Chapter 3: Newton's Laws of Motion

Mini Investigation: Predicting Forces, page 113

Answers may vary. Sample answers:

A. I predicted the reading in question 3 would be the sum of the readings from questions 1 and 2, and that the reading in question 4 would be half the reading from question 2. My predictions were accurate.

To make the results more accurate, the experiment should be performed in a vacuum. The object should be suspended above a table by the same distance for both the spring sensor and my arm. Ideally, my arm should be held up by a sling or other device so that the force I use to hold up the spring will be pretty much the same each time I suspend the object.

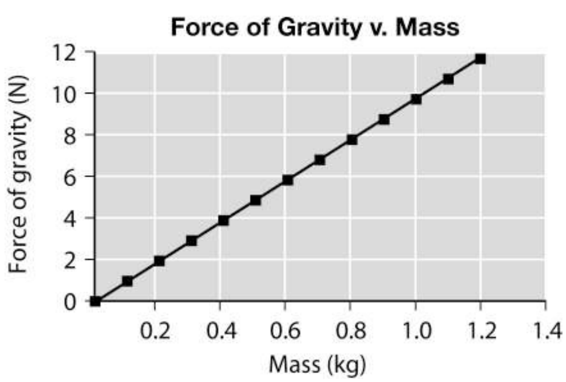
B. Forces such as gravity act upon all objects in the same way. Each force exerted on an object should have an equal but opposite force exerted on an object. For example, if I use 1 N of force to hold up an object, then there should be 1 N of gravitational force pulling the object down.

Section 3.1 Types of Forces

Mini Investigation: Measuring the Force of Gravity, page 116

Answers may vary. Sample answers:

A.



B. The slope of the line of best fit is 0.98. The slope represents the rate of change of gravity on objects of different masses. The heavier the objects are, the stronger the force of gravity is.

C. i. F_g = (0.30 kg)(9.8 m/s)

= 2.9 N

The force of gravity is 2.9 N.

ii. F_g = (0.50 kg)(9.8 m/s)

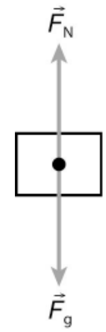
= 4.7 N

The force of gravity is 4.7 N.

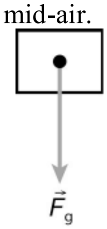
D. To find the force of gravity on an object, multiply the mass of the object, in kilograms, by 9.8 m/s^2.

Tutorial 1 Practice, page 119

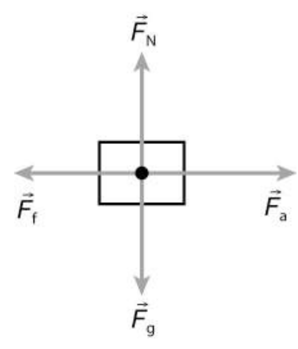
1. (a) System diagrams may vary. Students should draw a book on a flat surface.



(b) System diagrams may vary. Students should draw a basketball in mid-air.



(c) System diagrams may vary. Students should draw a large trunk being pushed directly east along a floor.



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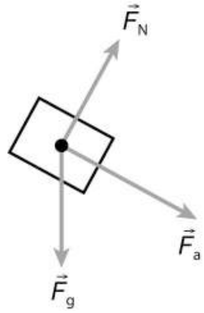
2. The normal force is exerted by the surface of the ramp that is in contact with the sliding block. So, the arrow representing F_N should be perpendicular to the base of the block and going up to the right.

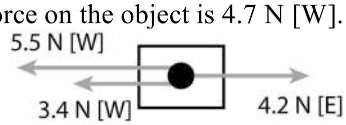


Tutorial 2 Practice, page 120

1. (a) Choose east as positive. So, west is negative.

$$\begin{aligned} F_{net} &= -5.5 \text{ N} + (-3.4 \text{ N}) + 4.2 \text{ N} \\ &= -4.7 \text{ N} \end{aligned}$$

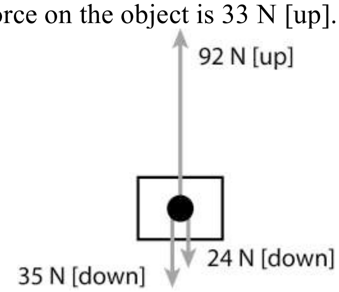
The net force on the object is 4.7 N [W].



(b) Choose up as positive. So, down is negative.

$$\begin{aligned} F_{net} &= +92 \text{ N} + (-35 \text{ N}) + (-24 \text{ N}) \\ &= +33 \text{ N} \end{aligned}$$

The net force on the object is 33 N [up].



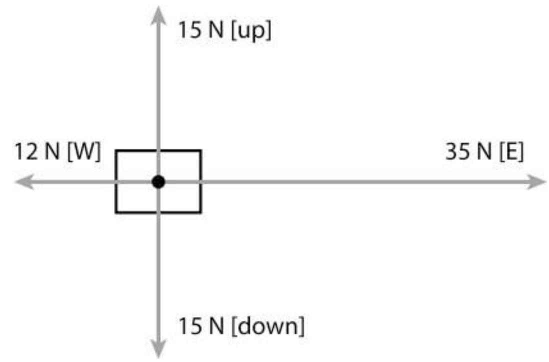
(c) Choose up and east as positive. So, down and west are negative. Define east and west forces as being along the x-axis. So, up and down forces are along the y-axis.

$$\begin{aligned} (F_{net})_x &= +35 \text{ N} + (-12 \text{ N}) \\ &= +23 \text{ N} \end{aligned}$$

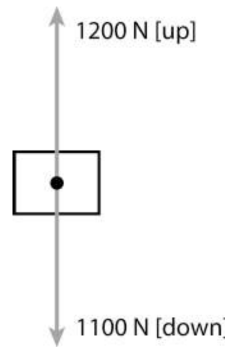
The net force on the x-axis is 23 N.

$$\begin{aligned} (F_{net})_y &= +15 \text{ N} + (-15 \text{ N}) \\ &= 0 \text{ N} \end{aligned}$$

The net force on the y-axis is 0 N.
Therefore, the net force on the object is 23 N [E].



2.

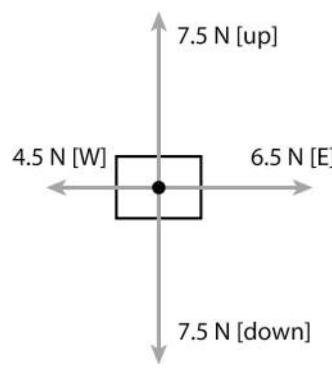


Choose up as positive. So, down is negative.

$$\begin{aligned} F_{net} &= +1200 \text{ N} + (-1100 \text{ N}) \\ &= +100 \text{ N} \end{aligned}$$

The net force on the beam is 100 N [up].

3.



Choose up and east as positive. So, down and west are negative. Define east and west forces as being along the x-axis. So, up and down forces are along the y-axis.

$$\begin{aligned} (F_{net})_x &= +6.5 \text{ N} + (-4.5 \text{ N}) \\ &= +2.0 \text{ N} \end{aligned}$$

The net force on the x-axis is 2.0 N.

$$\begin{aligned} (F_{net})_y &= +7.5 \text{ N} + (-7.5 \text{ N}) \\ &= 0 \text{ N} \end{aligned}$$

The net force on the y-axis is 0 N.
Therefore, the net force on the book is 2.0 N [E].

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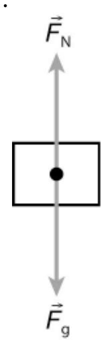
Section 3.1 Questions, page 122

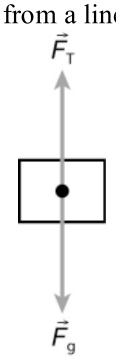
1. (a) The applied force is in the north direction.
(b) The applied force is in the south direction.
2. (a) The force of gravity causes the ball to fall toward the ground.
(b) The force of gravity pulls the person down toward the elevator floor. The tension in the rope of the elevator pulls the elevator up with a force greater than the force of gravity.
(c) The driver applies a force on the brakes. The brakes cause the car to slow down. The road exerts a force of friction on the wheels to stop the car.
3. If the force sensor is not set to zero before performing an investigation (when there is no force acting), the readings for the force changes will not be accurate. For example, when the net force is zero, the sensor will show a non-zero reading.
4. Answers may vary. Sample answer:

Force	Direction
force of gravity	downward
normal force	perpendicular from surface of contact
applied force	same direction as push or pull
friction	opposite to motion
tension	pulls object toward rope or string

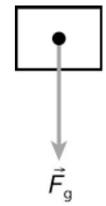
5. (a) System diagrams may vary. Students should draw a stationary car.



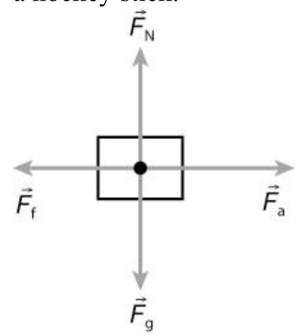
(b) System diagrams may vary. Students should draw a fish hanging from a line.



(c) System diagrams may vary. Students should draw a football in mid-air.



(d) System diagrams may vary. Students should draw a puck being pushed along an ice surface by a hockey stick.



6. Answers may vary. Students' posters could use charts or concept maps and should include at least two system diagrams and the corresponding FBDs. Posters can focus on one common everyday force or all five (applied force, tension, normal force, friction, and gravity), with an example of each. For example, holding a book shows the two vertical forces. Two children pushing and pulling a wagon (Figure 4 on page 115) shows how all five forces act on the same object.
7. (a) Given: m = 2.0 kg; $\vec{g}$ = 9.8 m/s^2 [down]

Required: $\vec{F}_g$

Analysis: $\vec{F}_g = m\vec{g}$

Solution:

$$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= 2.0\text{ kg} \times 9.8\text{ m/s}^2\text{ [down]}\\ \vec{F}_g &= 20\text{ N [down]}\end{aligned}$$

Statement: The force of gravity acting on the object is 2.0 × 10 N [down].
(b) Given: m = 62 kg; $\vec{g}$ = 9.8 m/s^2 [down]

Required: $\vec{F}_g$

Analysis: $\vec{F}_g = m\vec{g}$

Solution:

$$\begin{aligned}\vec{F}_g &= m\vec{g}\\ &= 62\text{ kg} \times 9.8\text{ m/s}^2\text{ [down]}\\ \vec{F}_g &= 6.1 \times 10^2\text{ N [down]}\end{aligned}$$

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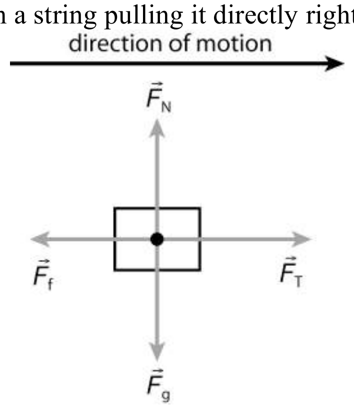
Statement: The force of gravity acting on the person is 6.1×10^2 N [down].

8. Answers may vary. Sample answer:
The statement is not valid. A normal force is a perpendicular force exerted by a surface on an object in contact with the surface. This force always points away from the surface. However, an applied force may be exerted by an object or a person in all directions, and the force can point toward the surface that the object or person applying the force is in contact with. For example, when you use your hand to push on a box, the applied force points toward the box surface that is in contact with your hand, and the force may not be perpendicular to the box surface.

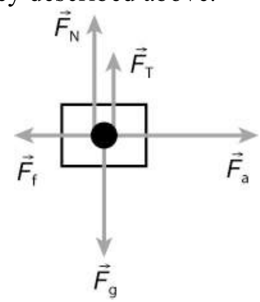
9. When you pull the cart with the string, the tension in the string applies a force that moves the cart forward. Since a string is not rigid, when you push the cart away with a string, it will sag and have no effect on the motion of the cart. As the FBD of the moving cart shows, the applied force, F_T, has to come from a pulled string but not a pushed string.
System diagrams may vary. Students should draw a cart with a string pulling it directly right.



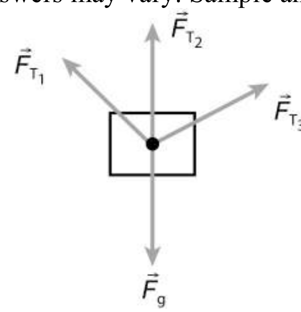
10. Contact forces, such as the normal force and the applied force, require an object to be in contact with another object. Forces that do not require contact, such as the force of gravity and the electromagnetic force, are action-at-a-distance forces. If only action-at-a-distance forces are acting on an object, then the FBD can only show the action-at-a-distance forces.

11. A system diagram tells you all the objects that are involved in a situation. It helps you determine which objects push or pull on other objects. A FBD shows all the forces acting on an object. It helps you determine the net force acting on the object.

12. Answers may vary. Sample answer:
Inflate the balloon. Tape the paperclip to the block of wood and use the elastic band to connect the block of wood to the balloon. Use the magnet to attract the paperclip and draw the wood to the end of the hall.
System diagrams may vary. Students should draw the system they described above.



13. The forces acting on the spider are the tension forces in the spider web strands and the force of gravity. Answers may vary. Sample answer:



14. (a) Answers may vary. Sample answer:
Since muscles are made of small fibres, they are not rigid. Like ropes and strings, they can only pull on an object, not push on an object. Therefore, muscles can only cause tension forces.
(b) Bones are rigid. Like other hard objects, they can push or pull on another object that they are in contact with, whereas muscles cannot push on an object with which they are in contact.

15. (a) Choose up as positive. So, down is negative.

$$F_{\text{net}} = +56\text{ N} + (-35\text{ N})$$
$$F_{\text{net}} = +21\text{ N}$$

The net force on the object is 21 N [up].
(b) Choose right as positive. So, left is negative.

$$F_{\text{net}} = +12.3\text{ N} + 14.4\text{ N} + (-32.7\text{ N})$$
$$F_{\text{net}} = -6.0\text{ N}$$

The net force on the object is 6.0 N [left].
(c) Choose up and east as positive. So, down and west are negative. Define east and west forces as being along the *x*-axis. So, up and down forces are along the *y*-axis.

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$\left(F_{\text{net}}\right)_y = +45\text{ N} + (-45\text{ N})$

$\left(F_{\text{net}}\right)_y = 0\text{ N}$

The net force on the y-axis is 0 N.

$\left(F_{\text{net}}\right)_x = -21\text{ N} + 21\text{ N}$

$\left(F_{\text{net}}\right)_x = 0\text{ N}$

The net force on the x-axis is 0 N.

Therefore, the net force on the object is 0 N.

16. (a) The four fundamental forces from weakest to strongest are the gravitational force, the weak nuclear force, the electromagnetic force, and the strong nuclear force.

(b) Gravity differs from the other three fundamental forces in that is has the farthest reach but is weakest in actual magnitude. Its effect is insignificant on objects with small masses. This force only attracts objects.

(c) Friction and tension are not fundamental forces because they arise out of other forces.

Friction is not a fundamental force because it originates from the electromagnetic forces and exchange force between atoms. Tension is the result of gravity and electrostatic forces between molecules.

Section 3.2: Newton's First Law of Motion

Tutorial 1 Practice, page 126

1. When a bus or train suddenly accelerates forward from rest, there is no force applied to your body. According to Newton's first law, your body will continue to remain at rest. Relative to the motion of the bus or train, your body might be thrown backward. If you are not holding onto something in the bus or subway train, you might hit something or fall, and get injured.

2. When the frictionless tablecloth is pulled on quickly, no friction or other forces are applied to the bottom of the plates. According to Newton's first law, the plates will remain at rest on top of the table.

3. When the driver pushes on the brakes, the wheels of the car experience no external force from the frictionless black ice surface. As a result, the car will continue to move at a constant velocity according to Newton's first law of motion.

4. According to Newton's first law, an applied external force can move the snow that is at rest off the shovel. To do this, you can hammer the shovel on the ground to shake off the snow.

5. (a) Given: three forces of 13 000 N [up], 1250 N [left], and 1400 N [left]

Required: $\vec{F}_1$; $\vec{F}_g$

Analysis: $\vec{F}_{net}$ = 0 N. Choose up and right as positive. So, down and left are negative. Define right and left forces as being along the *x*-axis. So, up and down forces are along the *y*-axis.

Solution:

The net force on the *x*-axis is 0 N.

$$\begin{aligned}
\left(F_{net}\right)_x &= F_1 + (-1250\text{ N}) + (-1400\text{ N}) \\
0 &= F_1 - 2650\text{ N} \\
F_1 &= +2650\text{ N} \\
\vec{F}_1 &= 2650\text{ N [right]}
\end{aligned}$$

The net force on the *y*-axis is 0 N.

$$\begin{aligned}
\left(F_{net}\right)_y &= +13\,000\text{ N} + F_g \\
0 &= +13\,000\text{ N} + F_g \\
F_g &= -13\,000\text{ N} \\
\vec{F}_g &= 13\,000\text{ N [down]}
\end{aligned}$$

Statement: $\vec{F}_1$ is 2650 N [right] and $\vec{F}_g$ is 13 000 N [down].

(b) The answers will not change because the change in the velocity of the car does not change the net forces along the *y*-axis and along the *x*-axis, which are still zero.

Mini Investigation: Testing Newton's First Law, page 127

1. Predictions may vary. Sample answers given.

Situation	Sketch of situation	Prediction/ explanation	Observation	Explanation
A. A coin is on top of a playing card on the left fist. Hit the card.		The coin will flip up into the air, travel in an arc, and land on the ground.	The coin flips up into the air and travels in an arc before landing on the ground.	The coin resting on the card responds to the force of the card moving upward and pushing the coin with it.
B. A moving ballistics cart fires a ball by exerting a force straight up.		The ball will move straight up in the air, slow down, and then fall to the ground.	The ball moves straight up in the air, slows, and then falls to the ground.	A force by the ballistics cart results in the ball moving upward.

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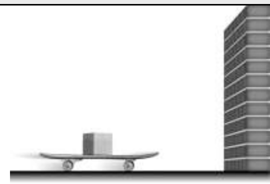
Situation	Sketch of situation	Prediction/ explanation	Observation	Explanation
C. A moving skateboard with an object on top hits a wall.		The skateboard will bounce back at the same time the object continues to move forward.	The skateboard bounces back at the same time the object continues to move forward.	The object continues to move forward even though the skateboard bounces back because the object is not subjected to the same force imposed on the skateboard by the wall.
D. A thread supports an object. Another thread is underneath. Pull slowly on the bottom thread.		The object will not move.	The object does not move.	The object continues to remain stationary when there is no net force to cause it to change.
E. A thread supports an object. Another thread is underneath. Pull quickly on the bottom thread.		The object will move.	The object moves.	The object begins moving when there is a net force to cause its position to change. Even if the quick pulling action does not cause the thread to break, the object will tend to vibrate as a result of the quick motion.

Section 3.2 Questions, page 129

1. Answers may vary. Sample answer:
The use of equipment such as air tables, where little friction is present, can help demonstrate Galileo's thought experiments. With frictionless surfaces available, the result of Galileo's thought experiment, **Figure 2 (a)**, should show that a ball rolling down an incline, onto a horizontal surface, and up another incline could roll up to the same height as its starting position.

2. The inertia of an object depends on the mass of the object. An object with more mass has more inertia, whereas an object with less mass has less inertia. Therefore, the truck, with the greatest mass, has the most inertia and the feather, with the least mass, has the least inertia.

3. The three skaters are either at rest or moving at constant velocity. According to Newton's first law, the net force on each skater is zero.

4. (a) When the pickup truck accelerates forward, your body will be pushed quickly backward due to inertia. If you are sitting in the back of the truck, you may collide with the truck cab and get injured.

(b) To keep the car moving at a constant velocity, the net force on the car in the direction of motion must be zero. The large applied force by the engine of the car has to be cancelled by the friction of the road surface to maintain a constant velocity. Slippery ice surface gives almost no friction so it is hard to get the car moving on ice.

(c) When the car suddenly accelerates forward, the object on the ledge of the car between the rear windshield and the rear seat will be bounced back toward the rear windshield due to inertia. Sharp and heavy objects may crack the windshield.

(d) During liftoff when the spacecraft accelerates upward by a large force, the astronauts will experience a downward push due to inertia. If they stay in a vertical position, this force will compress them from head to toe. It is easier on the body when the astronauts are placed horizontally in the capsule.

