. $\vec{F}$ is the force applied to the seat by the rod.



EXECUTE: **(a)** $\Sigma F_y = ma_y$ gives $F\cos 30.0° = mg$ and $F = \frac{mg}{\cos 30.0°}$. $\Sigma F_x = ma_x$ gives

$F\sin 30.0° = m\frac{v^2}{R}$. Combining these two equations gives

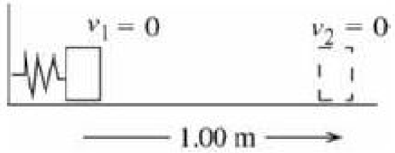
$v = \sqrt{Rg\tan\theta} = \sqrt{(5.50\text{ m})(9.80\text{ m/s}^2)\tan 30.0°} = 5.58\text{ m/s}$. Then the period is

$T = \frac{2\pi R}{v} = \frac{2\pi(5.50\text{ m})}{5.58\text{ m/s}} = 6.19\text{ s}$.

(b) The net force is proportional to m so in $\Sigma\vec{F} = m\vec{a}$ the mass divides out and the angle for a given rate of rotation is independent of the mass of the passengers.

SET UP: Let point 1 be where the block is released and let point 2 be where the block stops, as shown in Figure 7.43.

$K_1 + U_1 + W_{other} = K_2 + U_2$



Work is done on the block by the spring and by friction, so $W_{other} = W_f$ and $U = U_{el}$.

Figure 7.43

EXECUTE: $K_1 = K_2 = 0$

$U_1 = U_{1,el} = \frac{1}{2}kx_1^2 = \frac{1}{2}(100 \text{ N/m})(0.200 \text{ m})^2 = 2.00 \text{ J}$

$U_2 = U_{2,el} = 0$, since after the block leaves the spring has given up all its stored energy

$W_{other} = W_f = (f_k \cos\phi)s = \mu_k mg(\cos\phi)s = -\mu_k mgs$, since $\phi = 180°$ (The friction force is directed opposite to the displacement and does negative work.)

Putting all this into $K_1 + U_1 + W_{other} = K_2 + U_2$ gives

$U_{1,el} + W_f = 0$

$\mu_k mgs = U_{1,el}$

$$\mu_k = \frac{U_{1,el}}{mgs} = \frac{2.00 \text{ J}}{(0.50 \text{ kg})(9.80 \text{ m/s}^2)(1.00 \text{ m})} = 0.41.$$

6.89. **IDENTIFY:** Apply Eq. (6.6) to the skater.

SET UP: Let point 1 be just before she reaches the rough patch and let point 2 be where she exits from the patch. Work is done by friction. We don't know the skater's mass so can't calculate either friction or the initial kinetic energy. Leave her mass m as a variable and expect that it will divide out of the final equation.

EXECUTE: $f_k = 0.25mg$ so $W_f = W_{tot} = -(0.25mg)s$, where s is the length of the rough patch.

$$W_{tot} = K_2 - K_1$$

$$K_1 = \tfrac{1}{2}mv_0^2,\ \ K_2 = \tfrac{1}{2}mv_2^2 = \tfrac{1}{2}m(0.55v_0)^2 = 0.3025\left(\tfrac{1}{2}mv_0^2\right)$$

The work-energy relation gives $-(0.25mg)s = (0.3025 - 1)\tfrac{1}{2}mv_0^2$

The mass divides out, and solving gives $s = 1.3$ m.

EVALUATE: Friction does negative work and this reduces her kinetic energy.

10.39. **IDENTIFY and SET UP:** Use $L = I\omega$.

EXECUTE: The second hand makes 1 revolution in 1 minute, so

$\omega = (1.00 \text{ rev/min})(2\pi \text{ rad/1 rev})(1 \text{ min/60 s}) = 0.1047 \text{ rad/s}$.

For a slender rod, with the axis about one end,

$I = \frac{1}{3}ML^2 = \frac{1}{3}(6.00\times10^{-3} \text{ kg})(0.150 \text{ m})^2 = 4.50\times10^{-5} \text{ kg}\cdot\text{m}^2$.

Then $L = I\omega = (4.50\times10^{-5} \text{ kg}\cdot\text{m}^2)(0.1047 \text{ rad/s}) = 4.71\times10^{-6} \text{ kg}\cdot\text{m}^2\text{/s}$.

EVALUATE: $\vec{L}$ is clockwise.

8.24. **IDENTIFY:** In part (a) no horizontal force implies P_x is constant. In part (b) use the energy expression, Eq. 7.14, to find the potential energy initially in the spring.

SET UP: Initially both blocks are at rest.

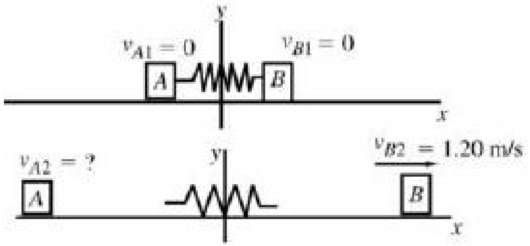


Figure 8.24

EXECUTE: (a) $m_A v_{A1x} + m_B v_{B1x} = m_A v_{A2x} + m_B v_{B2x}$

$$0 = m_A v_{A2x} + m_B v_{B2x}$$

$$v_{A2x} = -\left(\frac{m_B}{m_A}\right) v_{B2x} = -\left(\frac{3.00 \text{ kg}}{1.00 \text{ kg}}\right)(+1.20 \text{ m/s}) = -3.60 \text{ m/s}$$

Block A has a final speed of 3.60 m/s, and moves off in the opposite direction to B.

(b) Use energy conservation: $K_1 + U_1 + W_{\text{other}} = K_2 + U_2$.

Only the spring force does work so $W_{\text{other}} = 0$ and $U = U_{\text{el}}$.

$K_1 = 0$ (the blocks initially are at rest)

$U_2 = 0$ (no potential energy is left in the spring)

$$K_2 = \tfrac{1}{2} m_A v_{A2}^2 + \tfrac{1}{2} m_B v_{B2}^2 = \tfrac{1}{2}(1.00 \text{ kg})(3.60 \text{ m/s})^2 + \tfrac{1}{2}(3.00 \text{ kg})(1.20 \text{ m/s})^2 = 8.64 \text{ J}$$

$U_1 = U_{1,\text{el}}$ the potential energy stored in the compressed spring.

Thus $U_{1,\text{el}} = K_2 = 8.64$ J