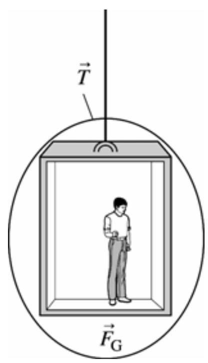
5

FORCE AND MOTION

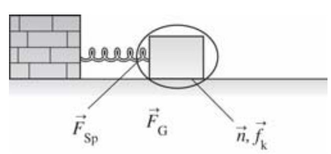
Conceptual Questions

5.1.



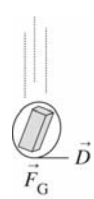
Two forces are present, tension $\vec{T}$ in the cable and gravitational force $\vec{F}_G$ as seen in the figure.

5.2.



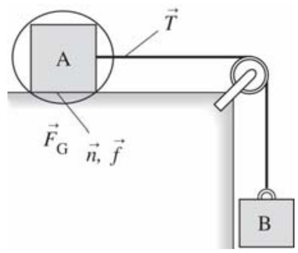
Four forces act on the block: the push of the spring $\vec{F}_{sp}$, gravitational force $\vec{F}_G$, a normal force from the table top $\vec{n}$, and a kinetic frictional force due to the rough table surface $\vec{f}_k$.

5.3.



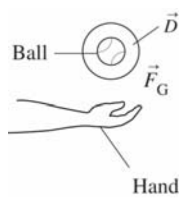
Two forces act on the brick. Air resistance, or drag $\vec{D}$, may be present, and the noncontact force due to gravity $\vec{F}_G$.

5.4. Four forces act on the block: the string tension $\vec{T}$, normal force $\vec{n}$ and friction $\vec{f}$ with the surface, and gravitational force $\vec{F}_G$.



5.5. (a) Two forces act on the ball after it leaves your hand: the long-range gravitational force $\vec{F}_G$ and the contact force of air resistance or drag $\vec{D}$.

(b) $\vec{F}_G$ is due to an interaction between the ball and earth, so earth is the agent. Drag $\vec{D}$ is due to an interaction between the ball and the air, so the air is the agent. Some students are tempted to list a force due to the hand acting on the ball. As can be seen in the figure, the hand is not touching the ball, and therefore it no longer applies a force to the ball.



5.6. (a) The object with the largest mass accelerates the slowest, since $a = \frac{F}{m}$. Thus B has the largest mass.

(b) The object with the smallest mass accelerates the fastest, so C has the smallest mass.

(c) Since the same force is applied to both blocks,

$$F_A = F_B \Rightarrow m_A a_A = m_B a_B \Rightarrow \frac{m_A}{m_B} = \frac{a_B}{a_A} = \frac{3}{5}$$

5.7. A force F causes an object of mass m to accelerate at $a = \frac{F}{m} = 10\ \text{m/s}^2$. Let a' be the new acceleration.

(a) If the force is doubled, $(2F) = ma' \Rightarrow a' = 2\left(\frac{F}{m}\right) = 2a = 20\ \text{m/s}^2$. The acceleration is proportional to the force, so if the force is doubled, the acceleration is also doubled.

(b) Doubling the mass means that $F = (2m)a' \Rightarrow a' = \frac{1}{2}\left(\frac{F}{m}\right) = \frac{a}{2} = 5.0\ \text{m/s}^2$.

(c) If the force and mass are both doubled, then $(2F) = (2m)a' \Rightarrow a' = \frac{F}{m} = a = 10\ \text{m/s}^2$.

5.8. A force F causes an object of mass m to accelerate at $a = \frac{F}{m} = 8\ \text{m/s}^2$. Let a' be the new acceleration.

(a) If the force is halved, $\left(\frac{F}{2}\right) = ma' \Rightarrow a' = \left(\frac{F}{2m}\right) = \frac{a}{2} = 4\ \text{m/s}^2$. The acceleration is proportional to the force, so if the force is halved, the acceleration is also halved.

(b) If the mass is halved, $F = \left(\frac{m}{2}\right)a' \Rightarrow a' = 2\left(\frac{F}{m}\right) = 2a = 16\ \text{m/s}^2$.

(c) If the force and mass are both halved, then $\left(\frac{F}{2}\right) = \left(\frac{m}{2}\right)a' \Rightarrow a' = \frac{F}{m} = a = 8\ \text{m/s}^2$.

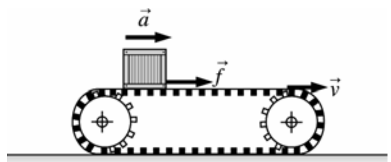
5.9. No. If an object is at rest its acceleration is zero, so you can only conclude that the net force is zero. Thus there may be several forces acting on the object, but they all must sum to zero.

5.10. Yes—other applied forces may act to cancel the first force, so that the *net* force may be zero.

5.11. False. An object will *accelerate* in the direction of the net force. Its initial velocity may be in any direction.

5.12. No. Newton's second law relates the applied net force $\vec{F}_{\text{net}}$ to the resulting change in motion $\vec{a}$. So the quantity $m\vec{a}$ is better understood as related to a change in motion. Note, however, that $m\vec{a}$ has units that are the same as force.

5.13.

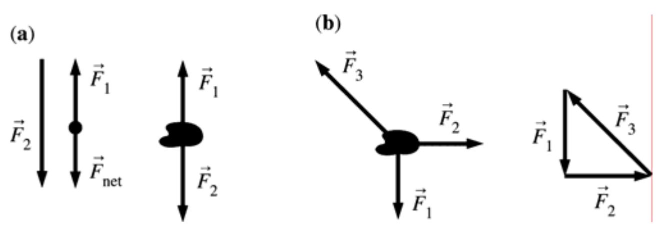


Yes, it is possible for the friction force on an object to be in the same direction as the object's motion. Consider the case shown in the figure, in which a box is dropped onto a moving conveyer belt. The box is pushed horizontally in the same direction as its motion. While an observer standing next to the conveyer belt sees the box move to the right and eventually reach a constant speed (same as the conveyer belt), an observer standing on the conveyer belt would see the box slide to the left and eventually come to a stop. The direction of the kinetic friction force is opposite to the relative direction of motion between the two adjacent surfaces. In the example above, the box is moving to the left in the reference frame of the conveyer belt and, as expected, the kinetic friction force is to the right.

5.14. The friction force between two surfaces is parallel to the surfaces. Since the wall is vertical, the friction force is also vertical. To determine whether the static friction force is up or down, imagine that friction slowly disappears. You can imagine the book beginning to slide downward as no vertical forces are left to counteract the gravitational force (the normal force is perpendicular to the surface, so is horizontal in this problem). Thus static friction must be up to balance the gravitational force downward, so the response is c.