5. (a) No, only seat belts significantly improve safety when the car suddenly slows down. In this situation, your body will be pushed quickly forward due to inertia. If there is no seat belt, you could slam into the steering wheel or hit the

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windshield with your head. Since you are moving forward, you do not use the headrest.
(b) No, only headrests significantly improve safety when the car suddenly speeds up. In this situation, your body will accelerate forward because the seat exerts a force on it. If there is no headrest, your head will snap backward due to inertia, possibly resulting in a neck injury. Since you are moving forward and your head is moving backward, and the seatbelt is not holding your head, you do not use the seatbelt.
6. When the car suddenly speeds up or slows down, the cup and the coffee that are at rest continue to stay at rest according to Newton's first law. This means they will move in the opposite direction as the acceleration of the car. A lid prevents the coffee from splashing out of the cup and the cup holder prevents the cup from falling.
7. Answers may vary. Sample answer:
The tension in the string is a force pulling the puck toward the spike. If the string is suddenly cut, according to Newton's first law, the puck will resist this change of motion by moving out of the circular path in a direction away from the spike.
8. For an object resting on a horizontal surface, the net force on the object is zero. The forces acting on the object are the normal force and the force gravity. Therefore, the normal force must be equal in magnitude to the force of gravity so that they can cancel each other to give a net force of zero on the object.
9. Answers may vary. Sample answer:
As the car turns, according to Newton's first law, you body continues to go straight. As a result, you will lean toward the door.
10. Answers may vary. Sample answer:
Since an icy highway is slippery with almost no friction, a fast-moving car will not slow down even when you push on the brakes because there is no force acting on the wheels that will stop the motion. When you go around a curve on an icy highway at a fast speed, according to Newton's first law, the car tends to remain in its high-speed straight motion. As a result, it will fly off the curve, causing a skid. So, you should always slow down when driving around a curve on an icy road.
11. **(a)** When the ring is suddenly pulled horizontally, the chalk will remain in its rest motion under gravity. So, it will fall straight down into the container.
(b) As the chalk falls to the bottom of the container due to gravity and hits it, it will be bounced back upward and break. The water in the container provides a frictional force on the chalk, slowing it down. The water keeps the chalk from breaking into pieces.
12. Answers may vary. Sample answer:
(a) When the bus moves at a constant velocity, there is no force acting on the apple or the bus. When the apple is thrown upward, the vertical velocity of the apple is changed but not its horizontal velocity. According to Newton's first law, both the apple and the bus will continue at the same velocity as your hand and the bus. So, the apple will land back in your hand.
(b) When the bus slows down, the bus is travelling slower than the apple, which continues to move forward at constant velocity. The apple will land farther in front of you.
13. (a) Given: two forces of 32 N [down] and 17 N [right]
Required: $\vec{F}_1$; $\vec{F}_2$
Analysis: $\vec{F}_{net}$ = 0. Choose up and right as positive. So, down and left are negative. Define right and left forces as being along the *x*-axis. So, up and down forces are along the *y*-axis.
Solution:
The net force on the *x*-axis is 0 N.

$$\begin{aligned}(F_{net})_x &= F_1 + 17\text{ N}\\ 0 &= F_1 + 17\text{ N}\\ F_1 &= -17\text{ N}\\ \vec{F}_1 &= 17\text{ N [left]}\end{aligned}$$

The net force on the *y*-axis is 0 N.

$$\begin{aligned}(F_{net})_y &= F_2 + (-32\text{ N})\\ 0 &= F_2 - 32\text{ N}\\ F_2 &= +32\text{ N}\\ \vec{F}_2 &= 32\text{ N [up]}\end{aligned}$$

Statement: $\vec{F}_1$ is 17 N [left] and $\vec{F}_2$ is 32 N [up].
(b) Given: three forces of 54 N [up], 60 N [right], and 86 N [left]
Required: $\vec{F}_1$; $\vec{F}_2$
Analysis: $\vec{F}_{net}$ = 0. Choose up and right as positive. So, down and left are negative. Define right and left forces as being along the *x*-axis. So, up and down forces are along the *y*-axis.
Solution:
The net force on the *x*-axis is 0 N.

$$
\begin{aligned}
\left(F_{\text{net}}\right)_x &= F_1 + 60\text{ N} + (-86\text{ N}) \\
0 &= F_1 - 26\text{ N} \\
F_1 &= +26\text{ N} \\
\vec{F}_1 &= 26\text{ N [right]}
\end{aligned}
$$

The net force on the y-axis is 0 N.

$$
\begin{aligned}
\left(F_{\text{net}}\right)_y &= +54\text{ N} + F_2 \\
0 &= +54\text{ N} + F_2 \\
F_2 &= -54\text{ N} \\
\vec{F}_2 &= 54\text{ N [down]}
\end{aligned}
$$

Statement: $\vec{F}_1$ is 26 N [right] and $\vec{F}_2$ is 54 N [down].

14. Answers may vary. Sample answer:
(a) Use the edge of a thin ruler to apply a very quick horizontal force to the quarter at the bottom. In doing this, the stack of quarters above will remain pulled on by gravity and move straight down onto the top of the desk, still as a stack. This procedure will allow you to take the stack apart one quarter at a time.
(b) This works because of Newton's first law, which states that an object remains in its motion if there is no force acting on it. So the stack of quarters will not be affected by the force from the ruler, but they will continue to be affected by gravity.
15. Answers may vary. Students' pamphlets should show proper headrest use and use Newton's first law of motion to show how it prevents injury during a car crash. Pamphlets should include statistics with references and could include diagrams such as Figure 6 on page 125.

Section 3.3: Newton's Second Law of Motion

Tutorial 1 Practice, page 133

1. Given: $\vec{F}_{\text{net}}$ = 126 N [S]; m = 70 kg

Required: $\vec{a}$

Analysis: $\vec{F}_{\text{net}} = m\vec{a}$. Choose north as positive. So, south is negative.

Solution:

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$$
$$a = \frac{-126\text{ N}}{70\text{ kg}}$$
$$= -1.8\text{ m/s}^2$$
$$\vec{a} = 1.8\text{ m/s}^2\text{ [S]}$$

Statement: The acceleration of the sprinter is 1.8 m/s^2 [S].

2. Given: $\vec{a}$ = 1.20 m/s^2 [forward]; $\vec{F}_{\text{net}}$ = 1560 N [forward]

Required: m

Analysis: $\vec{F}_{\text{net}} = m\vec{a}$. Choose forward as positive.

Solution:

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$m = \frac{\vec{F}_{\text{net}}}{\vec{a}}$$
$$= \frac{+1560\text{ N}}{+1.20\text{ m/s}^2}$$
$$m = 1300\text{ kg}$$

Statement: The mass of the car is 1300 kg.

3. Given: $\vec{v}_1$ = 6.0 m/s [E]; $\vec{v}_2$ = 14.0 m/s [E]; Δt = 6.0 s; m = 58 kg

Required: $\vec{F}_{\text{net}}$

Analysis: Choose east as positive. First calculate the acceleration using $\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$. Then calculate the net force using $\vec{F}_{\text{net}} = m\vec{a}$.

Solution:

$$a = \frac{v_2 - v_1}{\Delta t}$$
$$= \frac{+14.0\text{ m/s} - (+6.0\text{ m/s})}{6.0\text{ s}}$$
$$a = +1.33\text{ m/s}^2\text{ (one extra digit carried)}$$

Calculate the net force.

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$F_{\text{net}} = (58\text{ kg})(+1.33\text{ m/s}^2)$$
$$= +77\text{ N}$$
$$\vec{F}_{\text{net}} = 77\text{ N [E]}$$

Statement: The net force acting on the cyclist and bicycle is 77 N [E].

4. (a) Given: m = 1420 kg; $\vec{v}_1$ = 64.8 km/h [W]; $\vec{v}_2$ = 0 m/s; $\Delta\vec{d}$ = 729 m [W]

Required: $\vec{F}_{\text{net}}$

Analysis: $\vec{F}_{\text{net}} = m\vec{a}$. Choose east as positive. First convert the value of v_1 to SI units. Then calculate the acceleration using $\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$.

Solution:

$$v_1 = -64.8\text{ km/h}$$
$$= \left(-64.8\,\frac{\cancel{\text{km}}}{\cancel{\text{h}}}\right)\left(\frac{1\,\cancel{\text{h}}}{60\,\cancel{\text{min}}}\right)\left(\frac{1\,\cancel{\text{min}}}{60\text{ s}}\right)\left(\frac{1000\text{ m}}{1\,\cancel{\text{km}}}\right)$$
$$v_1 = -18.0\text{ m/s}$$

Since v_2 = 0 m/s,

$$0 = v_1^2 + 2a\Delta d$$
$$v_1^2 = -2a\Delta d$$
$$a = \frac{v_1^2}{-2\Delta d}$$
$$= \frac{(-18.0\text{ m/s})^2}{-2(-729\text{ m})}$$
$$a = +0.2222\text{ m/s}^2\text{ (one extra digit carried)}$$

Calculate the net force.

$$\vec{F}_{\text{net}} = m\vec{a}$$
$$F_{\text{net}} = (1420\text{ kg})(+0.2222\text{ m/s}^2)$$
$$F_{\text{net}} = +316\text{ N}$$
$$\vec{F}_{\text{net}} = 316\text{ N [E]}$$

Statement: The net force acting on the car is 316 N [E].

(b) The normal force and gravity will cancel when the car is on horizontal ground. When the car slows down, the net force acting on the car is the force of friction. Therefore, the force of friction is 316 N [E].

5. (a) Given: m = 8.0 kg; three forces of 24 N [left], 31 N [left], and 19 N [right]

Required: $\vec{F}_{\text{net}}$; $\vec{a}$

Analysis: Find $\vec{F}_{\text{net}}$ by adding all horizontal forces. Choose right as positive. So, left is negative. Calculate the acceleration using $\vec{F}_{net} = m\vec{a}$.

Solution:

$$\begin{aligned} F_{net} &= -24\text{ N} + (-31\text{ N}) + 19\text{ N} \\ &= -36\text{ N} \end{aligned}$$

$\vec{F}_{net} = 36\text{ N [left]}$

Calculate the acceleration.

$$\begin{aligned} \vec{F}_{net} &= m\vec{a} \\ \vec{a} &= \frac{\vec{F}_{net}}{m} \\ a &= \frac{-36\text{ N}}{8.0\text{ kg}} \\ &= -4.5\text{ m/s}^2 \\ \vec{a} &= 4.5\text{ m/s}^2\text{ [left]} \end{aligned}$$

Statement: The net force applied to the object is 36 N [left] and its acceleration is 4.5 m/s^2 [left].

(b) Given: m = 125 kg; three vertical forces of 1200 N [up], 1100 N [up], and 1300 N [down]; two horizontal forces of 600 N [right] and 600 N [left]

Required: $\vec{F}_{net}$; $\vec{a}$

Analysis: The left and right forces cancel each other. Find $\vec{F}_{net}$ by adding all vertical forces. Choose up as positive. So, down is negative. Calculate the acceleration using $\vec{F}_{net} = m\vec{a}$.

Solution:

$$\begin{aligned} F_{net} &= +1200\text{ N} + 1100\text{ N} + (-1300\text{ N}) \\ &= +1000\text{ N} \end{aligned}$$

$\vec{F}_{net} = 1000\text{ N [up]}$

Calculate the acceleration.

$$\begin{aligned} \vec{F}_{net} &= m\vec{a} \\ \vec{a} &= \frac{\vec{F}_{net}}{m} \\ a &= \frac{+1000\text{ N}}{125\text{ kg}} \\ &= +8\text{ m/s}^2 \\ \vec{a} &= 8\text{ m/s}^2\text{ [up]} \end{aligned}$$

Statement: The net force applied to the object is 1000 N [up] and its acceleration is 8 m/s^2 [up].

6. Given: $\vec{F}_1$ = 310 N [forward]; $\vec{F}_2$ = 354 N [forward]; $\vec{F}_f$ = 40 N [backward]; m = 390 kg

Required: $\vec{a}$

Analysis: Find $\vec{F}_{net}$ by adding all forward and backward forces. Choose forward as positive. So, backward is negative. Calculate the acceleration using $\vec{F}_{net} = m\vec{a}$.

Solution:

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_f$$

$$\begin{aligned} F_{net} &= +310\text{ N} + 354\text{ N} + (-40\text{ N}) \\ &= +624\text{ N} \end{aligned}$$

$\vec{F}_{net} = 624\text{ N [forward]}$

Calculate the acceleration.

$$\begin{aligned} \vec{F}_{net} &= m\vec{a} \\ \vec{a} &= \frac{\vec{F}_{net}}{m} \\ a &= \frac{+624\text{ N}}{390\text{ kg}} \\ &= +1.6\text{ m/s}^2 \\ \vec{a} &= 1.6\text{ m/s}^2\text{ [forward]} \end{aligned}$$

Statement: The acceleration of the bobsled is 1.6 m/s^2 [forward].

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1. (a) Given: m_1 = 1.20 kg; m_2 = 0.60 kg; $\vec{F}_f$ = 0 N

Required: $\vec{a}$

Analysis: Draw a FBD of each object.
For the cart, the normal force and gravity cancel each other.
So, $(F_{net})_{cart} = F_T = m_1a$.

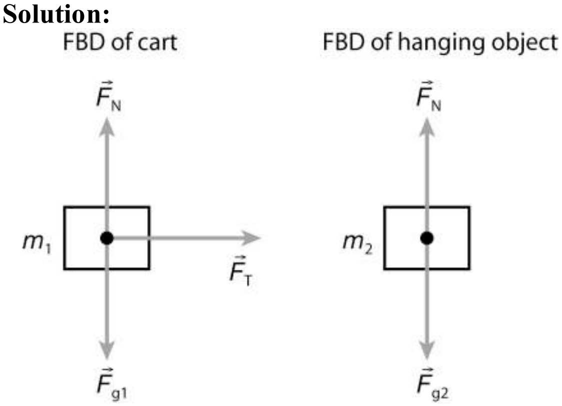
$m_1a = F_T$ (Equation 1)

For the hanging object,
$\left(F_{net}\right)_{object} = F_{g_2} - F_T = m_2a$.

$m_2a = m_2g - F_T$ (Equation 2)

The cart will accelerate to the right. Choose right as positive. So, left is negative. Solve the two equations for a.

Solution:



Add the equations to solve for a.

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$$m_1a + m_2a = F_T + m_2g - F_T$$
$$m_1a + m_2a = m_2g$$
$$(m_1 + m_2)a = m_2g$$
$$(1.20 \text{ kg} + 0.60 \text{ kg})a = (0.60 \text{ kg})(9.8 \text{ m/s}^2)$$
$$a = 3.3 \text{ m/s}^2$$

The acceleration of the cart is 3.3 m/s^2 [right].

(b) Given: m_1 = 1.20 kg; m_2 = 0.60 kg; $\vec{F}_f$ = 0.50 N [left]

Required: $\vec{a}$

Analysis: Draw a FBD of each object.

For the cart, the normal force and gravity cancel each other.

So, $(F_{net})_{cart} = F_T - F_N = m_1a$.

$m_1a = F_T - F_N$ (Equation 1)

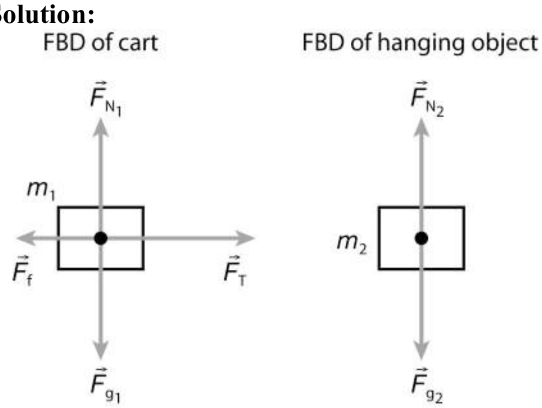
For the hanging object,

$(F_{net})_{object} = F_{g_2} - F_T = m_2a$.

$m_2a = m_2g - F_T$ (Equation 2)

The cart will accelerate to the right. Choose right as positive. So, left is negative. Solve the two equations for a.

Solution:



Add the equations to solve for a.

$$m_1a + m_2a = F_T - F_N + m_2g - F_T$$
$$m_1a + m_2a = m_2g - F_N$$
$$(m_1 + m_2)a = m_2g - F_N$$
$$(1.20 \text{ kg} + 0.60 \text{ kg})a = (0.60 \text{ kg})(9.8 \text{ m/s}^2) - 0.50 \text{ N}$$
$$a = 3.0 \text{ m/s}^2$$

The acceleration of the cart is 3.0 m/s^2 [right].

2. (a) Given: m_1 = 2.0 kg; m_2 = 0.40 kg; $\vec{F}_f$ = 0 N

Required: $\vec{a}$

Analysis: Draw a FBD of each object.

For the cart, the normal force and gravity cancel each other.

So, $(F_{net})_{cart} = F_T = m_1a$.

$m_1a = F_T$ (Equation 1)

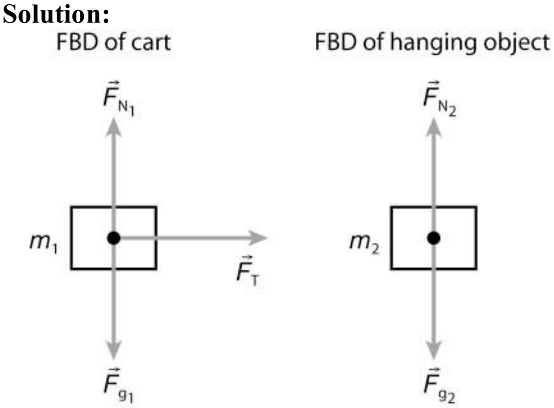
For the hanging object,

$(F_{net})_{object} = F_{g_2} - F_T = m_2a$.

$m_2a = m_2g - F_T$ (Equation 2)

The cart will accelerate to the right. Choose right as positive. So, left is negative. Solve the two equations for a.

Solution:



Add the equations to solve for a.

$$m_1a + m_2a = F_T + m_2g - F_T$$
$$m_1a + m_2a = m_2g$$
$$(m_1 + m_2)a = m_2g$$
$$(2.0 \text{ kg} + 0.40 \text{ kg})a = (0.40 \text{ kg})(9.8 \text{ m/s}^2)$$
$$a = 1.6 \text{ m/s}^2$$

The acceleration of the cart is 1.6 m/s^2 [right].

(b) If the mass of the object on top of the cart increases, the acceleration of the cart decreases. Using the equation for the acceleration of the cart, $a = \dfrac{m_2g}{(m_1 + m_2)}$, the value a decreases when the value m_1 increases.

(c) If an object is taken from the top of the cart and tied to the hanging object, the acceleration of the cart increases. Using the equation for the acceleration of the cart, $a = \dfrac{m_2g}{(m_1 + m_2)}$, the value a increases when the value m_1 decreases and the value m_2 increases.

Section 3.3 Questions, page 136

1. (a) Given: m = 72 kg; $\vec{a}$ = 1.6 m/s^2 [forward]

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose forward as positive.

Solution:

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

$F_{net} = (72 \text{ kg})(+1.6 \text{ m/s}^2)$

$= +120 \text{ N}$

$\vec{F}_{net} = 120 \text{ N [forward]}$

Statement: The net force on the rugby player is 120 N [forward].

(b) Given: $m = 2.3$ kg; $\vec{a} = 12 \text{ m/s}^2$ [up]

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose up as positive.

Solution:

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

$F_{net} = (2.3 \text{ kg})(+12 \text{ m/s}^2)$

$= +28 \text{ N}$

$\vec{F}_{net} = 28 \text{ N [up]}$

Statement: The net force on the model rocket is 28 N [up].

2. (a) Given: $\vec{F}_{net} = 2.4 \times 10^4$ N [E]; $m = 5.0$ kg

Required: $\vec{a}$

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose east as positive. So, west is negative.

Solution:

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

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

$a = \dfrac{+2.4\times10^4 \text{ N}}{5.0 \text{ kg}}$

$= +4800 \text{ m/s}^2$

$\vec{a} = 4800 \text{ m/s}^2 \text{ [E]}$

Statement: The acceleration of the shell is 4800 m/s^2 [E].

(b) Given: $m = 160$ g; $\vec{F}_{net} = 24$ N [forward]

Required: $\vec{a}$

Analysis: $\vec{F}_{net} = m\vec{a}$; First convert the value m to SI units. Choose forward as positive.

Solution:

$m = 160 = 0.16$ kg

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

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

$a = \dfrac{+24 \text{ N}}{0.16 \text{ kg}}$

$= +150 \text{ m/s}^2$

$\vec{a} = 150 \text{ m/s}^2 \text{ [forward]}$

Statement: The acceleration of the hockey puck is 150 m/s^2 [forward].

3. (a) Given: $\vec{a} = 1.2 \text{ m/s}^2$ [backward]; $\vec{F}_{net} = 1400$ N [backward]

Required: m

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose forward as positive.

Solution:

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

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

$= \dfrac{-1400 \text{ N}}{-1.2 \text{ m/s}^2}$

$m = 1200 \text{ kg}$

Statement: The mass of the car is 1200 kg.

(b) Given: $\vec{F}_{net} = 33$ N [forward]; $\vec{a} = 6.0 \text{ m/s}^2$ [forward]

Required: m

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose forward as positive.

Solution:

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

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

$= \dfrac{+33 \text{ N}}{+6.0 \text{ m/s}^2}$

$m = 5.5 \text{ kg}$

Statement: The mass of the shot put is 5.5 kg.

4. Given: $m = 54$ kg; $\vec{v}_1 = 0$ m/s; $\vec{v}_2 = 12$ m/s [downhill]; $\Delta t = 5.0$ s

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{a}$; First calculate the acceleration using $\vec{a} = \dfrac{\vec{v}_2 - \vec{v}_1}{\Delta t}$. Choose uphill as positive. So, downhill is negative.

Solution:

Since $v_1 = 0$ m/s,

$a = \dfrac{v_2}{\Delta t}$

$= \dfrac{-12 \text{ m/s}}{5.0 \text{ s}}$

$= -2.4 \text{ m/s}^2$

$\vec{a} = 2.4 \text{ m/s}^2 \text{ [downhill]}$

Calculate the net force.

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

$F_{net} = (54 \text{ kg})(-2.4 \text{ m/s}^2)$

$= -130 \text{ N}$

$\vec{F}_{net} = 130 \text{ N [downhill]}$

Statement: The net force acting on the skier is 130 N [downhill].

5. Given: $\vec{v}_1 = 0$ m/s; $\vec{F}_{net} = 1.2$ N [forward]; $\Delta\vec{d} = 6.6$ m [forward]; $\vec{v}_2 = 3.2$ m/s [forward]

Required: m

Analysis: $\vec{F}_{net} = m\vec{a}$; $\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$. Choose forward as positive. First calculate the acceleration using $\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$.

Solution:

Since $v_1 = 0$ m/s,

$v_2^{\,2} = 2a\Delta d$

$a = \dfrac{v_2^{\,2}}{2\Delta d}$

$= \dfrac{(+3.2 \text{ m/s})^2}{2(+6.6 \text{ m})}$

$a = +0.776 \text{ m/s}^2$ (one extra digit carried)

Calculate the mass.

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

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

$= \dfrac{+1.2 \text{ N}}{+0.776 \text{ m/s}^2}$

$m = 1.5 \text{ kg}$

Statement: The mass of the cart is 1.5 kg.

