Section 6

Forces Acting During Acceleration: Apparent Weight on a Roller Coaster

TECH LAB

Click Here

What Do You See?

Learning Outcomes

In this section, you will

• **Explore** the change in apparent weight as an object moves up or down with constant speed.

• **Explore** the change in apparent weight as an object accelerates up or down.

• **Analyze** the forces on a mass at rest, moving with constant velocity, or accelerating by drawing the appropriate force-vector diagrams.

• **Predict** mathematically the change in apparent weight as a mass accelerates up or down.
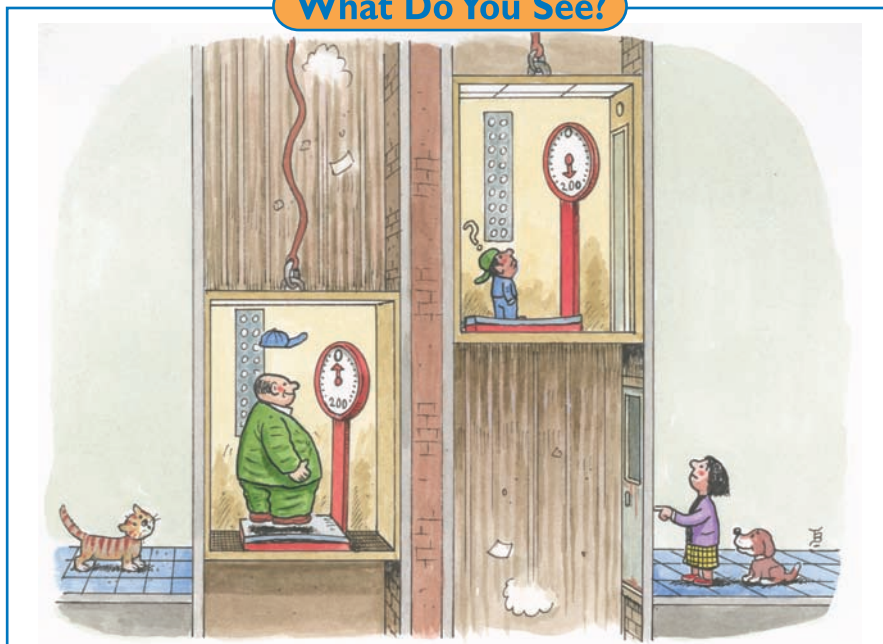
What Do You Think?

As the roller coaster moves down that first hill, up the second hill, and then over the top, you feel as if your weight is changing. As you go over the top of the hill, you have the feeling of floating when your body rises up out of the seat. In roller coaster terms, this is called airtime.

• **Does your weight change when you are riding on a roller coaster?**

• **If you were sitting on a bathroom scale, would the scale give different readings at different places on the roller coaster?**

Record your ideas about these questions in your *Active Physics* log. Be prepared to discuss your responses with your small group and the class.

Investigate

In this experiment, you will investigate the apparent weight changes you feel when you are on a roller coaster. You will use the spring scale for your observations. However, you will explain what you observe with both the spring scale and the bathroom scale.

406

Part A: Moving the Mass at a Constant Speed

1. Hang a mass from the spring scale and note the force indicated by the spring scale. When the mass is not moving and the acceleration equals 0, the force of gravity pulling the mass down and the force exerted by the spring pulling the mass up must be equal. The force of the spring has the same magnitude as the force of gravity. You could also just say, "The spring is measuring the weight."

> ⚠ Be careful when lifting and lowering the weight, as it could cause injury if it were to fall. Make smooth, unhurried movements.
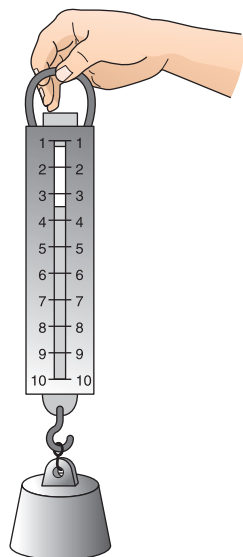
a) Record the weight of the mass in your log.

