9. We choose $+x$ horizontally rightwards and $+y$ upwards and observe that the 15 N force has components $F_x = F \cos\theta$ and $F_y = -F \sin\theta$.

(a) We apply Newton's second law to the y axis:

$$F_N - F\sin\theta - mg = 0 \;\Rightarrow\; F_N = (15\text{ N})\sin 40° + (3.5\text{ kg})(9.8\text{ m/s}^2) = 44\text{ N}.$$

With $\mu_k = 0.25$, Eq. 6-2 leads to $f_k = 11$ N.

(b) We apply Newton's second law to the x axis:

$$F\cos\theta - f_k = ma \;\Rightarrow\; a = \frac{(15\text{ N})\cos 40° - 11\text{ N}}{3.5\text{ kg}} = 0.14\text{ m/s}^2.$$

Since the result is positive-valued, then the block is accelerating in the $+x$ (rightward) direction.

18. (a) We apply Newton's second law to the "downhill" direction:

$$mg\sin\theta - f = ma,$$

where, using Eq. 6-11,

$$f = f_k = \mu_k F_N = \mu_k mg\cos\theta.$$

Thus, with $\mu_k = 0.600$, we have

$$a = g\sin\theta - \mu_k\cos\theta = -3.72\text{ m/s}^2$$

which means, since we have chosen the positive direction in the direction of motion (down the slope) then the acceleration vector points "uphill"; it is decelerating. With $v_0 = 18.0$ m/s and $\Delta x = d = 24.0$ m, Eq. 2-16 leads to

$$v = \sqrt{v_0^2 + 2ad} = 12.1\text{ m/s}.$$

(b) In this case, we find $a = +1.1$ m/s^2, and the speed (when impact occurs) is 19.4 m/s.

23. Let the tensions on the strings connecting m_2 and m_3 be T_{23}, and that connecting m_2 and m_1 be T_{12}, respectively. Applying Newton's second law (and Eq. 6-2, with $F_N = m_2 g$ in this case) to the *system* we have

$$m_3 g - T_{23} = m_3 a$$
$$T_{23} - \mu_k m_2 g - T_{12} = m_2 a$$
$$T_{12} - m_1 g = m_1 a$$

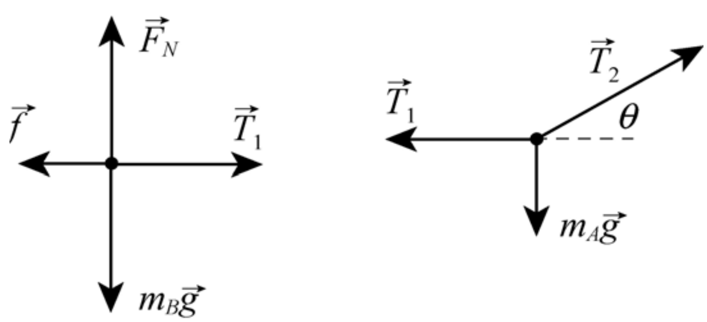
Adding up the three equations and using $m_1 = M, m_2 = m_3 = 2M$, we obtain

$$2Mg - 2\mu_k Mg - Mg = 5Ma .$$

With a = 0.500 m/s^2 this yields μ_k = 0.372. Thus, the coefficient of kinetic friction is roughly μ_k = 0.37.

25. **THINK** In order that the two blocks remain in equilibrium, friction must be present between block *B* and the surface.

EXPRESS The free-body diagrams for block *B* and for the knot just above block *A* are shown below. $\vec{T}_1$ is the tension force of the rope pulling on block *B* or pulling on the knot (as the case may be), $\vec{T}_2$ is the tension force exerted by the second rope (at angle θ = 30°) on the knot, $\vec{f}$ is the force of static friction exerted by the horizontal surface on block *B*, $\vec{F}_N$ is normal force exerted by the surface on block *B*, W_A is the weight of block *A* (W_A is the magnitude of $m_A\vec{g}$), and W_B is the weight of block *B* (W_B = 711 N is the magnitude of $m_B\vec{g}$).



For each object we take +*x* horizontally rightward and +*y* upward. Applying Newton's second law in the *x* and *y* directions for block *B* and then doing the same for the knot results in four equations:

$$T_1 - f_{s,\max} = 0$$
$$F_N - W_B = 0$$
$$T_2 \cos\theta - T_1 = 0$$
$$T_2 \sin\theta - W_A = 0$$

where we assume the static friction to be at its maximum value (permitting us to use Eq. 6-1). The above equations yield $T_1 = \mu_s F_N$, $F_N = W_B$ and $T_1 = T_2 \cos\theta$.