6. (a) Given: $m = 58$ kg; $\vec{F}_a = 720$ N [up]

Required: m

Analysis: Add all the vertical forces. Use $\vec{F}_{net} = \vec{F}_a + \vec{F}_g$. Choose up as positive.

Solution:

$\vec{F}_{net} = \vec{F}_a + \vec{F}_g$

$\vec{F}_{net} = \vec{F}_a + m\vec{g}$

$F_{net} = +720 \text{ N} + (58 \text{ kg})(-9.8 \text{ m/s}^2)$

$= +150 \text{ N}$

$\vec{F}_{net} = 150 \text{ N [up]}$

Statement: The net force acting on the person is 150 N [up].

(b) Given: $m = 58$ kg; $\vec{F}_{net} = 150$ N [up]

Required: $\vec{a}$

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose up as positive.

Solution:

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

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

$a = \dfrac{+150 \text{ N}}{58 \text{ kg}}$

$= +2.6 \text{ m/s}^2$

$\vec{a} = 2.6 \text{ m/s}^2 \text{ [up]}$

Statement: The acceleration of the person is 2.6 m/s^2 [up].

7. Given: $F_{net} = 36$ N [forward]; $a_1 = 6.0$ m/s^2 [forward]; $a_{1+2} = 2.0$ m/s^2 [forward]

Required: a_2

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose forward as positive.

Solution:

For mass m_1,

$\vec{F}_{net} = m_1\vec{a}_1$

$m_1 = \dfrac{F_{net}}{a_1}$

$= \dfrac{36 \text{ N}}{6.0 \text{ m/s}^2}$

$m_1 = 6.0 \text{ kg}$

For masses m_1 and m_2 together,

$F_{net} = (m_1 + m_2)a_{1+2}$

$m_1 + m_2 = \dfrac{F_{net}}{a_{1+2}}$

$m_2 = \dfrac{F_{net}}{a_{1+2}} - m_1$

$= \dfrac{36 \text{ N}}{2.0 \text{ m/s}^2} - 6.0 \text{ kg}$

$m_2 = 12 \text{ kg}$

For mass m_2,

$\vec{F}_{net} = m_2\vec{a}_2$

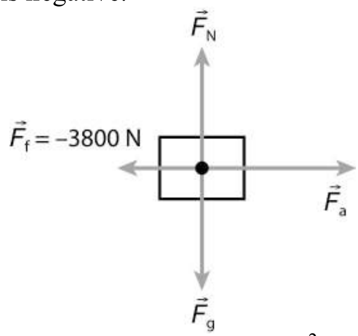
$\vec{a}_2 = \dfrac{\vec{F}_{net}}{m_2}$

$a_2 = \dfrac{36 \text{ N}}{12 \text{ kg}}$

$a_2 = 3.0 \text{ m/s}^2$

Statement: Mass m_2 will experience an acceleration of 3.0 m/s^2.

8. (a) Choose up and east as positive. So, down and west is negative.



(b) Given: m = 1300 kg; $\vec{a}$ = 1.6 m/s^2 [E]; $\vec{F}_f$ = 3800 N [W]

Required: $\vec{F}_a$

Analysis: The normal force and gravity cancel each other since the car is on horizontal ground. To find $\vec{F}_a$, add all the horizontal forces. Use $\vec{F}_{net} = m\vec{a}$ and $\vec{F}_{net} = \vec{F}_a + \vec{F}_f$.

Solution:

$$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$$
$$\vec{F}_a = \vec{F}_{net} - \vec{F}_f$$
$$\begin{aligned} F_a &= ma - F_f \\ &= (1300 \text{ kg})(+1.6 \text{ m/s}^2) - (-3800 \text{ N}) \\ &= +5900 \text{ N} \end{aligned}$$
$$\vec{F}_a = 5900 \text{ N [E]}$$

Statement: The applied force acting on the car is 5900 N [E].

9. Assume that no friction acts on the chain on top of the table.
m_1 = mass of chain on top of table
m_2 = mass of chain hanging over the edge
The tension, F_T, in the chain is the same for both m_1 and m_2.

(a) For the chain on top of the table, the normal force and gravity cancel each other.

$F_{net} = F_T = m_1 a$ (Equation 1)

For the hanging chain,

$F_{net} = F_g - F_T = m_2 a$ (Equation 2)

Add the equations.

$$m_1 a + m_2 a = F_T + m_2 g - F_T$$
$$(m_1 + m_2)a = m_2 g$$

The chain will accelerate to the right down the table. The force of gravity acting on the hanging chain, $m_2 g$, causes the acceleration.

(b) Solve the equations for a.

$$(m_1 + m_2)a = m_2 g$$
$$a = \frac{m_2 g}{m_1 + m_2}$$

From the equation, when the value m_2 increases, the value ($m_1 + m_2$) stays the same, and the value a increases. As more chain moves over the edge of the table, the acceleration of the chain increases.

10. (a) Given: m = 80 kg; three horizontal forces of 170 N [left], 170 N [left], and 150 N [right]

Required: a

Analysis: The normal force and gravity cancel each other since the crate is on the floor. Find $\vec{F}_{net}$ by adding all horizontal forces. Choose right as positive. So, left is negative. Calculate the acceleration using $\vec{F}_{net} = m\vec{a}$.

Solution:

$$\begin{aligned} F_{net} &= -170 \text{ N} + (-170 \text{ N}) + 150 \text{ N} \\ &= -190 \text{ N} \end{aligned}$$
$$\vec{F}_{net} = 190 \text{ N [left]}$$

Calculate the acceleration.

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$\begin{aligned} a &= \frac{-190 \text{ N}}{80 \text{ kg}} \\ &= -2.4 \text{ m/s}^2 \end{aligned}$$
$$\vec{a} = 2.4 \text{ m/s}^2 \text{ [left]}$$

Statement: The acceleration of the crate is 2.4 m/s^2 [left].

(b) If a fourth student jumps on top of the crate, the mass, m, of the crate increases but the net force $\vec{F}_{net}$ on the crate is the same. Using $\vec{F}_{net} = m\vec{a}$, as the value m increases, the value a decreases. So, the magnitude of the acceleration of the crate decreases.

11. Given: m = 30 kg; $\vec{v}_i$ = 0 m/s; Δd = 22 m; m_{max} = 12 kg

Required: Δt

Analysis: Use the equation $F_T = m_s g$ to find the maximum tension of the string when it holds up a 12 kg mass. Assume no friction on the ice. The normal force and gravity cancel each other since the object is on the ice. The net force acting on the pulled object is the tension in the string.
Use $F_T = ma$ to calculate the acceleration and use

$\Delta d = v_i \Delta t + \frac{1}{2} a \Delta t^2$ to calculate the minimum possible time.

Solution:

$$F_T = m_s g$$
$$= (12\ \text{kg})(9.8\ \text{m/s})$$
$$F_T = 117.6\ \text{N}$$

Calculate the acceleration.

$$F_T = ma$$
$$a = \frac{F_T}{m}$$
$$= \frac{117.6\ \text{N}}{30\ \text{kg}}$$
$$a = 3.92\ \text{m/s}^2$$

Calculate the minimum possible time.
Since $v_i = 0$ m/s,

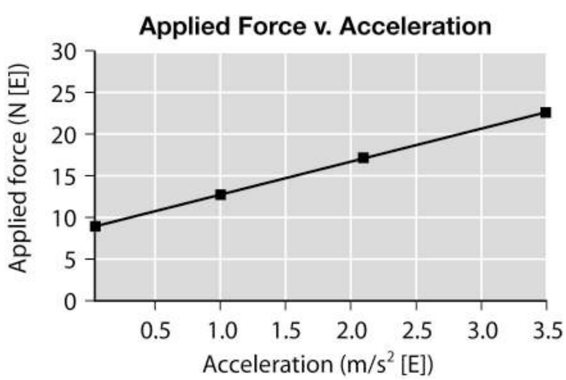
$$\Delta d = v_i \Delta t + \frac{1}{2} a \Delta t^2$$
$$\Delta d = \frac{1}{2} a \Delta t^2$$
$$\Delta t^2 = \frac{2\Delta d}{a}$$
$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$
$$= \sqrt{\frac{2(22\ \cancel{\text{m}})}{3.92\ \cancel{\text{m}}/\text{s}^2}}$$
$$\Delta t = 3.4\ \text{s}$$

Statement: The minimum possible time to complete the task is 3.4 s.

12. (a)

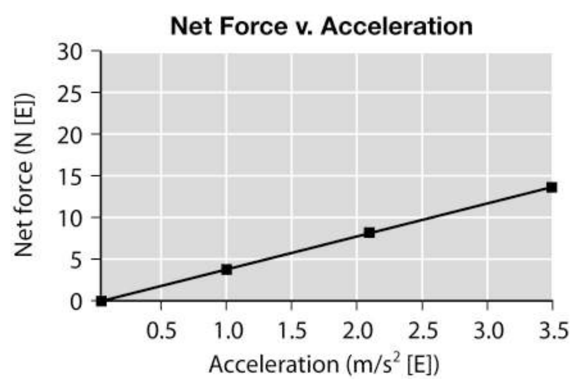
Mass (kg)	Friction (N) [W]	Applied force (N) [E]	Net force (N) [E]	Acceleration (m/s^2) [E]
4.0	9.0	9.0	**0.0**	**0.0**
4.0	9.0	13.0	**4.0**	**1.0**
4.0	9.0	**17.4**	8.4	**2.1**
4.0	9.0	**23.0**	**14.0**	3.5

(b)



The y-intercept represents the friction. When the applied force equals the friction, the net force on the object is zero and its acceleration will also be zero.

(c)



$$\text{slope} = \frac{\text{rise}}{\text{run}}$$
$$= \frac{1.4\ \text{N [E]}}{3.5\ \text{m/s}^2\ \text{[E]}}$$
$$\text{slope} = 4.0\ \text{kg}$$

For the same graph, $\text{slope} = \frac{F_{net}}{a} = m$. So, the slope represents the mass of the object, which is 4.0 kg.

Section 3.4: Newton's Third Law of Motion

Tutorial 1 Practice, page 138

1. (a) The pressure generated by the burning rocket fuel provides an action force that causes the expanding hot gases to accelerate from the bottom of the rocket. According to Newton's third law, the expanding hot gases exert a reaction force that pushes up on the rocket. When this reaction force is greater than the force of gravity that is pulling the rocket down, the rocket can accelerate out of Earth's atmosphere.

(b) The engine at the back of the motorboat exerts an action force on the water in the direction of west. According to Newton's third law, the water exerts an equal but opposite force on the motorboat, causing the motorboat to accelerate east in the water.

(c) Football player 1 exerts an action force toward football player 2. According to Newton's third law, player 2 exerts an equal but opposite force toward player 1. The players will hold together, stopping player 2 from gaining ground toward the goal.

Mini Investigation: Demonstrating the Third Law, page 138

A. Answers may vary. Sample answers:

(a) When I sit in a chair and push my arms against a wall, the force of my arm muscles on the wall causes an equal force of the wall against my arms. I move away from the wall in the chair.

(b) When I sit in a chair not touching a wall, the force of my arm muscles on my shoulders causes an equal force of my shoulders against my arms. I do not move in the chair.

(c) When I stand on a bathroom scale and push down on the desk beside me, the force of my arms on the table causes a force of the table against my arms (or hands). I weigh less than when I do not have a table for support.

(d) When I stand on a bathroom scale and push down on my head with my hands, the force of my arms on my head causes a force of my head against my arms (or hands). I weigh the same as when I do not push down on my head.

(e) When I use a spring-loaded ballistics cart to fire a ball horizontally, the force of the spring on the ball causes a force on the ball that is pushing back on the spring. The spring pushes the ball when released.

(f) When the fan on a fan cart (without a sail) is directed to the right and then turned on, the force of the air on the fan blades causes a force of the blades on the air. The cart moves to the left.

(g) When the fan on a fan cart (with a sail) is directed toward the sail and then turned on, the force of the air on the fan blades and sail causes a force of the blades on the air and a force of the sail on the air. The cart does not move.

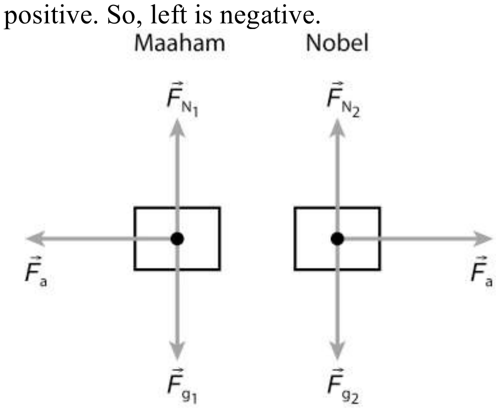
Tutorial 2 Practice, page 140

1. (a) The reaction force is the book pushing with 5.2 N backward on you.

(b) The reaction force is the water exerting a force of 450 N [E] on the boat.

(c) The reaction force is the boards exerting a force of 180 N [toward the hockey player]

2. (a) Draw a FBD for each person. Choose right as positive. So, left is negative.



For each person, the normal force and the force of gravity cancel each other. This means the applied force is equal to the net force.

For Maaham,

$$\vec{F}_a = \vec{F}_{net}$$
$$\vec{F}_a = m_1\vec{a}_1$$
$$F_a = (54 \text{ kg})(-1.2 \text{ m/s}^2)$$
$$= -65 \text{ N}$$
$$\vec{F}_a = 65 \text{ N [left]}$$

The force that Nobel exerts on Maaham is 65 N [left].

(b) For Nobel,

$$F_{net} = F_a$$
$$m_2a_2 = +65 \text{ N}$$
$$(62 \text{ kg})a_2 = +65 \text{ N}$$
$$a_2 = +1.0 \text{ m/s}^2$$
$$\vec{a}_2 = 1.0 \text{ m/s}^2 \text{ [right]}$$

Nobel's acceleration is 1.0 m/s^2 [right].

3. Answers may vary. Sample answer:
The statement is not valid when the action and reaction forces are not acting on the same object. If they act on the same object, the net force will be zero and nothing will accelerate. When the horse pulls forward on the cart, the cart pulls backward on the horse. According to Newton's third law, the horse will cause a reaction force of the same magnitude on the cart in the opposite direction, making the cart accelerate forward. The action and reaction forces do not cancel because they do not act on the same object. In addition, the mass of the horse would be much greater than the mass of the cart, or vice versa.
4. (a) When the student pushes on the wall with a force of 87 N [S], the wall exerts an equal but opposite force of 87 N [N] on the student who is on the skateboard.
Choose north as positive. So, south is negative. For the student on the skateboard, the net force is equal to the reaction force exerted by the wall.

$$\begin{aligned} F_{\text{net}} &= F_{\text{a}} \\ ma &= +87 \text{ N} \\ (58 \text{ kg})a &= +87 \text{ N} \\ a &= +1.5 \text{ m/s}^2 \\ \vec{a} &= 1.5 \text{ m/s}^2 \text{ [N]} \end{aligned}$$

The acceleration of the student is 1.5 m/s^2 [N].
(b) From the equation, $a = \dfrac{F_{\text{net}}}{m}$, for a large value of m, the value for a will be very small. The wall does not seem to move because it is massive and anchored to the ground. The force that the student pushes on the wall is not strong enough to have any noticeable effect on the motion of the wall.

Section 3.4 Questions, page 141

1. (a) The reaction force is the road exerting a force of 240 N [forward] on the tire.
(b) The reaction force is the desk pushing with a force of 25 N [S] on you.
2. Answers may vary. Sample answers:
(a) The water expelled by the squid exerts an action force backward on the water. According to Newton's third law, the water exerts an equal but opposite force forward on the squid, causing the squid to move through the water.
(b) When you walk on a wagon, the bottoms of your feet exert a horizontal backward action force on the wagon. According to Newton's third law, the reaction force is caused by friction when the wagon pushes you to accelerate forward. You may fall off the wagon.
(c) As a helicopter hovers, its rotors cause a downward flow of air. According to Newton's third law, the air exerts an equal upward push back on the helicopter, allowing it to hover in a stationary position.
3. Answers may vary. Sample answers:
(a) As the astronaut pulls on the tether, according to Newton's third law, there is a reaction force in the opposite direction that draws her closer toward the space station.
(b) If the astronaut pulls forward on her space suit, according to Newton's third law, the space suit will cause a reaction force that pulls her backward away from the space station so she cannot push herself back to the station.
(c) The astronaut could push the tool backward. According to Newton's third law, the tool will cause an equal forward push on her toward the space station.
4. Answers may vary. Sample answer:
As a cannon forces a cannon ball out of the cannon, the cannon applies an action force on the cannon ball. According to Newton's third law, the cannon ball will cause a reaction force that pushes the cannon backward. The ropes are necessary to prevent the cannon from hitting other parts of the ship when it is pushed backward.
5. Answers may vary. Sample answers:
(a) As the fan blows to the right, it pushes the air to the right. According to Newton's third law, there is a reaction force from the air that pushes the fan and the cart back to the left. When the sail is in place, the air pushes to the right on the sail. According to Newton's third law, there is a reaction force from the sail that pushes the air back to the left. The force pushing the fan to the left is balanced by the force from the air pushing toward the sail. As a result, the cart cannot accelerate.
(b) If the sail is removed, as the fan blows to the right, it pushes the air to the right. According to Newton's third law, there is a reaction force from the air that pushes the fan and the cart back to the left. The fan cart can then accelerate because there is an external force that pushes it to the left.

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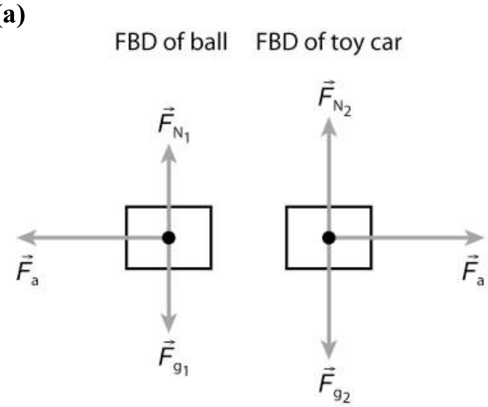
6. (a)



(b) The toy car applies an action force that shoots the plastic ball horizontally out the back, causing the ball to accelerate backward. According to Newton's third law, the ball causes a reaction force on the toy car, making it accelerate forward.
For the toy car, the normal force and the force of gravity cancel each other. Since there is no friction, the applied force is equal to the net force.
Choose east as positive.
Convert 200 g to 0.2 kg.

$$
\begin{aligned}
F_a &= F_{net} \\
F_a &= m_1 a_1 \\
&= (0.2\text{ kg})(+1.2\text{ m/s}^2) \\
&= +0.24\text{ N} \\
\vec{F}_a &= 0.24\text{ N [E]}
\end{aligned}
$$

The reaction force on the toy car is 0.24 N [E].
The action force on the plastic ball is 0.24 N [W].

7. (a) Skater 2 applies an action force that pushes skater 1 west, causing skater 1 to accelerate backward. According to Newton's third law, skater 1 causes a reaction force on skater 2, making skater 2 accelerate forward. For each skater, the normal force and the force of gravity cancel each other. This means the applied force is equal to the net force.
Choose east as positive. So, west is negative.
For skater 1,

$$
\begin{aligned}
F_{net} &= F_a \\
m_1 a_1 &= -64\text{ N} \\
(78\text{ kg})a_1 &= -64\text{ N} \\
a_1 &= -0.82\text{ m/s}^2 \\
\vec{a}_1 &= 0.82\text{ m/s}^2\text{ [W]}
\end{aligned}
$$

The acceleration of skater 1 is 0.82 m/s^2 [W].

For skater 2,

$$
\begin{aligned}
F_{net} &= F_a \\
m_2 a_2 &= +64\text{ N} \\
(56\text{ kg})a_2 &= +64\text{ N} \\
a_2 &= +1.1\text{ m/s}^2 \\
\vec{a}_2 &= 1.1\text{ m/s}^2\text{ [E]}
\end{aligned}
$$

The acceleration of skater 2 is 1.1 m/s^2 [E].

(b) Since the net force acting on each skater is in a different direction and the two skaters have different masses, the skaters move in opposite directions with different accelerations.

8. Answers may vary. Sample answer:
If you punch a hole into the carton, according to Newton's third law, the inward force will cause a reaction force exerted by the water flowing out of the container. If you punch two holes in the carton at the opposite corners, you will see two jets of water coming out. The suspended carton will start to turn because as water shoots out the holes, the water also pushes back on the carton with equal force. A turbine is formed as the energy of the moving liquid is converted into rotational energy.

9. (a) The female astronaut applies an action force of 16 N [left] on the male astronaut, causing him to accelerate to the left. According to Newton's third law, the male astronaut causes a reaction force on the female astronaut, making her accelerate in the opposite direction, to the right. For each astronaut, the applied force is equal to the net force.
Choose right as positive. So, left is negative.
For the male astronaut,

$$
\begin{aligned}
F_{net} &= F_a \\
m_1 a_1 &= -16\text{ N} \\
(82\text{ kg})a_1 &= -16\text{ N} \\
a_1 &= -0.20\text{ m/s}^2 \\
\vec{a}_1 &= 0.20\text{ m/s}^2\text{ [left]}
\end{aligned}
$$

The acceleration of the male astronaut is 0.20 m/s^2 [left].

For the female astronaut,

$$
\begin{aligned}
F_{net} &= F_a \\
m_2 a_2 &= +16\text{ N} \\
(64\text{ kg})a_2 &= +16\text{ N} \\
a_2 &= +0.25\text{ m/s}^2 \\
\vec{a}_2 &= 0.25\text{ m/s}^2\text{ [right]}
\end{aligned}
$$

The acceleration of the female astronaut is 0.25 m/s^2 [right].

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(b) In this situation, the action force on the female astronaut becomes the reaction force and the reaction force on the male astronaut becomes the action force. So, the answers to part (a) will not change.