2. With your arm extended down, move the mass up until your arm is as high as you can reach. Once you start the mass moving, you want to keep lifting it at a constant speed.

   Your group members will try their best to read the spring scale during the time that the mass is moving at constant speed. Ignore the readings when you first start moving the mass and when you stop it. You will return to those observations later. It may help if the mass is behind a barrier

and not visible when you begin or stop the motion. Setting this up will require some ingenuity.

You may have to repeat this step a few times so that you can lift the mass at a constant speed so that your group members can observe it.

a) In your log, make a table similar to the one below.

	Acceleration (up, down, zero)	Scale reading (larger, smaller, equal to weight)
Mass at rest	zero	equal
Mass up at constant speed	zero	
Mass accelerating upward	up	larger
Mass at rest at top	zero	
Mass moving down at constant speed	zero	
Mass accelerating downward	down	

b) In the table in your log, record your finding for mass moving up at a constant speed.

3. The observations in *Step 2* may have been difficult for you to make accurately. The spring scale should have displayed the same reading when the scale moved at constant speed as it did when it was suspended at rest. The same result will occur in an elevator. If you are on a bathroom scale, the scale will compress and display your weight when the elevator is at rest. It will display the same weight when the elevator is moving at a constant speed between floors. Repeat the observation with the spring scale moving down at a constant speed.

Is the weight once again the same? Note that you are only interested in the weight reading as the mass descends at a constant speed, not when you first get it to move or when you stop it.

a) In the table in your log, record your finding for mass moving down at a constant speed.

4. Newton's first law states that an object at rest remains at rest and an object in motion continues to move with constant velocity, unless acted upon by an unbalanced force. Newton's second law states that an accelerating object must have a net force acting upon it; $F_{net} = ma$. When the mass is being lifted at constant speed in a straight line, there is no acceleration since acceleration is defined as a change in velocity with respect to time. If there is no acceleration, then the net force is zero.

a) Draw a box (representing the mass) in your log. Draw arrows to show the forces on the box hanging on the spring when the box is not accelerating.

5. Recall that in physics and mathematics, the arrows you drew to represent the forces are called vectors. Check your drawing to see if the arrows (vectors) have the following features:

a) Was the vector representing the weight force drawn pointing down? Why did you draw it this way?

b) Was the vector representing the force of the spring drawn pointing up? Why did you draw it this way?

c) Were there any other force vectors? What do they represent?

d) Were the weight vector and the spring force vector equal in length? The length of the vector is proportional to the magnitude of the force. If the forces are equal in magnitude, then the lengths of the vectors should be the same. If needed, change your force diagram so that the length of

the vectors correctly represents the magnitude of the forces.

e) You may have drawn a vector indicating the force applied by the hand. The hand holds the spring scale, and not the mass, so this would not be a force on the mass. If needed, modify your force diagram.

6. Now consider the box when it was moving down with constant speed.

a) Draw a second box with the force vectors when the box is moving down at a constant speed. Provide an explanation using Newton's first law and Newton's second law (similar to *Step 4*) as a rationale for your diagram.

Part B: Accelerating the Mass

1. It is now time to return to the scale readings when you first started moving the mass. With your arm extended down, accelerate the mass up until your arm is as high as you can reach. Your group members will try their best to read the spring scale during the time that the mass is accelerating. Once again, you may have to repeat this a few times so that others can lift as you observe.

a) Record your observation in your *Active Physics* log.

b) Use Newton's second law ($F_{net} = ma$) to make sense of the observation in your log.

c) Draw a box representing the mass and draw the force vectors acting on the box as it first begins to move and is accelerating upward.

2. Check your drawing to see if the force vectors have the following features:

a) Was the weight vector drawn pointing down?

b) Was the force of the spring vector drawn pointing up?

c) Were there any other force vectors? What do they represent?

d) How do the weight vector and the spring-force vector compare in length? The length of the vectors is proportional to the magnitude of the force.

