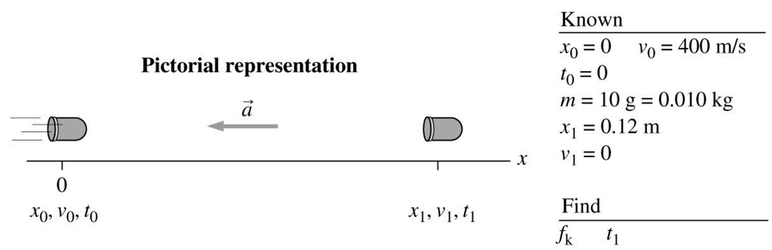
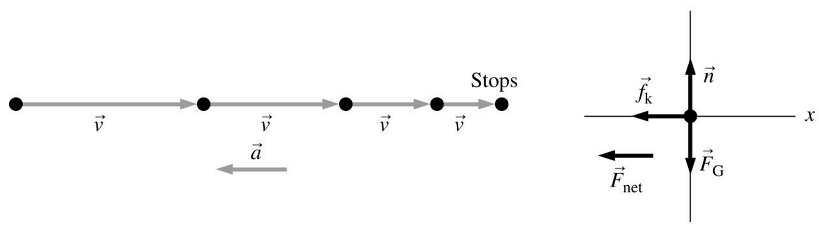
Solutions to HW9, Chapters 6 & 7

NOTE! The problems in masteringphysics.com had their numbers altered slightly for each individual student. The solutions below use the same numbers as those used in the book for that problem!

6.46. Model: We will represent the bullet as a particle.

Visualize:





Solve: (a) We have enough information to use kinematics to find the acceleration of the bullet as it stops. Then we can relate the acceleration to the force with Newton's second law. (Note that the barrel length is not relevant to the problem.) The kinematic equation is

$$v_1^2 = v_0^2 + 2a\Delta x \Rightarrow a = -\frac{v_0^2}{2\Delta x} = -\frac{(400 \text{ m/s})^2}{2(0.12 \text{ m})} = -6.67\times10^5 \text{ m/s}^2$$

Notice that a is negative, in agreement with the vector $\vec{a}$ in the motion diagram. Turning to forces, the wood exerts two forces on the bullet. First, an upward normal force that keeps the bullet from "falling" through the wood. Second, a retarding frictional force $\vec{f}_k$ that stops the bullet. The only horizontal force is $\vec{f}_k$, which points to the left and thus has a negative x-component. The x-component of Newton's second law is

$$(F_{net})_x = -f_k = ma \Rightarrow f_k = -ma = -(0.01 \text{ kg})(-6.67\times10^5 \text{ m/s}^2) = 6670 \text{ N} \approx 6700 \text{ N}$$

Notice how the signs worked together to give a positive value of the magnitude of the force.

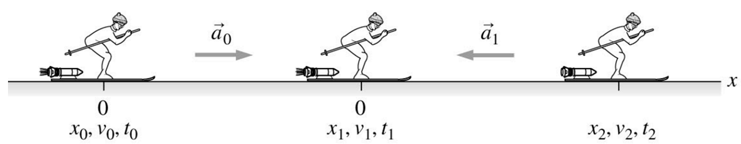
(b) The time to stop is found from $v_1 = v_0 + a\Delta t$ as follows:

$$\Delta t = -\frac{v_0}{a} = 6.00\times10^{-4} \text{ s} = 600\ \mu\text{s}$$

6.49. Model: We assume that Sam is a particle moving in a straight horizontal line under the influence of two forces: the thrust of his jet skis and the resisting force of friction on the skis. We can use one-dimensional kinematics.

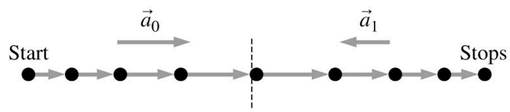
Visualize:

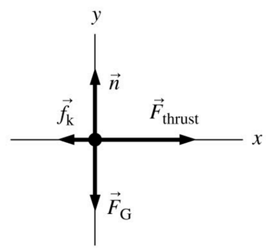
Pictorial representation



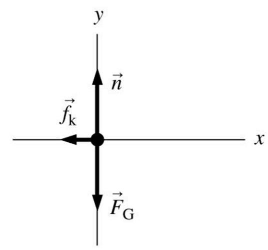
Known
$m = 75$ kg
$F_{\text{thrust}} = 200$ N
$\mu_k = 0.10$
$x_0 = 0$ m
$v_0 = 0$ m/s
$t_0 = 0$ s $\quad t_1 = 10$ s