(c) The magnitudes of the accelerations will double since each astronaut experiences an action as well as a reaction force of the same magnitude. So the acceleration of the male astronaut will be 0.40 m/s^2 [left] and the acceleration of the female astronaut will be 0.50 m/s^2 [right].

Section 3.5: Using Newton's Laws

Tutorial 1 Practice, page 144

1. (a) Since the objects are not moving, the net force on each object is zero.
To calculate the tension F_{TA} in rope A, you can treat the two objects as one single object and ignore the tension F_{TB} in rope B since F_{TB} is an internal force in this case.

$$\vec{F}_{TA} = (m_A + m_B)\vec{g}$$
$$\vec{F}_{TA} = m_A\vec{g} + m_B\vec{g}$$

For rope B:
$$\vec{F}_{TB} = m_B\vec{g}$$

So, rope A has the greater tension.
(b) Let m_1 be the smallest mass, m_2 the middle mass, and m_3 the largest mass. The three masses are moving with the same acceleration a.
The only force acting on m_3 is the tension F_{TB} in rope B.
$$F_{TB} = m_3 a$$

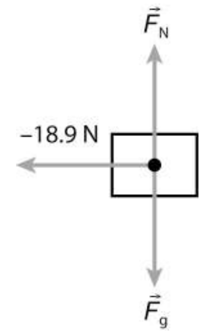
Consider the net force acting on mass m_2.
$$\vec{F}_{TA} - \vec{F}_{TB} = m_2\vec{a}$$
$$\vec{F}_{TA} = m_2\vec{a} + \vec{F}_{TB}$$
So, rope A has the greater tension.
2. (a) The total mass m_T of the locomotive is
$$m_T = 6.4\times10^5\ \text{kg} + 5.0\times10^5\ \text{kg}$$
$$m_T = 1.14\times10^6\ \text{kg}$$

Choose east as positive. So, west is negative.
$$\vec{F}_{net} = m_T\vec{a}$$
$$\begin{aligned} F_{net} &= (1.14\times10^6\ \text{kg})(-0.12\ \text{m/s}^2) \\ &= -1.4\times10^5\ \text{N} \end{aligned}$$
$$\vec{F}_{net} = 1.4\times10^5\ \text{N [W]}$$
The net force on the entire train is 1.4×10^5 N [W].
(b) The magnitude of the tension between the locomotive and the train car equals the magnitude of the net force on the train car.
The mass m_C of the train car is 5.0×10^5 kg.
$$\begin{aligned} F_{net} &= m_C a \\ &= (5.0\times10^5\ \text{kg})(0.12\ \text{m/s}^2) \end{aligned}$$
$$F_{net} = 6.0\times10^4\ \text{N}$$
The magnitude of the tension between the locomotive and the train car is 6.0×10^4 N.

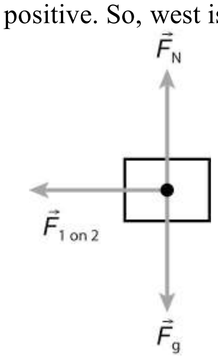
Tutorial 2 Practice, page 146

1. (a) Cart 1 and cart 2 are stuck together so they must move with the same acceleration.
$$\begin{aligned} m_T &= m_1 + m_2 \\ &= 1.2\ \text{kg} + 1.8\ \text{kg} \\ &= 3.0\ \text{kg} \end{aligned}$$

Assume no friction on the carts.
From the FBD of both boxes, the normal force and gravity cancel each other. Choose east as positive. So, west is negative.



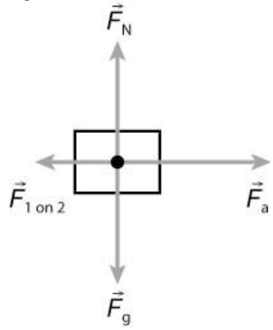
$$\begin{aligned} F_{net} &= m_T a \\ -18.9\ \text{N} &= m_T a \\ -18.9\ \text{N} &= (3.0\ \text{kg})a \\ a &= \frac{-18.9\ \text{N}}{3.0\ \text{kg}} \\ &= -6.3\ \text{m/s}^2 \\ \vec{a} &= 6.3\ \text{m/s}^2\ \text{[W]} \end{aligned}$$
The acceleration of each cart is $6.3\ \text{m/s}^2$ [W].
(b) To calculate $F_{1\text{ on }2}$, draw the FBD for cart 2. Choose east as positive. So, west is negative.



$$\begin{aligned} \vec{F}_{1\text{ on }2} &= \vec{F}_{net} \\ \vec{F}_{1\text{ on }2} &= m_2\vec{a} \\ F_{1\text{ on }2} &= (1.8\ \text{kg})(-6.3\ \text{m/s}^2) \\ &= -11\ \text{N} \\ \vec{F}_{1\text{ on }2} &= 11\ \text{N [W]} \end{aligned}$$
The force that cart 1 exerts on cart 2 is 11 N [W].
(c) If cart 2 were pushed with an equal but opposite force instead of cart 1, the net force on

the two carts would be 18.9 N [E]. The acceleration of each cart would be 6.3 m/s^2 [E].

To calculate $\vec{F}_{1\text{ on }2}$, draw the FBD for cart 2. Choose east as positive. So, west is negative.



$$\begin{aligned}
\vec{F}_a + \vec{F}_{1\text{ on }2} &= \vec{F}_{net} \\
\vec{F}_{1\text{ on }2} &= \vec{F}_{net} - \vec{F}_a \\
F_{1\text{ on }2} &= m_2a - (+18.9\text{ N}) \\
&= (1.8\text{ kg})(+6.3\text{ m/s}^2) - 18.9\text{ N} \\
&= -7.6\text{ N} \\
\vec{F}_{1\text{ on }2} &= 7.6\text{ N [W]}
\end{aligned}$$

The force that cart 1 exerts on cart 2 would be 7.6 N [W].

2. At first, the car moves at constant velocity for 0.50 s before the driver starts to slow down.

Given: $\vec{v}$ = 95 km/h [forward]; Δt = 0.50 s

Required: Δd_1

Analysis: Convert the velocity to SI units. Then use the equation $\Delta d_1 = \vec{v}\Delta t$ to determine the distance travelled. Choose forward as positive. So, backward is negative.

Solution:

$$\begin{aligned}
v &= +95\text{ km/h} \\
&= \left(+95\,\frac{\cancel{\text{km}}}{\cancel{\text{h}}}\right)\left(\frac{1\,\cancel{\text{h}}}{60\,\cancel{\text{min}}}\right)\left(\frac{1\,\cancel{\text{min}}}{60\text{ s}}\right)\left(\frac{1000\text{ m}}{1\,\cancel{\text{km}}}\right) \\
v &= +26.4\text{ m/s} \\
\vec{v} &= 26.4\text{ m/s [forward] (one extra digit carried)}
\end{aligned}$$

$$\begin{aligned}
\Delta d_1 &= v\Delta t \\
&= (+26.4\text{ m/s})(0.5\text{ s}) \\
\Delta d_1 &= +13.2\text{ m (one extra digit carried)}
\end{aligned}$$

Then, the car brakes with a net force of 2400 N [backward] for 2.0 s.

Given: m = 1200 kg; $\vec{F}_{net}$ = 2400 N [backward]; Δt = 2.0 s; $\vec{v}$ = 26.4 m/s [forward]

Required: Δd_2

Analysis: First calculate the acceleration of the car using $\vec{F}_{net} = m\vec{a}$. Use $\Delta d_2 = \vec{v}\Delta t + \frac{1}{2}\vec{a}\Delta t^2$ to calculate the distance travelled. Choose forward as positive. So, backward is negative.

Solution:

$$\begin{aligned}
F_{net} &= ma \\
-2400\text{ N} &= (1200\text{ kg})a \\
a &= \frac{-2400\text{ N}}{1200\text{ kg}} \\
a &= -2.0\text{ m/s}^2
\end{aligned}$$

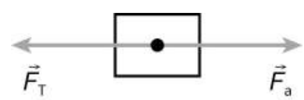
$$\begin{aligned}
\Delta d_2 &= v\Delta t + \frac{1}{2}a\Delta t^2 \\
&= (+26.4\text{ m/s})(2.0\text{ s}) + \frac{1}{2}(-2.0\text{ m/s}^2)(2.0\text{ s})^2 \\
\Delta d_2 &= +48.8\text{ m (one extra digit carried)}
\end{aligned}$$

Total distance travelled: 13.2 m + 48.8 m = 62 m

Statement: The total distance travelled by the car in 2.5 s is 62 m.

Section 3.5 Questions, page 147

1. (a) Draw a FBD of the rope.



The magnitude of the tension equals the magnitude of the applied force.

$$\begin{aligned}
F_T &= F_a \\
F_T &= 65\text{ N}
\end{aligned}$$

The tension in the rope is 65 N.

(b) Use the same FBD of the rope in part (a). The tension in the rope is 65 N.

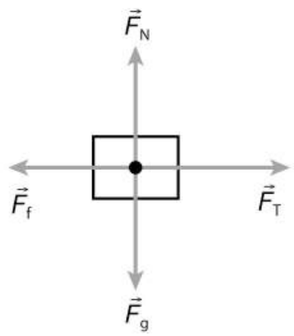
(c) Since there is no external force acting on the 12 kg object, the magnitude of the tension equals the magnitude of the applied force, which is 65 N.

2. (a) Given: m_1 = 72 kg; a = 2.0 m/s^2 [forward]; $\vec{F}_f$ = 120 N [backward]

Required: F_T

Analysis: Draw a FBD for the sled. Find F_T by adding all horizontal forces. Choose forward as positive. So, backward is negative.

Solution:



$$
\begin{aligned}
F_{\text{net}} &= F_{\text{T}} + F_{\text{f}} \\
m_1 a &= F_{\text{T}} + (-120\ \text{N}) \\
(72\ \text{kg})(+2.0\ \text{m/s}^2) &= F_{\text{T}} - 120\ \text{N} \\
F_{\text{T}} &= +260\ \text{N}
\end{aligned}
$$

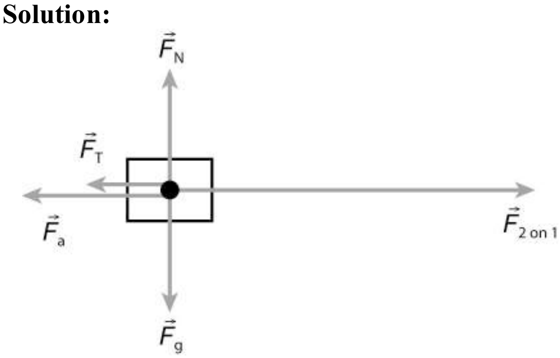
Statement: The tension in the rope is 260 N.

(b) Given: m_2 = 450 kg; a = 2.0 m/s^2 [forward]; $\vec{F}_{\text{T}}$ = 260 N [backward]; $\vec{F}_{\text{a}}$ = 540 N [backward]

Required: $\vec{F}_{2\text{ on }1}$

Analysis: Draw a FBD for the snowmobile. Find $\vec{F}_{2\text{ on }1}$ by adding all horizontal forces. Choose forward as positive. So, backward is negative.

Solution:



$$
\begin{aligned}
\vec{F}_{\text{net}} &= \vec{F}_{2\text{ on }1} + \vec{F}_{\text{a}} + \vec{F}_{\text{T}} \\
m_2 a &= F_{2\text{ on }1} + (-540\ \text{N}) + (-260\ \text{N}) \\
(450\ \text{kg})(+2.0\ \text{m/s}^2) &= F_{2\text{ on }1} - 540\ \text{N} - 260\ \text{N} \\
F_{2\text{ on }1} &= +1700\ \text{N} \\
\vec{F}_{2\text{ on }1} &= 1700\ \text{N [forward]}
\end{aligned}
$$

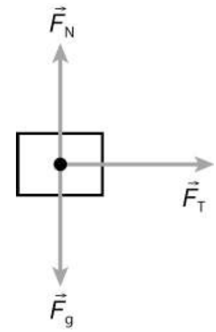
Statement: The force exerted by the snowmobile on the sled is 1700 N [forward].

3. Given: m = 70 kg; Δd = 15 m; $\vec{F}_{\text{T}}$ (rope on person) = 35 N [forward]

Required: Δt

Analysis: Draw a FBD for the skater reeling in the rope. First, find the acceleration of the person using $\vec{F}_{\text{net}} = m\vec{a}$. Use $\Delta d = \vec{v}\Delta t + \frac{1}{2}\vec{a}\Delta t^2$ to calculate the time it takes the two skaters to meet. Choose forward as positive. So, backward is negative.

Solution:



$$
\begin{aligned}
F_{\text{net}} &= F_{\text{T}} \\
ma &= +35\ \text{N} \\
(70\ \text{kg})a &= +35\ \text{N} \\
a &= +0.50\ \text{m/s}^2 \\
\vec{a} &= 0.50\ \text{m/s}^2\ \text{[forward]}
\end{aligned}
$$

At the starting position, v = 0 m/s.

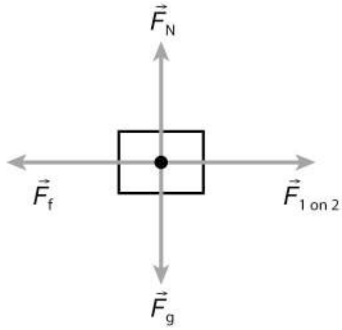
$$
\begin{aligned}
\Delta d &= v\Delta t + \frac{1}{2}a\Delta t^2 \\
\Delta d &= \frac{1}{2}a\Delta t^2 \\
\Delta t^2 &= \frac{2\Delta d}{a} \\
\Delta t &= \sqrt{\frac{2\Delta d}{a}} \\
&= \sqrt{\frac{2(15\ \cancel{\text{m}})}{0.50\ \cancel{\text{m}}/\text{s}^2}} \\
\Delta t &= 7.7\ \text{s}
\end{aligned}
$$

Statement: It takes 7.7 s for the skaters to meet.

4. (a) Given: m_2 = 820 kg; $\vec{F}_{\text{f}}$ = 650 N [backward]; $\vec{F}_{\text{net}}$ = 0 N (at constant velocity)

Required: $\vec{F}_{1\text{ on }2}$

Analysis: Draw a FBD of the trailer with mass m_2. Find $\vec{F}_{1\text{ on }2}$ by adding all horizontal forces. Choose forward as positive. So, backward is negative.



Solution:

$$\vec{F}_{1\text{ on }2} + \vec{F}_f = 0$$
$$\vec{F}_{1\text{ on }2} = -\vec{F}_f$$
$$F_{1\text{ on }2} = -(-650\text{ N})$$
$$F_{1\text{ on }2} = +650\text{ N}$$
$$\vec{F}_{1\text{ on }2} = 650\text{ N [forward]}$$

Statement: The force that the car exerts on the trailer is 650 N [forward].

(b) Since the trailer is moving at constant velocity, the net force $\vec{F}_{net}$ on the trailer is 0 N.

The forces acting on the trailer are the same as in part (a). Therefore, the force that the car exerts on the trailer is 650 N [forward].

(c) Use the same FBD in part (a).
For the trailer accelerating at 1.5 m/s^2 [forward], $\vec{F}_{net} = m_2\vec{a}$. Find $\vec{F}_{1\text{ on }2}$ by adding all horizontal forces. Choose forward as positive. So, backward is negative.

$$F_{1\text{ on }2} + F_f = F_{net}$$
$$F_{1\text{ on }2} + (-650\text{ N}) = m_2a$$
$$F_{1\text{ on }2} - 650\text{ N} = (820\text{ kg})(+1.5\text{ m/s}^2)$$
$$F_{1\text{ on }2} = +1900\text{ N}$$
$$\vec{F}_{1\text{ on }2} = 1900\text{ N [forward]}$$

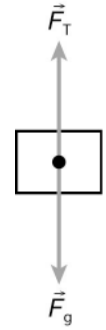
The force that the car exerts on the trailer is 1900 N [forward].

(d) Use the same FBD in part (a).
For the trailer accelerating at 1.2 m/s^2 [backward], $F_{net} = m_2a$. Find $F_{1\text{ on }2}$ by adding all horizontal forces. Choose forward as positive. So, backward is negative.

$$F_{1\text{ on }2} + F_f = F_{net}$$
$$F_{1\text{ on }2} + (-650\text{ N}) = m_2a$$
$$F_{1\text{ on }2} - 650\text{ N} = (820\text{ kg})(-1.2\text{ m/s}^2)$$
$$F_{1\text{ on }2} = -330\text{ N}$$
$$\vec{F}_{1\text{ on }2} = 330\text{ N [backwards]}$$

The force that the car exerts on the trailer is 330 N [backward].

5. Draw a FBD of the person climbing up the rope. Choose up as positive. So, down is negative.



Calculate the magnitude of the maximum tension in the rope.

$$\vec{F}_T = m_r\vec{g}$$
$$F_T = (120\text{ kg})(9.8\text{ m/s}^2)$$
$$F_T = 1176\text{ N (two extra digits carried)}$$

From the FBD, the tension on the person is upward. Calculate the acceleration of the person.

$$F_{net} = F_T + F_g$$
$$ma = +1176\text{ N} + mg$$
$$(85\text{ kg})a = +1176\text{ N} + (85\text{ kg})(-9.8\text{ m/s}^2)$$
$$a = +4.04\text{ m/s}^2$$
$$\vec{a} = 4.04\text{ m/s}^2\text{ [up]}$$

Use $\Delta d = v\Delta t + \frac{1}{2}a\Delta t^2$ to calculate the time to climb the entire length of the rope.
At the starting position, $v = 0$ m/s.

$$\Delta d = v\Delta t + \frac{1}{2}a\Delta t^2$$
$$\Delta d = \frac{1}{2}a\Delta t^2$$
$$\Delta t^2 = \frac{2\Delta d}{a}$$
$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$
$$= \sqrt{\frac{2(12.0\ \cancel{\text{m}})}{4.04\ \cancel{\text{m}}/\text{s}^2}}$$
$$\Delta t = 2.4\text{ s}$$

The minimum time required to climb the entire length of the rope is 2.4 s.

6. Let $\vec{F}_{T1}$ = tension between force sensors 1 and 2, $\vec{F}_{T2}$ = tension between force sensors 3 and 4, and $\vec{F}_{T3}$ = tension between force sensors 5 and 6.

(a) Consider forces on cart 1 with mass 2.2 kg. Choose forward as positive. So, backward is negative.

$$F_{\text{net}} = F_{\text{T1}}$$
$$m_1 a = +3.3 \text{ N}$$
$$(2.2 \text{ kg})a = +3.3 \text{ N}$$
$$a = +1.5 \text{ m/s}^2$$
$$\vec{a} = 1.5 \text{ m/s}^2 \text{ [forward]}$$

The acceleration of all the carts is 1.5 m/s^2 [forward].

(b) Use $\vec{F}_{\text{T1}}$ to calculate $\vec{F}_{\text{T2}}$. Consider forces on cart 2 with mass 2.5 kg. Choose forward as positive. So, backward is negative.

$$F_{\text{net}} = F_{\text{T1}} + F_{\text{T2}}$$
$$m_2 a = -3.3 \text{ N} + F_{\text{T2}}$$
$$(2.5 \text{ kg})(+1.5 \text{ m/s}^2) = -3.3 \text{ N} + F_{\text{T2}}$$
$$F_{\text{T2}} = +7.1 \text{ N}$$
$$\vec{F}_{\text{T2}} = 7.1 \text{ N [forward]}$$

Use $\vec{F}_{\text{T2}}$ to calculate $\vec{F}_{\text{T3}}$.

Consider forces on cart 3 with mass 1.8 kg.

$$F_{\text{net}} = F_{\text{T2}} + F_{\text{T3}}$$
$$m_3 a = -7.1 \text{ N} + F_{\text{T3}}$$
$$(1.8 \text{ kg})(+1.5 \text{ m/s}^2) = -7.1 \text{ N} + F_{\text{T3}}$$
$$F_{\text{T3}} = +9.8 \text{ N}$$
$$\vec{F}_{\text{T3}} = 9.8 \text{ N [forward]}$$

The reading on force sensor 1 is the same as the reading on force sensor 2, which is 3.3 N.
The reading on force sensor 2 is given as 3.3 N.
The reading on force sensor 3 is 7.1 N.
The reading on force sensor 4 is the same as the reading on force sensor 3, which is 7.1 N.
The reading on force sensor 5 is 9.8 N.
The reading on force sensor 6 is the same as the reading on force sensor 5, which is 9.8 N.

(c) The total mass m_{T} of the carts is:

$$m_{\text{T}} = 2.2 \text{ kg} + 2.5 \text{ kg} + 1.8 \text{ kg}$$
$$m_{\text{T}} = 6.5 \text{ kg}$$

Consider forces on force sensor 6. Choose forward as positive. So, backward is negative.

$$F_{\text{net}} = F_{\text{a}} + F_{\text{T3}}$$
$$m_{\text{T}} a = F_{\text{a}} + (-9.8 \text{ N})$$
$$(6.5 \text{ kg})(+1.5 \text{ m/s}^2) = F_{\text{a}} + (-9.8 \text{ N})$$
$$F_{\text{a}} = +20 \text{ N}$$
$$\vec{F}_{\text{a}} = 20 \text{ N [forward]}$$

The force applied to force sensor 6 is 20 N [forward].

7. The only force acting on car 2 is the tension F_{T2} between car 1 and car 2.

$$F_{\text{T2}} = m_2 a$$

F_{T1} is the tension between car 1 and the locomotive. Consider the net force acting on car 1.

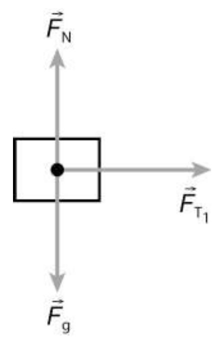
$$F_{\text{T1}} - F_{\text{T2}} = m_1 a$$
$$F_{\text{T1}} = m_1 a + F_{\text{T2}}$$

So, F_{T1} is always greater than F_{T2}.