5.15. The ball follows path C as it emerges from the tube. The centripetal force keeping it moving in a circle within the tube is the normal force exerted by the tube wall on the ball. When that force is removed, the ball moves in a straight line in accordance with Newton's first law with the velocity it had when the acceleration went to zero, which was tangential to the circle.

5.16.



(a) Basketball A is not in equilibrium because $|\vec{F}_2| > |\vec{F}_1|$, so there is a net downward force on A.

(b) Basketball B is in equilibrium because the vector sum of the three forces is zero: $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$.

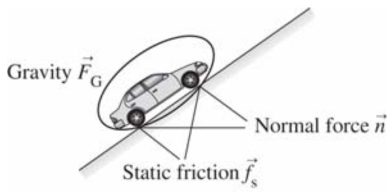
5.17. Only a and b are inertial reference frames because the car is at constant velocity in only those two cases.

Exercises and Problems

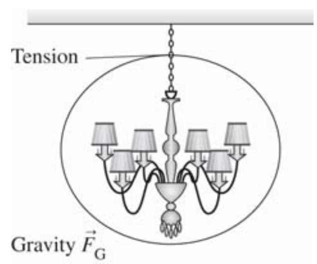
Exercises

Section 5.3 Identifying Forces

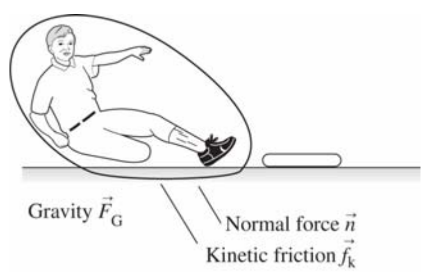
5.1 Visualize:



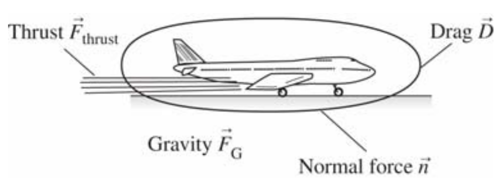
5.2. Visualize:



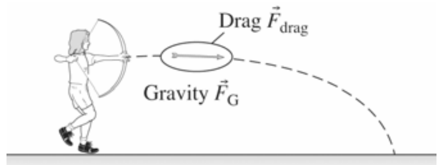
5.3. Visualize:



5.4. Model: Assume friction is negligible compared to other forces.
Visualize:



5.5. Visualize:



Section 5.4 What Do Forces Do?

5.6. Solve: Let the object have mass *m* and each rubber band exert a force *F*. For two rubber bands to accelerate the object with acceleration *a*, we must have $a = \frac{2F}{m}$. We will need *N* rubber bands to give acceleration 3*a* to a mass $\frac{1}{2}m$. Find *N*:

$$3a = \frac{NF}{m/2} \Rightarrow 3\left(\frac{2F}{m}\right) = \frac{2NF}{m} \Rightarrow N = 3$$

Three rubber bands are required.

5.7. Model: An object's acceleration is linearly proportional to the net force.
Solve: (a) One rubber band produces a force *F*, two rubber bands produce a force 2*F*, and so on. Because $F \propto a$ and two rubber bands (force 2*F*) produce an acceleration of $1.2\ \text{m/s}^2$, four rubber bands will produce an acceleration of $2.4\ \text{m/s}^2$.
(b) Now, we have two rubber bands (force 2*F*) pulling two glued objects (mass 2*m*). From part (a), we know that $2F/m = 1.2\ \text{m/s}^2$, we have

$$2F = (2m)a \quad \Rightarrow \quad a = F/m = 0.60\ \text{m/s}^2$$

5.8. Visualize: Please refer to Figure EX5.8.
Solve: Newton's second law is *F* = *ma*. Applying this to curves 1 at the point *F* = 3 rubber bands and to curve 2 at the point *F* = 5 rubber bands gives

$$\left.\begin{aligned} 3F &= m_1(5a_1) \\ 5F &= m_2(4a_1) \end{aligned}\right\} \frac{3}{5} = \frac{5m_1}{4m_2} \quad \Rightarrow \quad \frac{m_1}{m_2} = \frac{12}{25}$$

Assess: The line with the steepest slope should have the smallest mass, so we expect $m_1 < m_2$, which is consistent with our calculation.

5.9. Visualize: Please refer to Figure EX5.9.
Solve: Newton's second law is *F* = *ma*. Applying this to curves 1 and 2 at the point *F* = 2 rubber bands gives

$$\left.\begin{aligned} 2F &= m_1(5a_1) \\ 2F &= m_2(2a_1) \end{aligned}\right\} 1 = \frac{5m_1}{2m_2} \quad \Rightarrow \quad m_1 = \frac{2}{5}m_2 = \frac{2}{5}(0.20\ \text{kg}) = 0.080\ \text{kg}$$

Repeating the calculation for curves 2 and 3 at the point *F* = 5 rubber bands gives

$$\left.\begin{aligned} 5F &= m_2(5a_1) \\ 5F &= m_3(2a_1) \end{aligned}\right\} 1 = \frac{5m_2}{2m_3} \quad \Rightarrow \quad m_3 = \frac{5}{2}m_2 = \frac{5}{2}(0.20\ \text{kg}) = 0.50\ \text{kg}$$

Assess: The line with the steepest slope should have the smallest mass, so we expect $m_1 < m_2 < m_3$, which is consistent with our calculation.

5.10. Solve: Use proportional reasoning. Given that distance traveled is proportional to the square of the time, $d \propto t^2$, so $\frac{d}{t^2}$ should be constant. We have

$$\frac{2.0\ \text{furlongs}}{(2.0\ \text{s})^2} = \frac{x}{(4.0\ \text{s})^2} \quad \Rightarrow x = \frac{(4.0\ \text{s})^2}{(2.0\ \text{s})^2}(2.0\ \text{furlongs}) = 8.0\ \text{furlongs}$$

Thus the distance traveled by the object in 4.0 s is *x* = 8.0 furlongs.
Assess: A longer time should result in a longer distance traveled.

5.11. Visualize : Since the potential energy U is inversely proportional to the distance r, we can use the constant c to write $U = \dfrac{c}{r}$.

Solve:

$$U_{30} = \frac{c}{r_{30}} \qquad U_{20} = \frac{c}{r_{20}}$$

Now use ratios so the c will cancel.

$$\frac{U_{20}}{U_{30}} = \frac{c/r_{20}}{c/r_{30}} = \frac{r_{30}}{r_{20}} = \frac{30\text{ nm}}{20\text{ nm}}$$

And finally solve for U_{20}.

$$U_{20} = \left(\frac{3}{2}\right)U_{30} = \frac{3}{2}(1.0\text{ J}) = 1.5\text{ J}$$

Section 5.5 Newton's Second Law

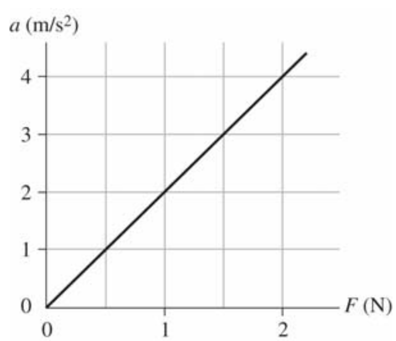
5.12. Solve: Newton's second law tells us that $F = ma$. Compute F for each case:

(a) $F = (0.200\text{ kg})(5\text{ m/s}^2) = 1\text{ N}$.

