Chapter 5

Newton's Laws

Practice Problem Solutions

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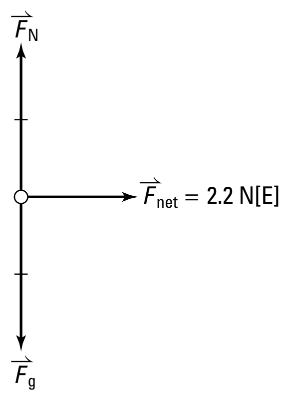
1. **Frame the Problem**
   - Draw a free body diagram of the problem.
   - The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the object.
   - The net force is the only horizontal force on the object.
   - The net force determines the acceleration of the object according to Newton's second law of motion.



Identify the Goal

The acceleration of the object

Variables and Constants

Known	Implied	Unknown
$m = 4.0$ kg		$\vec{a}$
$\vec{F}_{net} = 2.2$ N[E]		

Strategy

Since the net force is known, use Newton's second law in terms of acceleration.

Use $1\ \frac{N}{kg} = 1\ \frac{m}{s^2}$.

The acceleration of the object is $0.55\ m/s^2$[E].

Calculations

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$

$$\vec{a} = \frac{2.2\ N[E]}{4.0\ kg}$$

$$\vec{a} = 0.55\frac{m}{s^2}\ N[E]$$

Validate

The object accelerated in the direction of the net force. The unit for acceleration is m/s^2 which is correct.

2. Frame the Problem

- Draw a free body diagram of the problem.
- The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the object.
- The friction force is in the opposite direction of the applied force.
- The net force is the sum of the friction force and the applied force on the object.
- The net force determines the acceleration of the object according to Newton's second law of motion.

Identify the Goal

The acceleration of the object

Variables and Constants

Known	Implied	Unknown
$m = 6.0$ kg		$\vec{a}$
$\vec{F}_a = 4.4$ N[E]		$\vec{F}_{net}$
$\vec{F}_f = 1.2$ N[E]		

Strategy

Since the motion is all along one line, east and west, denote direction with signs only.

Let east be positive and west be negative.

Find the net force on the object by finding the vector sum of the applied force and the friction force acting on the object.

Calculations

$$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$$
$$\vec{F}_{net} = +4.4\text{ N} - 1.2\text{ N}$$
$$\vec{F}_{net} = +3.2\text{ N}$$

Apply Newton's second law in terms of acceleration and solve.

Use $1\ \frac{\text{N}}{\text{kg}} = 1\ \frac{\text{m}}{\text{s}^2}$.

$$\vec{a} = \frac{\vec{F}_{net}}{\text{m}}$$
$$\vec{a} = \frac{+3.2\text{ N}}{6.0\text{ kg}}$$
$$\vec{a} = +0.53\ \frac{\text{m}}{\text{s}^2}$$
$$\vec{a} = 0.53\ \frac{\text{m}}{\text{s}^2}[\text{E}]$$

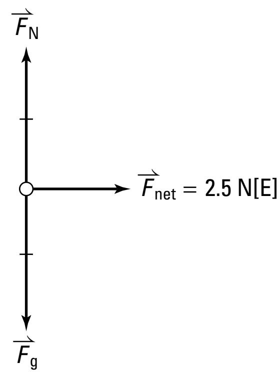
The acceleration of the object is 0.53m/s^2[E].

Validate

The object accelerated in the direction of the net force. The unit for acceleration is m/s^2 which is correct.

3. Frame the Problem

- Draw a free body diagram of the problem.
- The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the wheeled cart.
- Since frictional forces are ignored the net force on the wheeled cart is from the stretched elastic band only.
- The mass of the cart is related to the net force on the cart and to the acceleration of the cart.



Identify the Goal
The mass of the cart

Variables and Constants

Known	Implied	Unknown
$\vec{F}_a = 2.5$ N[E]	$\vec{F}_{net}$	m
$\vec{a} = 1.5\ \frac{m}{s^2}$[E]		

Strategy	Calculations
Find the net force on the wheeled cart.	$\vec{F}_{net} = \vec{F}_a$
	$\vec{F}_{net} = 2.5$ N[E]
Apply Newton's second law in terms of mass and solve.	$m = \frac{\vec{F}_{net}}{\vec{a}}$
Since $1\ \frac{N}{kg} = 1\ \frac{m}{s^2}$ it follows that $1\ N = 1\ kg \cdot \frac{m}{s^2}$ and the unit for mass is kg.	$m = \frac{2.5\ N[E]}{\frac{1.5\ m}{s^2[E]}}$
	$m = 1.67$ kg
The mass of the cart is 1.7 kg.	$m = 1.7$ kg

Validate
The unit for mass of the wheeled cart is kg, which is correct.

Practice Problem Solutions

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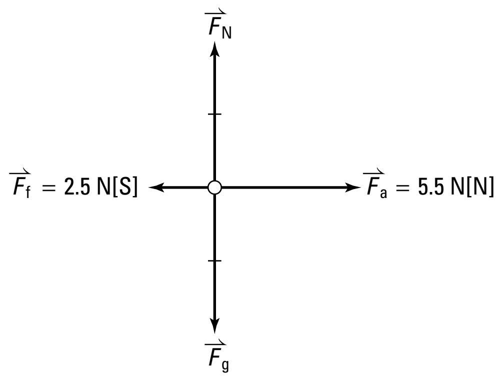
4. **Frame the Problem**
   - Draw a free body diagram of the problem.
   - The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the object.
   - The friction force is in the opposite direction of the applied force.
   - The net force is the sum of the friction force and the applied force on the object.
   - The net force determines the acceleration of the object according to Newton's second law of motion.
   - The equations of motion for uniform acceleration apply to the motion of the stone.



Identify the Goal
How far the object travelled

Variables and Constants

Known	Implied	Unknown
$m = 15$ kg	$\vec{v}_i = 0.0\ \frac{m}{s}$	$\vec{a}$
$\vec{F}_a = 5.5$ N[N]		$\vec{F}_{net}$
$\vec{F}_f = 2.5$ N[S]		$\Delta\vec{d}$
$\Delta t = 4.0$ s		

Strategy

Since the motion is all along one line, north and south, denote direction with signs only.

Let north be positive and south be negative.

Find the net force on the object by finding the vector sum of the applied force and the friction force acting on the object.

Apply Newton's second law in terms of acceleration and solve.
$1\ \frac{N}{kg} = 1\ \frac{m}{s^2}$.

Recall the equations of motion from Chapter 2. Use the equation that relates initial velocity, time, acceleration and displacement.

Substitute in the known values and solve for Δd.

The object travelled 1.6 m[N] after 4.0 s.

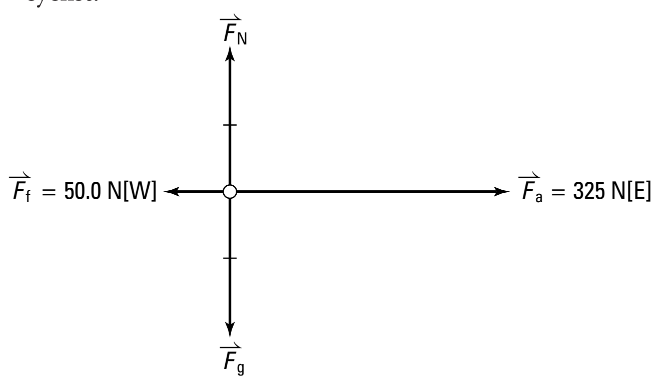
Calculations

$$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$$
$$\vec{F}_{net} = +5.5\text{ N} - 2.5\text{ N}$$
$$\vec{F}_{net} = +3\text{ N}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$\vec{a} = \frac{+3\text{ N}}{15\text{ kg}}$$
$$\vec{a} = +0.2\ \frac{m}{s^2}$$
$$\vec{a} = 0.2\ \frac{m}{s^2}[N]$$
$$\Delta d = v_i\Delta t + \frac{1}{2}a\Delta t^2$$
$$\Delta d = 0.0\ \frac{m}{s} + \frac{1}{2}(0.2\ \frac{m}{s^2})(4.0\text{ s})^2$$
$$\Delta d = (0.1)(16.0\text{ m})$$
$$\Delta d = 1.6\text{ m}$$
$$\Delta d = 1.6\text{ m[N]}$$

Validate
The object accelerated in the direction of the net force, which was north, and travelled in that direction. The unit for displacement is m, which is correct.

5. Frame the Problem

- Draw a free body diagram of the problem.
- The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the cyclist.
- The friction force is in the opposite direction of the cyclist's applied force.
- The net force is the sum of the friction force and the applied force on the cyclist.
- The net force determines the acceleration of the cyclist according to Newton's second law of motion.
- The equations of motion for uniform acceleration apply to the motion of the cyclist.



Identify the Goal

(a) The acceleration of the cyclist

(b) How far the student travelled

Variables and Constants

Known	Implied	Unknown
$\vec{F}_a = 325$ N[E]	$\vec{v}_i = 3.0\ \frac{m}{s}$[E]	$\vec{a}$
$\vec{F}_f = 50$ N[W]	$m_T = 49$ kg	$\vec{F}_{net}$
$\Delta t = 8.0$ s		$\Delta\vec{d}$

Strategy	Calculations
Find the total mass of the cyclist and the bicycle.	
Since the motion is all along one line, east and west, denote direction with signs only. Let east be positive and west be negative.	**(a)** $m_T = 45\text{ kg} + 4.0\text{ kg}$ $m_T = 49.0\text{ kg}$
Find the net force on the cyclist by finding the vector sum of the applied force and the friction force acting on the cyclist.	$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$ $\vec{F}_{net} = +325\text{ N} - 50.0\text{ N}$ $\vec{F}_{net} = +275\text{ N}$
Apply Newton's second law in terms of acceleration and solve. $1\ \frac{N}{kg} = 1\ \frac{m}{s^2}$.	$\vec{a} = \frac{\vec{F}_{net}}{m}$ $\vec{a} = \frac{+275\text{ N}}{49.0\text{ kg}}$ $\vec{a} = +5.6\ \frac{m}{s^2}$ $\vec{a} = +5.6\ \frac{m}{s^2}$[N]
Recall the equations of motion from Chapter 2. Use the equation that relates initial velocity, time, acceleration and displacement.	

Substitute in the known values and solve for Δd.

(b) $\Delta d = v_i \Delta t + \frac{1}{2} a \Delta t^2$

$\Delta d = 3.0\ \frac{\text{m}}{\text{s}}(8.0\ \text{s}) + \frac{1}{2}(+5.6\ \frac{\text{m}}{\text{s}^2})(8.0\ \text{s})^2$

$\Delta d = +24\ \text{m} + (2.8)(64.0\ \text{m})$

$\Delta d = +24\ \text{m} + 179.2\ \text{m}$

$\Delta d = +203.2\ \text{m}$

$\Delta d = 2.0 \times 10^2\ \text{m[E]}$

(a) The acceleration of the cyclist is $5.6\ \text{m/s}^2$[E].

