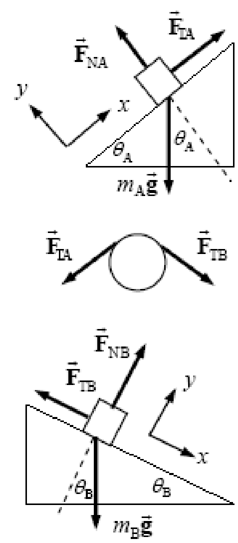
3. We find the diameter of the spot from the definition of radian angle measure.

$$\theta = \frac{\text{diameter}}{r_{\text{Earth-Moon}}} \rightarrow \text{diameter} = \theta r_{\text{Earth-Moon}} = \left(1.4\times10^{-5}\,\text{rad}\right)\left(3.8\times10^{8}\,\text{m}\right) = \boxed{5300\,\text{m}}$$

46. (*a*) The free body diagrams are shown. Note that only the forces producing torque are shown on the pulley. There would also be a gravity force on the pulley (since it has mass) and a normal force from the pulley's suspension, but they are not shown.



(*b*) Write Newton's second law for the two blocks, taking the positive x direction as shown in the free body diagrams.

$$m_A: \quad \sum F_x = F_{TA} - m_A g \sin\theta_A = m_A a \rightarrow$$

$$F_{TA} = m_A\left(g\sin\theta_A + a\right)$$

$$= (8.0\text{kg})\left[\left(9.80\,\text{m/s}^2\right)\sin 32° + 1.00\,\text{m/s}^2\right] = 49.55\,\text{N}$$

$$\approx \boxed{50\,\text{N}} \ (2\text{ sig fig})$$

$$m_B: \quad \sum F_x = m_B g \sin\theta_B - F_{TB} = m_B a \rightarrow$$

$$F_{TB} = m_B\left(g\sin\theta_B - a\right)$$

$$= (10.0\text{kg})\left[\left(9.80\,\text{m/s}^2\right)\sin 61° - 1.00\,\text{m/s}^2\right] = 75.71\,\text{N}$$

$$\approx \boxed{76\,\text{N}}$$

(*c*) The net torque on the pulley is caused by the two tensions. We take clockwise torques as positive.

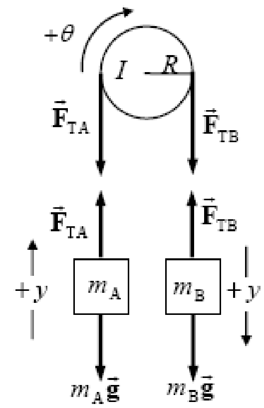
$$\sum\tau = \left(F_{TB} - F_{TB}\right)R = \left(75.71\,\text{N} - 49.55\,\text{N}\right)(0.15\,\text{m}) = 3.924\text{m}\cdot\text{N} \approx \boxed{3.9\text{m}\cdot\text{N}}$$

Use Newton's second law to find the rotational inertia of the pulley. The tangential acceleration of the pulley's rim is the same as the linear acceleration of the blocks, assuming that the string doesn't slip.

$$\sum\tau = I\alpha = I\frac{a}{R} = \left(F_{TB} - F_{TB}\right)R \rightarrow$$

$$I = \frac{\left(F_{TB} - F_{TB}\right)R^2}{a} = \frac{\left(75.71\,\text{N} - 49.55\,\text{N}\right)(0.15\,\text{m})^2}{1.00\,\text{m/s}^2} = \boxed{0.59\,\text{kg}\cdot\text{m}^2}$$

51. We assume that $m_B > m_A$, and so m_B will accelerate down, m_A will accelerate up, and the pulley will accelerate clockwise. Call the direction of acceleration the positive direction for each object. The masses will have the same acceleration since they are connected by a cord. The rim of the pulley will have that same acceleration since the cord is making it rotate, and so $\alpha_{pulley} = a/R$. From the free-body diagrams for each object, we have the following.



$$\sum F_{yA} = F_{TA} - m_A g = m_A a \quad \rightarrow \quad F_{TA} = m_A g + m_A a$$

$$\sum F_{yB} = m_B g - F_{TB} = m_B a \quad \rightarrow \quad F_{TB} = m_B g - m_B a$$

$$\sum \tau = F_{TB} r - F_{TA} r = I\alpha = I\frac{a}{R}$$

Substitute the expressions for the tensions into the torque equation, and solve for the acceleration.