3. Since the box is accelerating up, the force of the spring must have been larger than the force of gravity. Newton's second law indicates that acceleration up requires a net force up. In your force-vector diagram, the vector representing the spring scale should be longer than the vector representing the force of gravity.

a) If necessary, modify your diagram to show the spring-scale vector as longer than the force-of-gravity vector.

4. From your observations, you can see that when the mass is accelerating upward, the spring scale displays a value larger than the mass's weight. Suppose you were standing on a bathroom scale in an elevator. The elevator begins to move up. How would the reading on the bathroom scale compare to your weight at rest?

a) Record your answer in your log.

5. Returning to the mass hanging on the spring scales, predict what would happen to the scale reading when the mass stops moving upward.

a) Record your prediction in your log.

b) Repeat the observations for the moments when the mass stops its upward motion. Describe your observation in your log.

6. Suspend a mass from a spring scale. Raise the spring scale and mass slightly above eye level.

a) Slowly lower the spring scale and mass. Observe what happens to the value on the scale and write a description in your log.

b) Draw a force-vector diagram that has a net force in the direction of the acceleration.

c) Predict whether you think the scale will read a higher or lower value when it is accelerating downward as opposed to when the mass is at rest? Record your prediction.

d) Now try lowering the spring scale and mass quickly. Observe the scale and see if the value changes. Was your initial prediction correct? Explain.

7. As a summary of what changes occur to the spring-scale reading, complete the chart under *Part A*, *Step 2* in your log. Some responses are provided to help you get started.

a) Create a similar chart showing what would happen if you rode in an elevator while standing on a bathroom scale.

8. Riding in an elevator is similar to riding in a roller coaster. Although the physics is the same, the elevator ride does not have the excitement of a roller coaster.

a) Compare elevator rides and roller coasters by providing three similarities and three differences.

9. There is a ride at the amusement park today in which all you do is drop straight down. If you were to record your motion, you would find that your speed increases by 9.8 m/s every second. This value of 9.8 m/s^2 is the acceleration due to gravity near the surface of Earth. All objects near the surface of Earth fall at this same rate of change of velocity with respect to time if gravity is the only significant force acting on them.
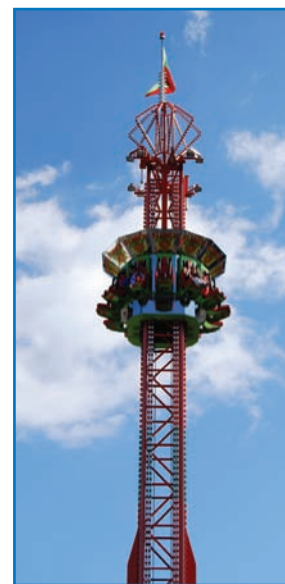
You have Galileo (1564-1642) to thank for this insight. As the story goes, he dropped two objects from the Leaning Tower of Pisa in Italy and observed them hitting the ground at the same time. The story may not be true, but Galileo did perform many experiments with balls rolling down inclined planes. The "dropping experiment" has been repeated many times with very precise equipment and with the effects of air resistance minimized or eliminated.

a) If you were at the Leaning Tower of Pisa and dropped a baseball and a bowling ball at the same time, which would hit the ground first? Explain your answer.

b) If you dropped a baseball and a piece of paper, which would hit the ground first? Explain your answer. Does the shape of the paper influence the way it drops? Do you think you could modify a sheet of paper to drop at the same time you drop a baseball? Try this and record your observations in your log.

c) How would you modify the statement, "All objects fall at the same acceleration" to account for your observation of a baseball and a sheet of paper?

The numerical value of the acceleration of falling objects, if gravity is the only significant force, is equal to the strength of the gravitational field (9.8 N/kg = 9.8 m/s^2 near the surface of Earth). That is why g is sometimes called "the acceleration due to gravity." But you should remember that in many cases, the object may experience other forces in addition to its weight. In these cases, the acceleration will not be equal to g. If you are falling under the influence of gravity alone, you are in "free fall."

