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.

20. Treating the two boxes as a single system of total mass $m_C + m_W = 1.0 + 3.0 = 4.0$ kg, subject to a total (leftward) friction of magnitude 2.0 N + 4.0 N = 6.0 N, we apply Newton's second law (with $+x$ rightward):

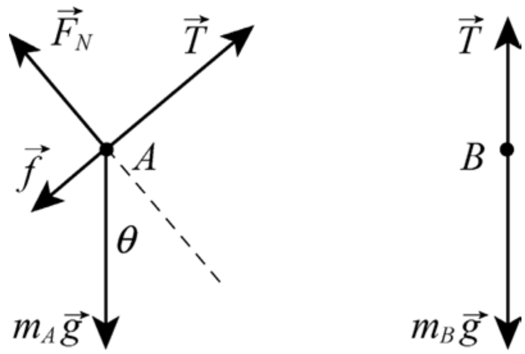
$$F - f_{\text{total}} = m_{\text{total}}\, a \quad \Rightarrow \quad 12.0\ \text{N} - 6.0\ \text{N} = (4.0\ \text{kg})a$$

which yields the acceleration $a = 1.5\ \text{m/s}^2$. We have treated F as if it were known to the nearest tenth of a Newton so that our acceleration is "good" to two significant figures. Turning our attention to the larger box (the Wheaties box of mass $m_W = 3.0$ kg) we apply Newton's second law to find the contact force F' exerted by the Cheerios box on it.

$$F' - f_W = m_W a \quad \Rightarrow \quad F' - 4.0\ \text{N} = (3.0\ \text{kg})(1.5\ \text{m/s}^2)\ .$$

From the above equation, we find the contact force to be $F' = 8.5$ N.

28. The free-body diagrams are shown below.



T is the magnitude of the tension force of the string, f is the magnitude of the force of friction on block A, F_N is the magnitude of the normal force of the plane on block A, $m_A\vec{g}$ is the force of gravity on body A (where m_A = 10 kg), and $m_B\vec{g}$ is the force of gravity on block B. θ = 30° is the angle of incline. For A we take the $+x$ to be uphill and $+y$ to be in the direction of the normal force; the positive direction is chosen *downward* for block B.

Since A is moving down the incline, the force of friction is uphill with magnitude $f_k = \mu_k F_N$ (where μ_k = 0.20). Newton's second law leads to

$$T - f_k + m_A g\sin\theta = m_A a = 0$$
$$F_N - m_A g\cos\theta = 0$$
$$m_B g - T = m_B a = 0$$

for the two bodies (where a = 0 is a consequence of the velocity being constant). We solve these for the mass of block B.

$$m_B = m_A\left(\sin\theta - \mu_k\cos\theta\right) = 3.3 \text{ kg}.$$

29. (a) Free-body diagrams for the blocks A and C, considered as a single object, and for the block B are shown below.

30. We use the familiar horizontal and vertical axes for x and y directions, with rightward and upward positive, respectively. The rope is assumed massless so that the force exerted by the child $\vec{F}$ is identical to the tension uniformly through the rope. The x and y components of $\vec{F}$ are $F\cos\theta$ and $F\sin\theta$, respectively. The static friction force points leftward.

(a) Newton's Law applied to the y-axis, where there is presumed to be no acceleration, leads to

$$F_N + F\sin\theta - mg = 0$$

which implies that the maximum static friction is $\mu_s(mg - F\sin\theta)$. If $f_s = f_{s,\max}$ is assumed, then Newton's second law applied to the x axis (which also has $a = 0$ even though it is "verging" on moving) yields

$$F\cos\theta - f_s = ma \quad \Rightarrow \quad F\cos\theta - \mu_s(mg - F\sin\theta) = 0$$

which we solve, for $\theta = 42°$ and $\mu_s = 0.42$, to obtain $F = 74$ N.

(b) Solving the above equation algebraically for F, with W denoting the weight, we obtain

$$F = \frac{\mu_s W}{\cos\theta + \mu_s\sin\theta} = \frac{(0.42)(180\text{ N})}{\cos\theta + (0.42)\sin\theta} = \frac{76\text{ N}}{\cos\theta + (0.42)\sin\theta}.$$

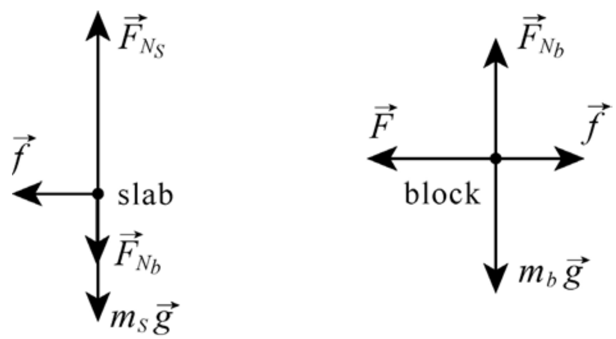
(c) We minimize the above expression for F by working through the condition:

$$\frac{dF}{d\theta} = \frac{\mu_s W(\sin\theta - \mu_s\cos\theta)}{(\cos\theta + \mu_s\sin\theta)^2} = 0$$

which leads to the result $\theta = \tan^{-1}\mu_s = 23°$.

(d) Plugging $\theta = 23°$ into the above result for F, with $\mu_s = 0.42$ and $W = 180$ N, yields $F = 70$ N.

34. The free-body diagrams for the slab and block are shown below.



$\vec{F}$ is the 100 N force applied to the block, $\vec{F}_{Ns}$ is the normal force of the floor on the slab, F_{Nb} is the magnitude of the normal force between the slab and the block, $\vec{f}$ is the force of friction between the slab and the block, m_s is the mass of the slab, and m_b is the mass of the block. For both objects, we take the $+x$ direction to be to the right and the $+y$ direction to be up.