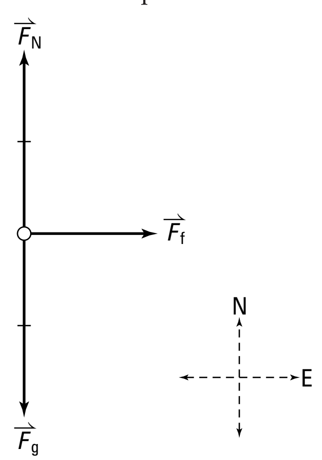
(b) The cyclist travelled 2.0×10^2 m[E] after 8.0 s.

Validate

The object accelerated in the direction of the net force, which was north, and travelled in that direction. The units for acceleration and displacement should be m/s^2 and m, respectively, and they are, which is correct.

6. Frame the Problem

- Draw a free body diagram of the problem.
- The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the car.
- The friction force is the only force acting on the car that will slow it down, so this is the net force.
- The mass of the car is related to the net force on the car and to the acceleration of the car.
- Use the equations of motion from Chapter 2 to solve for the acceleration.



Identify the Goal

The coefficient of friction between the road and the car tires.

Variables and Constants

Known	Implied	Unknown	
$m = 1.2 \times 10^3$ kg	$\vec{g} = 9.8\ \frac{\text{m}}{\text{s}^2}$	$\vec{F}_{net}$	$\vec{F}_f$
$\vec{v}_i = 45$ km/h		$\vec{a}$	$\vec{F}_N$
$\Delta d = 35$ m		$\vec{F}_g$	
$\vec{v}_f = 0$ km/h			

Strategy

Convert km/h to m/s.

To find the friction force acting on the car the acceleration must be known so that a relationship between the net force and the friction force can be obtained.

Use the equation of motion that relates initial and final velocity acceleration and displacement.

Find the net force on the car, knowing its mass and acceleration using Newton's second law.

Use the equation for weight to find the weight and thus the normal force.

Since $1\ \frac{\text{N}}{\text{kg}} = 1\ \frac{\text{m}}{\text{s}^2}$ it follows that $1\ \text{N} = 1\ \text{kg}\frac{\text{m}}{\text{s}^2}$ and the unit for mass is kg.

Apply the equation for a frictional force.

Calculations

$$45\ \frac{\text{km}}{\text{h}} \times \frac{1\ \text{h}}{3600\ \text{s}} \times \frac{1000\ \text{m}}{1\ \text{km}} = 12.5\ \frac{\text{m}}{\text{s}}$$

$$a = \frac{v_f^2 - v_i^2}{2d}$$

$$a = \frac{(0\ \frac{\text{m}}{\text{s}})^2 - (12.5\ \frac{\text{m}}{\text{s}})^2}{2d}$$

$$a = \frac{-156.25\ (\frac{\text{m}}{\text{s}})^2}{2(35\ \text{m})}$$

$$a = \frac{-156.25\ (\frac{\text{m}}{\text{s}})^2}{70\ \text{m}}$$

$$a = -2.23\ \frac{\text{m}}{\text{s}^2}$$

$$\vec{F}_{\text{net}} = m\vec{a} = (1.2 \times 10^3\ \text{kg})(2.23\ \frac{\text{m}}{\text{s}^2})$$

$$\vec{F}_{\text{net}} = 2678\ \text{N}$$

$$\vec{F}_{\text{f}} = \mu_k F_N$$

$$\vec{F}_{\text{N}} = m\vec{g} = (1.2 \times 10^3\ \text{kg})(2.23\ \frac{\text{N}}{\text{kg}})$$

$$= 11772\ \text{N}$$

$$\vec{F}_{\text{net}} = \vec{F}_{\text{f}}$$

$$\vec{F}_{\text{net}} = \mu_k F_N$$

$$2678.6\ \text{N} = \mu_k 11772\ \text{N}$$

$$\mu_k = \frac{2678.6\ \text{N}}{11772\ \text{N}} = 0.23$$

The coefficient of friction between the slippery road and the car tires is 0.23.

Validate

The coefficient of kinetic friction is low and it should be since the surface is a slippery road.

7. Conceptualize the Problem

- The ions are moving horizontally (the case in all linear accelerators), under an electric force.
- Due to the ion's small mass, the force of gravity on the ion is exceedingly small. And, as indicated, the time of flight is very short. Therefore, the effect of the force of gravity is too small to be detected and you can consider the electric force to be the only force affecting the ions. How the force works doesn't matter; all that matters is that it accelerates the ions in a horizontal direction.
- No frictional forces are present.
- The ion is initially at rest, meaning that the initial velocity is zero.
- Before finding the force, the acceleration can be found using the kinematics data.
- Newton's second law can be applied to find the force from the mass and acceleration.
- Let the direction of the force, and therefore the direction of the acceleration, be positive.

Identify the Goal

The magnitude of the force, F, required to accelerate the ion

Identify the Variables

Known	Implied	Unknown
$m_{ion} = 7.2 \times 10^{-25}$ kg	$v_1 = 0$ m/s	F
$v_2 = 7.3 \times 10^6$ m/s		a
$t = 5.5 \times 10^{-6}$ s		

Develop a Strategy	Calculations
Apply an appropriate kinematic equation to find the magnitude of the acceleration.	$v_2 = v_1 + at$
Substitute and solve.	$a = \frac{v_2 - v_1}{t}$ $a = \frac{7.3 \times 10^6 \text{ m/s} - 0 \text{ m/s}}{5.5 \times 10^{-6} \text{ s}}$ $a = 1.327 \times 10^{12} \text{ m/s}^2$ $a \cong 1.3 \times 10^{12} \text{ m/s}^2$
Apply Newton's second law to find the magnitude of the force.	$F = ma$ $F = (7.2 \times 10^{-25} \text{ kg})(1.327 \times 10^{12} \text{ m/s}^2)$ $F = 9.56 \times 10^{-13}$ N $F \cong 9.6 \times 10^{-13}$ N
The magnitude of the force is 9.6×10^{-13} N in the positive direction.	

Validate the Solution

Though the acceleration of the ions is relatively high, 1.3×10^{12} m/s^2, the mass of the ions is very small, so we expect that even a small force can produce this acceleration.

8. Conceptualize the Problem

- While the hockey stick is in contact with the hockey puck, it exerts an average force and accelerates the puck.
- The puck accelerates in the direction of the applied force. Define this direction as positive.
- The puck accelerates from rest ($v_1 = 0$ m/s) to some unknown final velocity ($v_2 = ?$) over the distance, d, that it's in contact with the hockey stick.
- It is assumed that friction between the puck and ice is negligible, so all of the applied force goes into accelerating the puck.

Identify the Goal

The final velocity, $\vec{v_2}$, of the hockey puck

Identify the Variables

Known	Implied	Unknown
$F = 39$ N	$v_1 = 0$ m/s	a
$m = 0.20$ kg		v_2
$d = 0.22$ m		
$m = 0.20$ kg		

Develop a Strategy

Apply Newton's second law to find the magnitude of the net force.

$F = ma$

Write Newton's second law in terms of acceleration.

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

Substitute and solve.

$a = \frac{39\ \text{N}}{0.22\ \text{kg}}$

$\frac{\text{N}}{\text{kg}}$ is equivalent to $\frac{\text{m}}{\text{s}^2}$

$a = 195\ \frac{\text{m}}{\text{s}^2}$

Apply an appropriate kinematics equation that relates initial velocity, acceleration and displacement to final velocity.

$v_2^2 = v_1^2 + 2ad$

$v_2^2 = 0 + 2(195\ \frac{\text{m}}{\text{s}^2})(0.22\ \text{m})$

$v_2 = 9.2628\ \frac{\text{m}}{\text{s}}$

$\therefore v_2 \cong 9.3\frac{\text{m}}{\text{s}}$

The final velocity of the puck is about 9.3 m/s in the direction of the applied force.

Validate the Solution

The acceleration is positive, as expected, because it is in the same direction as the applied force. The final velocity is 9.3 m/s, which is about 33 km/h, which is reasonable for a pass to a team-mate, but much too slow for a slapshot.

Practice Problem Solutions

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9. **Conceptualize the Problem**
   - Begin by drawing a free-body diagram.
   - *Motion* of the sled is in the *horizontal direction*, so the net *horizontal force* is causing the sled to *accelerate*.
   - Let the *direction* of the motion be the *positive* horizontal direction.
   - There is no motion in the vertical direction, so the *vertical acceleration* is zero. If the acceleration is zero, the *net vertical force* must be zero. The information leads to the value of the *normal force*. Let "up" be the *positive* vertical direction.
   - Once the *normal force* is known, the *force of friction* can be determined.
   - The sled is not initially at rest, so the *coefficient of kinetic friction* applies to the motion.

   Identify the Goal

   The acceleration, $\vec{a}$, of the sled

   Identify the Variables

Known	Implied	Unknown
$F = 1.3 \times 10^3$ N	$a_y = 0$ m/s^2	a_x
$m = 1.1 \times 10^4$ kg		F_N
$\mu = 0.80$		

   Develop a Strategy

   To find the normal force, apply Newton's second law to the vertical forces. Analyze the free-body

   Calculations

   $F_N - mg = ma_y$

   $F_N - mg = 0$

   $F_N = mg$

diagram to find all of the vertical forces that act on the crate.

To find the acceleration, apply Newton's second law to the horizontal forces. Analyze the free-body diagram to find all of the horizontal forces that act on the crate.

$$F - F_f = ma_x$$
$$F_f = \mu F_N = \mu mg$$
$$F - \mu mg = ma_x$$
$$a_x = \frac{F - \mu mg}{m}$$

Substitute and solve.

$$a_x = \frac{1.3 \times 10^3\ \text{N} - (0.8)(1.1 \times 10^4\ \text{kg})(9.81\ \text{m/s}^2)}{1.1 \times 10^4\ \text{kg}}$$

$\frac{\text{N}}{\text{kg}}$ is equivalent to $\frac{\text{m}}{\text{s}^2}$.

$$a_x = -7.73\ \text{m/s}^2$$
$$a_x \cong -7.7\ \text{m/s}^2$$

The acceleration of the sled is $-7.7\ \text{m/s}^2$[in the direction of the applied force].

