45. Objects with masses $m_1 = 10.0 \text{ kg}$ and $m_2 = 5.00 \text{ kg}$ are connected by a light string that passes over a frictionless pulley as in Figure P4.30. If, when the system starts from rest, m_2 falls 1.00 m in 1.20 s, determine the coefficient of kinetic friction between m_1 and the table.

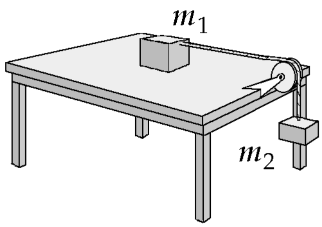
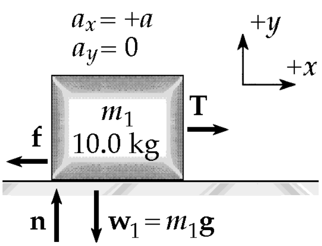
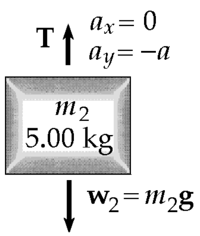


Figure P4.30

Solution The free-body diagrams of the two objects in this system are shown at the right. Note that the accelerations of the two objects have the same magnitude, a, with the acceleration of m_1 directed horizontally to the right and the acceleration of m_2 directed vertically downward.



Since m_2 is observed to drop downward 1.00 m in 1.20 s when the system is released, the magnitude of the acceleration is found using $\Delta y = v_{iy}t + \frac{1}{2}a_y t^2$ as



$$-1.00 \text{ m} = 0 + \tfrac{1}{2}(-a)(1.20 \text{ s})^2 \quad \text{so} \quad a = 1.39 \text{ m/s}^2$$

The weights of the objects are $w_1 = m_1 g = 98.0 \text{ N}$ and $w_2 = m_2 g = 49.0 \text{ N}$. Applying Newton's second law to m_2 gives us the tension T in the cord:

$$\sum F_y = m_2 a_y: \qquad +T - w_2 = m_2(-a)$$

$$T = 49.0 \text{ N} + (5.00 \text{ kg})(-1.39 \text{ m/s}^2) = 42.1 \text{ N}$$

Now, consider the vertical forces acting on m_1:

$$\sum F_y = m_1 a_y: \qquad +n - w_1 = 0 \quad \text{so} \quad n = w_1 = 98.0 \text{ N}$$

Finally, considering the horizontal forces acting on m_1,

$$\sum F_x = m_1 a_x: \qquad +T - f = m_1(+a)$$

$$f = T - m_1 a = 42.1 \text{ N} - (10.0 \text{ N})(1.39 \text{ m/s}^2)$$

so the friction force is $f = 28.2 \text{ N}$. The coefficient of kinetic friction between m_1 and the table is therefore

$$\mu_k = \frac{f}{n} = \frac{28.2 \text{ N}}{98.0 \text{ N}} = 0.287 \qquad \Diamond$$