Physics Talk

FORCES ACTING DURING ACCELERATION

Using Newton's First and Second Law to Explain Forces Acting During Constant Speed and Acceleration

As the roller coaster moves you about, you feel funny things happening in your stomach. These, however, are more than just feelings. These changes can be measured. You can use physics to explain these feelings.

When an object is at rest, the sum of the forces on that object equal zero. Both Newton's first law and Newton's second law can be used to explain this. Using Newton's first law (an object at rest stays at rest and an object in motion stays in motion unless acted upon by a force), the object is at rest and no net force acts on it. Using Newton's second law ($a = F/m$), you realize that the object is at rest and, therefore, has zero acceleration and, therefore, no net force acting on it.

When the object moves up at constant speed, many people are too quick to jump to the wrong conclusion that there must
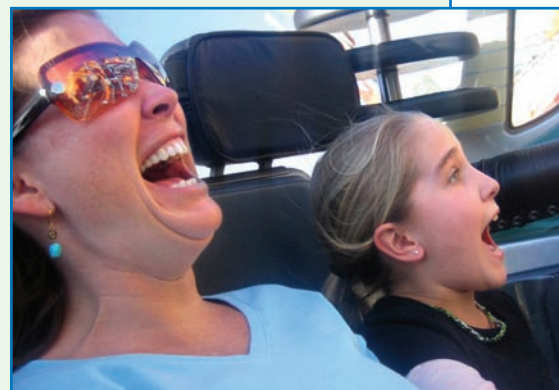
be a larger force up than down to keep the object moving up at constant speed. Both Newton's first and second laws can once again be used to explain correctly that the sum of the forces on that object equals zero. Using Newton's first law (an object at rest stays at rest and an object in motion stays in motion unless acted upon by a force) the object is in motion at constant speed and no net force acts on it. Using Newton's second law ($a = F/m$), you realize that the object is moving at constant speed and, therefore, has zero acceleration and, therefore, no net force acting on it.

The object moving down at constant speed is identical (in terms of forces and accelerations) to the object moving up at constant speed.

Your evidence for this is the observation in the *Investigate* that the spring scale exhibited the same weight whether the object was at rest or moving at a constant speed. You also observed that if the object accelerated up, there was an increase in the spring scale reading.

If you were sitting on a scale in a level roller-coaster cart, at rest or moving with a constant velocity, the scale reading would be equal to your weight. The force of Earth pulling on you (your weight), which is shown as a blue vector in the force diagram on the right, would be equal in magnitude to the force of the compressed spring within the bathroom scale, which is shown as a red vector.

Suppose you weigh 600 N. Then, the bathroom scale would have to provide a force of 600 N to make the net force on you zero. If the force were any smaller, you would accelerate down. Any larger, and you would accelerate up. When you first stand on the scale, the compression is too little and you do move down. The spring compresses and provides a larger force but you continue to move down. You go past the compression you need, and the spring then pushes up. You go back up and down and up and down and continue this movement until the spring's force is exactly equal to your weight.

600 N

600 N

As the roller coaster starts moving up, there is acceleration up. (Remember that acceleration is a change in velocity with respect to time.) For you to accelerate up, there must be a net force pushing you up. Since you are in contact with the bathroom scale, it must be the bathroom scale that is pushing you up. Yes, the roller coaster is pushing on the scale, but you only have to worry about the forces on you. Newton's second law states that it is the net force acting on you that is responsible for your acceleration.

