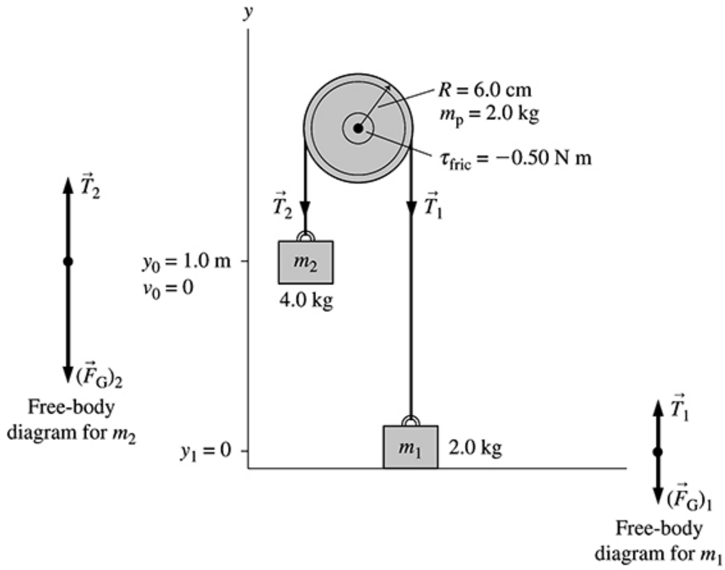
12.70. Model: The pulley is a rigid rotating body. We also assume that the pulley has the mass distribution of a disk and that the string does not slip.

Visualize:



Because the pulley is not massless and frictionless, tension in the rope on both sides of the pulley is *not* the same.

Solve: Applying Newton's second law to m_1, m_2, and the pulley yields the three equations:

$$T_1 - (F_G)_1 = m_1 a_1 \qquad -(F_G)_2 + T_2 = m_2 a_2 \qquad T_2 R - T_1 R - 0.50 \text{ N m} = I\alpha$$

Noting that $-a_2 = a_1 = a$, $I = \frac{1}{2} m_p R^2$, and $\alpha = a/R$, the above equations simplify to

$$T_1 - m_1 g = m_1 a \qquad m_2 g - T_2 = m_2 a \qquad T_2 - T_1 = \left(\frac{1}{2} m_p R^2\right)\left(\frac{a}{R}\right)\frac{1}{R} + \frac{0.50 \text{ N m}}{R} = \frac{1}{2} m_p a + \frac{0.50 \text{ N m}}{0.060 \text{ m}}$$

Adding these three equations,

$$(m_2 - m_1)g = a\left(m_1 + m_2 + \frac{1}{2} m_p\right) + 8.333 \text{ N}$$

$$\Rightarrow a = \frac{(m_2 - m_1)g - 8.333 \text{ N}}{m_1 + m_2 + \frac{1}{2} m_p} = \frac{(4.0 \text{ kg} - 2.0 \text{ kg})(9.8 \text{ m/s}^2) - 8.333 \text{ N}}{2.0 \text{ kg} + 4.0 \text{ kg} + (2.0 \text{ kg}/2)} = 1.610 \text{ m/s}^2$$

We can now use kinematics to find the time taken by the 4.0 kg block to reach the floor:

$$y_1 = y_0 + v_0(t_1 - t_0) + \frac{1}{2} a_2 (t_1 - t_0)^2 \Rightarrow 0 = 1.0 \text{ m} + 0 + \frac{1}{2}(-1.610 \text{ m/s}^2)(t_1 - 0 \text{ s})^2$$

$$\Rightarrow t_1 = \sqrt{\frac{2(1.0 \text{ m})}{(1.610 \text{ m/s}^2)}} = 1.11 \text{ s}$$