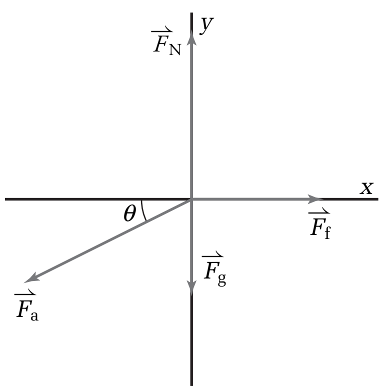
Validate the Solution

The sled has a negative acceleration, which indicates that the sled is slowing down. In these sorts of competitions, distances within the arena are small (less than 100 m), so accelerations must be high to ensure objects stop relatively quickly. For comparison, note that a vehicle which accelerates from rest to 100 km/h (27.8 m/s) in 6.0 seconds has an acceleration of $4.6\ \text{m/s}^2$. Thus, the magnitude of this result seems reasonable.

10. Solution is similar to Practice Problems 8 and 9.

(a) The force of friction of the ice on the curling stone is 0.249 N.

(b) The coefficient of kinetic friction between the ice and the curling stone is 1.27×10^{-3}.



11. Conceptualize the Problem

- Begin by drawing a free-body diagram.
- Motion is in the *horizontal* direction. Because the *velocity* is constant, the *acceleration* is zero in this direction.
- The x-component of the *applied force* and the *frictional force* act in opposite directions.
- The y-component of the *applied force* and the *gravitational force* act in the opposite direction to the *normal force*.
- Because the *coefficient of kinetic friction* is not given, the problem must be solved from the forces alone.

Identify the Goal

The frictional force, F_f, acting on the cart

Identify the Variables

Known	Implied	Unknown
$F = 95$ N	$a = 0\ \text{m/s}^2$	F_f
$v_1 = 1.2$ m/s		
$\theta = 35°$		

Develop a Strategy

To find the frictional force, apply Newton's second law in the x- and y-directions, noting that the acceleration is zero in each direction.

Calculations

$$F \cos\theta - F_f = ma = 0$$
$$F \cos\theta = F_f$$

Substitute and solve.

$$F_f = (95\ \text{N})(\cos 35°)$$
$$F_f = 77.82\ \text{N}$$
$$F_f \cong 78\ \text{N}$$

The frictional force is 78 N.

Note there is no need to apply Newton's law in the y-direction because the problem is already solved.

Validate the Solution
The frictional force is about 2/3 of the applied force, which seems reasonable considering the angle of the applied force.

12. Solution is similar to Practice Problem 8.
(a) The horizontal force is 58 N.
(b) The skateboard accelerates at $16\ \text{m/s}^2$, in the direction of the applied force.

13. Solution is similar to Practice Problems 8 and 9.
The bicycle travels 6.7 m after the brakes are applied.

Practice Problem Solutions

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14. Frame the Problem
- Draw a free body diagram representing the forces acting on the swimmer. The net force is the sum of the forces acting on the swimmer.
- Use both a scale diagram and a mathematical solution to determine the net force acting on the swimmer.

Identify the Goal
Find the resultant force acting on the swimmer using a scale diagram and a mathematical solution

Variables and Constants

Known	Implied	Unknown
$\vec{F}_1 = 35.0\ \text{N[N]}$		$\vec{F}_{\text{resultant}}$
$\vec{F}_2 = 20\ \text{N[E]}$		$\theta_{\text{resultant}}$

Strategies

Scale Vector Diagram Method

Draw a scale vector diagram, adding the vectors "tip to tail."

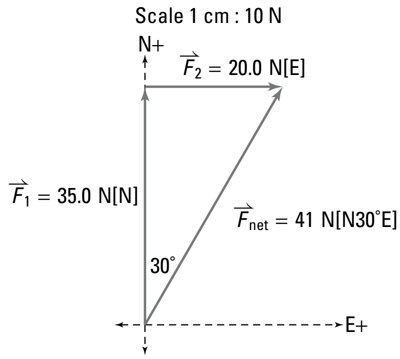
Measure the length of the resultant vector.

Use a scale factor to determine the magnitude of the force.

Use a protractor to measure the angle.

$$\left|\vec{F}_{\text{net}}\right| = 4.1\ \text{cm}$$
$$\left|\vec{F}_{\text{net}}\right| = (4.1\ \text{cm})\left(\frac{10\ \text{N}}{\text{cm}}\right)$$
$$\left|\vec{F}_{\text{net}}\right| = 41\ \text{N}$$
$$\theta = [\text{N}30°\text{E}]$$

Using the scale diagram method the net force is $41\text{ N[N}30^\circ\text{E]}$.



Components Method

Draw each vector with its tail at the origin at an *x*-*y*-coordinate system where $+y$ coincides with north and $+x$ coincides with east. Find the angle with the nearest *x*-axis.

North coincides with the *y*-axis so the angle is 90°. East coincides with the *x*-axis so the angle is 0°.

Find the *x*-component of each force vector.

$\vec{F}_{1x} = |\vec{F}_1| \cos 90^\circ = (35\text{ N})(0.0) = 0.0\text{ N}$

$\vec{F}_{2x} = |\vec{F}_2| \cos 0^\circ = (20\text{ N})(1.0) = 20.0\text{ N}$

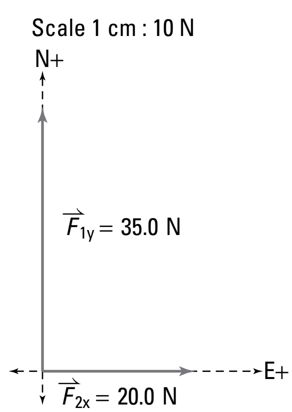
Find the *y*-component of each force vector.

$\vec{F}_{1y} = |\vec{F}_1| \sin 90^\circ = (35\text{ N})(1.0) = 35.0\text{ N}$

$\vec{F}_{2y} = |\vec{F}_2| \sin 0^\circ = (20\text{ N})(1.0) = 0.0\text{ N}$

Make a table in which to list the *x*-and *y*-components. Add them to find the components of the resultant vector.

Vector	*x*-component	*y*-component
$\vec{F}_1$	0.0 N	35.0 N
$\vec{F}_2$	20.0 N	0.0 N
$\vec{F}_{net}$	20.0 N	35.0 N



Use the Pythagorean Theorem to find the magnitude of the net force. Use trigonometry to find the angle θ. The angle will be in the first quadrant.

$$\left|\vec{F}_{net}\right|^2 = (F_{x\,net})^2 + (F_{y\,net})^2$$
$$\left|\vec{F}_{net}\right|^2 = (20\text{ N})^2 + (35.0\text{ N})^2$$
$$\left|\vec{F}_{net}\right|^2 = 400\text{ N}^2 + 1225\text{ N}^2$$
$$\left|\vec{F}_{net}\right|^2 = 1625\text{ N}^2$$
$$\left|\vec{F}_{net}\right| = 40.31\text{ N}$$
$$\left|\vec{F}_{net}\right| = 40\text{ N}$$
$$\tan\theta = \frac{35.0\text{ N}}{20\text{ N}}$$
$$\tan\theta = 1.75$$
$$\theta = \tan^{-1} 1.75$$
$$\theta = 60^\circ$$

The net force acting on the swimmer is 40[N60°N] or 40[N30°E].

Validate

The magnitude and direction of the resultant force vectors are correct. Using the scale diagram and the component method gives nearly the same result. The magnitude of the net force is 41 N for the scale diagram and 40 N for the component method. The directions are both [N30°E].

15. Frame the Problem

- Connect the forces acting on each object on a scale vector diagram. The resultant represents the sum of the forces acting on each object.

Identify the Goal

Find the resultant force acting on each object pictured

Variables and Constants

Known	Implied	Unknown
	$\vec{F}_1$ $\vec{F}_2$	$\vec{F}_{resultant}$
	$\vec{F}_3$ $\vec{F}_4$	$\theta_{resultant}$

Strategy and Calculations

Draw a scale vector diagram, adding the vectors "tip to tail".

Measure the length of the resultant vector.

Use a scale factor to determine the magnitude of the force.

Use a protractor to measure the angle.

(a) $\left|\vec{F}_{net}\right| = 0.86\text{cm}$

$$\left|\vec{F}_{net}\right| = (0.86\text{ cm})\left(\frac{50\text{ N}}{\text{cm}}\right)$$
$$\left|\vec{F}_{net}\right| = 43\text{ N}$$
$$\theta = [\text{E}]$$

The resultant force is 43 N[E].

(b) $\left|\vec{F}_{net}\right| = 0.148\text{ cm}$

$$\left|\vec{F}_{net}\right| = (0.148\text{ cm})\left(\frac{50\text{ N}}{\text{cm}}\right)$$
$$\left|\vec{F}_{net}\right| = 7.4\text{ N}$$
$$\theta = [\text{N}]$$

The resultant force is 7.4 N[N].

(c) $\left|\vec{F}_{\text{net}}\right| = 0.3\text{ cm}$

$\left|\vec{F}_{\text{net}}\right| = (0.3\text{ cm})\left(\frac{50\text{ N}}{\text{cm}}\right)$

$\left|\vec{F}_{\text{net}}\right| = 15\text{ N}$

$\theta = [\text{E}]$

The resultant force is 1 N[E].

(d) $\left|\vec{F}_{\text{net}}\right| = 0.3\text{ cm}$

$\left|\vec{F}_{\text{net}}\right| = (0.3\text{ cm})\left(\frac{50\text{ N}}{\text{cm}}\right)$

$\left|\vec{F}_{\text{net}}\right| = 15\text{ N}$

$\theta = [\text{W}28^\circ\text{S}]$

The resultant force is 15 N[W28°S].

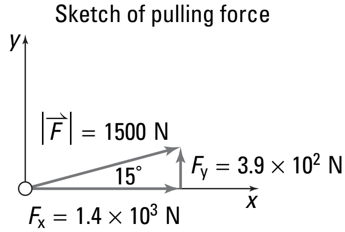
Validate

The magnitude and direction of the resultant force vectors are reasonable.

16. Frame the Problem

- Sketch the pulling force vector.
- Resolve the pulling force vector into its *x*- and *y*-components.

Sketch of pulling force



Identify the Goal

(a) Find the component of the pulling force in the direction of travel (*x*-component).

(c) Find the component of the pulling force perpendicular to the direction of travel (*y*-component).

Variables and Constants

Known	Implied	Unknown
$\vec{F} = 1500\text{ N[N]}$		F_x
$\theta = 15°$		F_y

Strategy and Calculations

Find the *x*-component and *y*-component of the force vector.