The scale reading will be greater in magnitude than your weight (the force on you due to Earth's gravity). The magnitude of the force of the Earth pulling on you (your weight) would be less than the magnitude of the force of the compressed spring within the bathroom scale.
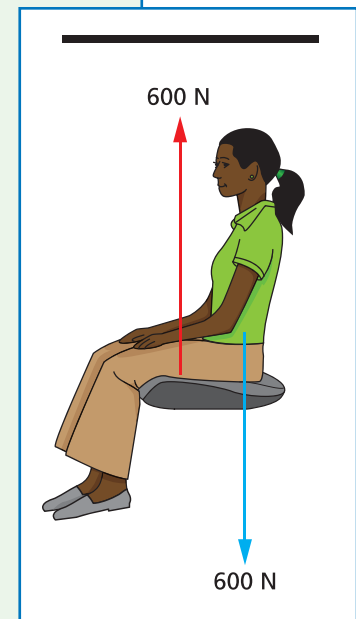
If your weight is 600 N (blue vector), then the bathroom scale would have to be providing a force of greater than 600 N (red vector).

Another way of looking at the situation is to look first at the forces. According to the vector diagram, the force of the scale is larger than the force of gravity. The net force is, therefore, up and according to Newton's second law, the object will accelerate up, $F_{net} = ma$. You observed this in the *Investigate* when you accelerated the mass up and observed the increased scale reading.

>600 N

600 N

Calculating Acceleration

Suppose you are standing on a bathroom scale in an elevator. You can calculate the acceleration of the elevator if you know your weight and measure the force as read on the spring scale during the acceleration. Assume you weigh 600.0 N and the force of the scale on you is 700.0 N up.

$$F_{net} = 700.0 \text{ N} - 600.0 \text{ N}$$
$$= 100.0 \text{ N (upward)}$$

To find the acceleration, you need to know your mass. If your weight is 600.0 N ($F_w = 600.0$ N), you can calculate your mass.

$$F_w = mg, \text{ where } g = 9.8 \text{ N/kg}$$

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

$$= \frac{600.0 \text{ N}}{9.8 \text{ N/kg}} \quad (\text{units: } \cancel{\text{N}} \times \frac{\text{kg}}{\cancel{\text{N}}})$$

$$= 61 \text{ kg}$$

Knowing the mass and the net force, you can calculate the acceleration using Newton's second law.

$$F_{net} = ma$$

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

$$= \frac{100.0 \text{ N}}{61 \text{ kg}} \quad (\text{units: } \frac{\cancel{\text{kg}} \times \text{m/s}^2}{\cancel{\text{kg}}})$$

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

Similarly, you can calculate the reading of the spring scale if you know the acceleration of the elevator.

F_{scale}

F_{weight}
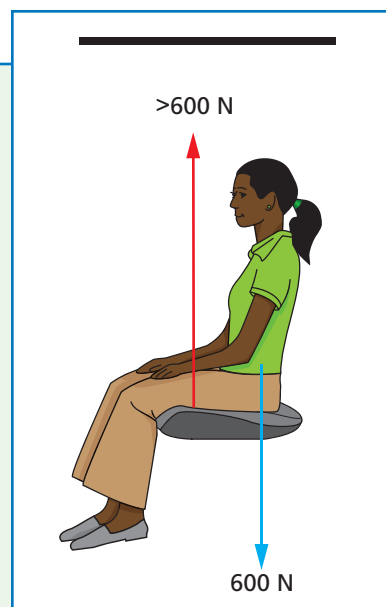
Sample Problem

An elevator at the top floor begins to descend with an acceleration of 2.0 m/s² downward. What will a bathroom scale read if a 50.0-kg person is standing on the scale while the elevator is accelerating?

Strategy: Since the elevator and the person are accelerating down, the net force on the person must be down. The force vectors are shown in the diagram on the right.

Newton's second law states that

$$F_{net} = ma$$

where F_{net} is the net force.

Since the weight is greater than the force of the spring and in the opposite direction, you can write this as

Weight – force due to bathroom scale = *ma* (downward)

Given: **Solution:**

$m = 50.0$ kg   First find the person's weight: Weight $= mg$

$a = 2.0$ m/s² $= (50.0 \text{ kg})(9.8 \text{ N/kg})$

      $= 490$ N

Using Newton's second law,

Weight $-$ force due to scale $= ma$

$$490 \text{ N} - F_{scale} = (50.0 \text{ kg})(2.0 \text{ m/s}^2)$$

Solve for the force due to the scale.

$$F_{scale} = 490 \text{ N} - (50.0 \text{ kg})(2.0 \text{ m/s}^2)$$
$$= 390 \text{ N}$$

The scale would read 390 N instead of the person's weight, which is 490 N.