Find
v_1
$x_2 - x_0$





Accelerating



Coasting

Solve: (a) The friction force of the snow can be found from the free-body diagram and Newton's first law, since there's no acceleration in the vertical direction:

$$n = F_G = mg = (75\text{ kg})(9.80\text{ m/s}^2) = 735\text{ N} \Rightarrow f_k = \mu_k n = (0.10)(735\text{ N}) = 73.5\text{ N}$$

Then, from Newton's second law:

$$(F_{\text{net}})_x = F_{\text{thrust}} - f_k = ma_0 \Rightarrow a_0 = \frac{F_{\text{thrust}} - f_k}{m} = \frac{200\text{ N} - 73.5\text{ N}}{75\text{ kg}} = 1.687\text{ m/s}^2$$

From kinematics:

$$v_1 = v_0 + a_0 t_1 = 0\text{ m/s} + (1.687\text{ m/s}^2)(10\text{ s}) = 16.9\text{ m/s}$$

(b) During the acceleration, Sam travels to

$$x_1 = x_0 + v_0 t_1 + \frac{1}{2}a_0 t_1^2 = \frac{1}{2}(1.687\text{ m/s}^2)(10\text{ s})^2 = 84\text{ m}$$

After the skis run out of fuel, Sam's acceleration can again be found from Newton's second law:

$$(F_{\text{net}})_x = -f_k = -73.5\text{ N} \Rightarrow a_1 = \frac{F_{\text{net}}}{m} = \frac{-73.5\text{ N}}{75\text{ kg}} = -0.98\text{ m/s}^2$$

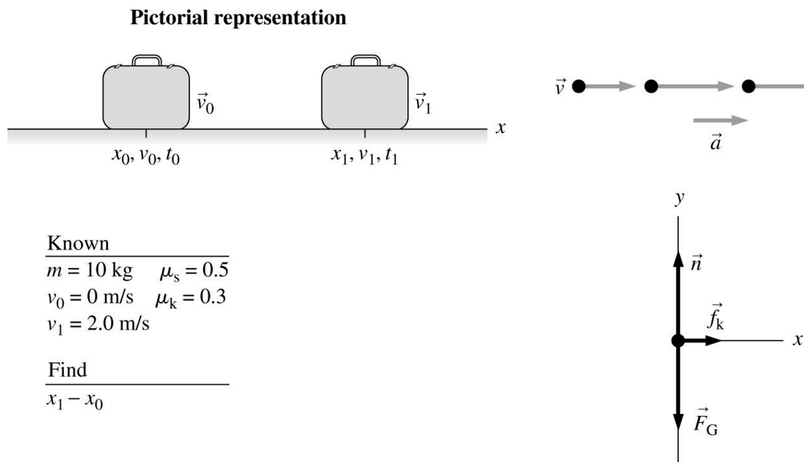
Since we don't know how much time it takes Sam to stop:

$$v_2^2 = v_1^2 + 2a_1(x_2 - x_1) \Rightarrow x_2 - x_1 = \frac{v_2^2 - v_1^2}{2a_1} = \frac{0\text{ m}^2/\text{s}^2 - (16.9\text{ m/s})^2}{2(-0.98\text{ m/s}^2)} = 145\text{ m}$$

The total distance traveled is $(x_2 - x_1) + x_1 = 145\text{ m} + 84\text{ m} = 229\text{ m}$.

Assess: A top speed of 16.9 m/s (roughly 40 mph) seems quite reasonable for this acceleration, and a coasting distance of nearly 150 m also seems possible, starting from a high speed, given that we're neglecting air resistance.