$F_x = \left|\vec{F}\right| \cos 15^\circ = (1500\text{ N})(0.9659) = 1448.9\text{ N}$

$F_x = 1.4 \times 10^3\text{ N}$

$F_y = \left|\vec{F}\right| \cos 15^\circ = (1500\text{ N})(0.2588) = 388.2\text{ N}$

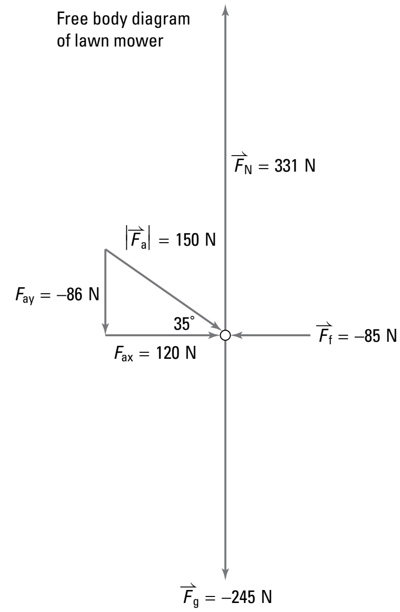
$F_y = 3.9 \times 10^2\text{ N}$

Validate

The magnitude and direction of the resultant force vectors are reasonable.

17. Frame the Problem

- Draw a free body diagram of the lawn mower showing all the forces acting on it.
- Resolve the applied force into its vertical and horizontal components.
- The student pushing down on the lawn mower will increase the normal force, so that the force of gravity on the lawn mower may be smaller than the normal force.
- Newton's second law applies to this problem.



Identify the Goal

(a) Find the vertical and horizontal components of the applied force

(b) Calculate the normal force supporting the lawn mower while it is being pushed

(c) Calculate the net force propelling the mower if a frictional force of 85 N exists

(d) Calculate the horizontal acceleration of the lawn mower

Variables and Constants

Known	Implied	Unknown	
$\vec{F}_a = 150$ N	$\vec{g} = 9.81\ \frac{m}{s^2}$	F_{ax}	$\vec{a}$
$\theta = 35°$		F_{ay}	
$m = 25$ kg		$\vec{F}_g$	$\vec{F}_N$

Strategy and Calculations

Find the vertical and horizontal components of the applied force.

Assume the lawn mower is moving to the right, which is positive and let "up" be positive.

$$F_{ax} = \left|\vec{F}_a\right| \cos 35° = (150\text{ N})(0.8192) = 122.88\text{ N}$$
$$F_{ax} = 120\text{ N}$$
$$F_{ay} = \left|\vec{F}_a\right| \sin 35° = (150\text{ N})(0.5736) = 86.03\text{ N}$$
$$F_{ay} = -86\text{ N}$$

The horizontal component of the applied force is 120 N to the right.

The vertical component of the applied force is 86 N down.

Calculate the normal force supporting the lawn mower. It is equal to all the downward forces acting on it, but opposite in sign.

$$\vec{F}_g = m\vec{g} = 25\text{ kg} \times (-9.81\ \frac{N}{kg})$$
$$\vec{F}_g = -245.25\text{ N}$$
$$\vec{F}_N = \vec{F}_g + F_{ay} = 245.25\text{ N} + 86\text{ N}$$
$$\vec{F}_N = 331.25\text{ N}$$
$$\vec{F}_N = 3.3 \times 10^2\text{ N}$$

Calculate the net force on the lawn mower if a 85 N friction force exists.

The sum of the vertical forces is zero, and the acceleration is in the direction of the sum of the horizontal forces only.

$\vec{F}_{net} = \vec{F}_x + \vec{F}_f$

$\vec{F}_{net} = 1.22.88\text{ N} - 85\text{ N} = 37.88\text{ N}$

$\vec{F}_{net} = 38\text{ N}$

The net force on the lawn mower is 38 N to the right along the horizontal.

Calculate the horizontal acceleration of the lawn mower.

$\vec{a} = \frac{\vec{F}_{net}}{\text{m}}$

$\vec{a} = \frac{38\text{ N}}{25\text{ kg}} = 1.52\ \frac{\text{m}}{\text{s}^2}$

$\vec{a} = 1.5\ \frac{\text{m}}{\text{s}^2}$

The lawn mower's horizontal acceleration is 1.5 m/s^2 to the right.

Validate

The magnitude and units of the component forces, normal force, net force and acceleration seem reasonable.

Practice Problem Solutions

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18. Conceptualize the Problem

- Represent directions to the right as *positive* and to the left as *negative*.
- The two cars accelerate as though they were one object, with a mass equal to the total mass of both vehicles.
- Only part of the applied force is transmitted by the rope to the second vehicle.
- By Newton's third law, the force applied to the rope (the tension it must stand without breaking) is equal to the force the rope applies to the second vehicle.

Identify the Goal

(a) The total force, F, needed to accelerate the vehicles

(b) The tension force, F_t, that the rope must withstand

Identify the Variables

Known	Implied	Unknown
$m_1 = 1700\text{ kg}$	$F_t = F_2$	a
$m_2 = 2400\text{ kg}$		F
$v_1 = 0\ \frac{\text{m}}{\text{s}}$		F_2
$v_2 = 15\ \frac{\text{km}}{\text{h}}$		
$\Delta t = 11\text{ s}$		

Develop a Strategy	Calculations
Apply the definition of acceleration and change to standard units.	$a = \frac{\Delta v}{\Delta t}$ $a = \frac{(15 - 0)\ \frac{\text{km}}{\text{h}} \times \frac{1000\text{ m}}{\text{km}} \times \frac{1\text{ h}}{3600\text{ s}}}{11\text{ s}}$ $a = 0.3787\ \frac{\text{m}}{\text{s}^2}$
Use Newton's second law to find the magnitude of the force necessary to cause this acceleration.	$F = ma$ $F = (1700\text{ kg} + 2400\text{ kg})\left(0.3787\ \frac{\text{m}}{\text{s}^2}\right)$ $F = 1553\text{ kg}\frac{\text{m}}{\text{s}^2}$ $\therefore F \cong 1.6 \times 10^3\text{ N}$

(a) The total force necessary to accelerate the two vehicles is about 1.6×10^3 N.

Use Newton's second law to find the magnitude of the force needed to cause the acceleration of the second vehicle.

$$F_2 = ma$$
$$F_2 = 2400 \text{ kg} \times 0.3787 \frac{\text{m}}{\text{s}^2}$$
$$F_2 = 908.88 \text{ N}$$

Find the magnitude of the reaction force applied by the second vehicle to the rope.

$$F_t = F_2$$
$$F_t = 908.88 \text{ N}$$
$$\therefore F_t \cong 9.1 \times 10^2 \text{ N}$$

(b) The rope must be strong enough to withstand a tension force of about 9.1×10^2 N.

Validate the Solution

The rope applies a force of 9.1×10^2 N to the first car, which opposes the force causing it to accelerate. The magnitude of the acceleration of the first car can be calculated from this force.

$$F = ma$$
$$a = \frac{F}{m_1}$$
$$a = \frac{(1553 - 908.88) \text{ N}}{1700 \text{ kg}}$$
$$a = 0.379 \frac{\text{m}}{\text{s}^2}$$

The acceleration calculated earlier for the two cars together was 0.379 m/s^2, in perfect agreement (within 3 significant figures) with that calculated for the first car here.

19. Solution is similar to Practice Problem 18.

(a) The total force necessary to accelerate the "train" is about 21 N[to the right].

(b) The second child feels a tension of about 15 N[to the right].

20. Solution is similar to Practice Problems 9 and 18.

(a) The frictional force acting on the toboggans is about 74 N.

(b) The tension in the rope attached to the second toboggan is about 34 N.

Practice Problem Solutions

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21. Conceptualize the Problem

- Begin framing the problem by drawing a *free-body diagram* of the forces acting on the person on the scale.
- The *forces* acting on the person are *gravity* ($\vec{F}_g$), which is downwards, and the *normal force* of the scale, which is upwards.
- According to Newton's third law, when the person exerts a *force* ($\vec{F}_{PS}$) on the scale, it exerts an *equal and opposite force* ($\vec{F}_{SP}$) on the person. Therefore, the reading on the scale is the same as the force that the person exerts on the scale.
- The motion is in one direction so let "up" be *positive* and "down" be *negative.*
- Because the motion is in one dimension, perform calculations with magnitudes only.
- The elevator is *accelerating* upwards and the person is *accelerating* at the same rate as the elevator. However, the elevator is slowing down, so, even though the *acceleration* is in the *positive* direction, the *sign of the acceleration* is negative.

- Apply Newton's second law to find the magnitude of ($\vec{F}_{SP}$).

Identify the Goal
The sign of the acceleration, and the reading on the scale, ($\vec{F}_{SP}$)

Identify the Variables

Known	Implied	Unknown
$m = 64$ kg	$g = 9.81$ m/s^2	$\vec{F}_{SP}$
$\vec{a} = -0.59$ m/s^2		$\vec{F}_{PS}$
		$\vec{F}_g$

Develop a Strategy / **Calculations**

Before applying Newton's second law to the forces, note that since the elevator is accelerating in the positive direction, but it is slowing down, the sign of the acceleration must be negative.

Apply Newton's second law to the free-body diagram.

$$F_{SP} + F_g = ma$$
$$F_{SP} = -F_g + ma$$
$$F_{SP} = -(-mg) + ma$$

Substitute and solve.

$$F_{SP} = (64\text{ kg})(9.81\text{ m/s}^2) + (64\text{ kg})(-0.59\text{ m/s}^2)$$
$$F_{SP} = 590.1\text{ N}$$
$$F_{SP} \cong 5.9 \times 10^2\text{ N}$$

The scale has a reading of about 5.9×10^2 N[up].

Validate the Solution
Because of the negative sign of the acceleration (i.e. directed downwards), the reading on the scale is slightly less than it would be if the elevator had zero acceleration. In that case, the scale would read $(64\text{ kg})(9.81\text{ m/s}^2) = 628$ N. This agrees with the experience of riding in an elevator: travelling upwards, as it comes to a stop, you feel lighter.

22. Solution is similar to Practice Problem 21.
The scale has a reading of about 6.9×10^2 N[up].

23. Solution is similar to Practice Problem 21.
The scale has a reading of about 5.9×10^2 N[up].

Practice Problem Solutions

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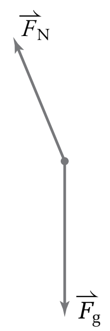
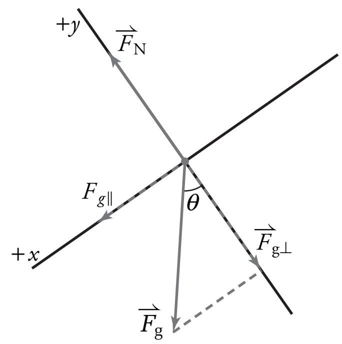
24. Conceptualize the Problem
- Begin framing the problem by drawing a *free-body diagram*.
- Define a coordinate system with the *x-axis parallel* to the hill and the *y-axis perpendicular* to the hill. On the coordinate system, draw the forces and *components of forces* acting on the car.
- Let the direction pointing *down* the hill be the *positive* direction.
- The *component of gravity parallel* to the hill causes the car to *accelerate* down the hill.