(b) $F = (0.200\text{ kg})(10\text{ m/s}^2) = 2\text{ N}$.

Assess: To double the acceleration we must double the force, as expected.

5.13. Visualize:



Solve: (a) Newton's second law is $F = ma$. When $F = 2\text{ N}$, we have $2\text{ N} = (0.5\text{ kg})a$, so $a = 4\text{ m/s}^2$.

(b) When $F = 1\text{ N}$, we have $1\text{ N} = (0.5\text{ kg})a$, so $a = 2\text{ m/s}^2$.

After repeating this procedure at various points, the above graph is obtained.

5.14. Visualize: Please refer to Figure EX5.14.

Solve: Newton's second law is $F = ma$. The graph tells us the acceleration as a function of mass. Knowing the mass and acceleration for any given point, we can find the force. We chose the m = 300 g = 0.30 kg, which gives a = 5.0 m/s^2. Newton's second law yields $F = ma = (0.30\text{ kg})(5.0\text{ m/s}^2) = 1.5\text{ N}$

Assess: To double-check the result insert F = 1.5 N into Newton's law for m = 100 g = 0.10 kg. This gives $a = F/m = (1.5\text{ N})/(0.1\text{ kg}) = 15\text{ m/s}^2$, which is consistent with the graph.

5.15. Visualize: Please refer to Figure EX5.15.
Solve: Newton's second law is $F = ma$. The graph tells us the acceleration as a function of force. Knowing the force and acceleration for any given point, we can find the mass. We chose the F = 100 N, which gives $a = 4.0\ \text{m/s}^2$. Newton's second law yields $m = F/a = (100\ \text{N})/(4.0\ \text{m/s}^2) = 25\ \text{kg}$.

Assess: To double-check the result insert m = 25 kg into Newton's law for F = 50 N. This gives a = 2.0 m/s^2, which is consistent with the graph.

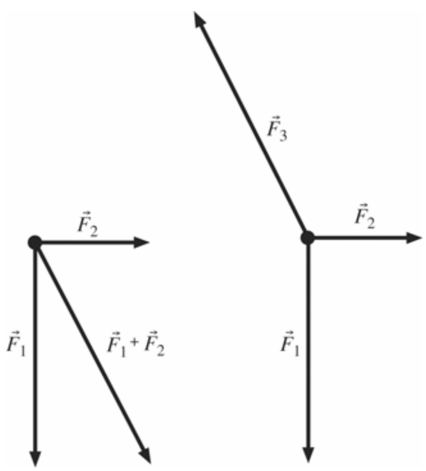
5.16. Solve: (a) This problem calls for an *estimate*, so we are looking for an approximate answer. Table 5.1 gives us no information on laptops, but does give the weight of a one-pound object. Place a pound weight in one hand and the laptop on the other. The sensation on your hand is the weight of the object. The sensation from the laptop is about five times the sensation from the pound weight. So we conclude the weight of the laptop is about five times the weight of the one-pound object or about 25 N.
(b) According to Table 5.1, the propulsion force on a car is 5000 N. A bicycle (including the rider) is about 100 kg. This is about one-tenth of the mass of a car, which is about 1000 kg for a compact model. The acceleration of a bicycle is somewhat less than that of a car, let's guess about one-fifth. We can write Newton's second law as follows:

$$F(\text{bicycle}) = \frac{1}{10}(\text{mass of car}) \times \frac{1}{5}(\text{acceleration of car}) = \frac{5000\ \text{N}}{50} = 100\ \text{N}$$

So we would *roughly estimate* the propulsion force of a bicycle to be 100 N.

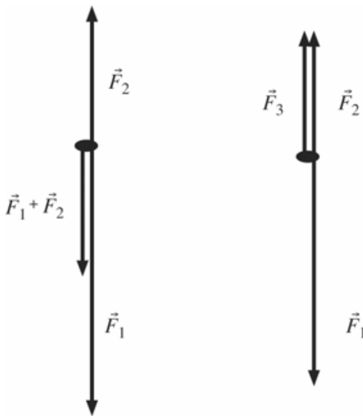
Section 5.6 Newton's First Law

5.17. Visualize:



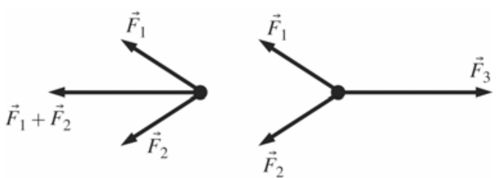
Solve: The object will be in equilibrium if $\vec{F}_3$ has the same magnitude as $\vec{F}_1 + \vec{F}_2$ but is in the opposite direction so that the sum of all the three forces is zero.

5.18. Visualize:



Solve: The object will be in equilibrium if $\vec{F}_3$ has the same magnitude as $\vec{F}_1 + \vec{F}_2$ but is in the opposite direction so that the sum of all three forces is zero.

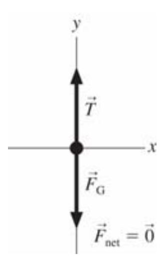
5.19. Visualize:



Solve: The object will be in equilibrium if $\vec{F}_3$ has the same magnitude as $\vec{F}_1 + \vec{F}_2$ but is in the opposite direction so that the sum of all the three forces is zero.

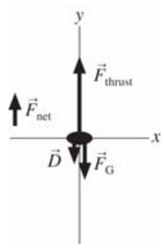
Section 5.7 Free-Body Diagrams

5.20. Visualize:



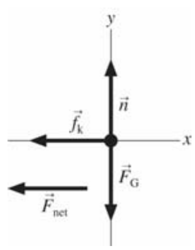
Solve: The free-body diagram shows two equal and opposite forces such that the net force is zero. The force directed down is labeled as a gravitational force, and the force directed up is labeled as a tension. With zero net force the acceleration is zero. So, a possible description is "an object hangs from a rope and is at rest" or "an object hanging from a rope is moving up or down with a constant speed."

5.21. Visualize:



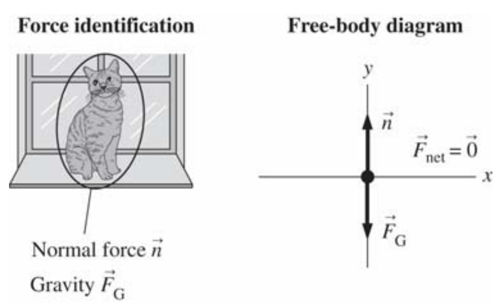
Solve: The free-body diagram shows three forces with a net force (and therefore net acceleration) upward. There is a force labeled $\vec{F}_G$ directed down, a force $\vec{F}_{thrust}$ directed up, and a force $\vec{D}$ directed down. So a possible description is: "A rocket accelerates upward."

