Chapter 4

1. You and your bike have a combined mass of 80 kg. How much braking force has to be applied to slow you from a velocity of 5 m/s to a complete stop in 2 s?

$$a = \frac{v_f - v_i}{t_f - t_i} = \frac{0.0\text{ m/s} - 5.0\text{ m/s}}{2.0\text{ s} - 0.0\text{ s}}$$

$$= 2.5\text{ m/s}^2$$

$$F = ma$$

$$= 80\text{ kg} \times (-2.5\text{ m/s}^2)$$

$$= -200\text{ N}$$

2. Before opening his parachute, a sky diver with a mass of 90.0 kg experiences an upward force from air resistance of 150 N.

   a. What net force is acting on the sky diver?

$$F_{gravity} = mg$$

$$= 90.0\text{ kg} \times 9.80\text{ m/s}^2$$

$$= 882\text{ N downward}$$

$$F_{net} = F_{air\ resistance} + F_{gravity}$$

$$F_{net} = 150\text{ N} + (-882\text{ N})$$

$$= -732\text{ N}$$

$$= 730\text{ N downward}$$

   b. What is the sky diver's acceleration?

$$a = \frac{F_{net}}{m}$$

$$= \frac{-730\text{ N}}{90.0\text{ kg}}$$

$$= -8.1\text{ m/s}^2$$

$$= 8.1\text{ m/s}^2\text{ downward}$$

3. A large helicopter is used to lift a heat pump to the roof of a new building. The mass of the helicopter is 5.0×10^3 kg and the mass of the heat pump is 1500 kg.

   a. How much force must the air exert on the helicopter to lift the heat pump with an acceleration of 1.5 m/s^2?

$$F_{net} = F_{lift} + F_{overcome\ gravity}$$

$$= ma + mg$$

$$= (6.5\times10^3\text{ kg})(1.5\text{ m/s}^2) + (6.5\times10^3\text{ kg })(9.80\text{ m/s}^2)$$

$$= 7.3\times10^4\text{ N upward}$$

   b. Two chains connected to the load each can withstand a tension of 15,000 N. Can the load be safely lifted at 1.5 m/s^2?

$$F_{load} = F_{lift} + F_{overcome\ gravity}$$

$$= ma + mg$$

$$= (1.5\times10^3\text{ kg})(1.5\text{ m/s}^2) + (1.5\times10^3\text{ kg})(9.80\text{ m/s}^2)$$

$$= 2.25\times10^3\text{ N} + 1.47\times10^4\text{ N}$$

$$= 1.7\times10^4\text{ N}$$

   The load can be safely lifted because the total force on the chains is less than their combined capability of 3.0×10^4 N

4. In a lab experiment, you attach a 2.0-kg weight to a spring scale. You lift the scale and weight with a constant reading of 22.5 N.

   a. What is the value and direction of the acceleration on the weight?

$$F_{net} = F_{scale} - F_{gravity}$$

$$= 22.5\text{ N} - (2.0\text{ kg})(9.80\text{ m/s}^2)$$

$$= 2.9\text{ N upward}$$

$$a = \frac{m}{F_{net}}$$

$$= \frac{2.0\text{ kg}}{2.9\text{ N}}$$

$$= 0.69\text{ m/s}^2$$

$$= 6.9\times10^{-1}\text{ m/s}^2$$

   b. How far do you lift the weight in the first 2.0-s interval?

$$d_f = d_i + v_i t + \frac{1}{2}at^2$$

$$= 0\text{ m} + (0\text{ m/s})(2.0\text{ s}) + \frac{1}{2}(6.9\times10^{-1}\text{ m/s}^2)(2.0\text{ s})^2$$

$$= 1.4\text{ m}$$

5. As a large jet flies at a constant altitude, its engines produce a forward thrust of 8.4×10^5 N. The mass of the plane is 2.6×10^5 kg.

Chapter 4 continued

a. What is the forward acceleration of the plane, ignoring air resistance?

$$F = ma$$

$$a = \frac{F}{m}$$

$$= \frac{8.4\times10^5\ \text{N}}{2.6\times10^5\ \text{kg}}$$

$$= 3.2\ \text{m/s}^2$$

b. How much upward force must the air exert on the plane when it is flying horizontally?