- As *friction* is neglected, it is not necessary to find the *normal force*, which is *perpendicular* to the hill.
- The *acceleration* of the car down the hill is found by applying *Newton's second law* to the forces or components of forces *parallel* to the hill.
- From the *acceleration*, the *final velocity* can be found from the appropriate *kinematics* equation.

Problem Tip
Considering forces in directions parallel or perpendicular to the direction of motion enables one to use magnitudes (instead of vectors) in the calculations.

Identify the Goal
The final speed, v_2, of the car at the bottom of the hill

Identify the Variables

Known	Implied	Unknown
$m = 1975$ kg	$g = 9.81$ m/s^2	$\vec{F}$ $\vec{a}$ $\vec{a}_\parallel$ $\vec{v}_2$
$d = 42$ m	$v_1 = 0$ m/s	$F_{g\parallel}$ $F_{g\perp}$
$\theta = 15°$		

Develop a Strategy

Apply Newton's second law to the forces parallel to the hill and solve for the acceleration parallel to the hill.

Calculations

$$\vec{F}_{net} = m\vec{a}$$
$$F_{g\parallel} = ma_\parallel$$
$$mg\sin\theta = ma_\parallel$$
$$a_\parallel = g\sin\theta$$

Substitute and solve.

$$a_\parallel = (9.81\text{ m/s}^2)(\sin 15°)$$
$$a_\parallel = 2.539\text{ m/s}^2$$

The acceleration down the ramp is about 2.539 m/s^2.

Apply an appropriate kinematics relation, involving displacement, acceleration and final velocity.
Substitute and solve.

$v_2^2 = v_1^2 + 2ad$, where $a = a_\parallel$
$$v_2^2 = 0 + 2(2.539\text{ m/s}^2)(42\text{ m})$$
$$v_2 = 14.6\text{ m/s}$$
$$v_2 \cong 15\text{ m/s}$$

The car is travelling 15 m/s at the bottom of the hill.

Validate the Solution
The acceleration of the car is less than 9.81 m/s^2, as expected.

The final speed, 15 m/s, is equivalent to 54 km/h, which seems reasonable for a car rolling 42 m down a hill.

25. Solution is similar to Practice Problem 24.
(a) Ignoring friction, the acceleration down the ramp is about 1.2 m/s^2.
(b) Considering friction, the acceleration of the bicycle down the ramp is about 0.16 m/s^2.
(c) The cyclist takes 12 s to get to the bottom of the ramp.

26. Conceptualize the Problem
- Begin framing the problem by drawing a *free-body diagram*. (The *free-body diagram* for this problem is the same as that in the Sample Problem, Sliding Down an Inclined Plane, in the Student Text).

- Define a coordinate system with the *x-axis parallel* to the slope and the *y-axis perpendicular* to the slope. On the coordinate system, draw the forces and *components of forces* acting on the skier.
- Let the direction pointing *down* the slope be the *positive* direction.
- The *component of gravity parallel* to the slope causes the skier to *accelerate* down the slope.
- *Friction* between the skier and the slope *opposes* the motion. To find the *normal force* that is needed to determine the magnitude of the *frictional force*, apply *Newton's second law* to the forces or components of forces that are *perpendicular* to the slope.
- The *acceleration perpendicular* to the slope is *zero*.
- The *acceleration* of the skier down the slope is found by applying *Newton's second law* to the forces or components of forces *parallel* to the slope, but note that in this case the *speed* is constant, which implies the *acceleration* is zero.

Identify the Goal

The coefficient of kinetic friction, μ_k, between the skier and the slope

Identify the Variables

Known	Implied	Unknown
$\theta = 3.5°$	$g = 9.81\ \text{m/s}^2$	$\vec{F}$ F_N $\vec{F}_f$
	$a_{\parallel} = 0\ \text{m/s}^2$	$F_{g\parallel}$ $F_{g\perp}$
	$a_{\perp} = 0\ \text{m/s}^2$	μ_k

Develop a Strategy / **Calculations**

Apply Newton's second law to the forces perpendicular to the ramp to find the frictional force.
The acceleration is zero in the perpendicular direction.

$$\vec{F}_{net} = m\vec{a}$$
$$F_N + F_{g\perp} = ma_{\perp} = 0$$
$$F_N + (-mg\cos\theta) = 0$$
$$F_N = mg\cos\theta$$

As the mass is unknown, do not substitute and solve.

Apply Newton's second law to the forces parallel to the ramp, including the force of friction.

$$\vec{F}_{net} = m\vec{a}$$
$$F_f + F_{g\parallel} = ma_{\parallel}$$
$$-\mu F_N + mg\sin\theta = ma_{\parallel} = 0$$

Note that the mass cancels.

$$-\mu(mg\cos\theta) + mg\sin\theta = 0$$
$$\mu = \frac{\sin\theta}{\cos\theta}$$

Substitute and solve.

$$\mu = 0.061$$

The coefficient of kinetic friction between the skier and the slope is 0.061.

Validate the Solution

The coefficient of kinetic friction is only slightly greater than zero. Comparison with Table 4.5 shows that the coefficient of kinetic friction for "ice on ice" is 0.03, so a value of 0.061 for wood or fiberglass on snow seems reasonable.

Practice Problem Solutions

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27. Solution is similar to Practice Problem 26.
The coin travels 0.34 m up the board before stopping.

28. Solution is similar to Practice Problem 26.
The coefficient of friction between the crate and ramp is about 0.37.

Practice Problem Solutions

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29. Conceptualize the Problem

- In each case, the *mass* is moving; therefore, it has *momentum*.
- The *direction* of an object's *momentum* is the same as the *direction* of its *velocity*.

Identify the Goal

The momentum, $\vec{p}$, of the given objects

Identify the Variables

	Known		Unknown
(a)	$m_b = 0.250$ kg	$v_b = 46.1$ m/s[E]	$\vec{p}_b$
(b)	$m_t = 7.5 \times 10^6$ kg	$v_t = 125$ km/h[W]	$\vec{p}_t$
(c)	$m_j = 4.00 \times 10^5$ kg	$v_j = 755$ km/h[S]	$\vec{p}_j$
(d)	$m_e = 9.11 \times 10^{-31}$ kg	$v_e = 6.45 \times 10^6$ m/s[N]	$\vec{p}_e$

Develop a Strategy

Use the equation that defines momentum.

Calculations

$$\vec{p}_b = m_b\vec{v}_b$$
$$\vec{p}_b = (0.250 \text{ kg})(46.1 \text{ m/s[E]})$$
$$\vec{p}_b = 11.525 \text{ kg m/s[E]}$$
$$\vec{p}_b \cong 11.5 \text{ kg m/s[E]}$$

(a) The momentum of the baseball is about 11.5 kg m/s[E].

$$\vec{p}_t = m_t\vec{v}_t$$
$$\vec{p}_t = (7.5 \times 10^6 \text{ kg})\left(125 \frac{\text{km}}{\text{h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}}[\text{W}]\right)$$
$$\vec{p}_t = 2.6042 \times 10^8 \text{ kg m/s[W]}$$
$$\vec{p}_t \cong 2.6 \times 10^8 \text{ kg m/s[W]}$$

(b) The momentum of the train is about 2.6×10^8 kg m/s[W].

$$\vec{p}_j = m_j\vec{v}_j$$
$$\vec{p}_j = (4.00 \times 10^5 \text{ kg})\left(755 \frac{\text{km}}{\text{h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}}[\text{S}]\right)$$
$$\vec{p}_t = 8.3889 \times 10^7 \text{ kg m/s[S]}$$
$$\vec{p}_t \cong 8.39 \times 10^7 \text{ kg m/s[S]}$$

(c) The momentum of the jet is about 8.39×10^7 kg m/s[S].

$\vec{p}_e = m_e\vec{v}_e$

$\vec{p}_e = (9.11 \times 10^{-31}\ \text{kg})(6.45 \times 10^{6}\ \text{m/s[N]})$

$\vec{p}_e = 5.8760 \times 10^{-24}\ \text{kg m/s[N]}$

$\vec{p}_e \cong 5.88 \times 10^{-24}\ \text{kg m/s[N]}$

(d) The momentum of the electron is about 5.88×10^{-24} kg m/s[N].

Validate the Solution

As expected, the high mass objects like the train and jet have much higher momenta than low mass objects like the baseball or very low mass objects like the electron. Though the electron is travelling at a very high speed compared to the other objects, its mass is so low that its momentum will remain smaller than the other objects.

Practice Problem Solutions

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30. Conceptualize the Problem

- The sledgehammer exerts an *average force* on the spike for a period of *time*. The product of these quantities is defined as *impulse*
- *Impulse* is a vector quantity.
- The *direction* of the impulse is the same as the *direction* of its *average* force.

Identify the Goal

The impulse, $\vec{J}$, of the interaction

Identify the Variables

Known	Unknown
$\vec{F} = 2125$ N[down]	$\vec{J}$
$\Delta t = 0.0205$ s	

Develop a Strategy

Use the equation that defines impulse.

Calculations

$\vec{J} = \vec{F}\Delta t$

$\vec{J} = (2125\ \text{N[down]})(0.0205\ \text{s})$

$\vec{J} = 43.562\ \text{N·s[down]}$

$\vec{J} \cong 43.6\ \text{N·s[down]}$

The sledgehammer strikes the spike with an impulse of 43.6 N·s[down].

Validate the Solution

Round the values in the data to 2000 N[down] and 0.02 s and do mental multiplication. The product is 40.0 N·s[down]. The answer, 43.6 N·s[down], is very close to this estimate.

31. Conceptualize the Problem

- The *impulse* is the product of the *average* force exerted by the car on the wall and the *time interval*.
- *Impulse* is a vector quantity.
- The *direction* of the impulse is the same as the *direction* of its *average force*.

Identify the Goal

The impulse, $\vec{J}$, of the interaction

Identify the Variables

Known

$\vec{F} = 1.23 \times 10^7$ N[S]

$\Delta t = 21.0$ m/s $= 21.0 \times 10^{-3}$ s

Unknown

$\vec{J}$

Develop a Strategy

Use the equation that defines impulse.

Calculations

$\vec{J} = \vec{F}\Delta t$

$\vec{J} = (1.23 \times 10^7 \text{ N[S]})(21.0 \times 10^{-3} \text{ s})$

$\vec{J} = 2.583 \times 10^5$ N·s[S]

$\vec{J} \cong 2.58 \times 10^5$ N·s[S]

The car hits the wall with an impulse of 2.58×10^5 N·s[S].