5.22. Visualize:



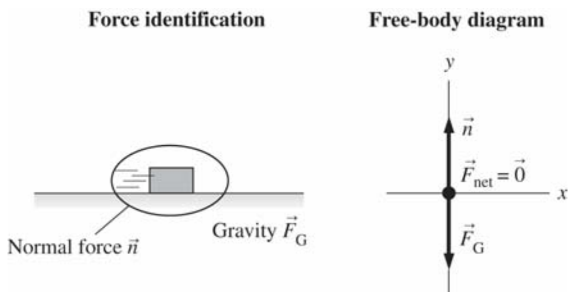
Solve: The free-body diagram shows three forces. There is a gravitational force $\vec{F}_G$, which is down. There is a normal force labeled $\vec{n}$, which is up. The forces $\vec{F}_G$ and $\vec{n}$ are shown with vectors of the same length so they are equal in magnitude and the net vertical force is zero. So we have an object on a surface and which is not moving vertically. The only horizontal force is a kinetic friction force $\vec{f}_k$ that acts to the left, so the velocity of the object must be to the right because friction always acts against the velocity. This means there is a net force to the left producing an acceleration to the left. A possible description is "a baseball player sliding into second base."

5.23. Visualize:



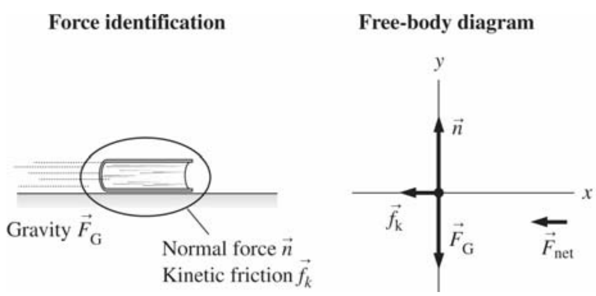
Assess: The cat is stationary, so there is no frictional force.

5.24. Visualize:



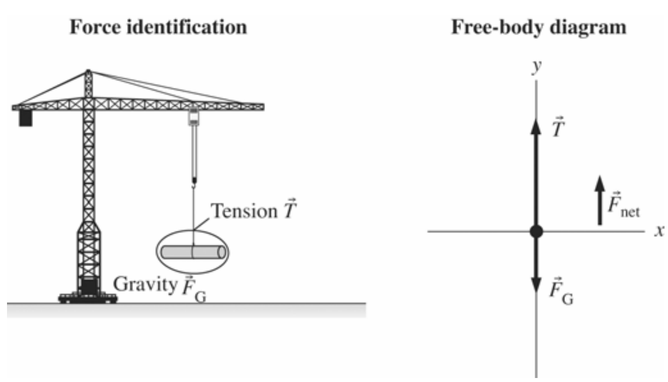
Assess: The problem says that there is no friction and it tells you nothing about any drag; so we do not include either of these forces. The only remaining forces are the weight and the normal force.

5.25. Visualize:



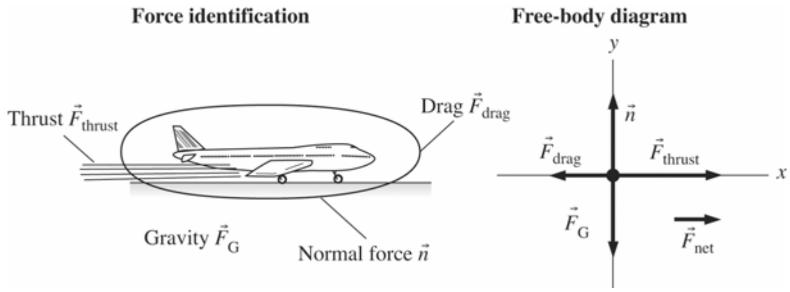
Assess: The problem uses the word "sliding." Any real situation involves friction with the surface. Since we are not told to neglect it, we show that force.

5.26. Visualize:



Assess: The problem uses the word "sliding." Any real situation involves friction with the surface. Since we are not told to neglect it, we show that force.

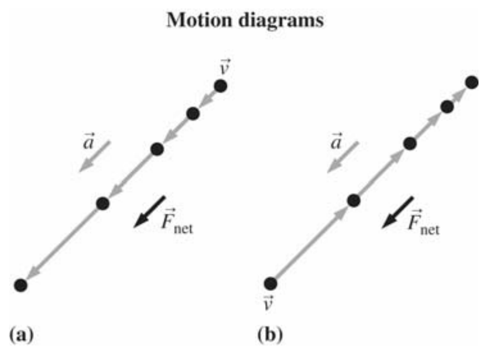
5.27. Visualize:



Assess: Since the velocity is constant, the acceleration is zero, and the net force is zero.

Problems

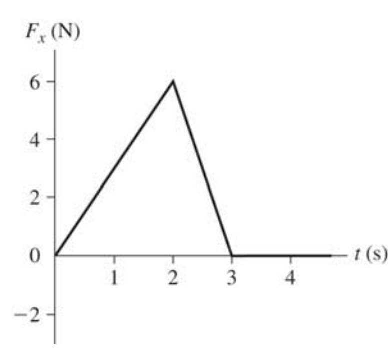
5.28. Visualize:



The velocity vector in figure (a) is shown downward and to the left, so movement is downward and to the left. The velocity vectors get successively longer, which means the speed is increasing. Therefore the acceleration is downward and to the left, as shown. By Newton's second law $\vec{F} = m\vec{a}$, the net force must be in the same direction as the acceleration. Thus, the net force is downward and to the left.

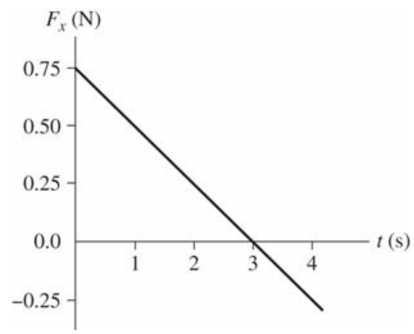
The velocity vector in (b) is shown to be upward and to the right. So movement is upward and to the right. The velocity vector gets successively shorter, which means the speed is decreasing. Therefore the acceleration is downward and to the left, as shown From Newton's second law, the net force must be in the direction of the acceleration, so it is directed downward and to the left.