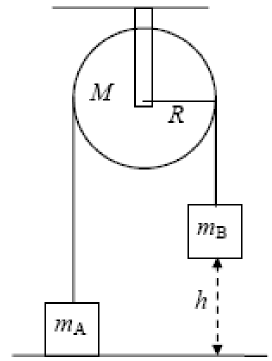
$$F_{TB}R - F_{TA}R = I\frac{a}{R} \quad \rightarrow \quad (m_B g - m_B a)R - (m_A g + m_A a)R = I\frac{a}{R} \quad \rightarrow$$

$$\boxed{a = \frac{(m_B - m_A)}{(m_A + m_B + I/R^2)} g}$$

If the moment of inertia is ignored, then from the torque equation we see that $F_{TB} = F_{TA}$, and the acceleration will be $\boxed{a_{I=0} = \frac{(m_B - m_A)}{(m_A + m_B)} g}$. We see that the acceleration with the moment of inertia included will be smaller than if the moment of inertia is ignored.

67. The only force doing work in this system is gravity, so mechanical energy is conserved. The initial state of the system is the configuration with m_A on the ground and all objects at rest. The final state of the system has m_B just reaching the ground, and all objects in motion. Call the zero level of gravitational potential energy to be the ground level. Both masses will have the same speed since

they are connected by the rope. Assuming that the rope does not slip on the pulley, the angular speed of the pulley is related to the speed of the masses by $\omega = v/R$. All objects have an initial speed of 0.



$$E_i = E_f \quad \rightarrow$$

$$\tfrac{1}{2}m_A v_i^2 + \tfrac{1}{2}m_B v_i^2 + \tfrac{1}{2}I\omega_i^2 + m_A g y_{1i} + m_B g y_{2i} = \tfrac{1}{2}m_A v_f^2 + \tfrac{1}{2}m_B v_f^2 + \tfrac{1}{2}I\omega_f^2 + m_A g y_{1f} + m_B g y_{2f}$$

$$m_B g h = \tfrac{1}{2}m_A v_f^2 + \tfrac{1}{2}m_B v_f^2 + \tfrac{1}{2}\left(\tfrac{1}{2}MR^2\right)\left(\frac{v_f^2}{R^2}\right) + m_A g h$$

$$v_f = \sqrt{\frac{2\left(m_B - m_A\right)gh}{\left(m_A + m_B + \tfrac{1}{2}M\right)}} = \sqrt{\frac{2\left(38.0\,\text{kg} - 35.0\,\text{kg}\right)\left(9.80\,\text{m/s}^2\right)\left(2.5\,\text{m}\right)}{\left(38.0\text{ kg} + 35.0\text{ kg} + \left(\tfrac{1}{2}\right)3.1\text{ kg}\right)}} = \boxed{1.4\,\text{m/s}}$$

94. Since frictional losses can be ignored, energy will be conserved for the marble. Define the 0 position of gravitational potential energy to be the bottom of the track, so that the bottom of the ball is initially a height h above the 0 position of gravitational potential energy. We also assume that the

marble is rolling without slipping, so $\omega = v/r$, and that the marble is released from rest. The marble has both translational and rotational kinetic energy.