Validate the Solution

If the time is rounded to 20×10^{-3}s, then the multiplication can easily be checked: the result is 2.46×10^5 N·s[S], close to the calculated value of 2.58×10^5 N·s[S].

32. Conceptualize the Problem

- The *impulse* is the product of the *average force* exerted by the car on the wall and the *time interval*.
- Impulse is a vector quantity.
- The *direction* of the impulse is the same as the *direction* of its *average force*.

Identify the Goal

The average force, $\vec{F}$, of the interaction

Identify the Variables

Known

$\vec{J} = 2.58 \times 10^5$ N·s[S]

$\Delta t = 57.1$ m/s $= 57.1 \times 10^{-3}$s

Unknown

$\vec{F}$

Develop a Strategy

Use the equation that defines impulse and solve for the average force.

Calculations

$\vec{J} = \vec{F}\Delta t$

$$\vec{F} = \frac{\vec{J}}{\Delta t}$$

$$\vec{F} = \frac{2.58 \times 10^5 \text{ N·s[S]}}{57.1 \times 10^{-3} \text{ s}}$$

$\vec{F} = 4.5184 \times 10^6$ N[S]

$\vec{F} \cong 4.52 \times 10^6$ N[S]

The car strikes the wall with an average force of 4.52×10^6 N[S].

Validate the Solution

In comparison with problem 3, the same impulse was applied over a longer time interval, an effect that is designed to reduce the average force. The resultant force is lower here than in problem 3, as expected.

Practice Problem Solutions

Student Textbook page 203

33. Conceptualize the Problem

- The *mass* and *velocities* before and after the interaction are known, so it is possible to calculate the *momentum* before and after the interaction.
- *Momentum* is a *vector* quantity, so all calculations must include directions.
- Let the initial direction of the ball be *forward*.
- You can find the *impulse* from the change in *momentum*.

Identify the Goal

The impulse, $\vec{J}$, of the racquet on the ball

Identify the Variables

Known	Implied	Unknown
$m = 0.060$ kg	$v_1 = 0$ m/s[forward]	$\vec{J}$
$v_2 = 43$ m/s[forward]		

Develop a Strategy

Use the impulse-momentum theorem to calculate the impulse.

Calculations

$$\vec{F}\Delta t = m\vec{v_2} - m\vec{v_1}$$
$$\vec{F}\Delta t = (0.060\text{ kg})(43\text{ m/s})[\text{forward}] - (0.060\text{ kg})(0\text{ m/s})[\text{forward}]$$
$$\vec{F}\Delta t = 2.58\text{ kg m/s}[\text{forward}]$$
$$\vec{F}\Delta t \cong 2.6\text{ kg m/s}[\text{forward}]$$

The impulse of the racquet on the ball is about 2.6 kg m/s[forward].

Validate the Solution

Check the units: kg m/s = (kg m/s^2)·(s) = N·s

34. Conceptualize the Problem

- The *mass* and *velocities* before and after the interaction are known, so it is possible to calculate the *momentum* before and after the interaction.
- *Momentum* is a *vector* quantity, so all calculations must include directions.
- Since the motion is all in one dimension (i.e. the horizontal dimension), use plus and minus to denote direction. Let the *initial direction* be the *positive direction*.
- You can find the *impulse* from the change in *momentum*.

Identify the Goal

The impulse, $\vec{J}$, of the bat on the ball

Identify the Variables

Known	Unknown
$m = 0.35$ kg	$\vec{J}$
$v_1 = 46$ m/s	
$v_2 = -62$ m/s	

Develop a Strategy

Use the impulse-momentum theorem to calculate the impulse.

Calculations

$$\vec{F}\Delta t = m\vec{v_2} - m\vec{v_1}$$
$$\vec{F}\Delta t = (0.35\text{ kg})(-62\text{ m/s}) - (0.35\text{ kg})(46\text{ m/s})$$
$$\vec{F}\Delta t = 37.8\text{ kg m/s}$$
$$\vec{F}\Delta t \cong -38\text{ kg m/s}$$

The impulse of the bat on the ball is about −38 kg m/s, and the negative sign indicates the direction is away from the batter.

Validate the Solution
The impulse is in the opposite direction to the ball's initial velocity, so it is expected that the impulse will be negative, and it is.

35. Conceptualize the Problem

- The book is *displaced* through a known distance from rest, so its velocity before striking the floor can be calculated from the appropriate *kinematics* equation.
- After striking the floor with a certain velocity, the floor exerts an upward *force* on the book over a certain length of time and because of this *impulse*, the book's *final velocity* will be zero.
- The *mass* and *velocities* before and after the interaction can thus be determined, so it is possible to calculate the momentum before and after the interaction, and the *impulse*.
- *Momentum* is a *vector* quantity, so all calculations must include directions.
- Since the motion is all in *one dimension* (i.e. the vertical dimension), use plus and minus to denote direction (with the *magnitudes* of the quantities). Let the *downward direction* be the *negative direction*.
- You can find the *impulse* from the change in momentum.

Identify the Goal
The impulse, $\vec{J}$, of the floor on the book

Identify the Variables

Known	Implied	Unknown
$m = 1.5$ kg	$v_1 = 0$ m/s	$\vec{J}$
$\Delta y = -1.75$m	$a = -9.81$ m/s^2	v_2

Develop a Strategy
Apply the kinematics equation that relates acceleration, displacement and initial velocity to final velocity.

Calculations

$$v_2^2 = v_1^2 + 2a\Delta y$$
$$v_2^2 = (0\text{ m/s})^2 + 2(-9.81\text{ m/s}^2)(-1.75\text{ m})$$
$$v_2^2 = 34.335\text{ m}^2/\text{s}^2$$
$$v_2^2 = \pm 5.860\text{ m/s}$$
$$v_2 = -5.860\text{ m/s}$$

Choose the negative sign because the book is travelling in the negative direction before hitting the floor. Use the impulse-momentum theorem to calculate the impulse. Note that as the book strikes the floor, its initial velocity is $v_1 = -5.860$ m/s and its final velocity, after interaction with the floor is $v'_2 = 0$ m/s.

$$F\Delta t = mv'_2 - mv_1$$
$$F\Delta t = (1.5\text{ kg})(0\text{ m/s}) - (1.5\text{ kg})(-5.860\text{ m/s})$$
$$F\Delta t = 8.789\text{ kg m/s}$$
$$F\Delta t \cong 8.8\text{ kg m/s}$$

The floor exerts an impulse on the book of about 8.8 kg m/s (in the upward direction).

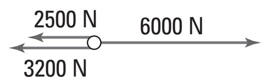
Validate the Solution
The impulse of the floor on the book is expected to be in a direction opposite to the book's downward velocity, that is upwards, and it is.

Chapter 5 Review

Answers to Problems for Understanding

Student Textbook pages 208–209

23. **(a)**



$$\vec{F}_{net} = -3200\text{ N} - 2500\text{ N} + 6000\text{ N}$$
$$\vec{F}_{net} = +300\text{ N}$$

(b)

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$\vec{a} = \frac{+300\text{ N}}{400\text{ kg}}$$
$$\vec{a} = +0.75\,\frac{\text{m}}{\text{s}^2}$$
$$\vec{a} \cong +0.8\,\frac{\text{m}}{\text{s}^2}$$

24. The acceleration is due to the net force in the *x* direction. The sum of the forces cancels in the *y* direction, so only forces in the *x* direction need be calculated.

$$\vec{F}_g = 15\text{ kg} \times -9.81\ \frac{\text{m}}{\text{s}^2}$$
$$\vec{F}_g = -147.15\text{ N}$$

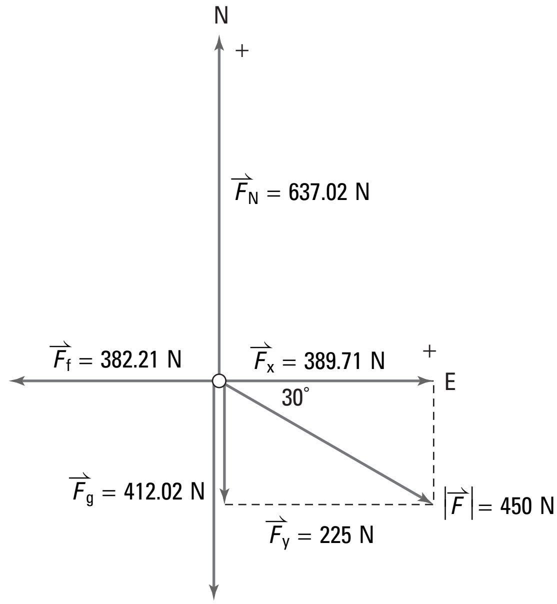
$$\vec{F}_x = \left|\vec{F}\right| \cos\theta$$
$$\vec{F}_x = |45\text{ N}|\cos 40°$$
$$\vec{F}_x = (45\text{ N})(0.7660)$$
$$\vec{F}_x = 34.47\text{ N}$$

$$\vec{F}_f = -28\text{ N}$$

$$\vec{F}_{net} = F_x - F_f$$
$$\vec{F}_{net} = 34.47\text{ N} - 28\text{ N}$$
$$\vec{F}_{net} = 6.47\text{ N}$$

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$\vec{a} = \frac{6.47\text{ N}}{15\text{ kg}}$$
$$\vec{a} = 0.43\ \frac{\text{m}}{\text{s}^2}$$

25. (a) Add the sum of all the vertical forces to obtain the normal force.



$$\vec{F}_g = 42\ \text{kg} \times -9.81\frac{\text{m}}{\text{s}^2}$$
$$\vec{F}_g = -412.02\ \text{N}$$

$$\vec{F}_y = |\vec{F}|\sin\theta$$
$$\vec{F}_y = |450\ \text{N}|\sin 30^\circ$$
$$\vec{F}_y = 450\ \text{N}\ (0.5)$$
$$\vec{F}_y = -225\ \text{N}$$

$$\vec{F}_N = \vec{F}_g + \vec{F}_y$$
$$\vec{F}_N = 412.02\ \text{N} + 225\ \text{N}$$
$$\vec{F}_N = 637.02\ \text{N}$$

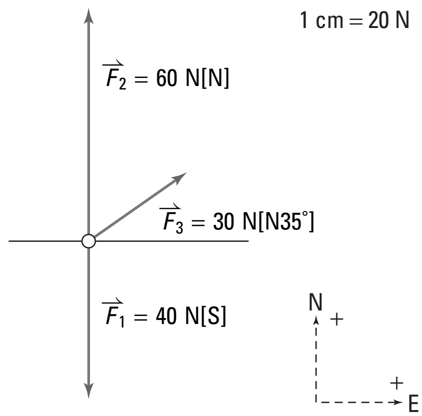
$$\vec{F}_f = \mu_k\vec{F}_N$$
$$\vec{F}_f = (0.60)(637.02\ \text{N})$$
$$\vec{F}_f = -382.21\ \text{N}$$
$$\therefore \vec{F}_f = -3.8 \times 10^2\ \text{N}$$

(b) The acceleration of the grocery cart is in the horizontal direction. Find the sum of all the forces in the *x* direction. (The sum of the forces in the *y* direction is zero.)