Because the plane is not changing altitude,

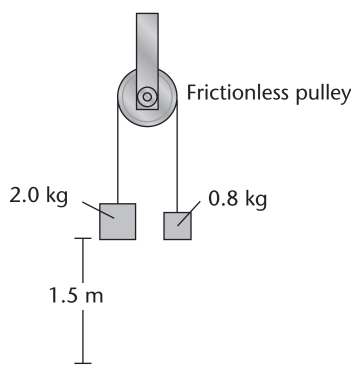
$$F_{net} = 0,\ \text{so}\ F_{lift} = -F_{gravity}$$

$$F_{lift} = -F_{gravity}$$

$$= -(2.6\times10^5\ \text{kg})(-9.80\ \text{m/s}^2)$$

$$= 2.5\times10^6\ \text{N}$$

6. Two masses are tied to a rope on a pulley, as shown below.



a. When the system is released from this position, what is the acceleration of the 2.00-kg mass?

$$F_{net} = F_{g\text{-large}} - F_{g\text{-small}} + m_{large}g - m_{small}g$$

$$= (2.00\ \text{kg})(9.80\ \text{m/s}^2) - (0.80\ \text{kg})(9.80\ \text{m/s}^2)$$

$$= 11.8\ \text{N downward}$$

$$a = \frac{F}{m}$$

$$= \frac{11.8\ \text{N}}{2.8\ \text{kg}}$$

$$= 4.2\ \text{m/s}^2\ \text{downward}$$

b. How long does it take for the 2.0-kg mass to fall to the floor?

Solve $d_f = d_i + v_it + \frac{1}{2}at^2$ **for** t

while $d_i = 0$ **m,** $v_i = 0$ **m/s**

$$t = \sqrt{\frac{2d}{a}}$$

$$= \sqrt{\frac{(2)(1.5\ \text{m})}{4.2\ \text{m/s}^2}}$$

$$= 0.85\ \text{s}$$

7. A man is standing on a scale inside an airplane. When the airplane is traveling horizontally (in other words, the vertical acceleration of the plane is zero) the scale reads 705.6 N. What is the vertical acceleration of the plane in each of the following situations?

a. When the scale reads 950.0 N.

$$F_g = mg$$

$$m = \frac{F_g}{g}$$

$$F_{net} = ma$$

$$F_{net} = F_{scale} + (-F_g)$$

$$ma = F_{scale} - F_g$$

$$a = \frac{F_{scale} - F_g}{m}$$

$$= \frac{F_{scale} - F_g}{\left(\frac{F_g}{g}\right)}$$

$$= \frac{g(F_{scale} - F_g)}{F_g}$$

$$= \frac{(9.80\ \text{m/s}^2)(950.0\ \text{N} - 705.6\ \text{N})}{705.6\ \text{N}}$$

$$= 3.39\ \text{m/s}^2$$

b. When the scale reads 500.0 N.

$$F_g = mg$$

$$m = \frac{F_g}{g}$$

$$F_{net} = ma$$

$$F_{net} = F_{scale} + (-F_g)$$

Chapter 4 continued

$$ma = F_{scale} - F_g$$

$$a = \frac{F_{scale} - F_g}{m}$$

$$= \frac{F_{scale} - F_g}{\left(\frac{F_g}{g}\right)}$$

$$= \frac{g(F_{scale} - F_g)}{F_g}$$

$$= \frac{(9.80\ \text{m/s}^2)(500.0\ \text{N} - 705.6\ \text{N})}{705.6\ \text{N}}$$

$$= -2.86\ \text{m/s}^2$$

8. An airboat glides across the surface of the water on a cushion of air. Perform the following calculations for a boat in which the mass of the boat and passengers is 450 kg.

a. If there is no friction, how much force must the propeller fan exert on the air to accelerate the boat at 5.00 m/s^2?

$$F = ma$$

$$= (450\ \text{kg})(5.00\ \text{m/s}^2)$$

$$= 2.2\times10^3\ \text{N}$$

b. If the actual acceleration with the fan generating the force calculated in part **a** is only 4.95 m/s^2, how much friction does the air cushion exert on the boat?

$$a_{friction} = a_{ideal} - a_{actual}$$

$$F_{friction} = ma_{friction}$$

$$m(a_{ideal} - a_{actual})(450\ \text{kg})$$

$$= (5.00\ \text{m/s}^2 - 4.95\ \text{m/s}^2)$$

$$= 22\ \text{N}$$

c. What is the upward force exerted by the air cushion on the boat?