6.50. Model: We assume the suitcase is a particle accelerating horizontally under the influence of friction only.
Visualize:



Solve: Because the conveyor belt is already moving, friction drags your suitcase to the right. It will accelerate until it matches the speed of the belt. We need to know the horizontal acceleration. Since there's no acceleration in the vertical direction, we can apply Newton's first law to find the normal force:

$$n = F_G = mg = (10 \text{ kg})(9.80 \text{ m/s}^2) = 98.0 \text{ N}$$

The suitcase is accelerating, so we use μ_k to find the friction force

$$f_k = \mu_k mg = (0.3)(98.0 \text{ N}) = 29.4 \text{ N}$$

We can find the horizontal acceleration from Newton's second law:

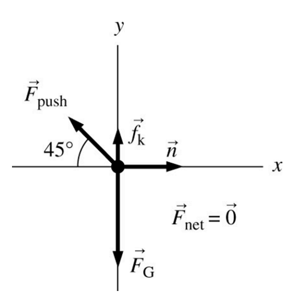
$$(F_{net})_x = \Sigma F_x = f_k = ma \Rightarrow a = \frac{f_k}{m} = \frac{29.4 \text{ N}}{10 \text{ kg}} = 2.94 \text{ m/s}^2$$

From one of the kinematic equations:

$$v_1^2 = v_0^2 + 2a(x_1 - x_0) \Rightarrow x_1 - x_0 = \frac{v_1^2 - v_0^2}{2a} = \frac{(2.0 \text{ m/s})^2 - (0 \text{ m/s})^2}{2(2.94 \text{ m/s}^2)} = 0.68 \text{ m}$$

The suitcase travels 0.68 m before catching up with the belt and riding smoothly.
Assess: If we imagine throwing a suitcase at a speed of 2.0 m/s onto a motionless surface, 0.68 m seems a reasonable distance for it to slide before stopping.

6.56. Model: The box will be treated as a particle. Because the box slides down a vertical wood wall, we will also use the model of kinetic friction.
Visualize:



Solve: The normal force due to the wall, which is perpendicular to the wall, is here to the right. The box slides down the wall at constant speed, so $\vec{a} = \vec{0}$ and the box is in dynamic equilibrium. Thus, $\vec{F}_{net} = \vec{0}$. Newton's second law for this equilibrium situation is

$$(F_{net})_x = 0 \text{ N} = n - F_{push}\cos 45°$$

$$(F_{net})_y = 0 \text{ N} = f_k + F_{push}\sin 45° - F_G = f_k + F_{push}\sin 45° - mg$$

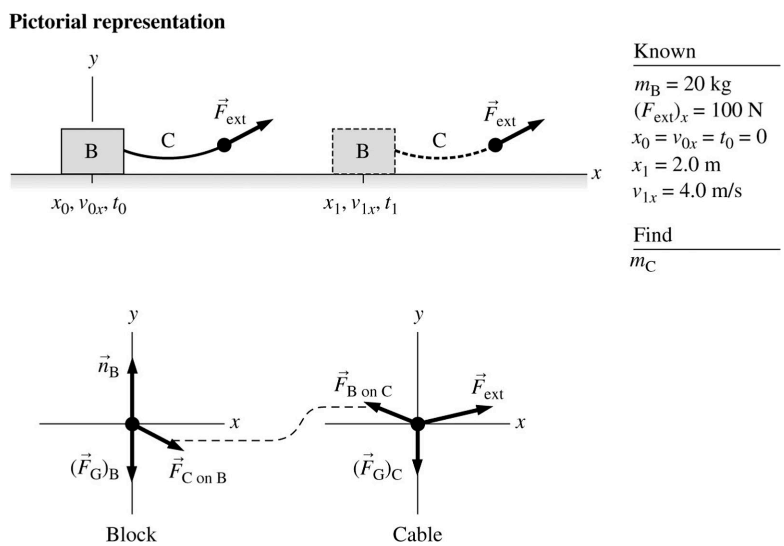
The friction force is $f_k = \mu_k n$. Using the x-equation to get an expression for n, we see that $f_k = \mu_k F_{push}\cos 45°$. Substituting this into the y-equation and using Table 6.1 to find $\mu_k = 0.20$ gives,

$$\mu_k F_{push}\cos 45° + F_{push}\sin 45° - mg = 0 \text{ N}$$

$$\Rightarrow F_{push} = \frac{mg}{\mu_k \cos 45° + \sin 45°} = \frac{(2.0 \text{ kg})(9.80 \text{ m/s}^2)}{0.20\cos 45° + \sin 45°} = 23 \text{ N}$$

7.12. Model: We treat the two objects of interest, the block (B) and steel cable (C), like particles. The motion of these objects is governed by the constant-acceleration kinematic equations. The horizontal component of the external force is 100 N.