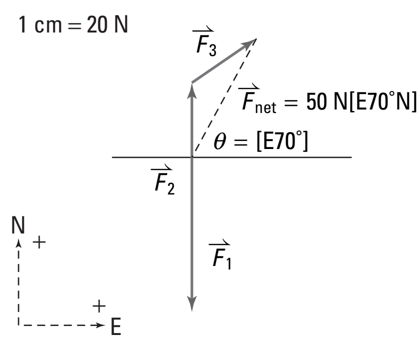
$$\vec{F}_x = |\vec{F}|\cos\theta$$
$$\vec{F}_x = |450\ \text{N}|\cos 30^\circ$$
$$\vec{F}_x = (450\ \text{N})(0.8660)$$
$$\vec{F}_x = 389.71\ \text{N}$$

$$\vec{F}_{net} = \vec{F}_f + \vec{F}_x$$
$$\vec{F}_{net} = -382.21\ \text{N} + 389.71\ \text{N}$$
$$\vec{F}_{net} = 7.5\ \text{N}$$

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$\vec{a} = \frac{7.5 \text{ N}}{42 \text{ kg}}$$
$$\vec{a} = 0.179 \ \frac{\text{m}}{\text{s}^2}$$
$$\therefore \vec{a} = 0.18 \ \frac{\text{m}}{\text{s}^2}$$



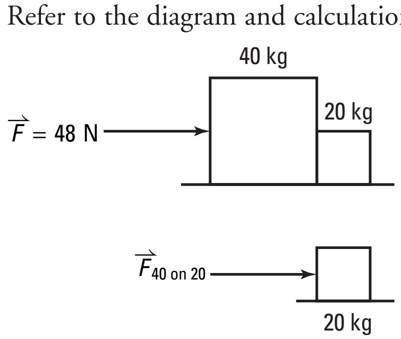
26. Refer to the scale diagram below:



$$\vec{F}_1 = 40 \text{ N[S]}$$
$$\vec{F}_2 = 60 \text{ N[N]}$$
$$\vec{F}_3 = 30 \text{ N[N35°E]}$$
$$\left|\vec{F}_{net}\right| = (2.5 \text{ cm})(20 \frac{\text{N}}{\text{cm}})$$
$$\left|\vec{F}_{net}\right| = 50 \text{ N}$$

$$\theta = \text{[E70°N]}$$
$$\vec{F}_{net} = 50 \text{ N[E70°N]}$$

27. (a) Refer to the diagram and calculations below:



$m_T = 40\text{ kg} + 20\text{ kg} = 60\text{ kg}$

$\vec{a} = \frac{\vec{F}_{net}}{m_T} = \frac{48\text{ N}}{60\text{ kg}} = 0.8\ \frac{\text{m}}{\text{s}^2}[\rightarrow]$

b) $\vec{F}_{40\text{ on }20} = m\vec{a}$

$= (20\text{ kg})\left(0.8\ \frac{\text{m}}{\text{s}^2}\right)[\rightarrow]$

$\therefore \vec{F}_{40\text{ on }20} = 16\text{ N}[\rightarrow]$

28. (a) The initial velocity of the watch in a frame attached to the elevator is 0.0 m/s and the initial acceleration is –9.81 m/s^2, where positive is up and negative is down.

$$v_i = 0.0\frac{\text{m}}{\text{s}} \text{ and } a = -9.8\frac{\text{m}}{\text{s}^2}$$

(b) The initial velocity of the watch in a frame attached to the building is 3.5 m/s and the initial acceleration is −9.81 m/s^2, where positive is up and negative is down.

$$v_i = 3.5\frac{\text{m}}{\text{s}} \text{ and } a = -9.8\frac{\text{m}}{\text{s}^2}$$

29. (a) Acceleration of the crate is 1.35 m/s^2, where the direction of the applied force is positive.

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$

$$\vec{a} = \frac{\vec{F}_{app} + \vec{F}_f}{m}$$

$$\vec{a} = \frac{425\text{N} + (-\mu \text{mg})}{m}$$

$$\vec{a} = \frac{425\text{ N} - (0.500)(68.0\text{ kg})(9.81\ \frac{\text{m}}{\text{s}^2})}{68.0\text{ kg}}$$

$$\vec{a} \cong 1.35\ \frac{\text{m}}{\text{s}^2}$$

(b) To move the crate at constant velocity requires that the net force be zero. The applied force must have a magnitude of 334 N.

$$\vec{F}_{net} = 0$$

$$\vec{F}_{app} + \vec{F}_f = 0$$

$$\vec{F}_{app} = -\vec{F}_f$$

$$\vec{F}_{app} = -(-\mu mg)$$

$$\vec{F}_{app} = (0.500)(68.0\text{ kg})\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)$$

$$\vec{F}_{app} \cong 334\text{ N}$$

30. The magnitude of the force acting on the ball is 1.2 N.

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

$$\left|\vec{F}\right| = (0.24\text{ kg})\left(5.0\ \frac{\text{m}}{\text{s}^2}\right)$$

$$\left|\vec{F}\right| = 1.2\text{ N}$$

31. (a) Acceleration of the brick is $0.063\ \text{m/s}^2$.

$$\Delta d = v_i\Delta t + \frac{1}{2}a\Delta t^2$$
$$\Delta d = 0.0 + \frac{1}{2}a\Delta t^2$$
$$a = \frac{2\Delta d}{\Delta t^2}$$
$$a = \frac{2(2.0\ \text{m})}{(8.0\ \frac{\text{m}}{\text{s}})^2}$$
$$a \cong 0.063\ \frac{\text{m}}{\text{s}^2}$$

(b) The ratio of the applied force to the mass is 0.40 N/kg.

$$\frac{F}{m} = \frac{4.0\ \text{N}}{10.0\ \text{kg}}$$
$$\frac{F}{m} = 0.40\ \frac{\text{N}}{\text{kg}}$$

(c) The numbers do not agree because, from Newton's second law, acceleration is the ratio of net force over mass, not applied force over mass as found in part (b). Friction must be included to determine the net force. If the acceleration is $0.063\ \text{m/s}^2$, the force of friction must be

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$\vec{F}_{\text{app}} + \vec{F}_{\text{f}} = m\vec{a}$$
$$\vec{F}_{\text{f}} = -\vec{F}_{\text{app}} + m\vec{a}$$
$$\vec{F}_{\text{f}} = -4.0\text{N} + (10.0\ \text{kg})\left(0.0625\ \frac{\text{m}}{\text{s}^2}\right)$$
$$\vec{F}_{\text{f}} \cong -3.4\ \text{N}$$

32. The car went 11.4 m before coming to a stop. First find the car's acceleration while braking. Let the direction of the car's motion be positive. Then, use the acceleration to find the stopping distance of the car.

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{\text{f}}}{m}$$
$$\vec{a} = \frac{-\mu \cancel{m} g}{\cancel{m}}$$
$$\vec{a} = -(0.70)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)$$
$$\vec{a} = -6.867\ \frac{\text{m}}{\text{s}^2}$$

$$v_f^2 = v_i^2 + 2a\Delta d$$
$$\Delta d = \frac{v_f^2 - v_i^2}{2a}$$
$$\Delta d = \frac{\left(0\ \frac{\text{m}}{\text{s}}\right)^2 - \left[\left(45\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}}\right)\left(\frac{1000\ \text{m}}{\cancel{\text{km}}}\right)\left(\frac{\cancel{\text{h}}}{3600\ \text{s}}\right)\right]^2}{2\left(-6.867\ \frac{\text{m}}{\text{s}^2}\right)}$$
$$\Delta d = 11.4\ \text{m}$$
$$\Delta d \cong 11\ \text{m}$$

33. (a) The woman's velocity just before touching the floor was 5.4 m/s downward. (Note that the answer could have been positive or negative. Since you know that the woman was moving down, you can choose the negative direction for her velocity.)

$$v_f^2 = v_i^2 + 2a\Delta d$$
$$v_f = \sqrt{v_i^2 + 2a\Delta d}$$
$$v_f = \sqrt{\left(0\ \frac{\text{m}}{\text{s}^2}\right)^2 + 2\left(-9.81\ \frac{\text{m}}{\text{s}^2}\right)(-1.5\text{m})}$$
$$v_f \cong \pm 5.4\ \frac{\text{m}}{\text{s}}$$

(b) The floor exerted a force of 3.7×10^4 N up on the woman's feet.

$$\vec{F} = m\vec{a}$$
$$\vec{F} = m\frac{v_f - v_i}{\Delta t}$$
$$\vec{F} = 55.0 \text{ kg } \frac{(0 \frac{\text{m}}{\text{s}}) - (-5.4 \frac{\text{m}}{\text{s}})}{8.00 \times 10^{-3} \text{ s}}$$
$$\vec{F} \cong 3.7 \times 10^4 \text{ N[up]}$$

34. The new acceleration is one half of the original amount, since the new mass is twice the original amount.

35. (a) The new acceleration will be 5/2 times the original acceleration.

$$\vec{F}_1 = m_1\vec{a}_1 \qquad \vec{F}_2 = m_2\vec{a}_2 \qquad m_2 = 2m_1 \qquad \vec{a}_2 = \frac{5\vec{F}_1}{2m_1}$$
$$\vec{a}_1 = \frac{\vec{F}_1}{m_1} \qquad \vec{a}_2 = \frac{\vec{F}_2}{m_2} \qquad \vec{F}_2 = 5\vec{F}_1 \qquad \vec{a}_2 = \frac{5}{2}\vec{a}_1$$

(b) The body will travel a distance $\frac{3}{4}a_1\Delta t^2$ greater than the distance travelled by the original body. If the bodies started from rest, the second would have travelled $\frac{5}{2}$ or 2.5 times as far as the original travelled.

$$\Delta d_1 = v_i\Delta t + \frac{1}{2}a_1\Delta t^2$$
$$\Delta d_2 = v_i\Delta t + \frac{1}{2}a_2\Delta t^2$$
$$\Delta d_2 = v_i\Delta t + \frac{1}{2}\left(\frac{5}{2}a_1\right)\Delta t^2$$
$$\Delta d_2 = v_i\Delta t + \frac{5}{4}a_1\Delta t^2$$
$$\Delta d_2 = v_i\Delta t + \frac{1}{2}a_1\Delta t^2 + \frac{3}{4}a_1\Delta t^2$$
$$\Delta d_2 = \Delta d_1 + \frac{3}{4}a_1\Delta t^2$$

$$\frac{\Delta d_2}{\Delta d_1} = \frac{0 + \cancel{\frac{1}{2}}\left(\frac{5}{2}\cancel{a_1}\right)\cancel{\Delta t^2}}{0 + \cancel{\frac{1}{2}}\cancel{a_1}\cancel{\Delta t^2}}$$
$$\frac{\Delta d_2}{\Delta d_1} = \frac{5}{2}$$

36. (a) The magnitude of the net force acting horizontally on the box is 9.00 N.