$$F_{lift} = -F_{gravity} = -mg$$

$$= -(450\ \text{kg})(-9.80\ \text{m/s}^2)$$

$$= 4.4\times10^3\ \text{N}$$

9. A golf ball with a mass of 45 g is struck by a club, leaving the tee with a speed of 1.8×10^2 km/h. The period of acceleration was 0.50 m/s.

a. What is the average acceleration on the ball as it was struck (in m/s^2)?

$$a = \frac{v_f - v_i}{t}, \text{ where } v_i = 0\ \text{km/h}$$

$$a = \frac{(1.8\times10^2\ \text{km/h})\left(\frac{1000\ \text{m}}{1\ \text{km}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)}{(0.50\ \text{ms})\left(\frac{1\ \text{s}}{1000\ \text{ms}}\right)}$$

$$= \frac{50\ \text{m/s}}{5.0\times10^{-4}\ \text{s}}$$

$$= 1.0\times10^5\ \text{m/s}^2$$

b. What is the force exerted on the club?

$$F = ma$$

$$= (45\ \text{g})\left(\frac{1\ \text{kg}}{1000\ \text{g}}\right) \times (1.0\times10^5\ \text{m/s}^2)$$

$$= 4.5\times10^3\ \text{N}$$

c. What is the force exerted on the club by the ball?

$$F_{ball} = -F_{club}$$

$$= -4.5\times10^3\ \text{N}$$

10. A package of instruments is attached to a helium-filled weather balloon that exerts an upward force of 45 N.

a. If the instrument package weighs 10.0 kg, will the balloon be able to lift it?

$$F_{lift} = ma$$

$$a = \frac{F_{lift}}{m}$$

$$= \frac{45\ \text{N}}{10.0\ \text{kg}}$$

$$= 4.5\ \text{m/s}^2$$

The balloon cannot lift the package because the upward acceleration is less than the downward acceleration of gravity, 9.80 m/s^2.

Alternative calculation:

$$F_{gravity} = (10.0\ \text{kg})(9.80\ \text{m/s}^2)$$

$$= 98.0\ \text{N, which exceeds the upward force}$$

b. What is the upward acceleration if the instruments weigh 2.0 kg?

$$F_{net} = F_{lift} - F_{gravity}$$

$$F_{net} = ma - mg$$

Chapter 4 continued

$= 45\ \text{N} - (2.0\ \text{kg})(9.80\ \text{m/s}^2)$

$= 25.4\ \text{N}$

$a = \frac{F_{net}}{m}$

$= \frac{25.4\ \text{N}}{2.0\ \text{kg}}$

$= 13\ \text{m/s}^2$ **upward**

11. A 12-kg block sits on a table. A 10.0-kg block sits on top of the 12-kg block. If there is nothing on top of the 10.0-kg block, what is the force that the table exerts on the 12-kg block?

$F_{table} = F_{block\ 1} + F_{block\ 2}$

$= (12\ \text{kg})(9.80\ \text{m/s}^2) + (10.0\ \text{kg})(9.80\ \text{m/s}^2)$

$= 220\ \text{N}$

12. A box experiences a net force of 41 N while it is being lifted. What is the acceleration of the box?

$F_{net} = ma$

$a = \frac{F_{net}}{m}$

$= \frac{41\ \text{N}}{9.7\ \text{kg}}$

$= 4.2\ \text{m/s}^2$

13. A rope can withstand 1.000×10^3 N of tension. If the rope is being used to pull a 10.0-kg package across a frictionless surface, what is the greatest acceleration that will not break the rope?

$F = ma$

$a = \frac{F}{m}$

$= \frac{1.000\times10^3\ \text{N}}{10.0\ \text{kg}}$

$= 1.00\times10^2\ \text{m/s}^2$

14. A 0.100-kg weight is attached to a spring scale. Find the reading on the scale for each of the following situations.

a. When the scale is not moving.

$F_g = mg$

$= (0.100\ \text{kg})(9.80\ \text{m/s}^2)$

$= 0.980\ \text{N}$

b. When the scale accelerates at 2.4 m/s^2 in the horizontal direction.

The vertical component of the acceleration is zero, so the reading on the scale is calculated the same way as when the scale is not moving.

$F_g = mg$

$= (0.100\ \text{kg})(9.80\ \text{m/s}^2)$

$= 0.980\ \text{N}$

15. A penny is dropped from the top of a 30.0-m-tall tower. The tower, however, is not located on Earth. The penny has a mass of 2.5 g and experiences a gravitational force of 0.028 N.

a. What is acceleration due to gravity on this planet?