(a) Since $r \ll R$, the marble's CM is very close to the surface of the track. While the marble is on the loop, we then approximate that its CM will be moving in a circle of radius R. When the marble is at the top of the loop, we approximate that its CM is a distance of $2R$ above the 0 position of gravitational potential energy. For the marble to just be on the verge of leaving the track means the normal force between the marble and the track is zero, and so the centripetal force at the top must be equal to the gravitational force on the marble.

$$\frac{mv^2_{\substack{\text{top of}\\\text{loop}}}}{R} = mg \quad\to\quad v^2_{\substack{\text{top of}\\\text{loop}}} = gR$$

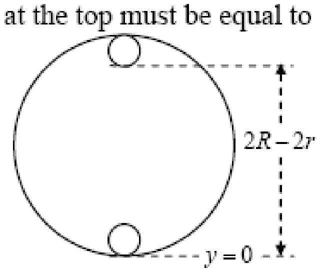
Use energy conservation to relate the release point to the point at the top of the loop.

$$E_{\text{release}} = E_{\substack{\text{top of}\\\text{loop}}} \quad\to\quad K_{\text{release}} + U_{\text{release}} = K_{\substack{\text{top of}\\\text{loop}}} + U_{\substack{\text{top of}\\\text{loop}}}$$

$$0 + mgh = \tfrac{1}{2}mv^2_{\substack{\text{top of}\\\text{loop}}} + \tfrac{1}{2}I\omega^2_{\substack{\text{top of}\\\text{loop}}} + mg2R = \tfrac{1}{2}mv^2_{\substack{\text{top of}\\\text{loop}}} + \tfrac{1}{2}\left(\tfrac{2}{5}mr^2\right)\frac{v^2_{\substack{\text{top of}\\\text{loop}}}}{r^2} + 2mgR$$

$$mgh = \tfrac{7}{10}mv^2_{\substack{\text{top of}\\\text{loop}}} + 2mgR = \tfrac{7}{10}mgR + 2mgR = 2.7mgR \quad\to\quad \boxed{h = 2.7R}$$

(b) Since we are not to assume that $r \ll R$, then while the marble is on the loop portion of the track, it is moving in a circle of radius $R - r$, and when at the top of the loop, the bottom of the marble is a height of $2(R - r)$ above the 0 position of gravitational potential energy (see the diagram). For the marble to just be on the verge of leaving the track means the normal force between the marble and the track is zero, and so the centripetal force at the top must be equal to the gravitational force on the marble.



$$\frac{mv^2_{\substack{\text{top of}\\\text{loop}}}}{R - r} = mg \quad\to\quad v^2_{\substack{\text{top of}\\\text{loop}}} = g(R - r)$$

Use energy conservation to equate the energy at the release point to the energy at the top of the loop.

$$E_{\text{release}} = E_{\substack{\text{top of}\\\text{loop}}} \quad\to\quad K_{\text{release}} + U_{\text{release}} = K_{\substack{\text{top of}\\\text{loop}}} + U_{\substack{\text{top of}\\\text{loop}}}$$

$$0 + mgh = \tfrac{1}{2}mv^2_{\substack{\text{top of}\\\text{loop}}} + \tfrac{1}{2}I\omega^2_{\substack{\text{top of}\\\text{loop}}} + mg2(R - r) = \tfrac{1}{2}mv^2_{\substack{\text{top of}\\\text{loop}}} + \tfrac{1}{2}\left(\tfrac{2}{5}mr^2\right)\frac{v^2_{\substack{\text{top of}\\\text{loop}}}}{r^2} + 2mg(R - r)$$

$$mgh = \tfrac{7}{10}mv^2_{\substack{\text{top of}\\\text{loop}}} + 2mg(R - r) = \tfrac{7}{10}mg(R - r) + 2mg(R - r) = 2.7mg(R - r)$$

$$\boxed{h = 2.7(R - r)}$$

98. (a) If there is no friction, then conservation of mechanical energy can be used to find the speed of the block. We assume the cord unrolls from the cylinder without slipping, and so $v_{\text{block}} = v_{\text{cord}} = \omega_{\text{cord}}R$. We take the zero position of gravitational potential energy to be the

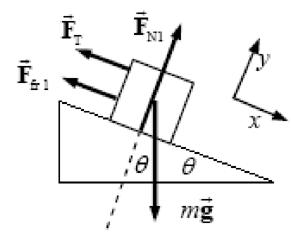
bottom of the motion of the block. Since the cylinder does not move vertically, we do not have to consider its gravitational potential energy.