5.29. Visualize:



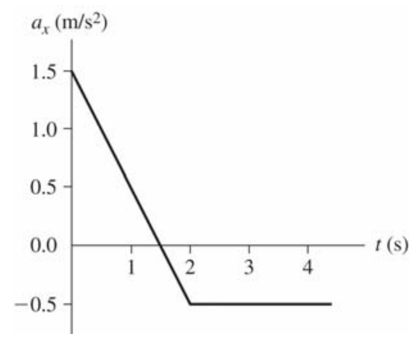
Solve: According to Newton's second law $F = ma,$ the force at any time is found simply by multiplying the value of the acceleration by the mass of the object. Thus, for example, the point at (2 s, 3 m/s^2) become (2 s, 2 m/s^2 × 2.0 kg) = (2 s, 6 N).

5.30. Visualize:



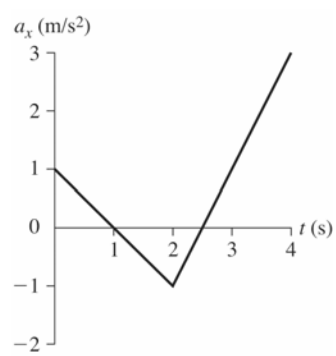
Solve: According to Newton's second law $F = ma,$ the force at any time is found simply by multiplying the value of the acceleration by the mass of the object. Thus, for example, the point at (1 s, 1 m/s^2) become (1 s, 1 m/s^2 × 0.5 kg) = (1 s, 0.5 N).

5.31. Visualize:



Solve: According to Newton's second law $F = ma,$ the acceleration at any time is found simply by dividing the value of the force by the mass of the object. Thus, for example, the point at (0 s, 3 N) become [0 s, (3 N)/(2.0 kg)] = (0 s, 1.5 m/s^2).

5.32. Visualize:



Solve: According to Newton's second law $F = ma,$ the acceleration at any time is found simply by dividing the value of the force by the mass of the object. Thus, for example, the point at (2 s, −0.5 N) become [2 s, (−0.5 N)/(0.5 kg)] = (0 s, −1 m/s^2).

5.33. Model: Use the particle model for the object.

Solve: (a) We are given that, for an unknown force (call it F_0) acting on an unknown mass (call it m_0), the acceleration of the mass is $a_0 = 8.0\text{ m/s}^2$. According to Newton's second law, $F_0 = m_0 a_0$ so $F_0/m_0 = a_0$. If the force is doubled to $F' = 2F_0$, Newton's second law gives

$$F' = m_0 a'$$

$$a' = F'/m_0 = 2F_0/m_0 = 2a_0 = 16\text{ m/s}^2$$

(b) The force is F_0 and the mass is now $m' = 2m_0$. Newton's second law gives

$$F_0 = m'a'$$

$$F_0 = 2m_0 a' \quad \Rightarrow \quad a' = F_0/(2m_0) = a_0/2 = 4.0\text{ m/s}^2$$

(c) The force is $F' = 2F_0$ and the mass is $m' = 2m_0$. By inspection of Newton's second law, it is evident that the acceleration stays the same, so $a' = 8.0\text{ m/s}^2$.

(d) The force is $F' = 2F_0$ and the mass is $m' = m_0/2$. Newton's second law gives

$$F' = m'a'$$

$$2F_0 = (m_0/2)a' \quad \Rightarrow \quad a' = 4F_0/m_0 = 4a_0 = 32\text{ m/s}^2$$

5.34. Model: Use the particle model for the object.

Solve: (a) We are told that, for an unknown force (call it F_0) acting on an unknown mass (call it m_0), the acceleration of the mass is $a_0 = 10\text{ m/s}^2$. According to Newton's second law, $F_0 = m_0 a_0$ so $F_0/m_0 = a_0 = 10\text{ m/s}^2$. If the force becomes $F' = \frac{1}{2}F_0$, Newton's second law gives

$$F' = m_0 a'$$

$$F_0/2 = m_0 a' \quad \Rightarrow \quad a' = F_0/(2m_0) = \tfrac{1}{2}a_0 = 5.0\text{ m/s}^2$$

(b) The force is F_0 and the mass is now $m' = \frac{1}{2}m_0$. Newton's second law gives

$$F_0 = m'a'$$

$$F_0 = \tfrac{1}{2}m_0 a' \quad \Rightarrow \quad a' = 2F_0/m_0 = 2a_0 = 20\text{ m/s}^2$$

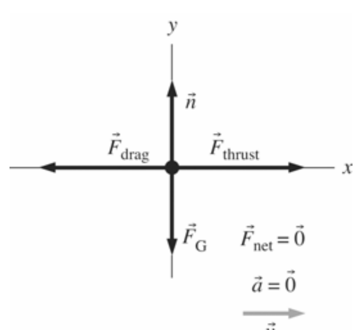
(c) The force is $F' = \frac{1}{2}F_0$ and the mass is $m' = \frac{1}{2}m_0$. By inspection of Newton's second law, it is evident that the acceleration stays the same, so $a' = 10\text{ m/s}^2$.

(d) The force is $F' = \frac{1}{2}F_0$ and the mass is $m' = 2m_0$ Newton's second law gives

$$F' = m'a'$$

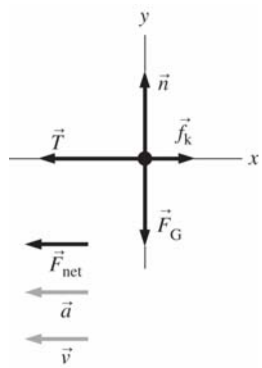
$$\tfrac{1}{2}F_0 = 2m_0 a' \quad \Rightarrow \quad a' = \tfrac{1}{4}F_0/m_0 = \tfrac{1}{4}a_0 = 2.5\text{ m/s}^2$$

5.35. Visualize:



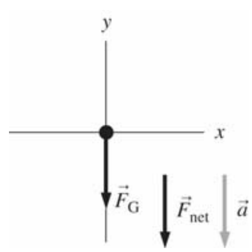
Solve: (d) There is a normal force and a gravitational force that are equal and opposite, so this is an object on a horizontal surface, or at least balanced in the vertical direction. The velocity vector is most likely in the same direction as the thrust. The description of this free-body diagram could be "a jet-powered race car driving at constant speed."

5.36. Visualize:



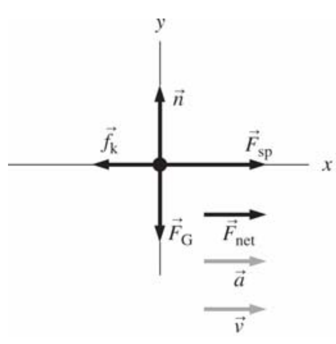
Solve: (d) There are a normal force and a gravitational force that are equal and opposite, so this is an object on a horizontal surface. The object is being pulled to the left with a nonzero net force, so it is accelerating to the left. Because the friction force is kinetic, we know that the velocity is nonzero, and is most likely in the direction of the net force. The description could be "a tow truck pulls a car out of the mud."