$a_g = \frac{F_g}{m}$

$= \frac{0.028\ \text{N}}{0.0025\ \text{kg}}$

$= 11\ \text{m/s}^2$

b. After 1.00 s, the penny has a velocity of 10.1 m/s. Assuming the force exerted on the penny by air resistance is uniform and independent of speed, what is the magnitude of the force of air resistance on the penny?

$F_{net} = m\bar{a}$

$= F_g + (-F_a)$

$F_a = F_g - ma$, **where** $a = \bar{a} = \frac{\Delta v}{\Delta t}$

$= F_g - m\left(\frac{\Delta v}{\Delta t}\right)$

Chapter 4 continued

$$= F_g - m\left(\frac{v_f - v_i}{\Delta t}\right)$$

$$= 0.028\ \text{N} - (0.0025\ \text{kg})\left(\frac{10.1\ \text{m/s} - 0.0\ \text{m/s}}{1.00\ \text{s}}\right)$$

$$= 0.0028\ \text{N}$$

The air resistance is in the opposite direction from the force of gravity and the penny's motion, as it should be.

16. The combined mass of a sled and its rider is 46.4 kg. The sled is pulled across a frozen lake so that the force of friction between the sled and the ice is very small.

a. Assuming that friction between the sled and the ice is negligible, what force is required to accelerate the sled at 3.45 m/s^2?

$$F = ma$$

$$= (46.4\ \text{kg})(3.45\ \text{m/s}^2)$$

$$= 1.60\times10^2\ \text{N}$$

b. A force of 150.0 N is applied to the sled and produces an acceleration of 3.00 m/s^2. What is the magnitude of the force of friction that resists the acceleration?

$$F_{net} = ma$$

$$F_{net} = F_{applied} - F_f$$

$$ma = F_{applied} - F_f$$

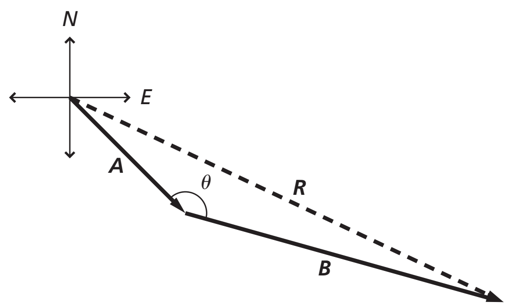
$$F_f = F_{applied} - ma$$

$$= 150.0\ \text{N} - (46.4\ \text{kg})(3.00\ \text{ms}^2)$$

$$= 10.8\ \text{N}$$

Chapter 5

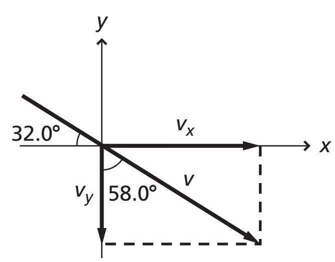
1. A small plane takes off and flies 12.0 km in a direction southeast of the airport. At this point, following the instructions of an air traffic controller, the plane turns 20.0° to the east of its original flight path and flies 21.0 km. What is the magnitude of the plane's resultant displacement from the airport?



$$\boldsymbol{R^2 = A^2 + B^2 - 2AB \cos \theta}$$

$$\boldsymbol{R = \sqrt{(12.0\ \text{km})^2 + (21.0\ \text{km})^2 - 2(12.0\ \text{km})(21.0\ \text{km})(\cos 160.0°)}}$$
$$\boldsymbol{= 32.5\ \text{km}}$$

2. A hammer slides down a roof that makes a 32.0° angle with the horizontal. What are the magnitudes of the components of the hammer's velocity at the edge of the roof if it is moving at a speed of 6.25 m/s?



Fourth quadrant: $v_x > 0$ and $v_y < 0$.

$$\boldsymbol{v_x = v \cos \theta}$$
$$\boldsymbol{= (6.25\ \text{m/s})(\cos -32.0°)}$$
$$\boldsymbol{= 5.30\ \text{m/s}}$$
$$\boldsymbol{v_y = v \sin \theta}$$
$$\boldsymbol{= (6.25\ \text{m/s})(\sin -32.0°)}$$
$$\boldsymbol{= -3.31\ \text{m/s}}$$

Chapter 5 continued

3. A worker has to move a 17.0-kg crate along a flat floor in a warehouse. The coefficient of kinetic friction between the crate and the floor is 0.214. The worker pulls horizontally on a rope attached to the crate, with a 49.0-N force. What is the resultant acceleration of the crate?