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$a = \frac{v_f - v_i}{\Delta t}$$
$$\left|\vec{F}_{\text{net}}\right| = m\frac{v_f - v_i}{\Delta t}$$
$$\left|\vec{F}_{\text{net}}\right| = 45.0 \text{ kg } \frac{1.50 \frac{\text{m}}{\text{s}} - 1.00 \frac{\text{m}}{\text{s}}}{2.50 \text{ s}}$$
$$\left|\vec{F}_{\text{net}}\right| = 9.00 \text{ N}$$

(c) In order to find the frictional force in part (b), it is necessary to find the horizontal (x) component of the applied force. Therefore, solve part (c) first. The horizontal component of the applied force is 141 N.

$$F_{x(\text{app})} = \left|\vec{F}_{\text{app}}\right| \cos\theta$$
$$F_{x(\text{app})} = (205 \text{ N})(\cos 46.5°)$$
$$F_{x(\text{app})} \cong 141 \text{ N}$$

(b) The frictional force acting on the box is 132 N in the direction opposite to the applied force.

$$F_{x(\text{net})} = F_{x(\text{app})} + F_{x(\text{f})}$$
$$F_{x(\text{f})} = F_{x(\text{net})} - F_{x(\text{app})}$$
$$F_{x(\text{f})} = 9.0\text{ N} - 141\text{ N}$$
$$F_{x(\text{f})} \cong -132\text{ N}$$

(d) The coefficient of friction is 0.450. First find the normal force. The normal force is entirely in the y direction, as is the gravitational force.

$$F_{\text{N}} + F_{\text{g}} + F_{y(\text{app})} = 0$$
$$F_{\text{N}} = -F_{\text{g}} - F_{y(\text{app})}$$
$$F_{\text{N}} = -(-mg) - \left|\overrightarrow{F}_{\text{app}}\right| \sin\theta$$
$$F_{\text{N}} = (45.0\text{ kg})\left(9.81\tfrac{\text{m}}{\text{s}^2}\right) - (205\text{ N})(\sin 46.5°)$$
$$F_{\text{N}} \cong 293\text{ N}$$

$$F_{\text{f}} = \mu_{\text{k}} F_{\text{N}}$$
$$\mu_{\text{k}} = \frac{F_{\text{F}}}{F_{\text{N}}}$$
$$\mu_{\text{k}} = \frac{132\text{ N}}{293\text{ N}}$$
$$\mu_{\text{k}} \cong 0.450$$

37. Momentum of the bowling ball

$$\vec{p} = m\vec{v}$$
$$\vec{p} = (5.0\text{ kg})\left(3.5\tfrac{\text{m}}{\text{s}}[\text{N}]\right)$$
$$\vec{p} = 17.5\tfrac{\text{kg}\cdot\text{m}}{\text{s}}[\text{N}]$$
$$\vec{p} \cong 18\tfrac{\text{kg}\cdot\text{m}}{\text{s}}[\text{N}]$$

38. Mass of the car

$$\vec{p} = m\vec{v}$$
$$m = \frac{\vec{p}}{\vec{v}}$$
$$m = \frac{4.2 \times 10^4\ \frac{\text{kg}\cdot\cancel{\text{m}}}{\cancel{\text{s}}}[\text{W}]}{28\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}[W]}$$
$$m = 1.5 \times 10^3\text{ kg}$$

39. Velocity of the in-line skater

$$\vec{p} = m\vec{v}$$
$$\vec{v} = \frac{\vec{p}}{m}$$
$$\vec{v} = \frac{66.0\ \frac{\cancel{\text{kg}}\cdot\text{m}}{\text{s}}[\text{S}]}{55.0\cancel{\text{kg}}}$$
$$m = 1.20\tfrac{\text{m}}{\text{s}}[\text{S}]$$

40. Velocity of the golf ball

$$m_{\text{g}}\vec{v}_{\text{g}} = m_6\vec{v}_6$$
$$\vec{v}_{\text{g}} = \frac{m_{\text{b}}\vec{v}_{\text{b}}}{m_{\text{g}}}$$
$$\vec{v}_{\text{g}} = \frac{(5.0\ \cancel{\text{kg}})(6.0\ \frac{\text{m}}{\text{s}}[\text{forward}])}{5.0 \times 10^{-3}\ \cancel{\text{kg}}}$$
$$\vec{v}_{\text{g}} \cong 6.0 \times 10^3\ \tfrac{\text{m}}{\text{s}}[\text{forward}]$$

41. (a) Impulse for a person knocking on a door

$$\vec{J} = \vec{F}\Delta t$$
$$\vec{J} = (9.1\text{ N[E]})(2.5 \times 10^{-3}\text{ s})$$
$$\vec{J} \cong 2.3 \times 10^{-3}\text{ N}\cdot\text{s[E]}$$

(b) Impulse for a wooden mallet striking a gong

$$\vec{J} = \vec{F}\Delta t$$
$$\vec{J} = (4.2\text{ N[S]})(8.6 \times 10^{-3}\text{ s})$$
$$\vec{J} \cong 3.6 \times 10^{-2}\text{ N}\cdot\text{s[S]}$$

42. Average applied force

$$\left|\vec{J}\right| = \left|\vec{F}\right|\Delta t$$

$$\left|\vec{F}\right| = \frac{\left|\vec{J}\right|}{\Delta t}$$

$$\left|\vec{F}\right| = \frac{8.8\ \frac{\text{kg}\cdot\text{m}}{\text{s}}}{2.3 \times 10^{-3}\ \text{s}}$$

$$\left|\vec{F}\right| \cong 3.8 \times 10^{3}\ \text{N}$$

43. Duration of the contact

$$\vec{J} = \vec{F}\Delta t$$

$$\Delta t = \frac{\vec{J}}{\vec{F}}$$

$$\Delta t = \frac{2.0\ \cancel{\text{N}}\cdot\text{s}}{55\ \cancel{\text{N}}}$$

$$\Delta t \cong 3.6 \times 10^{-2}\ \text{s}$$

44. (a) Impulse of the hockey puck slapshot

$$\vec{F}\Delta t = \Delta\vec{p}$$

$$\vec{F}\Delta t = m\vec{v}_{\text{f}} - m\vec{v}_{\text{i}}$$

$$\vec{F}\Delta t = 0.300\ \text{kg}\left(9.2\ \tfrac{\text{m}}{\text{s}}[\text{S}]\right) - 0.300\ \text{kg}\left(44\ \tfrac{\text{m}}{\text{s}}[\text{N}]\right)$$

$$\vec{F}\Delta t = 2.76\ \frac{\text{kg}\cdot\text{m}}{\text{s}}[\text{S}] - 13.2\ \frac{\text{kg}\cdot\text{m}}{\text{s}}[\text{N}]$$

$$\vec{F}\Delta t = 2.76\ \frac{\text{kg}\cdot\text{m}}{\text{s}}[\text{S}] + 13.2\ \frac{\text{kg}\cdot\text{m}}{\text{s}}[\text{S}]$$

$$\vec{F}\Delta t = 15.96\ \frac{\text{kg}\cdot\text{m}}{\text{s}}[\text{S}]$$

$$\vec{F}\Delta t \cong 16\ \frac{\text{kg}\cdot\text{m}}{\text{s}}[\text{S}]$$

(b) Duration of the interaction

$$\vec{F}\Delta t = 15.96\ \frac{\text{kg}\cdot\text{m}}{\text{s}}[\text{S}]$$

$$\Delta t = \frac{15.96\ \frac{\text{kg}\cdot\text{m}}{\text{s}}[\text{S}]}{\vec{F}}$$

$$\Delta t = \frac{15.96\ \frac{\text{kg}\cdot\text{m}}{\text{s}}[\text{S}]}{2.5 \times 10^{3}\ \text{N}[\text{S}]}$$

$$\Delta t \cong 6.4 \times 10^{-3}\ \text{s}$$

45. Velocity of the bullet just before it hit the wood

$$\vec{F}\Delta t = \Delta\vec{p}$$

$$\vec{F} = \frac{m\vec{v}_{\text{f}} - m\vec{v}_{\text{i}}}{\Delta t}$$

$$\vec{F} = \frac{0 - (2.5\ \text{kg})(3.5\ \frac{\text{m}}{\text{s}}[\text{W}])}{3.5 \times 10^{-4}\ \text{s}}$$

$$\vec{F} \cong -2.5 \times 10^{4}\ \text{N}[\text{W}]$$

$$\vec{F} \cong 2.5 \times 10^{4}\ \text{N}[\text{E}]$$

46. Force that the seat belt exerts on the crash dummy on impact

$$\Delta\vec{d} = \left(\frac{\vec{v}_{\text{i}} + \vec{v}_{\text{f}}}{2}\right)\Delta t$$

$$\Delta t = \left(\frac{2}{\vec{v}_{\text{i}} + \vec{v}_{\text{f}}}\right)\Delta\vec{d}$$

$$\Delta t = \left(\frac{2}{28\ \frac{\cancel{\text{m}}}{\text{s}}[\text{forward}] + 0}\right)1.0\ \cancel{\text{m}}[\text{forward}]$$

$$\Delta t = 0.0714\ \text{s}$$

$$\vec{F}\Delta t = m\vec{v}_{\text{f}} - m\vec{v}_{\text{i}}$$

$$\vec{F} = \frac{m\left(\vec{v}_{\text{f}} - \vec{v}_{\text{i}}\right)}{\Delta t}$$

$$\vec{F} = \frac{75.0\ \text{kg}\left(0 - 28\ \frac{\text{m}}{\text{s}}[\text{forward}]\right)}{0.714\ \text{s}}$$

$$\vec{F} = 2.94 \times 10^{4}\ \text{N}[\text{backward}]$$

$$\vec{F} \cong 2.9 \times 10^{4}\ \text{N}[\text{backward}]$$