Given: $m_1 = 5.0 \times 10^5$ kg; $m_2 = 3.6 \times 10^5$ kg; $m = 6.4 \times 10^5$ kg; $F_{\text{T1}} = 2.0 \times 10^5$ N

Required: $\vec{a}$

Analysis: Since car 1 and car 2 are locked together, they can be treated as one single object. Draw a FBD of this object. Use the equation $\vec{F}_{\text{net}} = m_{\text{T}}\vec{a}$ to find the maximum acceleration. Choose forward as positive. So, backward is negative.



Solution: The total mass m_{T} of the two cars is:

$$m_{\text{T}} = 5.0 \times 10^5 \text{ kg} + 3.6 \times 10^5 \text{ kg}$$
$$= 8.6 \times 10^6 \text{ kg}$$

$$F_{\text{net}} = F_{\text{T1}}$$
$$m_{\text{T}} a = +2.0 \times 10^5 \text{ N}$$
$$(8.6 \times 10^5 \text{ kg})a = +2.0 \times 10^5 \text{ N}$$
$$a = +0.23 \text{ m/s}^2$$
$$\vec{a} = 0.23 \text{ m/s}^2 \text{ [forward]}$$

Statement: The maximum acceleration of the train that does not break the locking mechanism is 0.23 m/s^2 [forward].

8. (a) Given: m = 68 kg; F_{net} = 92 N; Δt_1 = 8.2 s

Required: $\vec{v}_1$

Analysis: First find the acceleration using the equation $\vec{F}_{net} = m\vec{a}$. Use $\vec{a} = \frac{\vec{v}_1 - \vec{v}_i}{\Delta t}$ to calculate $\vec{v}_1$.

Choose forward as positive. So, backward is negative.

Solution:

$$\begin{aligned} F_{net} &= m_1 a_1 \\ (68\ \text{kg})a_1 &= +92\ \text{N} \\ a_1 &= +1.35\ \text{m/s}^2\ \text{(one extra digit carried)} \end{aligned}$$

Since $v_i = 0$,

$$\begin{aligned} \vec{a}_1 &= \frac{\vec{v}_1}{\Delta t_1} \\ v_1 &= a_1\Delta t_1 \\ &= (+1.35\ \text{m/s}^2)(8.2\ \text{s}) \\ &= +11\ \text{m/s} \\ \vec{v}_1 &= 11\ \text{m/s [forward]} \end{aligned}$$

Statement: The speed of the skier is 11 m/s.

(b) Given: m = 68 kg; $\vec{v}_1$ = 11 m/s [forward]; Δt_2 = 3.5 s; $\vec{F}_{net}$ = 22 N [backward]

Required: $\vec{v}_2$

Analysis: First find the acceleration using the equation $\vec{F}_{net} = m\vec{a}$. Use $\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$ to calculate $\vec{v}_2$.

Choose forward as positive. So, backward is negative.

Solution:

$$\begin{aligned} F_{net} &= m_2 a_2 \\ (68\ \text{kg})a_2 &= -22\ \text{N} \\ a_2 &= -0.324\ \text{m/s}^2\ \text{(one extra digit carried)} \\ a_2 &= \frac{v_2 - v_1}{\Delta t_2} \\ v_2 - v_1 &= a_2\Delta t_2 \\ v_2 - (+11\ \text{m/s}) &= \left(-0.324\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\right)(3.5\ \cancel{\text{s}}) \\ v_2 &= +10\ \text{m/s} \\ \vec{v}_2 &= 10\ \text{m/s [forward]} \end{aligned}$$

Statement: The speed of the skier is 10 m/s.

(c) Use $\Delta d = v\Delta t + \frac{1}{2}a\Delta t^2$ to calculate the distance travelled. Choose forward as positive. So, backward is negative.

For part (a), at the starting position, v = 0 m/s.

$$\begin{aligned} \Delta d_1 &= \frac{1}{2}a_1\Delta t_1^2 \\ &= \frac{1}{2}(+1.35\ \text{m/s}^2)(8.2\ \text{s})^2 \\ \Delta d_1 &= +45.4\ \text{m (one extra digit carried)} \end{aligned}$$

For part (b), at the starting position, v = 11 m/s [forward].

$$\begin{aligned} \Delta d_2 &= v\Delta t_2 + \frac{1}{2}a_2\Delta t_2^2 \\ &= \left(+11\ \frac{\text{m}}{\cancel{\text{s}}}\right)(3.5\ \cancel{\text{s}}) + \frac{1}{2}\left(-0.324\ \frac{\text{m}}{\cancel{\text{s}^2}}\right)(3.5\ \cancel{\text{s}})^{\cancel{2}} \\ \Delta d_2 &= +36.5\ \text{m (one extra digit carried)} \end{aligned}$$

$$\begin{aligned} \Delta d &= \Delta d_1 + \Delta d_2 \\ &= 45.4\ \text{m} + 36.5\ \text{m} \\ &= 81.9\ \text{m} \\ \Delta d &= 82\ \text{m} \end{aligned}$$

Statement: The total distance travelled by the skier before coming to rest is 82 m.

Section 3.6: Physics Journal
Section 3.6 Questions, page 149

Answers may vary. Sample answers:

1. The statement means that the work of physicists is often based on the contributions and accomplishments of physicists in the past. For example, Einstein’s work on relativity followed a path very similar to that of Newton’s laws. Einstein’s special theory of relativity was an extension of Newton’s first law and Einstein’s theory of general relativity was an extension of Newton’s second and third laws. Hawking’s work on topics such as black holes and the nature of gravity deals mainly with extending the concepts explored by Newton and Einstein.

2. Newton’s laws of motion explain the forces acting on a person’s body during a car collision, inside a car making a sharp turn in the road, or during driving on icy highways. These explanations led to the requirements of safety equipment such as headrests, seat belts, and air bags to be installed in the cars we drive today.

3. Both Newton and Einstein put forward a theory of mechanics and a theory of gravity. Einstein was able to base his theory on the mathematical theory constructed by Riemann, while Newton developed his own mathematical machinery. Therefore, it is more appropriate to place Newton ahead of Einstein as the greatest figure in mathematical physics.

4. Topics could include Newton’s law of universal gravitation or a derivation of Kepler’s laws of planetary motion. Students’ reports should include a description of the topic and a brief explanation of its significance and applications.

Chapter 3 Investigations

Investigation 3.3.1: Investigating Newton's Second Law, page 151

Analyze and Evaluate

(a) The relationships being tested are net force versus acceleration, acceleration versus total mass, and acceleration versus the inverse of total mass.

(b) $\vec{F}_{\text{net}} = m_{\text{total}}\vec{a}$

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

Trial 1:

$$\vec{a}_1 = \frac{980.0 \text{ N}}{1.40 \text{ kg}}$$

$$\vec{a}_1 = 7.00 \times 10^2 \text{ m/s}^2$$

Trial 2:

$$\vec{a}_2 = \frac{1960.0 \text{ N}}{1.40 \text{ kg}}$$

$$\vec{a}_2 = 1.40 \times 10^3 \text{ m/s}^2$$

Trial 3:

$$\vec{a}_3 = \frac{2940.0 \text{ N}}{1.40 \text{ kg}}$$

$$\vec{a}_3 = 2.10 \times 10^3 \text{ m/s}^2$$

Trial 4:

$$\vec{a}_4 = \frac{2940.0 \text{ N}}{2.40 \text{ kg}}$$

$$\vec{a}_4 = 1.23 \times 10^3 \text{ m/s}^2$$

Trial 5:

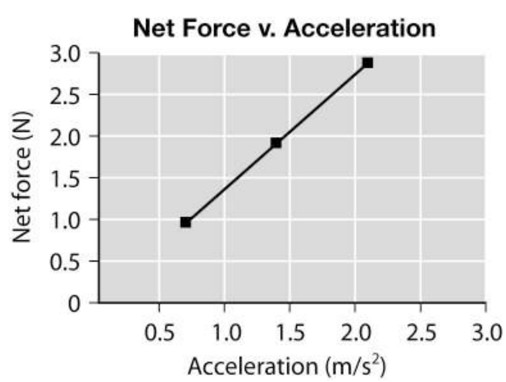
$$\vec{a}_5 = \frac{2940.0 \text{ N}}{3.40 \text{ kg}}$$

$$\vec{a}_5 = 8.64 \times 10^2 \text{ m/s}^2$$

(c) The ratio of the net force to the total mass represents the acceleration of the cart. This makes sense since the net force acting on an object is the product of the object's mass and its acceleration. The ratio of the net force to the total mass as obtained by the motion sensor are

Step 4: 701.00 m/s^2
Step 5: 1402.00 m/s^2
Step 6: 2103.00 m/s^2
Step 8: 1226.02 m/s^2
Step 9: 865.21 m/s^2

(d)

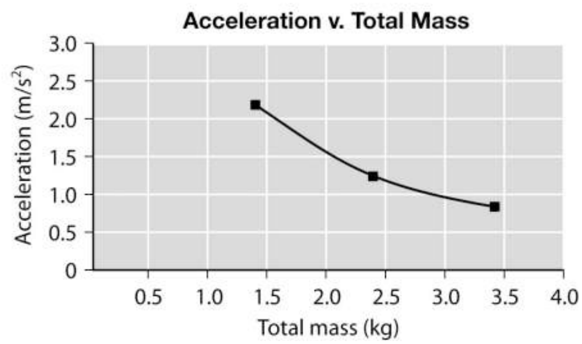


The graph shows that for a constant mass, as the acceleration of an object increases, then the net force increases, that is, the acceleration and net force are directionally proportional.
The slope of the graph represents the total mass of the object.

$$\begin{aligned} \text{mass} &= \text{slope} \\ &= \frac{\Delta F}{\Delta a} \\ &= \frac{1960 \text{ N} - 980 \text{ N}}{1.40 \times 10^3 \text{m/s}^2 - 7.00 \times 10^2 \text{ m/s}^2} \\ &= \frac{980 \text{ N}}{7.00 \times 10^2 \text{ m/s}^2} \\ \text{mass} &= 1.4 \text{ kg} \end{aligned}$$

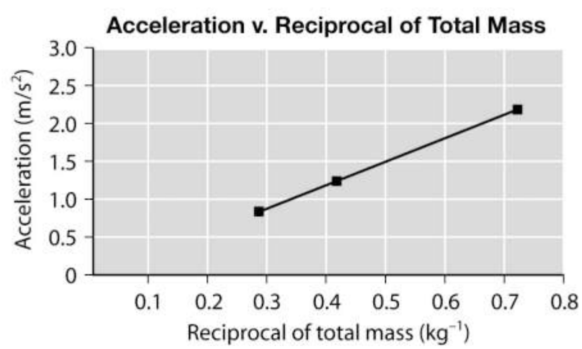
The total mass of the object is 1.4 kg.

(e)



The graph indicates that as the total mass of an object increases, its acceleration decreases, that is, the total mass of an object and its acceleration are inversely proportional.

(f)



The graph indicates that as the inverse of the total mass of an object increases, its acceleration increases, that is, the inverse of the total mass and acceleration are directionally proportional.
The slope of the graph represents the net force on the cart.

(g) • If the total mass of a cart is constant, then as the net force on the cart increases so does its acceleration.
• If the net force on the cart is constant, then as the total mass of the cart increases, its acceleration decreases.
(h) Answers may vary. Sample answer:
My hypothesis was based on the information in the student textbook. My hypothesis was accurate.
(i) Some possible sources of error in this investigation are the masses of the objects loaded onto the cart are not exact, the surface the cart rolls across is a source of friction, and the pulley does not move freely. To reduce or avoid the errors, you could measure the mass of the objects before starting the investigation, you could clean the surface the cart rolls over each time you carry out a step in the investigation, and you could make sure the pulley rope is new or not stuck in the pulley wheel.

Apply and Extend

(j) Friction will cause the cart to slow down at some point. When graphing acceleration versus mass, there will be a very small section with a slope of zero near the origin of the graph. This small region represents an acceleration of zero.
(k) A graph of net force versus acceleration must pass through the origin when the total mass is constant because when the net force acting on an object is zero, the acceleration of that object is zero, that is, it will be stationary.
(l) A graph of the acceleration versus the reciprocal of the total mass of an object must pass through the origin when the net force acting on the object is constant because when the acceleration is zero then the net force must equal zero.
(m) The greater the total mass of the airplane, the greater the force needed to accelerate the airplane. This would mean more fuel required to fly the airplane. Commercial airlines are limiting the number of pieces and the mass of luggage to cut down on fuel costs.

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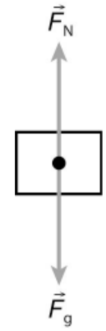
Chapter 3 Review, pages 154–159

Knowledge

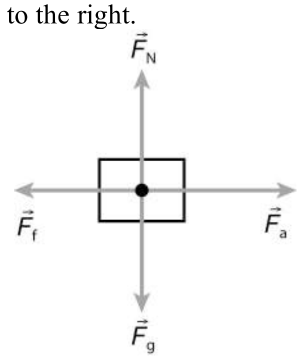
1. (c)
2. (a)
3. (d)
4. (d)
5. (d)
6. (c)
7. (b)
8. (c)
9. False. One newton is equal to 1 kg·m/s^2.
10. False. A *normal* force is a perpendicular force acting on an object that is exerted by the surface with which it is in contact.
11. True
12. True
13. False. To determine the net force, you *do* need to consider the direction of each force acting on an object.
14. False. An object with less mass has *less* inertia. An object with *more* mass has more inertia.
15. True
16. True
17. False. Newton's third law states that for every action force there is a simultaneous reaction force of *equal* magnitude in the opposite direction.
18. (a) (iii)
(b) (v)
(c) (ii)
(d) (i)
(e) (iv)
19. The acceleration due to gravity is 9.8 m/s^2.
20. Answers may vary. Sample answer:
An object that has a lot of inertia has a much stronger resistance to changes in motion. If it is at rest, then it will require more force to start moving it. If it is in motion, then it will require more force to change that motion. Similarly, an object with less inertia has less resistance to changes in motion.
21. Answers may vary. Sample answer:
Newton's third law states that for any force that acts on an object, whether a push or a pull, in contact or at a distance, that object will exert a force of equivalent strength in the opposite direction. For example, if a water bottle sits on a desk, the water bottle exerts a downward force on the desk and the desk exerts an equivalent upward force on the water bottle.

Understanding

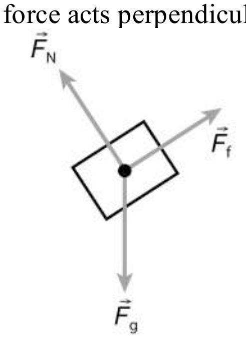
22.



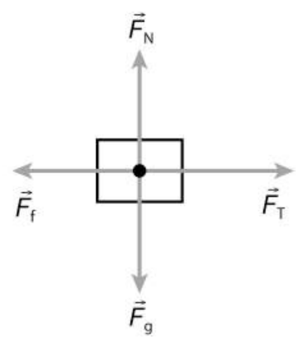
23. The frictional force acting to the left is missing. It is equal in magnitude to the applied force acting to the right.



24. The FBD is incomplete. The normal force exerted by the surface of the ramp on the block is missing. This force acts perpendicular to the ramp.



25. (a)



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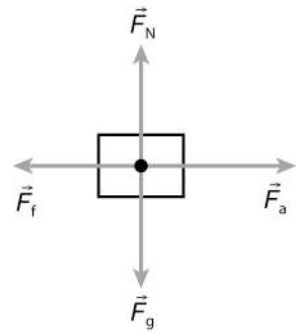
(b)



(c) Answers may vary. Sample answer:
The only difference between the FBDs in parts (a) and (b) is the label for the force the student puts on the box (a push versus a tension force). The direction of each arrow depends on the direction you choose to start drawing a FBD. If you choose right for the direction of the pulling force in (a) and you choose right for the direction of the pushing force in (b), you will end up with the same force diagram for the two different situations.

26. Choose force northward as positive. So, force southward is negative.

Given: $\vec{F}_{northward} = 37\ 850$ N [northward];
$\vec{F}_{southward} = 850$ N [southward]

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = \vec{F}_{northward} + \vec{F}_{southward}$

Solution:
$\vec{F}_{net} = \vec{F}_{northward} + \vec{F}_{southward}$
$F_{net} = +37\ 850\text{ N} + (-850\text{ N})$
$F_{net} = +37\ 000\text{ N}$

Statement: The net horizontal force on the plane is 37 000 N [northward].

27. Choose east as positive. So, west is negative.

Given: $\vec{F}_{downward1} = 35\ 000$ N [westward];
$\vec{F}_{downward2} = 1200$ N [westward]

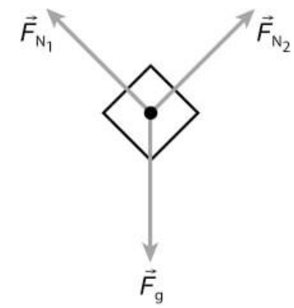
Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = \vec{F}_{downward1} + \vec{F}_{downward2}$

Solution:
$\vec{F}_{net} = \vec{F}_{downward} + \vec{F}_{downward}$
$= -35\ 000\text{ N} + (-1200\text{ N})$
$F_{net} = -36\ 200\text{ N}$
$\vec{F}_{net} = 36\ 200$ N [westward]

Statement: The net horizontal force on the plane is 36 200 N [westward].

28.



29. Answers may vary. Sample answer:
Newton's first law implies that since the object is at rest, the net force on the object must be zero. So, the normal force pushing upward on the book must be equal to the force of gravity pulling downward. Otherwise, the book would move either upward or downward.

30. Choose right as positive. So, left is negative.
Since the rope is stationary, $\vec{F}_{net} = 0$.

Given: $\vec{F}_{net} = 0$; $\vec{F}_{R1} = 84$ N [right];
$\vec{F}_{R2} = 86$ N [right]; $\vec{F}_{L1} = 83$ N [left]

Required: the second child's force of pull, $\vec{F}_{L2}$

Analysis: $\vec{F}_{net} = \vec{F}_{R1} + \vec{F}_{R2} + \vec{F}_{L1} + \vec{F}_{L2}$
$\vec{F}_{net} = \vec{F}_{R1} + \vec{F}_{R2} + \vec{F}_{L1} + \vec{F}_{L2}$
$F_{net} = F_{R1} + F_{R2} + F_{L1} + F_{L2}$
$0 = +84\text{ N} + 86\text{ N} + (-83\text{ N}) + F_{l2}$
$F_{L2} = -87\text{ N}$
$\vec{F}_{L2} = 87\text{ N}$

Statement: The second child on the left is pulling with a force of 87 N [left].

31. If the box does not move, the net force on the box is zero. So, the magnitude of the frictional force exerted by the ground on the box is 20 N.

32. (a) According to Newton's second law, the acceleration of an object is directly proportional to the net force and inversely proportional to the mass of the object. If the same force acts on two cars with different masses, the car with less mass will have a greater acceleration.

(b) Since the mass of the box is decreasing and the person continues to pull with a constant force, the acceleration of the cart will increase.

33. (a) Given: $m = 69$ kg; $\vec{a} = 2.1\text{ m/s}^2$ [forward]

Required: $\vec{F}_{net}$

Analysis: According to Newton's second law,
$\vec{F}_{net} = m\vec{a}$

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$= (69\text{ kg})(2.1\text{ m/s}^2)\text{ [forward]}$$
$$\vec{F}_{net} = 140\text{ N [forward]}$$

Statement: The net force is 140 N [forward].

(b) Since the basketball is falling due to gravity, $\vec{a} = \vec{g} = 9.8\text{ m/s}^2$ [down].

Given: $m = 620\text{ g} = 0.62\text{ kg}$; $\vec{g} = 9.8\text{ m/s}^2$ [down]

Required: $\vec{F}_{net}$

Analysis: According to Newton's second law, $\vec{F}_{net} = m\vec{a} = m\vec{g}$

Solution:

$$\vec{F}_{net} = m\vec{g}$$
$$= (0.62\text{ kg})(9.8\text{ m/s}^2)\text{ [down]}$$
$$\vec{F}_{net} = 6.1\text{ N [down]}$$

Statement: The net force is 6.1 N [down].

34. (a) Given: $m = 260$ kg; $\vec{F}_{net} = 468$ N [N]

Required: $\vec{a}$

Analysis: According to Newton's second law, $\vec{F}_{net} = m\vec{a}$

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$= \frac{468\text{ N [N]}}{260\text{ kg}}$$
$$\vec{a} = 1.8\text{ m/s}^2\text{ [N]}$$

Statement: The net acceleration of the boat is 1.8 m/s^2 [N].

(b) Given: $m = 70.0$ kg; $\vec{F}_{net} = 236$ N [up]

Required: $\vec{a}$

Analysis: According to Newton's second law, $\vec{F}_{net} = m\vec{a}$

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$= \frac{236\text{ N [up]}}{70.0\text{ kg}}$$
$$\vec{a} = 3.37\text{ m/s}^2\text{ [up]}$$

Statement: The net acceleration of the skydiver is 3.37 m/s^2 [up].

35. Given: $m = 10$ kg; $F_{net} = 40$ N

Required: a

Analysis: According to Newton's second law, $F_{net} = ma$

Solution:
The net force on the box acts in the opposite direction of the frictional force.

$$F_{net} = ma$$
$$a = \frac{F_{net}}{m}$$
$$= \frac{40\text{ N}}{10\text{ kg}}$$
$$a = 4\text{ m/s}^2$$

Statement: The box slows down with an acceleration of 4 m/s^2 [opposite direction of motion].