5.37. Visualize:



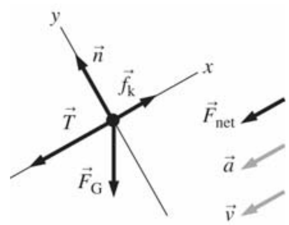
Solve: (d) There is only a single force, which is the force due to gravity. We are unable to determine the direction of motion. The description could be "Galileo has dropped a ball from the Leaning Tower of Pisa."

5.38. Visualize:



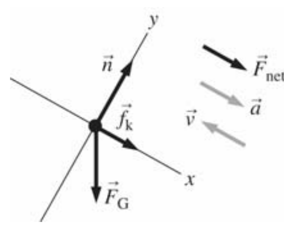
Solve: (d) This is an object on a horizontal surface because $F_G = n$. It must be moving to the right because the kinetic friction is to the left. It is experiencing a net force to the right, so it is accelerating to the right. The description of the free-body diagram could be "a compressed spring is pushing a wooden block to the right over a table top."

5.39. Visualize:



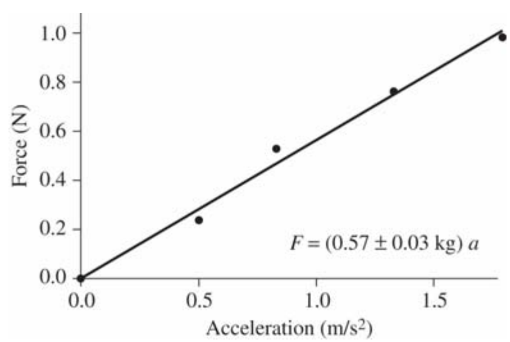
Solve: (d) There is an object on an inclined surface with a tension force pulling down the surface. There is a small kinetic frictional force directed up the surface, which implies that the object is sliding down the slope. A description could be "a box is being pulled down a slope with a rope that is parallel to the slope."

5.40. Visualize:



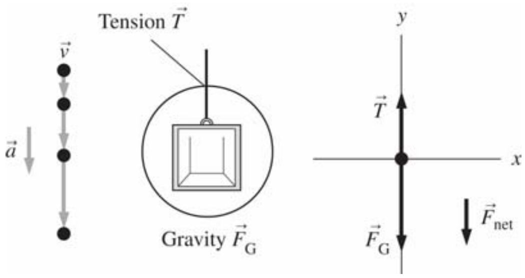
Solve: (d) There is an object on an inclined surface. The net force is down the surface so the acceleration is down the surface. The net force includes both a kinetic frictional force and a component of the gravitational force. Because the kinetic frictional force is pointing down the slope, the object must be moving upward. The description could be "a car is skidding up an embankment."

5.41. Visualize:



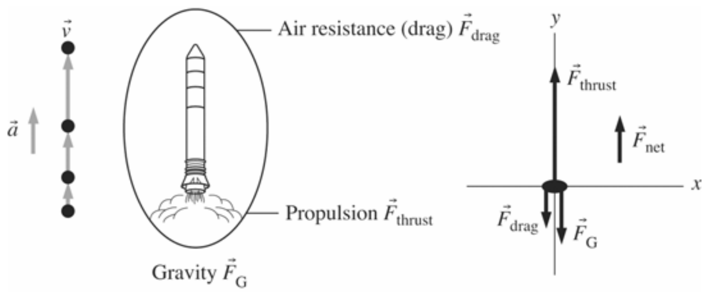
Solve: (a) Newton's second law is $F = ma$, so if we plot force as a function of acceleration (i.e., force is on vertical axis, acceleration on horizontal axis), the slope of the curve should be the acceleration (see figure above).
(b) It would be reasonable to add the point (0 m/s^2, 0 N) because Newton's second law tells us that zero force corresponds to an acceleration of zero.
(c) From the figure, we can estimate the mass from the slope. The result is $m = 0.57$ kg.

5.42. Visualize:

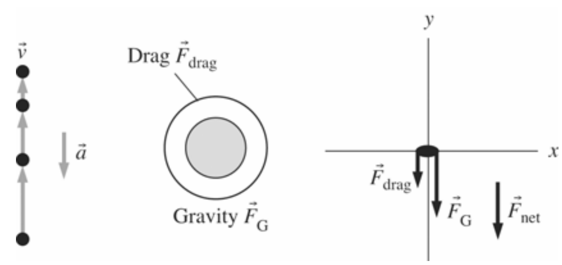


Tension is the only contact force. The downward acceleration implies that $F_G > T$.

5.43. Visualize:

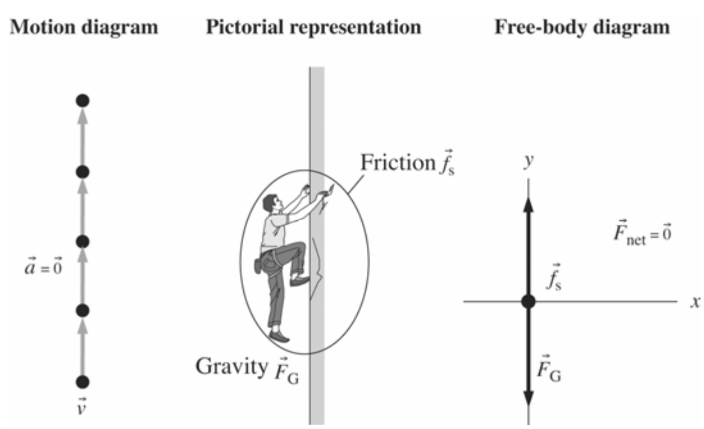


5.44. Visualize:



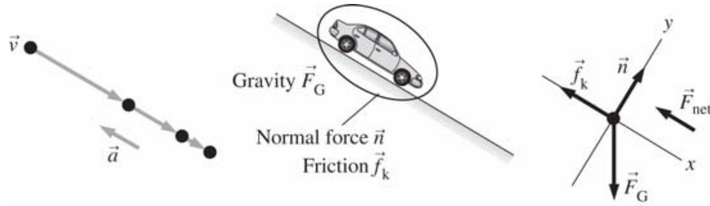
The drag force due to air is directed opposite to the motion.

5.45. Visualize:



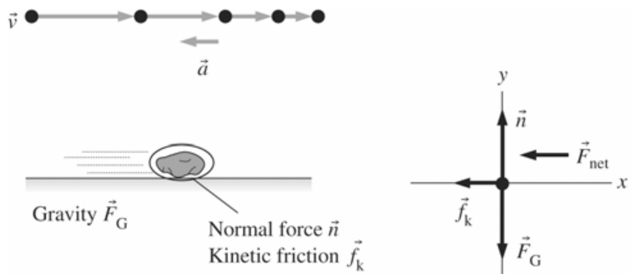
Since the wall is vertical it can’t provide a vertical component of the normal force, so the static friction force is the only other candidate. In reality there are small protrusions from a real wall that can provide an upward normal force.