Visualize:



Solve: Using $v_{1x}^2 = v_{0x}^2 + 2a_x(x_1 - x_0)$, we find

$$(4.0 \text{ m/s})^2 = 0 \text{ m}^2/\text{s}^2 + 2a_x(2.0 \text{ m}) \Rightarrow a_x = 4.0 \text{ m/s}^2$$

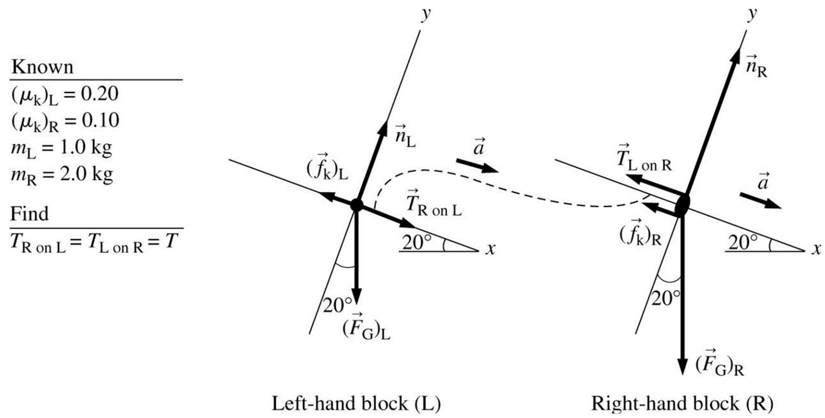
From the free-body diagram on the block:

$$\Sigma(F_{\text{on B}})_x = (F_{\text{C on B}})_x = m_B a_x \quad \Rightarrow \quad (F_{\text{C on B}})_x = (20 \text{ kg})(4.0 \text{ m/s}^2) = 80 \text{ N}$$

Also, according to Newton's third law $(F_{\text{B on C}})_x = (F_{\text{C on B}})_x = 80$ N. Applying Newton's second law to the cable gives

$$\Sigma(F_{\text{on C}})_x = (F_{ext})_x - (F_{\text{B on C}})_x = m_C a_x \quad \Rightarrow \quad 100 \text{ N} - 80 \text{ N} = m_C(4.0 \text{ m/s}^2) \quad \Rightarrow \quad m_C = 5.0 \text{ kg}$$

7.34. Model: The two blocks form a system of interacting objects. We shall treat them as particles.
Visualize: Please refer to Figure P7.34.



Solve: It is possible that the left-hand block (block L) is accelerating down the slope faster than the right-hand block (block R), causing the string to be slack (zero tension). If that were the case, we would get a zero or negative answer for the tension in the string. Newton's first law applied in the y-direction on block L yields

$$(\Sigma F_L)_y = 0 = n_L - (F_G)_L \cos(20°) \quad \Rightarrow \quad n_L = m_L g \cos(20°)$$

Therefore

$$(f_k)_L = (\mu_k)_L m_L g \cos(20°) = (0.20)(1.0 \text{ kg})(9.80 \text{ m/s}^2)\cos(20°) = 1.84 \text{ N}$$

A similar analysis of the forces in the y-direction on block R gives $(f_k)_R = 1.84$ N as well. Using Newton's second law in the x-direction for block L gives

$$(\Sigma F_L)_x = m_L a = T_{R\text{ on }L} - (f_k)_L + (F_G)_L \sin(20°) \quad \Rightarrow \quad m_L a = T_{R\text{ on }L} - 1.84 \text{ N} + m_L g \sin(20°)$$

For block R,

$$(\Sigma F_R)_x = m_R a = (F_G)_R \sin(20°) - 1.84 \text{ N} - T_{L\text{ on }R} \quad \Rightarrow \quad m_R a = m_R g \sin(20°) - 1.84 \text{ N} - T_{L\text{ on }R}$$

Solving these two equations in the two unknowns a and $T_{L\text{ on }R} = T_{R\text{ on }L} \equiv T$, we obtain $a = 2.12 \text{ m/s}^2$ and $T = 0.61$ N.

Assess: The tension in the string is positive, and is about 1/3 of the kinetic friction force on each of the blocks, which is reasonable.