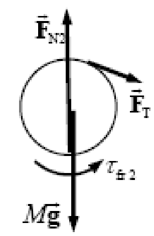
$$E_{\text{initial}} = E_{\text{final}} \rightarrow U_{\text{initial}} = K_{\text{final}} = K_{\text{block}} + K_{\text{cylinder}} \rightarrow$$

$$mgh = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2 \rightarrow mgD\sin\theta = \tfrac{1}{2}mv^2 + \tfrac{1}{2}\left(\tfrac{1}{2}MR^2\right)\left(\frac{v^2}{R^2}\right) \rightarrow$$

$$v = \sqrt{\frac{2mgD\sin\theta}{\left(m+\frac{1}{2}M\right)}} = \sqrt{\frac{2(3.0\,\text{kg})(9.80\,\text{m/s}^2)(1.80\,\text{m})\sin 27^\circ}{(19.5\,\text{kg})}} = 1.570\,\text{m/s} \approx \boxed{1.6\,\text{m/s}}$$

(*b*) The first printing of the textbook has $\mu = 0.055$, while later printings will have $\mu = 0.035$. The results are fundamentally different in the two cases. Consider the free body diagrams for both the block and the cylinder. We make the following observations and assumptions. Note that for the block to move down the plane from rest, $F_T < mg$. Also note that $mg < 0.1Mg$ due to the difference in masses. Thus $F_T < 0.1Mg$. Accordingly, we will ignore F_T when finding the net vertical and horizontal forces on the cylinder, knowing that we will make less than a 10% error. Instead of trying to assign a specific direction for the force of friction between the cylinder and the depression $\left(F_{\text{fr}\,2}\right)$, we show a torque in the counterclockwise direction (since the cylinder will rotate clockwise). Finally, we assume that $F_{\text{fr}\,2} = \mu F_{\text{N2}} = \mu Mg$.





Write Newton's second law to analyze the linear motion of the block and the rotational motion of the cylinder, and solve for the acceleration of the block. We assume the cord unrolls without slipping.

$$\sum F_y = F_N - mg\cos\theta = 0 \rightarrow F_N = mg\cos\theta$$

$$\sum F_x = mg\sin\theta - F_T - F_{\text{fr}\,1} = mg\sin\theta - F_T - \mu mg\cos\theta = ma$$

$$\sum \tau = F_T R - \tau_{\text{fr}\,2} = F_T R - \mu F_{\text{N2}} R = F_T R - \mu MgR = I\alpha = I\frac{a}{R} = \tfrac{1}{2}MRa \rightarrow$$

$$F_T - \mu Mg = \tfrac{1}{2}Ma$$

Add the x equation to the torque equation.

$$mg\sin\theta - F_T - \mu mg\cos\theta = ma \ ; \ F_T - \mu Mg = \tfrac{1}{2}Ma \rightarrow$$

$$mg\sin\theta - \mu Mg - \mu mg\cos\theta = ma + \tfrac{1}{2}Ma \rightarrow$$

$$a = g\frac{m(\sin\theta - \mu\cos\theta) - \mu M}{\left(m + \frac{1}{2}M\right)}$$

If $\mu = 0.055$, $a = g\dfrac{(3.0\,\text{kg})(\sin 27^\circ - 0.055\cos 27^\circ) - (0.055)(33\,\text{kg})}{(19.5\,\text{kg})} = -0.302\,\text{m/s}^2$. But the object cannot accelerate UP the plane from rest. So the conclusion is that object will not move with $\mu = 0.055$. The small block is not heavy enough to move itself, rotate the cylinder, and overcome friction.

If $\mu = 0.035$, $a = g\dfrac{(3.0\,\text{kg})(\sin 27^\circ - 0.035\cos 27^\circ) - (0.035)(33\,\text{kg})}{(19.5\,\text{kg})} = 0.057\,\text{m/s}^2$.

Use Eq. 2-12c to find the speed after moving 1.80 m.

$$v^2 = v_0^2 + 2a\Delta x \quad \rightarrow \quad v = \sqrt{2\left(0.057\,\text{m/s}^2\right)\left(1.80\,\text{m}\right)} = \boxed{0.45\,\text{m/s}}\,.$$