36. Given: $m = 175\text{ g} = 0.175$ kg; $a = 1.5\text{ m/s}^2$

Required: $\vec{F}_f$

Analysis: According to Newton's second law, $\vec{F}_f = m\vec{a}$

Solution:
The frictional force on the puck acts in the opposite direction of the puck's motion.

$$\vec{F}_f = m\vec{a}$$
$$F_f = (0.175\text{ kg})(1.5\text{ m/s}^2)$$
$$F_f = 0.26\text{ N}$$

Statement: The frictional force acting on the puck is 0.26 N [opposite direction of motion].

37. Given: $F_{net} = 800\ 000$ N; $\vec{a} = 8.0\text{ m/s}^2$ [forward]

Required: m

Analysis: For the airplane, $\vec{F}_{net} = m\vec{a}$.

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$m = \frac{\vec{F}_{net}}{\vec{a}}$$
$$= \frac{800\ 000\text{ N}}{8\text{ m/s}^2}$$
$$m = 100\ 000\text{ kg}$$

Statement: The mass of the plane is 100 000 kg.

38. Given: $\vec{F}_{net} = 1.80 \times 10^3$ N [S]; $m = 145\text{ g} = 0.145$ kg

Required: $\vec{a}$

Analysis: For the baseball, $\vec{F}_{net} = m\vec{a}$.

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$= \frac{1.80 \times 10^3\text{ N [S]}}{0.145\text{ kg}}$$
$$\vec{a} = 1.24 \times 10^4\text{ m/s}^2\text{ [S]}$$

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Statement: The acceleration of the ball is 1.24×10^4 m/s^2 [S].

39. (a) Given: $m_1 = 2.3$ kg; $m_2 = 1.7$ kg; $g = 9.8$ m/s^2

Required: $\vec{a}$

Analysis: For the cart, $\vec{F}_{\text{net}} = \vec{F}_{\text{T}}$.

$m_1\vec{a} = \vec{F}_{\text{T}}$ (Equation 1)

For the hanging object, $\vec{F}_{\text{net}} = \vec{F}_{\text{g}} - \vec{F}_{\text{T}}$.

$m_2\vec{a} = m_2\vec{g} - \vec{F}_{\text{T}}$ (Equation 2)

Solution: Add the equations to solve for a.

$$m_1\vec{a} + m_2\vec{a} = \vec{F}_{\text{T}} + m_2\vec{g} - \vec{F}_{\text{T}}$$
$$(m_1 + m_2)\vec{a} = m_2\vec{g}$$
$$\vec{a} = \frac{m_2\vec{g}}{m_1 + m_2}$$
$$a = \frac{(1.7\ \cancel{\text{kg}})(9.8\ \text{m/s}^2)}{2.3\ \cancel{\text{kg}} + 1.7\ \cancel{\text{kg}}}$$
$$a = 4.2\ \text{m/s}^2$$

Statement: The acceleration of the cart is 4.2 m/s^2 [right].

(b) Given: $m_1 = 2.3$ kg; $m_2 = 1.7$ kg; $g = 9.8$ m/s^2 ; $F_{\text{f}} = 0.6$ N

Required: $\vec{a}$

Analysis: For the cart, $\vec{F}_{\text{net}} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}}$.

$m_1\vec{a} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}}$ (Equation 1)

For the hanging object, $\vec{F}_{\text{net}} = \vec{F}_{\text{g}} - \vec{F}_{\text{T}}$.

$m_2\vec{a} = m_2\vec{g} - \vec{F}_{\text{T}}$ (Equation 2)

Solution: Add the equations to solve for $\vec{a}$.

$$m_1\vec{a} + m_2\vec{a} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}} + m_2\vec{g} - \vec{F}_{\text{T}}$$
$$(m_1 + m_2)\vec{a} = m_2\vec{g} - \vec{F}_{\text{f}}$$
$$\vec{a} = \frac{m_2\vec{g} - \vec{F}_{\text{f}}}{m_1 + m_2}$$
$$a = \frac{(1.7\ \cancel{\text{kg}})(9.8\ \text{m/s}^2) - 0.6\ \text{N}}{2.3\ \cancel{\text{kg}} + 1.7\ \cancel{\text{kg}}}$$
$$a = 4.0\ \text{m/s}^2$$

Statement: The acceleration of the cart is 4.0 m/s^2 [right].

40. (a) Given: $m_1 = 1.8$ kg; $g = 9.8$ m/s^2; $a = 2.5$ m/s^2

Required: m_2, mass of the attached object

Analysis: For the cart, $\vec{F}_{\text{net}} = \vec{F}_{\text{T}}$.

$m_1\vec{a} = \vec{F}_{\text{T}}$ (Equation 1)

For the hanging object, $\vec{F}_{\text{net}} = \vec{F}_{\text{g}} - \vec{F}_{\text{T}}$.

$m_2\vec{a} = m_2\vec{g} - \vec{F}_{\text{T}}$ (Equation 2)

Solution: Add the equations to solve for m_2.

$$m_1\vec{a} + m_2\vec{a} = \vec{F}_{\text{T}} + m_2\vec{g} - \vec{F}_{\text{T}}$$
$$m_1\vec{a} + m_2\vec{a} = m_2\vec{g}$$
$$m_1\vec{a} = m_2\vec{g} - m_2\vec{a}$$
$$m_1\vec{a} = m_2(\vec{g} - \vec{a})$$
$$m_2 = \frac{m_1\vec{a}}{\vec{g} - \vec{a}}$$
$$= \frac{(1.8\ \text{kg})(2.5\ \cancel{\text{m/s}^2})}{9.8\ \cancel{\text{m/s}^2} - 2.5\ \cancel{\text{m/s}^2}}$$
$$m_2 = 0.62\ \text{kg}$$

Solution: The mass of the attached object is 0.62 kg.

(b) Given: $m_1 = 1.8$ kg; $g = 9.8$ m/s^2; $a = 2.5$ m/s^2; $F_{\text{f}} = 0.6$ N

Required: m_2, mass of the attached object

Analysis: For the cart, $\vec{F}_{\text{net}} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}}$.

$m_1\vec{a} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}}$ (Equation 1)

For the hanging object, $\vec{F}_{\text{net}} = \vec{F}_{\text{g}} - \vec{F}_{\text{T}}$.

$m_2\vec{a} = m_2\vec{g} - \vec{F}_{\text{T}}$ (Equation 2)

Solution: Add the equations to solve for m_2.

$$m_1\vec{a} + m_2\vec{a} = \vec{F}_{\text{T}} - \vec{F}_{\text{f}} + m_2\vec{g} - \vec{F}_{\text{T}}$$
$$m_1\vec{a} + m_2\vec{a} = m_2\vec{g} - \vec{F}_{\text{f}}$$
$$m_1\vec{a} + \vec{F}_{\text{f}} = m_2\vec{g} - m_2\vec{a}$$
$$m_1\vec{a} + \vec{F}_{\text{f}} = m_2(\vec{g} - \vec{a})$$
$$m_2 = \frac{m_1\vec{a} + \vec{F}_{\text{f}}}{g - a}$$
$$= \frac{(1.8\ \text{kg})(2.5\ \cancel{\text{m/s}^2}) + 0.4\ \text{N}}{9.8\ \cancel{\text{m/s}^2} - 2.5\ \cancel{\text{m/s}^2}}$$
$$m_2 = 0.67\ \text{kg}$$

Statement: The mass of the attached object is 0.67 kg.

41. (a) The boat exerts a downward force on the water. The water exerts an equal reaction force that pushes upward on the boat.

(b) The dolphin exerts a downward force on the water. The water exerts an equal reaction force that pushes upward on the dolphin.

(c) As the student jumps off the raft to the right, the student's feet exert an action force pushing the raft to the left. The raft exerts a reaction force pushing the student to the right.

42. As a cannon forces a cannon ball out of the cannon, the cannon applies an action force on the cannon ball. According to Newton's third law, the cannon ball will cause a reaction force that pushes the cannon backward.

43. (a) Given: m = 58 kg; F_{net} = 89 N

Required: $\vec{a}$

Analysis: For the student on the skateboard, $\vec{F}_{net} = m\vec{a}$.

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$a = \frac{89\text{ N}}{58\text{ kg}}$$
$$a = 1.5\text{ m/s}^2$$

Statement: The acceleration of the student is 1.5 m/s^2 away from the wall.

(b) The wall does not seem to move because it is massive and anchored to the ground. Since $\vec{a} = \frac{\vec{F}_{net}}{m}$, the force that the student pushes on the wall is not strong enough to have any noticeable effect on the motion of the wall.

44. (a) Given: F_a = 75 N; F_f = 4.0 N

Required: $\vec{a}$

Analysis: For the girl on her skates, $\vec{F}_{net} = m\vec{a}$.

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{F}_a - \vec{F}_f = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_a - \vec{F}_f}{m}$$
$$a = \frac{75\text{ N} - 4.0\text{ N}}{62\text{ kg}}$$
$$a = 1.1\text{ m/s}^2$$

Statement: The acceleration of the girl is 1.1 m/s^2 away from the rail.

(b) The rail does not appear to move because it is anchored to the ground and a part of a large mass. Since $\vec{a} = \frac{\vec{F}_{net}}{m}$, the force that the girl pushes on the rail is so small compared to the mass of the rail that the acceleration of the rail is not noticeable.

45. (a) The forces on the object are the tension pulling it upward and the gravity pulling it downward. Add all the vertical forces. Choose up as positive. So, down is negative. Since the elevator is stationary, $\vec{F}_{net} = 0$.

Given: F_{net} = 0 N; m = 3.0 kg, g = –9.8 m/s^2

Required: $\vec{F}_T$

Analysis: $\vec{F}_{net} = \vec{F}_T + \vec{F}_g$

Solution:

$$\vec{F}_{net} = \vec{F}_T + \vec{F}_g$$
$$0 = \vec{F}_T + m\vec{g}$$
$$\vec{F}_T = -m\vec{g}$$
$$F_T = -(3.0\text{ kg})(-9.8\text{ m/s}^2)$$
$$F_T = +29\text{ N}$$

Statement: The tension in the string is 29 N.

(b) Choose up as positive. So, down is negative.

Given: m = 3.0 kg; g = –9.8 m/s^2; a = +1.2 m/s^2

Required: $\vec{F}_T$

Analysis: In this situation, $\vec{F}_{net} = m\vec{a}$.

$$\vec{F}_{net} = \vec{F}_T + \vec{F}_g$$
$$m\vec{a} = \vec{F}_T + m\vec{g}$$
$$\vec{F}_T = m\vec{a} - m\vec{g}$$
$$F_T = (3.0\text{ kg})(+1.2\text{ m/s}^2) - (3.0\text{ kg})(-9.8\text{ m/s}^2)$$
$$F_T = +33\text{ N}$$

Statement: The tension in the string is 33 N.

(c) Choose up as positive. So, down is negative.

Given: m = 3.0 kg; $\vec{g}$ = –9.8 m/s^2; $\vec{a}$ = –1.4 m/s^2

Required: $\vec{F}_T$

Analysis: In this situation, $\vec{F}_{net} = m\vec{a}$.

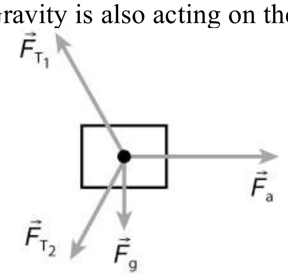
Solution:

$$\vec{F}_{net} = \vec{F}_T + \vec{F}_g$$
$$m\vec{a} = \vec{F}_T + m\vec{g}$$
$$\vec{F}_T = m\vec{a} - m\vec{g}$$
$$F_T = (3.0\text{ kg})(-1.4\text{ m/s}^2) - (3.0\text{ kg})(-9.8\text{ m/s}^2)$$
$$F_T = -25\text{ N}$$

Statement: The tension in the string is 25 N.

Analysis and Application

46. Answers may vary. Sample answer:
The other forces acting on the flag are the forces from the rope or attachments to the pole that hold the flag in place. These forces would be acting westward. Gravity is also acting on the flag.



47. (a) Given: m = 71.5 kg; g = 9.8 m/s^2

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{g}$

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Solution:

$\vec{F}_{net} = m\vec{g}$

$F_{net} = (71.5 \text{ kg})(9.8 \text{ m/s}^2)$

$F_{net} = 700 \text{ N}$

Statement: The force of gravity acting on the skydiver is 700 N when he jumps.

(b) Given: $m = 71.5$ kg; $g = 9.8$ m/s^2

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{g}$

Solution:

$\vec{F}_{net} = m\vec{g}$

$F_{net} = (71.5 \text{ kg})(9.8 \text{ m/s}^2)$

$F_{net} = 700 \text{ N}$

Statement: The force of gravity acting on the skydiver is 700 N when he lands.

48. Since the girl is not moving, $\vec{F}_{net} = 0$. Add all the vertical forces. Choose up as positive. So, down is negative.

Given: $\vec{F}_{net} = 0$; $m = 45.0$ kg, $g = -9.8$ m/s^2

Required: F_N

Analysis: $\vec{F}_{net} = \vec{F}_N + \vec{F}_g$

Solution:

$\vec{F}_{net} = \vec{F}_N + \vec{F}_g$

$0 = \vec{F}_N + m\vec{g}$

$\vec{F}_N = -m\vec{g}$

$F_N = -(45.0 \text{ kg})(-9.8 \text{ m/s}^2)$

$F_N = +440 \text{ N}$

Statement: The magnitude of the force the bench pushes against the girl is 440 N.

49. The force on a free-falling object is gravity.

Given: $F_{net} = 1100$ N; $g = 9.8$ m/s^2

Required: m

Analysis: $\vec{F}_{net} = m\vec{g}$

Solution:

$\vec{F}_{net} = m\vec{g}$

$m = \dfrac{\vec{F}_{net}}{\vec{g}}$

$m = \dfrac{1100 \text{ N}}{9.8 \text{ m/s}^2}$

$m = 110 \text{ kg}$

Statement: The mass of the boulder is 110 kg.

50. The force on the water is the force of gravity.

Given: $F_{net} = 7.6$ N; $g = 9.8$ m/s^2

Required: m

Analysis: $\vec{F}_{net} = m\vec{g}$

Solution:

$\vec{F}_{net} = m\vec{g}$

$m = \dfrac{\vec{F}_{net}}{\vec{g}}$

$= \dfrac{7.6 \text{ N}}{9.8 \text{ m/s}^2}$

$m = 0.78 \text{ kg}$

Statement: The mass of the water is 0.78 kg.

51. Given: $v = 35$ m/s; $\Delta t = 0.50$ s; $m = 0.25$ kg; $a = 70$ m/s^2

Required: F_{net}

Analysis: $\vec{F}_{net} = m\vec{a}$. First find the acceleration of the T-shirt launcher using $\vec{a} = \dfrac{\Delta\vec{v}}{\Delta\vec{t}}$.

Solution:

$\vec{a} = \dfrac{\Delta\vec{v}}{\Delta\vec{t}}$

$a = \dfrac{35 \text{ m/s}}{0.50 \text{ s}}$

$a = 70 \text{ m/s}^2$

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

$F_{net} = (0.25 \text{ kg})(70 \text{ m/s}^2)$

$F_{net} = 18 \text{ N}$

Statement: The launcher exerts a force of 18 N on the shirts.

52. Given: $v_i = 6.0$ m/s; $v_f = 15$ m/s; $\Delta t = 3.0$ s

Required: F_{net}

Analysis: $\vec{F}_{net} = m\vec{a}$. First find the acceleration of the runner using $\vec{a} = \dfrac{\Delta\vec{v}}{\Delta t}$.

Solution:

$\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$a = \dfrac{15 \text{ m/s} - 6.0 \text{ m/s}}{3.0 \text{ s}}$

$a = 3.0 \text{ m/s}^2$

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

$F_{net} = (72 \text{ kg})(3.0 \text{ m/s}^2)$

$F_{net} = 220 \text{ N}$

Statement: The net force acting on the runner is 220 N.

53. (a) Given: $m_1 = 30.0$ kg; $m_2 = 10.0$ kg; $\vec{F}_f = 240$ N [backward]; $\vec{F}_a = 3.0 \times 10^2$ N [forward]

Required: $\vec{a}$
Analysis: $\vec{F}_{\text{net}} = \vec{F}_{\text{a}} + \vec{F}_{\text{f}}$. Treat the two boxes as a single object with mass 40.0 kg and a total force of friction of 240 N. Choose forward as positive. So, backward is negative.
Solution:

$$\begin{aligned}\vec{F}_{\text{net}} &= \vec{F}_{\text{a}} + \vec{F}_{\text{f}}\\(m_1 + m_2)\vec{a} &= \vec{F}_{\text{a}} + \vec{F}_{\text{f}}\\\vec{a} &= \frac{\vec{F}_{\text{a}} + \vec{F}_{\text{f}}}{m_1 + m_2}\\a &= \frac{+3.0\times10^2\ \text{N} + (-240\ \text{N})}{30\ \text{kg} + 10\ \text{kg}}\\a &= +1.5\ \text{m/s}^2\\\vec{a} &= 1.5\ \text{m/s}^2\ [\text{forward}]\end{aligned}$$

Statement: The acceleration of the boxes is 1.5 m/s^2 [forward].
(b) If there is no applied force, the only horizontal force acting on the boxes is the force of friction, which acts in the opposite direction of their motion and causes them to slow down.
(c) Given: $\vec{a}_1$ = 1.5 m/s^2 [forward]; Δt = 5.0 s
Required: Δd
Analysis: First calculate the distance when the boxes are accelerating using $\Delta\vec{d}_1 = \frac{1}{2}\vec{a}_1\Delta t^2$. Then calculate the velocity before the boxes slow down using $\vec{v}_{\text{i}} = \vec{a}_1\Delta t$. Then calculate the acceleration of the boxes when the applied force is removed using $\vec{F}_{\text{net}} = \vec{F}_{\text{f}}$. Then find the distance travelled when the boxes are slowing down using $\vec{v}_{\text{f}}^{\,2} = \vec{v}_{\text{i}}^{\,2} + 2\vec{a}_2\Delta\vec{d}_2$. Finally, add the two distances.
Solution:

$$\begin{aligned}\Delta d_1 &= \frac{1}{2}a_1\Delta t^2\\&= \frac{1}{2}\left(+1.5\ \frac{\text{m}}{\cancel{\text{s}^2}}\right)(5.0\ \cancel{\text{s}})^{\cancel{2}}\\\Delta d_1 &= 18.75\ \text{m (two extra digits carried)}\end{aligned}$$

$$\begin{aligned}\vec{v}_{\text{i}} &= \vec{a}_1\Delta t\\v_{\text{i}} &= (+1.5\ \text{m/s}^{\cancel{2}})(5.0\ \cancel{\text{s}})\\v_{\text{i}} &= +7.5\ \text{m/s}\end{aligned}$$

$$\begin{aligned}\vec{F}_{\text{net}} &= \vec{F}_{\text{f}}\\(m_1 + m_2)\vec{a}_2 &= \vec{F}_{\text{f}}\\\vec{a}_2 &= \frac{\vec{F}_{\text{f}}}{m_1 + m_2}\\a_2 &= \frac{-240\ \text{N}}{30\ \text{kg} + 10\ \text{kg}}\\a_2 &= -6.0\ \text{m/s}^2\end{aligned}$$

As the boxes are slowing down:
$\vec{v}_{\text{i}}$ = 7.5 m/s [backward]; a = 6.0 m/s^2 [backward];
v_{f} = 0 m/s

$$\begin{aligned}0 &= \vec{v}_{\text{i}}^{\,2} + 2\vec{a}_2\Delta d_2\\\vec{v}_{\text{i}}^{\,2} &= -2\vec{a}_2\Delta d_2\\\Delta d_2 &= \frac{\vec{v}_{\text{i}}^{\,2}}{-2\vec{a}_2}\\&= \frac{(-7.5\ \text{m/s})^2}{-2(-6.0\ \text{m/s}^2)}\\\Delta d_2 &= 4.6875\ \text{m (three extra digits carried)}\end{aligned}$$

$$\begin{aligned}\Delta d &= \Delta d_1 + \Delta d_2\\&= 18.75\ \text{m} + 4.6875\ \text{m}\\&= 23.4675\ \text{m}\\\Delta d &= 23\ \text{m}\end{aligned}$$

Statement: The total distance travelled is 23 m.
54. Choose right as positive. So, left is negative.
Given: F_{R1} = +55 N; F_{R2} = +65 N; F_{L1} = –58 N; F_{L2} = –70 N
Required: $\vec{a}$
Analysis: $\vec{F}_{\text{net}} = \vec{F}_{\text{R1}} + \vec{F}_{\text{R2}} + \vec{F}_{\text{L1}} + \vec{F}_{\text{L2}}$; $\vec{F}_{\text{net}} = m\vec{a}$
Solution:

$$\begin{aligned}\vec{F}_{\text{net}} &= \vec{F}_{\text{R1}} + \vec{F}_{\text{R2}} + \vec{F}_{\text{L1}} + \vec{F}_{\text{L2}}\\F_{\text{net}} &= +55\ \text{N} + 65\ \text{N} + (-58\ \text{N}) + +(-70\ \text{N})\\F_{\text{net}} &= -8\ \text{N}\end{aligned}$$

The net force on the students is 8 N to the left.

$$\begin{aligned}\vec{F}_{\text{net}} &= m\vec{a}\\\vec{a} &= \frac{\vec{F}_{\text{net}}}{m}\\a &= \frac{-8\ \text{N}}{60\ \text{kg} + 62\ \text{kg} + 59\ \text{kg} + 64\ \text{kg}}\\a &= -0.03\ \text{m/s}^2\end{aligned}$$

Statement: The students are accelerating 0.03 m/s^2 [left].

55. (a) Given: $F_a = +10$ N; $F_b = +30$ N; $F_c = +25$ N; $F_d = -10$ N; $F_e = -22$ N

Required: $\left(\vec{F}_{net}\right)_{horizontal}$; $\left(\vec{F}_{net}\right)_{vertical}$

Analysis: $\left(F_{net}\right)_{horizontal} = F_b + F_c + F_e$; $\left(F_{net}\right)_{vertical} = F_a + F_d$. Choose right and up as positive. So, left and down are negative.