Applying Newton's second law for the x and y axes for (first) the slab and (second) the block results in four equations:

$$\begin{aligned} -f &= m_s a_s \\ F_{Ns} - F_{Ns} - m_s g &= 0 \\ f - F &= m_b a_b \\ F_{Nb} - m_b g &= 0 \end{aligned}$$

from which we note that the maximum possible static friction magnitude would be

$$\mu_s F_{Nb} = \mu_s m_b g = (0.60)(10 \text{ kg})(9.8 \text{ m/s}^2) = 59 \text{ N} .$$

We check to see whether the block slides on the slab. Assuming it does not, then $a_s = a_b$ (which we denote simply as a) and we solve for f:

$$f = \frac{m_s F}{m_s + m_b} = \frac{(40 \text{ kg})(100 \text{ N})}{40 \text{ kg} + 10 \text{ kg}} = 80 \text{ N}$$

which is greater than $f_{s,\max}$ so that we conclude the block is sliding across the slab (their accelerations are different).

(a) Using $f = \mu_k F_{Nb}$ the above equations yield

$$a_b = \frac{\mu_k m_b g - F}{m_b} = \frac{(0.40)(10 \text{ kg})(9.8 \text{ m/s}^2) - 100 \text{ N}}{10 \text{ kg}} = -6.1 \text{ m/s}^2.$$

$$a_b = \frac{\mu_k m_b g - F}{m_b} = \frac{(0.40)(10\text{ kg})(9.8\text{ m/s}^2) - 100\text{ N}}{10\text{ kg}} = -6.1\text{ m/s}^2.$$

The negative sign means that the acceleration is leftward. That is, $\vec{a}_b = (-6.1\text{ m/s}^2)\hat{\mathrm{i}}$.

(b) We also obtain

$$a_s = -\frac{\mu_k m_b g}{m_s} = -\frac{(0.40)(10\text{ kg})(9.8\text{ m/s}^2)}{40\text{ kg}} = -0.98\text{ m/s}^2.$$

As mentioned above, this means it accelerates to the left. That is, $\vec{a}_s = (-0.98\text{ m/s}^2)\hat{\mathrm{i}}$.

56. We refer the reader to Sample Problem – "Car in banked circular turn," and use the result Eq. 6-26:

$$\theta = \tan^{-1}\left(\frac{v^2}{gR}\right)$$

with v = 60(1000/3600) = 17 m/s and R = 200 m. The banking angle is therefore θ = 8.1°. Now we consider a vehicle taking this banked curve at v' = 40(1000/3600) = 11 m/s. Its (horizontal) acceleration is $a' = v'^2/R$, which has components parallel to the incline and perpendicular to it:

$$a_{||} = a' \cos\theta = \frac{v'^2 \cos\theta}{R}$$
$$a_{\perp} = a' \sin\theta = \frac{v'^2 \sin\theta}{R}.$$

These enter Newton's second law as follows (choosing downhill as the +x direction and away-from-incline as +y):

$$mg\sin\theta - f_s = ma_{||}$$
$$F_N - mg\cos\theta = ma_{\perp}$$

and we are led to

$$\frac{f_s}{F_N} = \frac{mg\sin\theta - mv'^2\cos\theta/R}{mg\cos\theta + mv'^2\sin\theta/R}.$$

We cancel the mass and plug in, obtaining f_s/F_N = 0.078. The problem implies we should set $f_s = f_{s,\max}$ so that, by Eq. 6-1, we have μ_s = 0.078.

57. For the puck to remain at rest the magnitude of the tension force T of the cord must equal the gravitational force Mg on the cylinder. The tension force supplies the centripetal force that keeps the puck in its circular orbit, so $T = mv^2/r$. Thus $Mg = mv^2/r$. We solve for the speed:

$$v = \sqrt{\frac{Mgr}{m}} = \sqrt{\frac{(2.50\ \text{kg})(9.80\ \text{m/s}^2)(0.200\ \text{m})}{1.50\ \text{kg}}} = 1.81\ \text{m/s}.$$

58. (a) Using the kinematic equation given in Table 2-1, the deceleration of the car is

$$v^2 = v_0^2 + 2ad \quad \Rightarrow \quad 0 = (35\ \text{m/s})^2 + 2a(107\ \text{m})$$

which gives $a = -5.72\ \text{m/s}^2$. Thus, the force of friction required to stop the car is

$$f = m\,|a| = (1400\ \text{kg})(5.72\ \text{m/s}^2) \approx 8.0\times10^3\ \text{N}.$$

(b) The maximum possible static friction is

$$f_{s,\max} = \mu_s mg = (0.50)(1400\ \text{kg})(9.80\ \text{m/s}^2) \approx 6.9\times10^3\ \text{N}.$$

(c) If $\mu_k = 0.40$, then $f_k = \mu_k mg$ and the deceleration is $a = -\mu_k g$. Therefore, the speed of the car when it hits the wall is

$$v = v_0^2 + 2ad = (35\ \text{m/s})^2 - 2(0.40)(9.8\ \text{m/s}^2)(107\ \text{m}) \approx 20\ \text{m/s}.$$

(d) The force required to keep the motion circular is

$$F_r = \frac{mv_0^2}{r} = \frac{(1400\ \text{kg})(35.0\ \text{m/s})^2}{107\ \text{m}} = 1.6\times10^4\ \text{N}.$$

(e) Since $F_r > f_{s,\max}$, no circular path is possible.