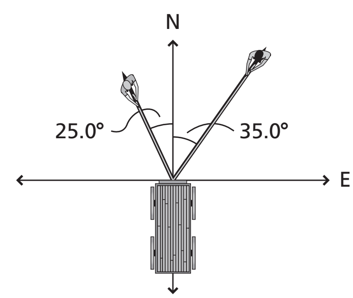
***y*-direction:**

$$F_N = F_g = mg$$

***x*-direction:**

$$F_{net,\,x} = F_p - F_f$$
$$= ma_x = ma$$
$$F_f = \mu_k F_N = \mu_k mg$$
$$ma = F_p - \mu_k mg$$
$$a = \frac{F_p - \mu_k mg}{m}$$
$$= \frac{49.0\text{ N} - (0.214)(17.0\text{ kg})(9.80\text{ m/s}^2)}{17.0\text{ kg}}$$
$$= 0.785\text{ m/s}^2$$

4. To get a cart to move, two farmers pull on ropes attached to the cart, as shown below. One farmer pulls with a force of 50.0 N in a direction 35.0° east of north, while the other exerts a force of 30.0 N in a direction 25.0° west of north. What are the magnitude and the direction of the combined force exerted on the cart?

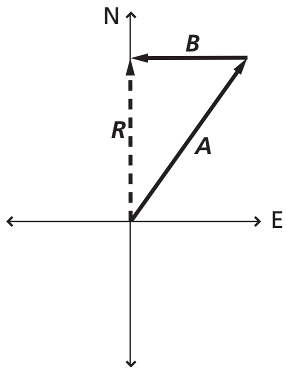


$$R_x = A_x + B_x = A\cos\theta_1 + B\cos\theta_2$$
$$R_y = A_y + B_y = A\sin\theta_1 + B\sin\theta_2$$
$$R = \sqrt{R_x^2 + R_y^2}$$
$$= \sqrt{(A\cos\theta_1 + B\cos\theta_2)^2 + (A\sin\theta_1 + B\sin\theta_2)^2}$$
$$= \sqrt{((50.0\text{ N})(\cos 55.0°) + (30.0\text{ N})(\cos 115.0°))^2 + ((50.0\text{ N})(\sin 55.0°) + (30.0\text{ N})(\sin 115.0°))^2}$$
$$= 70.0\text{ N}$$
$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right) = \tan^{-1}\left(\frac{A\sin\theta_1 + B\sin\theta_2}{A\cos\theta_1 + B\cos\theta_2}\right)$$
$$= \tan^{-1}\left(\frac{(50.0\text{ N})(\sin 55.0°) + (30.0\text{ N})(\sin 115.0°)}{(50.0\text{ N})(\cos 55.0°) + (30.0\text{ N})(\cos 115.0°)}\right)$$
$$= 76.8°$$

***R* = 70.0 N at 76.8° north of east**

Chapter 5 continued

5. Takashi trains for a race by rowing his canoe on a lake. He starts by rowing along a straight path. Then he turns and rows 260.0 m west. If he then finds he is located 360.0 m exactly north of his starting point, what was his displacement along the straight path?



$R_x = 0.0$ m, $R_y = 360.0$ m

$B_x = -260.0$ m, $B_y = 0.0$ m

$R = A + B$, $A = R - B$

$A_x = R_x - B_x = 0.0 \text{ m} - (-260.0 \text{ m})$

$= 260.0$ m

$A_y = R_y - B_y = 360.0 \text{ m} - 0.0 \text{ m}$

$= 360.0$ m

$A = \sqrt{A_x^2 + A_y^2}$

$= \sqrt{(260.0 \text{ m})^2 + (360.0 \text{ m})^2}$

$= 444.1$ m

$\theta = \tan^{-1}\left(\frac{A_y}{A_x}\right)$

$= \tan^{-1}\left(\frac{360.0 \text{ m}}{260.0 \text{ m}}\right) = 54.16°$

$A = 444.1$ m at $54.16°$ north of east

6. Mira received a 235-N sled for her birthday. She takes the sled out to a flat snowy field. When she pushes it with a 45.0-N horizontal force, it slides along at a constant speed. What is the coefficient of kinetic friction between the sled and the snow?