5.46. Visualize:



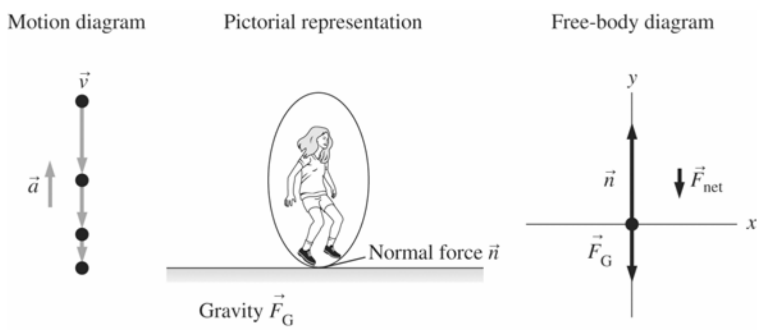
The normal force is perpendicular to the hill. The frictional force is parallel to the hill.

5.47. Visualize:



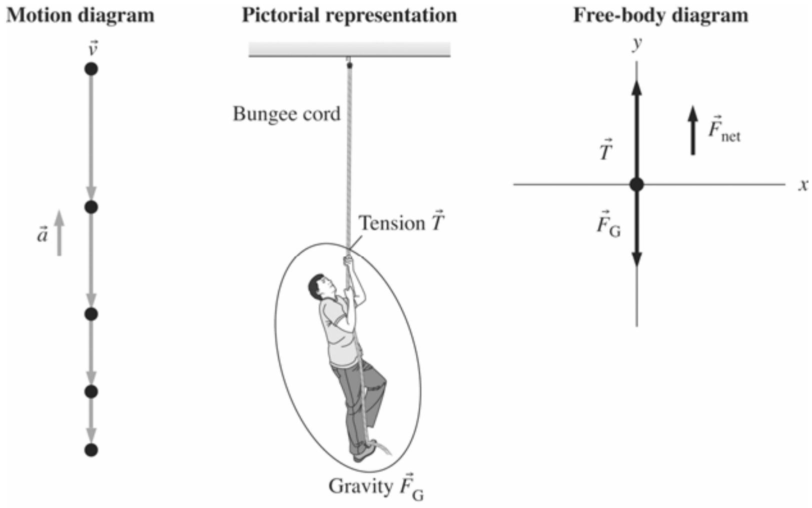
As the rock slides there is kinetic friction between it and the rough concrete sidewalk. Since the rock stays on the level surface, the net force must be along that surface, and is equal to the kinetic friction.

5.48. Visualize:



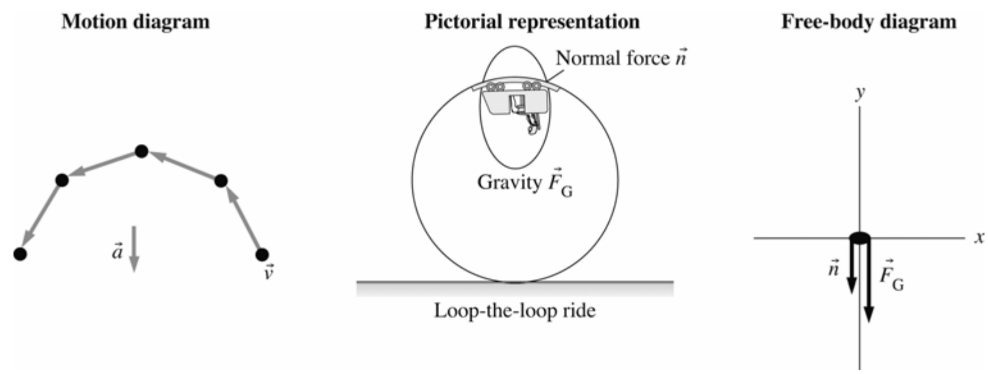
You are going down but accelerating upward.

5.49. Visualize:



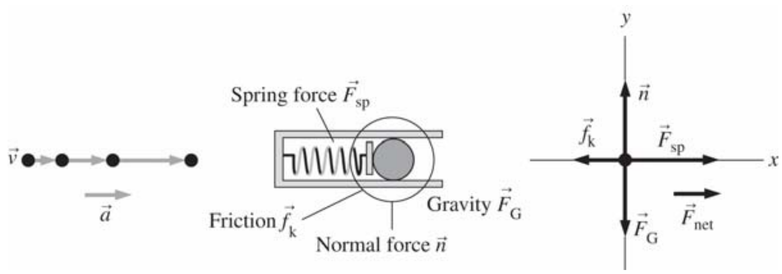
You are going down but accelerating upward.

5.50. Visualize:



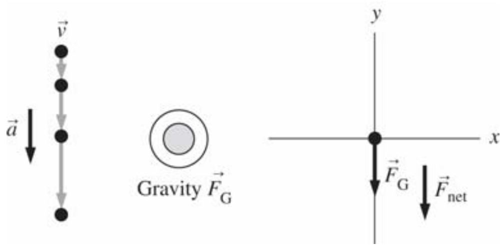
The acceleration is toward the center of the circle, which is down in this case.

5.51. Visualize:



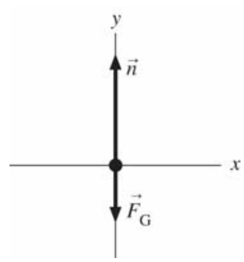
The ball rests on the floor of the barrel because the gravitational force is equal to the normal force. The force of the spring pushes to the right and causes an acceleration to the right.

5.52. Visualize:



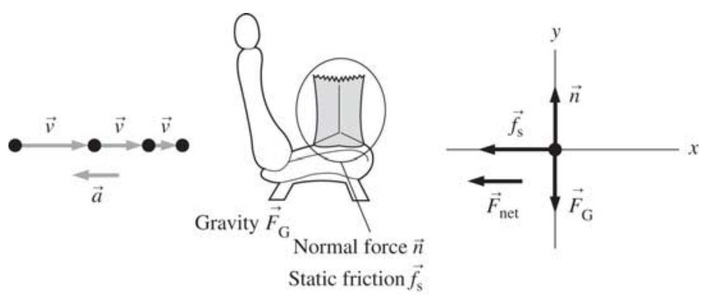
There are no contact forces on the rock. The gravitational force is the only force acting on the rock.