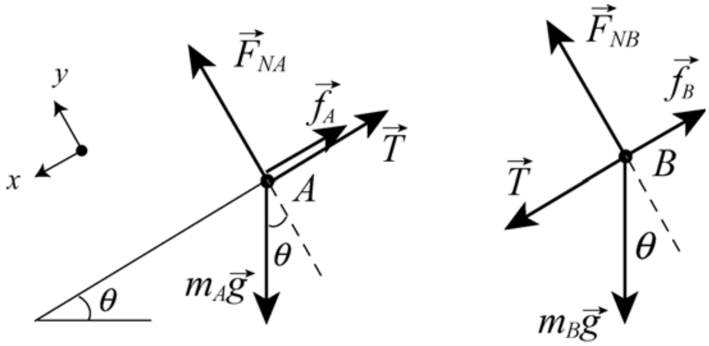
ANALYZE Solving these equations with μ_s = 0.25, we obtain

$$W_A = T_2 \sin\theta = T_1 \tan\theta = \mu_s F_N \tan\theta = \mu_s W_B \tan\theta$$
$$= (0.25)(711\,\text{N}) \tan 30° = 1.0\times 10^2\ \text{N}$$

LEARN As expected, the maximum weight of *A* is proportional to the weight of *B*, as well as the coefficient of static friction. In addition, we see that W_A is proportional to $\tan\theta$ (the larger the angle, the greater the vertical component of T_2 that supports its weight).

31. **THINK** In this problem we have two blocks connected by a string sliding down an inclined plane; the blocks have different coefficient of kinetic friction.

EXPRESS The free-body diagrams for the two blocks are shown below. *T* is the magnitude of the tension force of the string, $\vec{F}_{NA}$ is the normal force on block *A* (the leading block), $\vec{F}_{NB}$ is the normal force on block *B*, $\vec{f}_A$ is kinetic friction force on block *A*, $\vec{f}_B$ is kinetic friction force on block *B*. Also, m_A is the mass of block *A* (where $m_A = W_A/g$ and W_A = 3.6 N), and m_B is the mass of block *B* (where $m_B = W_B/g$ and W_B = 7.2 N). The angle of the incline is θ = 30°.



For each block we take +*x* downhill (which is toward the lower-left in these diagrams) and +*y* in the direction of the normal force. Applying Newton's second law to the *x* and *y* directions of both blocks *A* and *B*, we arrive at four equations:

$$W_A \sin\theta - f_A - T = m_A a$$
$$F_{NA} - W_A \cos\theta = 0$$
$$W_B \sin\theta - f_B + T = m_B a$$
$$F_{NB} - W_B \cos\theta = 0$$

which, when combined with Eq. 6-2 ($f_A = \mu_{kA} F_{NA}$ where μ_{kA} = 0.10 and $f_B = \mu_{kB} F_{NB}$ f_B where μ_{kB} = 0.20), fully describe the dynamics of the system so long as the blocks have the same acceleration and $T > 0$.

ANALYZE (a) From these equations, we find the acceleration to be

$$a = g\left(\sin\theta - \left(\frac{\mu_{kA}W_A + \mu_{kB}W_B}{W_A + W_B}\right)\cos\theta\right) = 3.5\ \text{m/s}^2.$$

(b) We solve the above equations for the tension and obtain

$$T = \left(\frac{W_A W_B}{W_A + W_B}\right)\left(\mu_{kB} - \mu_{kA}\right)\cos\theta = \frac{(3.6\ \text{N})(7.2\ \text{N})}{3.6\ \text{N} + 7.2\ \text{N}}\left(0.20 - 0.10\right)\cos 30° = 0.21\ \text{N}.$$

LEARN The tension in the string is proportional to $\mu_{kB} - \mu_{kA}$, the difference in coefficients of kinetic friction for the two blocks. When the coefficients are equal ($\mu_{kB} = \mu_{kA}$), the two blocks can be viewed as moving independent of one another and the tension is zero. Similarly, when $\mu_{kB} < \mu_{kA}$ (the leading block *A* has larger coefficient than the *B*), the string is slack, so the tension is also zero.