If the elevator accelerates up, the scale reads a value higher than the person's weight of 490 N. There is really no limit to the upward acceleration although the person would become unconscious if the acceleration were greater than about nine times the acceleration due to gravity. This has been experimentally determined by test pilots.

If the elevator accelerates down, the scale reads a value lower than the weight of 490 N. There is a lower limit on the scale reading. If the elevator accelerates down at 9.8 m/s² (for example, the cable broke and the elevator is in free fall), the scale would not push up at all and its reading would be 0 N.
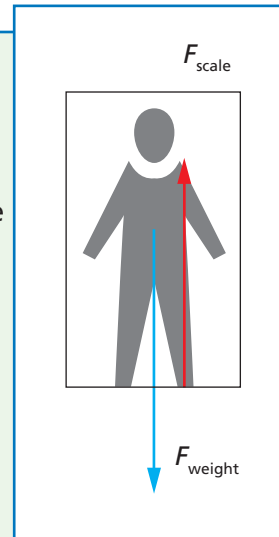
Using Newton's second law,

$$F_{scale} = ma$$

$$\text{Weight} - \text{Force by spring} = ma$$

Substitute the numerical values.

$$(50.0 \text{ kg})(9.8 \text{ N/kg}) - F_{scale} = (50.0 \text{ kg})(9.8 \text{ N/kg})$$

$$490 \text{ N} - F_{scale} = 490 \text{ N}$$

Solve for the force due to the scale.

$$F_{scale} = 0 \text{ N}$$

This is what you experience when you jump off a diving board. It is also felt for a few moments in the amusement park ride where you are in free fall.

Apparent Weight

When the elevator is at rest or moving up or down at constant velocity, your weight readings are identical. That's because at rest or moving at a constant velocity requires no net force. The force of the scale up on you is equal to the weight force down. The bathroom scale denotes the value of the force up on you.

When an object accelerates (changes its velocity), you know there must be a net force acting on the object. When the elevator accelerates up, you also accelerate up. This is because Earth pulls down on you with a force that is smaller than the force that the scale exerts on you upward. The scale reads a larger force than before.

You also feel as if you weigh more. Why is that? You feel your weight because of the contact forces between your body and other objects. When you stand on the floor, you feel the floor pushing up on you. Also, some parts of your body are only loosely connected to other parts. For example, when you are standing straight up, your stomach moves down a bit until the connective tissues in your body (acting like springs) exert a large enough force upward to hold your stomach in place against the force due to gravity. Nerve endings in those tissues allow you to feel that stretching. When the elevator accelerates upward, you feel the larger contact force between you and the bathroom scale. Also, the connective tissues have to stretch more to get your stomach to accelerate. All of this leads to a feeling of larger apparent weight.

When the elevator accelerates down, you also accelerate down. This is because the force of the scale up on you is less than the force of your weight down. The scale reads a smaller force than before. You also feel as if you weigh less because the contact force with the bathroom scale is smaller and because the connective tissues stretch a bit less. If the elevator cable were to break, you would have only the force of your weight pulling you down. The scale would not push up and you and

the force reading on the scale would be zero. You feel "weightless" because the contact force between you and the bathroom scale is zero and because the connective tissues within your body relax. (People often describe the feeling as "stomach floating.") Roller coasters, like elevators, have parts of their motion where the acceleration is up or down. At these locations, people feel as if they weigh more or less.