5.53. Visualize:



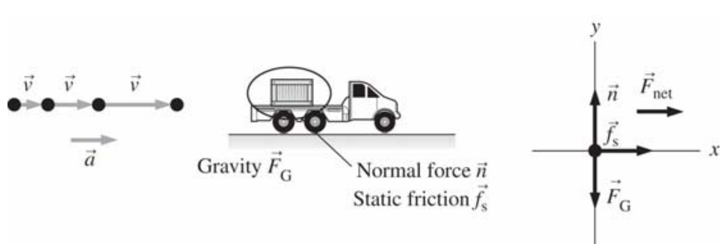
Solve: (b) While the leaf hopper is in the act of jumping, it experiences an upward acceleration of 4 m/s^2, so the net force acting on it must be upward. Because only the normal force and the force due to gravity are acting in the vertical direction, the normal force from the ground must be greater than the force due to gravity.

5.54. Visualize:



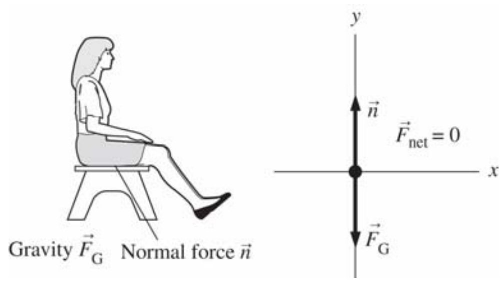
You can see from the motion diagram that the bag accelerates to the left along with the car as the car slows down. According to Newton's second law, $\vec{F} = m\vec{a}$, there must be a force to the *left* acting on the bag. This is friction, but not kinetic friction. The bag is not sliding across the seat. Instead, it is static friction, the force that prevents slipping. Were it not for static friction, the bag would slide off the seat as the car stops. Static friction acts in the direction needed to prevent slipping. In this case, friction must act in the backward (toward the left) direction.

5.55. Visualize:

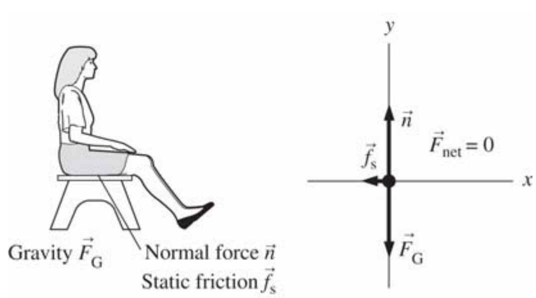


You can see from the motion diagram that the box accelerates to the right along with the truck. According to Newton's second law, $\vec{F} = m\vec{a}$, there must be a force to the *right* acting on the box. This is friction, but not kinetic friction. The box is not sliding against the truck. Instead, it is static friction, the force that prevents slipping. Were it not for static friction, the box would slip off the back of the truck. Static friction acts in the direction needed to prevent slipping. In this case, friction must act in the forward (toward the right) direction.

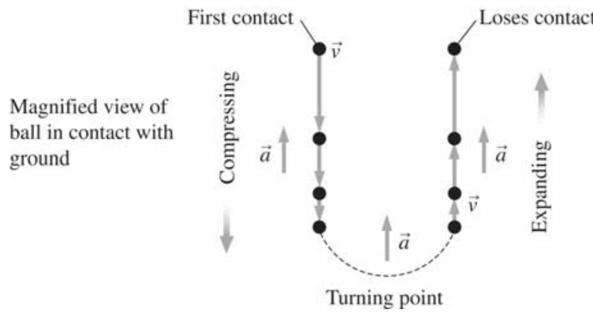
5.56. Visualize: (a)



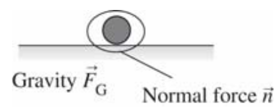
You are sitting on a bench driving along to the right. Both you and the bench are moving with a *constant* speed, so there are no horizontal forces. There is a force on you due to gravity, which is directed down. There is a contact force between you and the bench, which is directed up. Since you are not accelerating up or down the net vertical force on you is zero, which means the two vertical forces are equal in magnitude. The statement of the problem gives no indication of any other contact forces. Specifically, we are told that the bench is *very* slippery. We can take this to mean there is no frictional force. So our force diagram includes only the normal force up, the gravitational force down, and no horizontal force.
(b) The above considerations lead to the free-body diagram that is shown.
(c) The car (and therefore the bench) slows down. Does this create any new force *on you*? No. The forces remain the same. This means the pictorial representation and the free-body diagram are unchanged.
(d) The car slows down because of some new contact force on the car (maybe the brakes lock the wheels and the road exerts a force on the tires). But there is no new contact force on *you*. So the force diagram for *you* remains unchanged. There are no horizontal forces on *you*. You do not slow down and you continue at constant velocity until something in the picture changes for you (for example, you fall off the bench or hit the windshield).
(e) The net force on *you* has remained zero because the net vertical force is zero and there are no horizontal forces at all. According to Newton's first law, if the net force on you is zero, then you continue to move in a straight line with a constant velocity. That is what happens to you when the car slows down. You continue to move forward with a constant velocity. The statement that you are "thrown forward" is misleading and incorrect. To be "thrown" there would need to be a net force on you and there is none. It might be correct to say that the car has been "thrown backward" leaving you to continue onward (until you part company with the bench).
(f) We are now asked to consider what happens if the bench is NOT slippery. That implies there is a frictional force between the bench and you. This force is certainly horizontal (parallel to the surface of the bench). Is the frictional force directed forward (in the direction of motion) or backward? The car is slowing down and you are staying on the bench. That means you are slowing down with the bench. Your velocity to the right is decreasing (you are moving right and slowing down), so you are *accelerating* to the left. By Newton's second law that means the force producing the acceleration must be to the left. That force is the force of static friction and it is shown on the free-body diagram below. Of course, when the car *accelerates* (increases in speed to the right) and you accelerate with it, then your acceleration is to the right and the frictional force must be to the right.



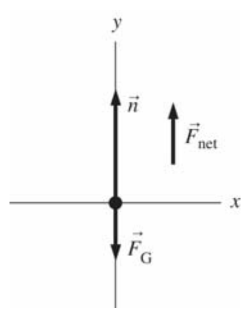
5.57. Visualize: (a)



(b)



(c)



(d) The ball accelerates downward until the instant it makes contact with the ground. Once it makes contact, it begins to compress and slow down. The compression covers a short but nonzero distance, as shown in the motion diagram above. The point of maximum compression is the turning point, where the ball has an instantaneous speed of $v = 0$ m/s and reverses direction. The ball then expands and speeds up until it loses contact with the ground. The motion diagram shows that the acceleration vector $\vec{a}$ points *upward* the entire time that the ball is in contact with the ground. An upward acceleration implies that there is a net upward force $\vec{F}_{net}$ on the ball. The only two forces on the ball are the gravitational force downward and the normal force of the ground upward. To have a net force upward requires $n > F_G$, so the ball bounces because the normal force of the ground *exceeds* the gravitational force, causing a net upward force during the entire time that the ball is in contact with the ground. This net upward force accelerates the ball in the upward direction to first slow it down, then reverse its velocity, and finally accelerate it upward until it loses contact with the ground. Once contact with the ground is lost, the normal force vanishes and the ball is simply in free fall.