Solution:

$$\begin{aligned}\left(F_{net}\right)_{horizontal} &= F_b + F_c + F_e \\ &= +30\text{ N} + 25\text{ N} + (-22\text{ N}) \\ &= +33\text{ N}\end{aligned}$$

$$\left(\vec{F}_{net}\right)_{horizontal} = 33\text{ N [right]}$$

$$\begin{aligned}\left(F_{net}\right)_{vertical} &= F_a + F_d \\ &= +10\text{ N} + (-10\text{ N})\end{aligned}$$

$$\left(F_{net}\right)_{vertical} = 0\text{ N}$$

Statement: The net horizontal force is 33 N [right] and the net vertical force is 0 N.

(b) Given: From part (a), $\vec{F}_{net} = 33$ N [right]; $m = 85$ kg

Required: $\vec{a}$

$$\begin{aligned}\vec{F}_{net} &= m\vec{a} \\ \vec{a} &= \frac{\vec{F}_{net}}{m} \\ &= \frac{33\text{ N [right]}}{85\text{ kg}} \\ \vec{a} &= 0.39\text{ m/s}^2\text{ [right]}\end{aligned}$$

The acceleration of the box is 0.39 m/s^2 [right].

56. (a) Choose right and up as positive. So, left and down are negative.

Given: $F_a = +13$ N; $F_b = +12$ N; $F_c = +19$ N; $F_d = -26$ N; $F_e = -31$ N

Required: $\left(\vec{F}_{net}\right)_{horizontal}$; $\left(\vec{F}_{net}\right)_{vertical}$

Analysis: $\left(F_{net}\right)_{horizontal} = F_b + F_c + F_e$; $\left(F_{net}\right)_{vertical} = F_a + F_d$

Solution:

$$\begin{aligned}\left(F_{net}\right)_{horizontal} &= F_b + F_c + F_e \\ &= +12\text{ N} + 19\text{ N} + (-31\text{ N})\end{aligned}$$

$$\left(F_{net}\right)_{horizontal} = 0\text{ N}$$

$$\begin{aligned}\left(F_{net}\right)_{vertical} &= F_a + F_d \\ &= +13\text{ N} + (-26\text{ N}) \\ &= -13\text{ N}\end{aligned}$$

$$\left(\vec{F}_{net}\right)_{vertical} = 13\text{ N [down]}$$

Statement: The net horizontal force is 0 N and the net vertical force is 13 N [down].

(b) Given: From part (a), $\vec{F}_{net} = 13$ N [down]; $\vec{a} = 5.5$ m/s^2 [down]

Required: m

Analysis: $\vec{F}_{net} = m\vec{a}$

Solution:

$$\begin{aligned}\vec{F}_{net} &= m\vec{a} \\ m &= \frac{\vec{F}_{net}}{\vec{a}} \\ &= \frac{13\text{ N [down]}}{5.5\text{ m/s}^2\text{ [down]}} \\ m &= 2.4\text{ kg}\end{aligned}$$

Statement: The mass of the box is 2.4 kg.

57. (a) Choose right and up as positive. So, left and down are negative.

Given: $m = 12$ kg, $a = 1.5$ m/s^2; $F_a = +13$ N; $F_b = +82$ N; $F_d = -26$ N; $F_e = -31$ N

Required: F_c

Analysis: $\vec{F}_{net} = m\vec{a}$; $F_{net} = F_b + F_c + F_e$

Solution:

$$\begin{aligned}\vec{F}_{net} &= m\vec{a} \\ &= (12\text{ kg})(1.5\text{ m/s}^2\text{ [right]}) \\ \vec{F}_{net} &= 18\text{ N [right]}\end{aligned}$$

$$\begin{aligned}F_{net} &= F_b + F_c + F_e \\ +18\text{ N} &= +82\text{ N} + F_c + (-112\text{ N}) \\ F_c &= +48\text{ N}\end{aligned}$$

The magnitude of F_c is 48 N.

(b) If the box is moving to the left, $\vec{F}_{net} = 18$ N [left].

Given: $F_{net} = -18$ N; $F_b = +82$ N; $F_e = -31$ N

Required: F_c

Analysis: $F_{net} = F_b + F_c + F_e$

Solution:

$$\begin{aligned}F_{net} &= F_b + F_c + F_e \\ -18\text{ N} &= +82\text{ N} + F_c + (-112\text{ N}) \\ F_c &= +12\text{ N}\end{aligned}$$

Statement: The magnitude of F_c is 12 N.

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58. (a) Given: m = 100 kg; Δv = 45 km/h; Δt = 2.5 s
Required: F_{dog}
Analysis: First, convert the velocity to SI units. Then calculate the acceleration using $a = \frac{\Delta v}{\Delta t}$.
Calculate the average applied force using $\vec{F}_{net} = m\vec{a}$. Then determine the average applied force per dog.
Solution:

$$\Delta v = 45 \text{ km/h}$$
$$= \left(45 \frac{\cancel{\text{km}}}{\cancel{\text{h}}}\right)\left(\frac{1 \cancel{\text{h}}}{60 \cancel{\text{min}}}\right)\left(\frac{1 \cancel{\text{min}}}{60 \text{ s}}\right)\left(\frac{1000 \text{ m}}{1 \cancel{\text{km}}}\right)$$
$$\Delta v = 12.5 \text{ m/s}$$

$$a = \frac{\Delta v}{\Delta t}$$
$$= \frac{12.5 \text{ m/s}}{2.5 \text{ s}}$$
$$a = 5.0 \text{ m/s}^2$$

$$\vec{F}_{net} = m\vec{a}$$
$$F_{net} = (100 \text{ kg})(5.0 \text{ m/s}^2)$$
$$F_{net} = 500 \text{ N}$$

$$F_{dog} = \frac{500 \text{ N}}{4}$$
$$F_{dog} = 125 \text{ N}$$

Statement: The average force applied by each dog is 125 N.
(b) The frictional force equals the total force applied by the dogs.
Given: F_{dog} = 150 N; F_{net} = 500 N
Required: F_f
Analysis: $F_{net} = F_a - F_f$
Solution:

$$F_a = 4 \times 150 \text{ N}$$
$$= 600 \text{ N}$$

During the pulling motion,

$$F_{net} = F_a - F_f$$
$$500 \text{ N} = 600 \text{ N} - F_f$$
$$F_f = 100 \text{ N}$$

Statement: The frictional force acting on the sled is 100 N [opposite direction of motion]

59. (a) To find the acceleration due to gravity on the Moon, divide the gravitational constant by 6.

$$\frac{9.8 \text{ m/s}^2}{6} = 1.6 \text{ m/s}^2$$

The acceleration due to gravity on the Moon is 1.6 m/s^2.
(b) To find the weight of a person on the Moon, multiply the mass by the unrounded value in part (a).

$$72 \text{ kg} \times \frac{9.8 \text{ m/s}^2}{6} = 120 \text{ N}$$

A 72 kg person would weigh 120 N on the Moon.
(c) The mass of an object on the Moon is its weight divided by the gravitational constant.
The mass of the object is $\frac{700 \text{ N}}{9.8 \text{ m/s}^2}$.
The force on this object on the Moon is its mass multiply by acceleration due to gravity on the Moon. Use the unrounded value in part (a).

$$\frac{700 \text{ N}}{9.8 \text{ m/s}^2} \times \frac{9.8 \text{ m/s}^2}{6} = 120 \text{ N}$$

The force on this object on the Moon is 120 N.
60. (a) As the girl jumps off the raft to the right, the girl's feet exert an action force pushing the raft to the left. The raft exerts a reaction force pushing the girl to the right.
(b) Given: m_g = 55 kg; m_r = 120 kg; F_{net} = 100 N
Required: $\vec{a}_g$; $\vec{a}_r$
Analysis: $\vec{F}_{net} = m\vec{a}$
Solution:
For the girl,

$$\vec{F}_{net} = m_g\vec{a}_g$$
$$\vec{a}_g = \frac{\vec{F}_{net}}{m_g}$$
$$\vec{a}_g = \frac{100 \text{ N [right]}}{55 \text{ kg}}$$
$$\vec{a}_g = 1.8 \text{ m/s}^2 \text{ [right]}$$

For the raft,

$$\vec{F}_{net} = m_r\vec{a}_r$$
$$\vec{a}_r = \frac{\vec{F}_{net}}{m_r}$$
$$= \frac{100 \text{ N [left]}}{120 \text{ kg}}$$
$$\vec{a}_r = 0.83 \text{ m/s}^2 \text{ [left]}$$

Statement: The acceleration of the girl is 1.8 m/s^2 [right]. The acceleration of the raft is 0.83 m/s^2 [left].

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61. (a) The action force is the force exerted by the boy pushing on the girl. The reaction force is a force of equal magnitude in the opposite direction by the girl pushing back on the boy.

(b) Given: $m_b = 62$ kg; $m_g = 59$ kg; $F_{net} = 74$ N

Required: $\vec{a}_b$; $\vec{a}_g$

Analysis: $\vec{F}_{net} = m\vec{a}$

Solution:

For the boy,

$$\vec{a}_b = \frac{\vec{F}_{net}}{m_b}$$
$$= \frac{74 \text{ N [right]}}{62 \text{ kg}}$$
$$\vec{a}_b = 1.2 \text{ m/s}^2 \text{ [right]}$$

For the girl,

$$\vec{a}_g = \frac{\vec{F}_{net}}{m_g}$$
$$= \frac{74 \text{ N [left]}}{59 \text{ kg}}$$
$$\vec{a}_g = 1.3 \text{ m/s}^2 \text{ [left]}$$

Statement: The acceleration of the boy is 1.2 m/s^2 [right]. The acceleration of the girl is 1.3 m/s^2 [left].

62. (a) The force on each skater is of equal magnitude. Since $F_{net} = ma$ and skater B has a slower acceleration, skater B has more mass.

(b) The action force is the force of skater A pushing on skater B. The reaction force is the force of skater B pushing back on skater A. The magnitudes of both forces are equal.

Given: $m = 75$ kg; $a = 1.2 \text{ m/s}^2$

Required: F_{net}

Analysis: $\vec{F}_{net} = m\vec{a}$

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$F_{net} = (75 \text{ kg})(1.2 \text{ m/s}^2)$$
$$F_{net} = 90 \text{ N}$$

Statement: The magnitude of the force is 90 N.

(c)
$$F_{net} = ma$$
$$m = \frac{F_{net}}{a}$$
$$= \frac{90 \text{ N}}{0.8 \text{ m/s}^2}$$
$$m = 110 \text{ kg}$$

The mass of skater B is 110 kg.

63. (a) Given: $m_{\text{student A}} = 58$ kg; $F_{net} = 80.0$ N

Required: a

Analysis: $\vec{F}_{net} = m_{\text{student A}}\vec{a}$

Solution:

$$\vec{F}_{net} = m_{\text{student A}}\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m_{\text{student A}}}$$
$$a = \frac{80.0 \text{ N}}{58 \text{ kg}}$$
$$a = 1.4 \text{ m/s}^2$$

Statement: The acceleration of student A is 1.4 m/s^2.

(b) If student B accelerates faster than student A, the total mass on student B's skateboard would be less than 58 kg. So, the mass of the block would be between 0 kg and 3 kg. Similarly, if student B accelerates slower than student A, the total mass on student B's skateboard would be greater than 58 kg. So, the mass of the block would be greater than 3 kg.

(c) Student B and the block accelerate as one single object, so their mass is m.

Given: $a = 1.25 \text{ m/s}^2$; $F_{net} = 80.0$ N; $m_{\text{student B}} = 55$ kg

Required: m_{block}

Analysis: $\vec{F}_{net} = m\vec{a}$

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$m = \frac{\vec{F}_{net}}{\vec{a}}$$
$$= \frac{80.0 \text{ N}}{1.25 \text{ m/s}^2}$$
$$m = 64 \text{ kg}$$

$$m_{\text{block}} = m - m_{\text{student B}}$$
$$= 64 \text{ kg} - 55 \text{ kg}$$
$$m_{\text{block}} = 9 \text{ kg}$$

Statement: The mass of the block is 9 kg.

64. (a) Choose right as positive. So, left is negative.

Given: $m_1 = 82$ kg; $m_2 = 64$ kg; $\vec{F}_{net} = 16$ N [left]

Required: $\vec{a}$

Analysis: $\vec{F}_{net} = m\vec{a}$

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Solution:
For the male astronaut,

$$\vec{F}_{net} = m_1\vec{a}_1$$

$$\vec{a}_1 = \frac{\vec{F}_{net}}{m_1}$$

$$a_1 = \frac{-16\text{ N}}{82\text{ kg}}$$

$$= -0.20\text{ m/s}^2$$

$$\vec{a}_1 = 0.20\text{ m/s}^2\text{ [left]}$$

For the female astronaut,

$$\vec{F}_{net} = m_2\vec{a}_2$$

$$\vec{a}_2 = \frac{\vec{F}_{net}}{m_2}$$

$$a_2 = \frac{+16\text{ N}}{64\text{ kg}}$$

$$= +0.25\text{ m/s}^2$$

$$\vec{a}_2 = 0.25\text{ m/s}^2\text{ [right]}$$

Statement: The acceleration of the male astronaut is 0.20 m/s^2 [left]. The acceleration of the female astronaut is 0.25 m/s^2 [right].

(b) The answers to part (a) will not change if the male astronaut pushes on the female astronaut instead. In this situation, the action force on the female astronaut becomes the reaction force and the reaction force on the male astronaut becomes the action force.

65. (a) Given: $m_1 = 6.4 \times 10^5$ kg; $m_2 = 5.3 \times 10^5$ kg; $a = 0.12$ m/s^2

Required: F_{net}

Analysis: $\vec{F}_{net} = m\vec{a}$

Solution:
total mass of the train, $m = m_1 + m_2$

$m = m_1 + m_2$

$= 6.4 \times 10^5\text{ kg} + 5.3 \times 10^5\text{ kg}$

$m = 1.17 \times 10^6$ kg (one extra digit carried)

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

$$F_{net} = (1.17\times10^6\text{ kg})(0.12\text{ m/s}^2)$$

$$F_{net} = 1.4\times10^5\text{ N}$$

Statement: The net force on the entire train is 1.4×10^5 N.

(b) The magnitude of the tension between the locomotive and the train car equals the magnitude of the net force on the train car.

Given: $a = 0.12$ m/s^2; $m = 5.3 \times 10^5$ kg

Required: F_{net}

Analysis: $\vec{F}_{net} = m\vec{a}$

Solution:

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

$$F_{net} = (5.3\times10^5\text{ kg})(0.12\text{ m/s}^2)$$

$$F_{net} = 6.4\times10^4\text{ N}$$

Statement: The magnitude of the tension between the locomotive and the train car is 6.4×10^4 N.

66. (a) Given: $m_1 = 18$ kg; $m_2 = 12$ kg; $g = 9.8$ m/s^2

Required: F_{TA}; F_{TB}

Analysis: $\vec{F}_{TA} = (m_1 + m_2)\vec{g}$; $\vec{F}_{TB} = m_2\vec{g}$

Solution:
For string A,

$$\vec{F}_{TA} = (m_1 + m_2)\vec{g}$$

$$F_{TA} = (18\text{ kg} + 12\text{ kg})(9.8\text{ m/s}^2)$$

$$F_{TA} = 290\text{ N}$$

For string B,

$$\vec{F}_{TB} = m_2\vec{g}$$

$$F_{TB} = (12\text{ kg})(9.8\text{ m/s}^2)$$

$$F_{TB} = 120\text{ N}$$

Statement: The tension in string A is 290 N. The tension in string B is 120 N.

(b) Given: $m_1 = 18$ kg; $m_2 = 12$ kg; $g = 9.8$ m/s^2; $F_{pull} = 45$ N

Required: F_{TA}; F_{TB}

Analysis: $\vec{F}_{TA} = (m_1 + m_2)\vec{g} + \vec{F}_{pull}$; $\vec{F}_{TB} = m_2\vec{g}$

Solution:
For string A,

$$\vec{F}_{TA} = (m_1 + m_2)\vec{g} + \vec{F}_{pull}$$

$$F_{TA} = (18\text{ kg} + 12\text{ kg})(9.8\text{ m/s}^2) + 45\text{ N}$$

$$F_{TA} = 340\text{ N}$$

For string B,

$$\vec{F}_{TB} = m_2\vec{g}$$

$$F_{TB} = (12\text{ kg})(9.8\text{ m/s}^2)$$

$$F_{TB} = 120\text{ N}$$

Statement: The tension in string A is 340 N. The tension in string B is 120 N.

(c) Given: $m_1 = 18$ kg; $m_2 = 12$ kg; $g = 9.8$ m/s^2; $F_{pull} = 45$ N

Required: F_{TA}; F_{TB}

Analysis: $\vec{F}_{TA} = (m_1 + m_2)\vec{g} + \vec{F}_{pull}$; $\vec{F}_{TB} = m_2\vec{g}$

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Solution:
For string A,

$$\vec{F}_{TA} = (m_1 + m_2)\vec{g} + \vec{F}_{pull}$$
$$F_{TA} = (18\text{ kg} + 12\text{ kg})(9.8\text{ m/s}^2) + 45\text{ N}$$
$$F_{TA} = 340\text{ N}$$

For string B,

$$\vec{F}_{TB} = m_2\vec{g} + \vec{F}_{pull}$$
$$F_{TB} = (12\text{ kg})(9.8\text{ m/s}^2) + 45\text{ N}$$
$$F_{TB} = 160\text{ N}$$

Statement: The tension in string A is 340 N. The tension in string B is 160 N.

(d) In part (b), the pull on m_1 does not affect the tension in string B, so the tension in string B stays as 120 N. In part (c), the pull on m_2 affects both strings. So, the tension in string B also increases.

(e) If you keep increasing the downward force on m_2, string A will likely break first because the tension in string A is always greater than the tension in string B.

67. Choose right as positive. So, left is negative. Consider the forces on block m_1.

Given: $m_1 = 4.0$ kg; $m_2 = 2.3$ kg; $a = +1.1$ m/s^2; $F_{pull} = 45$ N

Required: F_{TA}; F_{TB}

Analysis: $\vec{F}_{TA} = \vec{F}_{net}$; $\vec{F}_{net} = \vec{F}_{TA} + \vec{F}_{TB}$;

$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$

Solution:
Consider the forces on block m_1.

$$\vec{F}_{net} = \vec{F}_{TA}$$
$$\vec{F}_{TA} = m_1\vec{a}$$
$$F_{TA} = (4.0\text{ kg})(+1.1\text{ m/s}^2)$$
$$F_{TA} = +4.4\text{ N}$$

Consider the forces on block m_2.

$$\vec{F}_{net} = \vec{F}_{TA} + \vec{F}_{TB}$$
$$m_2 a = -4.4\text{ N} + F_{TB}$$
$$F_{TB} = m_2 a + 4.4\text{ N}$$
$$= (2.3\text{ kg})(+1.1\text{ m/s}^2) + 4.4\text{ N}$$
$$F_{TB} = +6.93\text{ N (one extra digit carried)}$$

Consider the forces on block m_3.

$$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$$
$$m_3 a = -6.93\text{ N} + F_{TC}$$
$$F_{TC} = m_3 a + 6.93\text{ N}$$
$$F_{TC} = (3.4\text{ kg})(+1.1\text{ m/s}^2) + 6.93\text{ N}$$
$$= +10.67\text{ N}$$
$$F_{TC} = +11\text{ N}$$

Statement: The tension in string A is 4.4 N. The tension in string B is 6.9 N. The tension in string C is 11 N.

68. Choose right as positive. So, left is negative.

Given: $m_1 = 4.3$ kg; $m_2 = 5.5$ kg; $m_3 = 3.1$ kg; $a = +1.1$ m/s^2; $F_{net} = +15$ N

Required: $\vec{a}$; F_{TA}; F_{TB}; F_{TC}

Analysis: $\vec{F}_{TA} = \vec{F}_{net}$; $\vec{F}_{net} = \vec{F}_{TA} + \vec{F}_{TB}$;

$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$

Solution:
Consider the net force acting on the blocks.

$$\vec{F}_{net} = (m_1 + m_2 + m_3)\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m_1 + m_2 + m_3}$$
$$a = \frac{+15\text{ N}}{4.3\text{ kg} + 5.5\text{ kg} + 3.1\text{ kg}}$$
$$= \frac{+15\text{ N}}{12.9\text{ kg}}$$
$$= +1.16\text{ m/s}^2\text{ (one extra digit carried)}$$
$$a = +1.2\text{ m/s}^2$$

Consider the forces on block m_1.

$$\vec{F}_{net} = \vec{F}_{TA}$$
$$\vec{F}_{TA} = m_1\vec{a}$$
$$= (4.3\text{ kg})(+1.16\text{ m/s}^2)$$
$$= +4.99\text{ N (one extra digit carried)}$$
$$F_{TA} = +5.0\text{ N}$$

Consider the forces on block m_2.

$$\vec{F}_{net} = \vec{F}_{TA} + \vec{F}_{TB}$$
$$m_2 a = -4.99\text{ N} + F_{TB}$$
$$F_{TB} = m_2 a + 4.99\text{ N}$$
$$= (5.5\text{ kg})(+1.16\text{ m/s}^2) + 4.99\text{ N}$$
$$= +11.4\text{ N (one extra digit carried)}$$
$$F_{TB} = +11\text{ N}$$

Consider the forces on block m_3.

$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$

$m_3 a = -11.4\text{ N} + F_{TC}$

$F_{TC} = m_3 a + 11.4\text{ N}$

$= (3.1\text{ kg})(+1.16\text{ m/s}^2) + 11.4\text{ N}$

$F_{TC} = +15\text{ N}$

Statement: The acceleration of the blocks is 1.2 m/s^2 [right]. The tension in string A is 5.0 N. The tension in string B is 11 N. The tension in string C is 15 N.