y-direction: $F_N = F_g$

x-direction: $F_p - F_f = ma$

$a = 0$ (since v = constant)

$F_p - F_f = 0$

$F_p = F_f$

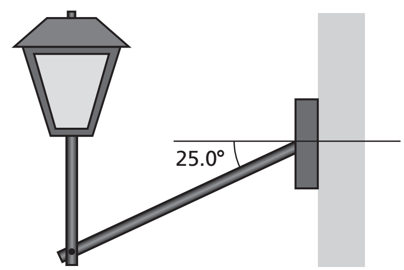
$= \mu_k F_N = \mu_k F_g$

$\mu_k = \frac{F_p}{F_g}$

$= \frac{45.0 \text{ N}}{235 \text{ N}}$

$= 0.191$

7. A rod supports a 2.35-kg lamp, as shown below.



a. What is the magnitude of the tension in the rod?

y-direction:

$T_y = F_g$

$T \sin \theta = mg$

$T = \frac{mg}{\sin \theta}$

$= \frac{(2.35 \text{ kg})(9.80 \text{ m/s}^2)}{\sin 25.0°}$

$= 54.5$ N

b. Calculate the components of the force that the bracket exerts on the rod.

x-direction:

$T_x - F_x = 0$

$F_x = T \cos \theta$

$= (54.5 \text{ N})(\cos 25.0°)$

$F_x = 49.4$ N, inward

y-direction:

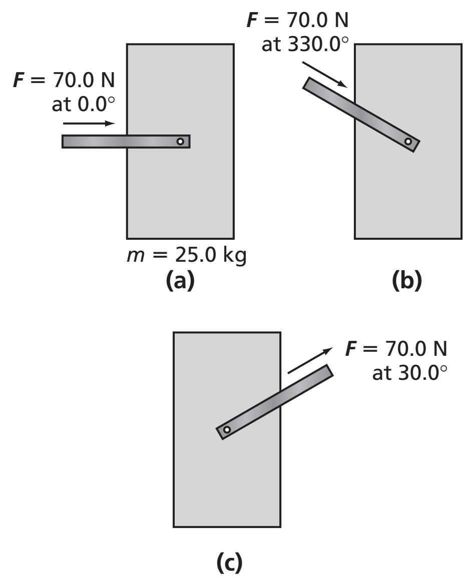
$F_y = T_y$

$= mg$

$= (2.35\ \text{kg})(9.80\ \text{m/s}^2)$

$F_y = 23.0\ \text{N, upward}$

8. A 25.0-kg crate has an adjustable handle so that it can be pushed or pulled by the handle at various angles. Determine the acceleration of the crate for each situation shown in the diagram, given that the coefficient of sliding friction between the floor and the bottom of the crate is 0.20.



For (a)

y-direction:

$F_N = F_g = mg$

$F_N = mg$

x-direction:

$F_{\text{net}, x} = F_p - F_f$

$F_{\text{net}, x} = ma_x = ma$

$ma = F_p - F_f$

$F_f = \mu_k F_N = \mu_k mg$

$ma = F_p - \mu_k mg$

$$a = \frac{F_p - \mu_k mg}{m} = \frac{F_p}{m} - \mu_k g$$

$$= \frac{70.0\ \text{N}}{25.0\ \text{kg}} - (0.20)(9.80\ \text{m/s}^2)$$

$= 0.84\ \text{m/s}^2$

For (b)

y-direction:

$F_N = F_g + F_y$

$F_N = mg + F \sin\theta$

x-direction:

$F_{\text{net}, x} = F_p - F_f$

$F_{\text{net}, x} = ma_x = ma$

$ma = F_p - F_f$

$F_p = F \cos \theta$

$F_f = \mu_k F_N = \mu_k(mg + F \sin \theta)$

$F_{net,\,x} = F \cos \theta - \mu_k(mg + F \sin \theta) = ma$

$$a = \frac{F_{net}}{m}$$

$$= \frac{F \cos \theta - \mu_k(mg + F \sin \theta)}{m}$$

$$= \frac{F \cos \theta - \mu_k F \sin \theta}{m} - \mu_k g$$

$$= \frac{(70.0\text{ N})(\cos 30.0°) - (0.20)(70.0\text{ N})(\sin 30.0°)}{25.0\text{ kg}} - (0.20)(9.80\text{ m/s}^2)$$

$$= 0.18\text{ m/s}^2$$

For (c)

y-direction:

$F_N = F_g - F_y$

$F_N = mg - F \sin \theta$

x-direction:

$F_{net,\,x} = F_p - F_f$

$F_{net,\,x} = ma_x = ma$

$ma = F_p - F_f$

$F_p = F \cos \theta$

$F_f = \mu_k F_N = \mu_k(mg - F \sin \theta)$

$F_{net,\,x} = F \cos \theta - \mu_k(mg - F \sin \theta) = ma$

$$a = \frac{F_{net}}{m}$$

$$= \frac{F \cos \theta - \mu_k(mg - F \sin \theta)}{m}$$

$$= \frac{F \cos \theta + \mu_k F \sin \theta}{m} - \mu_k g$$

$$= \frac{(70.0\text{ N})(\cos 30.0°) + (0.20)(70.0\text{ N})(\sin 30.0°)}{25.0\text{ kg}} - (0.20)(9.80\text{ m/s}^2)$$

$$= 0.74\text{ m/s}^2$$

Chapter 5 continued

9. A child shoves a small toboggan weighing 100.0 N up a snowy hill, giving the toboggan an initial speed of 6.0 m/s. If the hill is inclined at an angle of 32° above the horizontal, how far along the hill will the toboggan slide? Assume that the coefficient of sliding friction between the toboggan and the snow is 0.15.

***y*-direction:**

$F_{\text{net}, y} = ma_y = 0$

$F_N - F_{gy} = 0$

$F_N = F_{gy} = mg \cos \theta$

***x*-direction:**

$F_{\text{net}, x} = ma_x = ma$

$F_{gx} = mg \sin \theta$

$F_{gx} - F_f = ma$

$F_f = \mu_k F_N = \mu_k mg \cos \theta$

$mg \sin \theta - \mu_k mg \cos \theta = ma$

$a = g(\sin \theta - \mu_k \cos \theta)$

$v_f^2 = v_i^2 + 2a(d_f - d_i)$

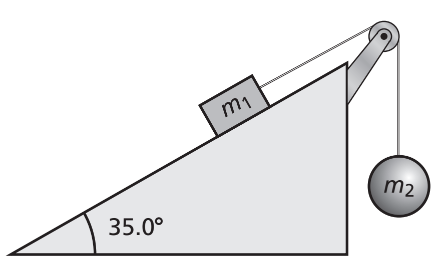
$0 = v_i^2 + 2ad$

$$d = -\frac{v_i^2}{2a} = \frac{v_i^2}{2g(\sin \theta - \mu_k \cos \theta)}$$

$$= \frac{(6.0 \text{ m/s}^2)}{(2)(9.80 \text{ m/s}^2)(\sin 32° - (0.15)\cos 32°)}$$

$= 4.6$ **m, up the hill**

10. Two objects are connected by a string passing over a frictionless, massless pulley. As shown below, the block is on an inclined plane and the ball is hanging over the top edge of the plane. The block has a mass of 60.0 kg, and the coefficient of kinetic friction between the block and the inclined plane is 0.22. If the block moves at a constant speed down the incline, and the ball rises at a constant speed, what is the mass of the hanging ball?



v is constant, so there is no acceleration.

Ball (m_2):

y-direction:

$F_{net,\,y} = m_2 a_y = 0$

$F_T - F_g = 0$

$F_T = m_2 g$

Block (m_1):

y-direction: (parallel to the incline)

$F_{net,\,y} = m_1 a_y = 0$

$F_N = F_{gy} = 0$

$F_N = F_{gy} = m_1 g \cos\theta$

$F_f = \mu_k F_N = \mu_k m_1 g \cos\theta$

x-direction: (perpendicular to the incline)

$F_{net,\,x} = m_1 a_x = 0$

$F_{gx} - F_f - F_T = 0$

$F_{gx} = m_1 g \sin\theta$

$m_1 g \sin\theta - \mu_k m_1 g \cos\theta - F_T = 0$

$m_1 g \sin\theta - \mu_k m_1 g \cos\theta - m_2 g = 0$

$$m_2 = \frac{m_1 g \sin\theta - \mu_k m_1 g \cos\theta}{g}$$

$$= m_1 \sin\theta - \mu_k m_1 \cos\theta$$

$$= (60.0\ \text{kg})(\sin 35.0^\circ) - (0.22)(60.0\ \text{kg})(\cos 35.0^\circ)$$

$$= 24\ \text{kg}$$