69. Choose right as positive. So, left is negative.

Given: $m_1 = 10$ kg; $m_3 = 8$ kg; $F_{net} = +24$ N

Required: m_2; F_{TA}; F_{TB}; F_{TC}

Analysis: $\vec{F}_{TA} = \vec{F}_{net}$; $\vec{F}_{net} = \vec{F}_{TA} + \vec{F}_{TB}$; $\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$

Solution:

For block m_1,

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

$m_1\vec{a} = \vec{F}_{TA}$

For block m_2, $F_{TB} = 2F_{TA}$, F_{TA} acts to the left.

$\vec{F}_{net} = -\vec{F}_{TA} + \vec{F}_{TB}$

$m_2\vec{a} = -\vec{F}_{TA} + 2\vec{F}_{TA}$

$m_2\vec{a} = \vec{F}_{TA}$

So, $m_1 = m_2 = 10$ kg.

Consider the net force acting on the blocks.

$\vec{F}_{net} = (m_1 + m_2 + m_3)\vec{a}$

$\vec{a} = \dfrac{\vec{F}_{net}}{m_1 + m_2 + m_3}$

$a = \dfrac{+24\text{ N}}{10\text{ kg} + 10\text{ kg} + 8\text{ kg}}$

$= \dfrac{+24\text{ N}}{28\text{ kg}}$

$a = +0.86\text{ m/s}^2$ (one extra digit carried)

For string A,

$\vec{F}_{TA} = m_1\vec{a}$

$F_{TA} = (10\text{ kg})(0.86\text{ m/s}^2)$

$= 8.6\text{ N}$

$F_{TA} = 9\text{ N}$

For string B,

$\vec{F}_{TB} = 2\vec{F}_{TA}$

$= 2(8.6\text{ N})$

$= 17\text{ N}$ (one extra digit carried)

$F_{TB} = 20\text{ N}$

For string C,

$\vec{F}_{net} = \vec{F}_{TB} + \vec{F}_{TC}$

$m_3 a = -17\text{ N} + F_{TC}$

$F_{TC} = m_3 a + 17\text{ N}$

$= (8\text{ kg})(+0.86\text{ m/s}^2) + 17\text{ N}$

$= 23.9\text{ N}$

$F_{TC} = 24\text{ N}$

Statement: The mass of the second block is 10 kg. The tension in string A is 9 N. The tension in string B is 20 N. The tension in string C is 24 N.

70. (a) Choose forward as positive. So, backward is negative. Since the sleds are tied together, treat them as one single object. Consider forces acting on this object to find the total frictional force.

Given: $m_1 = 60.0$ kg; $m_2 = 55.0$ kg; $a = +1.02$ m/s^2; $F_a = +230$ N; $F_{front} = 58.8$ N

Required: F_f

Analysis: $\vec{F}_{net} = \vec{F}_a + \vec{F}_f$

Solution:

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

$(m_1 + m_2)a = +230\text{ N} + F_f$

$F_f = (m_1 + m_2)a - 230\text{ N}$

$= (60.0\text{ kg} + 55.0\text{ kg})(+1.02\text{ m/s}^2) - 230\text{ N}$

$F_f = -112.7\text{ N}$ (two extra digits carried)

The force of friction for the back sled is now the positive direction.

$F_{back} = F_f - F_{front}$

$= 112.7\text{ N} - 58.8\text{ N}$

$= 53.9\text{ N}$ (one extra digit carried)

$F_{back} = 54\text{ N}$

Statement: The frictional force on the back sled is 54 N.

(b) Given: $m_1 = 60.0$ kg; $F_a = +230$ N; $a = +1.02$ m/s^2; $F_a = +230$ N; $F_f = -58$ N

Required: F_T

Analysis: $\vec{F}_{net} = \vec{F}_a + \vec{F}_T + \vec{F}_f$

Solution:
Consider forces acting on the front sled,

$$\vec{F}_{\text{net}} = \vec{F}_{\text{a}} + \vec{F}_{\text{T}} + \vec{F}_{\text{f}}$$
$$m_1 a = +230\text{ N} + F_{\text{T}} + (-58.8\text{ N})$$
$$F_{\text{T}} = m_1 a - 230\text{ N} + 58.8\text{ N}$$
$$= (60.0\text{ kg})(+1.02\text{ m/s}^2) - 230\text{ N} + 58.8\text{ N}$$
$$F_{\text{T}} = -110\text{ N}$$

Statement: The tension in the rope connecting the sleds is 110 N.

(c) Given: $m_1 = 60.0$ kg; $m_2 = 55.0$ kg; $a = +1.02\text{ m/s}^2$; $\Delta t = 3.0$ s; $F_{\text{f}} = -112.7$ N

Required: F_{T}

Analysis: $\Delta d_1 = \frac{1}{2}\vec{a}\Delta t^2$; $\vec{v} = \vec{a}\Delta t$; $\vec{F}_{\text{net}} = \vec{F}_{\text{f}}$

Solution:
Calculate the distance when the sleds are accelerating.

$$\Delta d_1 = \frac{1}{2}\vec{a}\Delta t^2$$
$$= \frac{1}{2}(1.02\text{ m/s}^2)(3.0\text{ s})^2$$
$$\Delta d_1 = 4.59\text{ m (one extra digit carried)}$$

Calculate the velocity before the sleds slow down.

$$\vec{v} = \vec{a}\Delta t$$
$$v = \left(1.02\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\right)(3.0\ \cancel{\text{s}})$$
$$v = 3.06\text{ m/s}$$

Calculate the acceleration a_1 of the sleds when the applied force is removed.

$$\vec{F}_{\text{net}} = \vec{F}_{\text{f}}$$
$$(m_1 + m_2)\vec{a}_1 = \vec{F}_{\text{f}}$$
$$\vec{a}_1 = \frac{\vec{F}_{\text{f}}}{m_1 + m_2}$$
$$a = \frac{-112.7\text{ N}}{60.0\text{ kg} + 55.0\text{ kg}}$$
$$a = -0.98\text{ m/s}^2$$

Use the equation $\vec{v}_{\text{f}}^{\,2} = \vec{v}_{\text{i}}^{\,2} + 2\vec{a}\Delta d$ to find the distance travelled when the sleds slow down, given $v_{\text{i}} = -3.06$ m/s; $a = -0.98\text{ m/s}^2$; $v_{\text{f}} = 0$ m/s.

$$0 = \vec{v}^2 + 2\vec{a}\Delta d_2$$
$$\vec{v}^2 = -2\vec{a}\Delta d_2$$
$$\Delta d_2 = \frac{\vec{v}^2}{-2\vec{a}}$$
$$= \frac{(-3.06\text{ m/s})^2}{-2(-9.8\text{ m/s}^2)}$$
$$\Delta d_2 = 4.777\text{ m (one extra digit carried)}$$

$$\Delta d = \Delta d_1 + \Delta d_2$$
$$= 4.59\text{ m} + 4.777\text{ m}$$
$$= 9.367\text{ m (one extra digit carried)}$$
$$\Delta d = 9.37\text{ m}$$

Statement: The total distance travelled is 9.37 m.

Evaluation

71. Answers may vary. Sample answer:
The mass of the Sun is about 1000 times the combined mass of all the planets, which means it has much more inertia. Even if all the planets were aligned and did not have any forces in opposite directions due to their positions, this would still have very little effect on the position of the Sun.

72. (a) Yes, objects on Earth are attracted by the Moon. For example, the gravitational attraction between the Moon and Earth causes the tides.
(b) Nothing on Earth flies off to the Moon because the force of gravity from Earth is much greater than the pull from the Moon.

73. (a) If an action force and a reaction force act on the same object, the net force will be zero and nothing will accelerate. When the fan blows to the right, there is a force on the cart in one direction and there is a force on the cart in the opposite direction resulting from the air hitting the sail. According to Newton’s third law, the active fan will cause a reaction force of the same magnitude on the sail but in the opposite direction. The action and reaction forces act on the same object, the sail. As a result the cart will not accelerate.
(b) If the sail is removed, as the fan blows to the right, it pushes the air to the right. According to Newton’s third law, there is a reaction force on the air by the fan. The blowing air exerts an equal force but opposite in direction to the blowing fan. The fan cart can then accelerate because there is an external force that pushes it in the opposite direction or to the left.

74. (a) It is possible for the two blocks to remain in place if there is frictional force in the pulleys that could stop the motion.
(b) Since the blocks are stationary, the frictional

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force in the pulleys must be greater than or equal to the difference of the weights. If the friction were greater than the difference in weights and one of the blocks were tapped downward, the motion would slow down and stop. If the friction were exactly equal to the difference in weights, the tapped block would keep moving downward.

Reflect on Your Learning

75. Answers may vary. Sample answer:
The statement is not valid when the action and reaction forces are not acting on the same object. If they act on the same object, the net force will be zero and nothing will accelerate. For example, when a ballistic cart pushes backward on a ball, the ball accelerates backward. According to Newton's third law, the ball will cause a reaction force of the same magnitude on the cart in the opposite direction, making the cart accelerate forward. The action and reaction forces do not cancel because they do not act on the same object.

Research

76. Answers may vary. Sample answer:
Students' reports should describe the characteristics of the strong force and how close protons need to be for this interaction to occur. Reports should give estimates, if possible, of the relative strength of this force compared to the electromagnetic force and gravity. There should also be a discussion on how in heavier elements the number of protons is so large that the electromagnetic repulsion is stronger than the strong force, which leads to nuclear fission.

77. Answers may vary. Sample answer:
Students' presentations should mention the experiments and theories of 16th- and early 17th-century scientists, such as Galileo's falling bodies experiment, Kepler's planetary motion theories, and Déscartes' coordinate system. Presentations could include how these views conflicted with popular beliefs of the time.

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Chapter 3 Self-Quiz, page 153

1. (b)
2. (c)
3. (d)
4. (c)
5. (c)
6. (b)
7. (b)
8. (b)
9. True
10. False. The *reaction* force is the force resisting the motion or attempted motion of an object.
11. False. A *system diagram* is a simple sketch of all the objects involved in a situation.
12. False. *Contact* forces require objects to be in contact and cannot act at a distance.
13. True
14. True
15. False. An object *cannot* change its motion even if the net force acting on it is zero.
16. True
17. False. Newton's third law states that for every action force, there is a simultaneous reaction force of equal magnitude acting in the *opposite* direction.

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Unit 2: Forces

Note: The style for free-body diagrams was changed after the first printing of the Student Book. The updated style is shown throughout the Solutions Manual.

Are You Ready?, pages 110–111

1. The car starts its motion from rest, accelerates to a constant velocity, and then accelerates in a direction opposite to the initial motion to come to a stop.

2. (a) Given: $\vec{v}_i = 0$ m/s; $\vec{v}_f = 9.6$ m/s [E]; $\Delta t = 6.0$ s

Required: $\vec{a}$

Analysis: $\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

Solution:

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$= \frac{9.6 \text{ m/s [E]} - 0 \text{ m/s}}{6.0 \text{ s}}$$
$$\vec{a} = 1.6 \text{ m/s}^2 \text{ [E]}$$

Statement: The acceleration of the runner is 1.6 m/s^2 [E].

(b) Given: $\vec{v}_i = 0$ m/s; $\vec{a} = \vec{g} = 9.8$ m/s^2 [down]; $\Delta\vec{d} = 3.2$ m [down]

Required: v_f

Analysis: $\vec{v}_f^{\,2} = \vec{v}_i^{\,2} + 2\vec{a}\Delta\vec{d}$

Solution: Since $\vec{v}_i = 0$ m/s,

$$\vec{v}_f = \sqrt{2\vec{a}\Delta\vec{d}}$$
$$v_f = \sqrt{2\left(9.8\,\frac{\cancel{\text{m}}}{\text{s}^2}\right)(3.2\ \cancel{\text{m}})}$$
$$v_f = 7.9 \text{ m/s}$$
$$\vec{v}_f = 7.9 \text{ m/s [down]}$$

Statement: The ball is travelling at 7.9 m/s [down] before it hits the ground.

(c) Given: $\vec{v}_i = 32$ km/h [N]; $\vec{v}_f = 65$ km/h [N]; $\Delta t = 8.2$ s

Required: $\vec{a}$

Analysis: Calculate the change in velocity, $\vec{v}_f - \vec{v}_i$, in metres. Then use $\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$ to determine the average acceleration.

Solution:

$$\vec{v}_f - \vec{v}_i = 65 \text{ km/h [N]} - 32 \text{ km/h [N]}$$
$$= 33 \text{ km/h [N]}$$
$$= \left(33\,\frac{\cancel{\text{km}}}{\cancel{\text{h}}}\text{ [N]}\right)\left(\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right)\left(\frac{1\ \cancel{\text{min}}}{60 \text{ s}}\right)\left(\frac{1000 \text{ m}}{1\ \cancel{\text{km}}}\right)$$
$$\vec{v}_f - \vec{v}_i = 9.17 \text{ m/s [N] (one extra digit carried)}$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$= \frac{9.17 \text{ m/s [N]}}{8.2 \text{ s}}$$
$$\vec{a} = 1.1 \text{ m/s}^2 \text{ [N]}$$

Statement: The average acceleration of the car is 1.1 m/s^2 [N].

(d) Given: $\vec{v}_f = 7.4$ m/s [W]; $\Delta t = 4.0$ s; $\Delta\vec{d} = 42$ m [W]

Required: $\vec{a}$; $\vec{v}_i$

Analysis: First rearrange the equation $\Delta\vec{d} = \left(\dfrac{\vec{v}_f + \vec{v}_i}{2}\right)\Delta t$ to solve for $\vec{v}_i$.

$$2\Delta\vec{d} = (\vec{v}_f + \vec{v}_i)\Delta t$$
$$\vec{v}_f + \vec{v}_i = \frac{2\Delta\vec{d}}{\Delta t}$$
$$\vec{v}_i = \frac{2\Delta\vec{d}}{\Delta t} - \vec{v}_f$$

Use this equation to determine the initial velocity. Then use the value of $\vec{v}_i$ and the equation $\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$ to determine the acceleration.

Solution:

$$\vec{v}_i = \frac{2\Delta\vec{d}}{\Delta t} - \vec{v}_f$$
$$= \frac{2(42 \text{ m [W]})}{4.0 \text{ s}} - 7.4 \text{ m/s [W]}$$
$$= 21.0 \text{ m/s [W]} - 7.4 \text{ m/s [W]}$$
$$\vec{v}_i = 13.6 \text{ m/s [W]}$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$= \frac{7.4 \text{ m/s [W]} - 13.6 \text{ m/s [W]}}{4.0 \text{ s}}$$
$$= -1.6 \text{ m/s}^2 \text{ [W]}$$
$$\vec{a} = 1.6 \text{ m/s}^2 \text{ [E]}$$

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Statement: The skater's acceleration is 1.6 m/s^2 [E], and the initial velocity is 13.6 m/s [W].

3. (a) A force is a push or a pull. It can cause objects to change their motion.

(b) Answers may vary. Sample answer:
The force of gravity causes a free-falling object to accelerate toward Earth's centre. For example, a ball dropped from a height falls quickly toward the ground as a result of the force of gravity. The force of friction causes an object to move toward the opposite direction of motion. For example, a sliding hockey puck on a table slows down and eventually as a result of the force of friction exerted by the surface of the table.

4. (a) The displacement of an object moving with uniform motion over time is constant. The velocity of the object is constant.

(b) The acceleration of the object is in the same direction as the initial motion. The velocity of the object is increasing.

(c) The acceleration is in the opposite direction to the initial motion. The velocity of the object is decreasing.

5. (a) The slope of a velocity-time graph gives the acceleration of an object. The acceleration of each object in **Figure 2** is uniform because the velocity of each object is changing at a constant rate, as shown by each straight-line graph.

(b) Acceleration is given by the equation

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{change in time}} \quad \text{or} \quad \vec{a} = \frac{\vec{v}_\text{f} - \vec{v}_\text{i}}{\Delta t}$$

Object A:

$$\begin{aligned}\vec{a} &= \frac{\vec{v}_\text{f} - \vec{v}_\text{i}}{\Delta t}\\ &= \frac{16 \text{ m/s [N]} - 4 \text{ m/s [N]}}{10 \text{ s}}\\ \vec{a} &= 1.2 \text{ m/s}^2 \text{ [N]}\end{aligned}$$

The acceleration of object A is 1.2 m/s^2 [N].

Object B:

$$\begin{aligned}\vec{a} &= \frac{\vec{v}_\text{f} - \vec{v}_\text{i}}{\Delta t}\\ &= \frac{12 \text{ m/s [N]} - 4 \text{ m/s [N]}}{10 \text{ s}}\\ \vec{a} &= 0.8 \text{ m/s}^2 \text{ [N]}\end{aligned}$$

The acceleration of object B is 0.8 m/s^2 [N].

Object C:

$$\begin{aligned}\vec{a} &= \frac{\vec{v}_\text{f} - \vec{v}_\text{i}}{\Delta t}\\ &= \frac{8 \text{ m/s [N]} - 4 \text{ m/s [N]}}{10 \text{ s}}\\ \vec{a} &= 0.4 \text{ m/s}^2 \text{ [N]}\end{aligned}$$

The acceleration of object C is 0.4 m/s^2 [N].

(c) The area under a velocity-time graph gives an object's displacement. Object A has the greatest area under the graph, so it travelled the greatest distance.

6. (a) Line A represents the motion of the brass weight, line B represents the motion of the golf ball, and line C represents the motion of the coffee filter. Initially, each object undergoes an accelerated motion owing to gravity. The velocity of the brass weight is the greatest because it is least affected by air resistance due to its heavy weight.

(b) The coffee filter experiences the greatest air resistance due to its low weight. When the air resistance equals the force of gravity acting on the coffee filter, the coffee filter stops accelerating and stays at a constant velocity, as shown by the horizontal line on its graph.

(c) The acceleration of the golf ball and the brass weight are not significantly different because air resistance does not have a significant effect on the motion of either object.

7. (a) Each ticker tape represents a linear motion with constant velocity in the direction of motion of the object because the objects are equally spaced.

(b) Tape 3 represents the greatest velocity because the object travels the same distance in the least time. Tape 2 represents the slowest velocity because the object travels the same distance in the longest time.

(c) Velocity is given by $v = \dfrac{\Delta d}{\Delta t}$.

Object 1:

$$\begin{aligned}\vec{v} &= \frac{\Delta \vec{d}}{\Delta t}\\ v &= \frac{7.5 \text{ cm}}{\frac{4}{60} \text{ s}}\\ &= 7.5\ \cancel{\text{cm}}\left(\frac{60}{4 \text{ s}}\right)\left(\frac{1 \text{ m}}{100\ \cancel{\text{cm}}}\right)\\ v &= 1.1 \text{ m/s}\\ \vec{v} &= 1.1 \text{ m/s [forward]}\end{aligned}$$

The velocity of object 1 is 1.1 m/s [forward].

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Object 2:

$\vec{v} = \dfrac{\Delta \vec{d}}{\Delta t}$

$v = \dfrac{7.5\text{ cm}}{\frac{6}{60}\text{ s}}$

$= 7.5\ \cancel{\text{cm}} \left(\dfrac{60}{6\text{ s}}\right)\left(\dfrac{1\text{ m}}{100\ \cancel{\text{cm}}}\right)$

$v = 0.75$ m/s

$\vec{v} = 0.75$ m/s [forward]

The velocity of object 2 is 0.75 m/s [forward].

Object 3:

$\vec{v} = \dfrac{\Delta \vec{d}}{\Delta t}$

$v = \dfrac{7.5\text{ cm}}{\frac{3}{60}\text{ s}}$

$v = 7.5\ \cancel{\text{cm}} \left(\dfrac{60}{3\text{ s}}\right)\left(\dfrac{1\text{ m}}{100\ \cancel{\text{cm}}}\right)$

$v = 1.5$ m/s

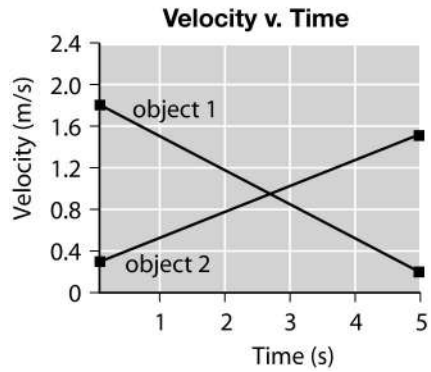
$\vec{v} = 1.5$ m/s [forward]

The velocity of object 3 is 1.5 m/s [forward].

8. (a) Ticker tape 1 represents a deceleration in the same direction as the motion of the object. The decreasing distances between dots show that the velocity of the object is decreasing over time. Then the object really slows down as shown by the significantly decreased distances between the last three dots.

Ticker tape 2 represents an acceleration in the same direction as the motion of the object. At first, the object is slowly accelerating as indicated by the distances between the first three dots. Then distances between the dots increases greatly. The last three dots show that the velocity of the object is increasing over time.

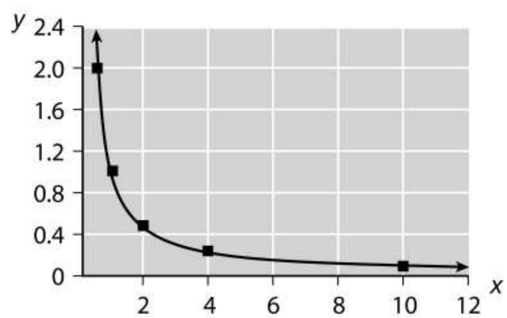
(b)



9. (a)

x	*y*
0.5	**2**
1	**1**
2	**0.5**
4	**0.25**
10	**0.1**

(b)



(c) The graph is curved. The slope, or steepness, of the graph changes from one point to another. The slope is negative and is getting shallower.