Air Resistance

A roller coaster in free fall will accelerate at 9.8 m/s every second. Every second, the speed will increase by 9.8 m/s. This acceleration due to gravity is identical for all objects falling on Earth, if there are no other forces acting on the object. You know that raindrops, snowflakes, and leaves falling to the ground do not accelerate at this rate. The air must be applying a force to these materials that opposes the force of gravity. This force is often referred to as air resistance. Often, in introductory physics courses, you are told to ignore air resistance. Ignoring this force makes the analysis of moving objects simpler, but incorrect. When analyzing a roller coaster, ignoring air resistance also means pretending that there is no wind on your face or clothing as you descend a big hill. When analyzing falling rain, ignoring air resistance means pretending that the rain can be going so fast that it could seriously harm you. Whenever you consider the forces on an object and decide to "ignore air resistance" you have to be aware of how much this analysis differs from the real world you live in.

Checking Up

1. What is the sum of all the forces acting on an object when it is moving up a constant speed?

2. A person sitting on a bathroom scale on a roller coaster is accelerating upward. How does the reading on the bathroom scale compare to the person's weight?

3. When you accelerate upward, why do you feel as if you weigh more?

4. Suppose you are standing on a bathroom scale in an elevator when the cable breaks. What does the bathroom scale read when you are falling with the elevator?

5. What is the force that slows a falling raindrop?

Active Physics
Plus

+Math	+Depth	+Concepts	+Exploration
	◆◆	◆◆	◆

Einstein's Theory of Gravity

When an object is falling under the influence of gravity alone, the object is in "free fall." You learned that in free fall, all objects fall with the same acceleration. Let's look at that issue more closely.

When a ball, for example, is in free fall, it is accelerating (downward) because there is a net force (gravity) acting on the ball. That force is the ball's weight, $F_{net} = F_w = mg$. Note that weight (force) is determined by the ball's mass and the strength of the gravitational field at the location of the ball.

The mass m tells you how strong the gravitational force will be. Newton's second law tells you how the net force and the ball's acceleration are related ($F_{net} = ma$). Here the mass, m, plays the role of inertia. It tells you how much the ball "resists" being accelerated.

If you combine the two equations, $mg = ma$, the mass terms cancel out and you find that in free fall, the acceleration of the ball is equal to g ($a = g$). This tells you that all objects, no matter what their mass, should have the same acceleration under free-fall conditions.

If you stop and think for a moment, it may be surprising to recognize that mass plays two different roles here. On one hand, it determines the strength of the gravitational force acting on the ball. On the other hand, it determines the inertia of the ball (its resistance to being accelerated). Why should those two effects be the same? Most scientists took this relationship for granted until Albert Einstein, in about 1915, recognized the deep significance of having the same "mass" for both the gravitational force and for inertia. From this insight, he developed an entirely new theory of gravity based on ideas such as curved space-time.

The following exercise will provide some insights into Einstein's theory of gravity (the General Theory of Relativity).

1. Rewrite the equations on the previous page using subscripts to distinguish between $m_{inertial}$ and $m_{gravitational}$.

2. Below is a diagram of two balls of different mass being dropped. The student is at rest on Earth and drops the massive red ball and the less-massive blue ball at the same time from the same height.

Woman at Rest on Earth

$t = 0.0$ s $t = 0.2$ s $t = 0.4$ s $t = 0.6$ s
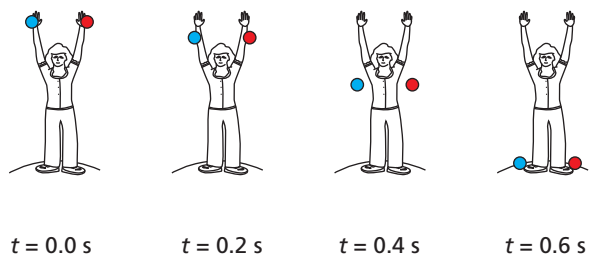
a) How does the student describe the motion of the ball?

b) What value will the student get for her measurement of the acceleration of the ball?

3. In the diagram below, the procedure is repeated, only this time in a rocket ship accelerating up at 9.8 m/s every second. The rocket ship is in deep space and there is no net gravitational force acting on it.

Rocket Accelerating up in Deep Space with No Net Gravitational Force

$t = 0.0$ s $t = 0.2$ s $t = 0.4$ s $t = 0.6$ s
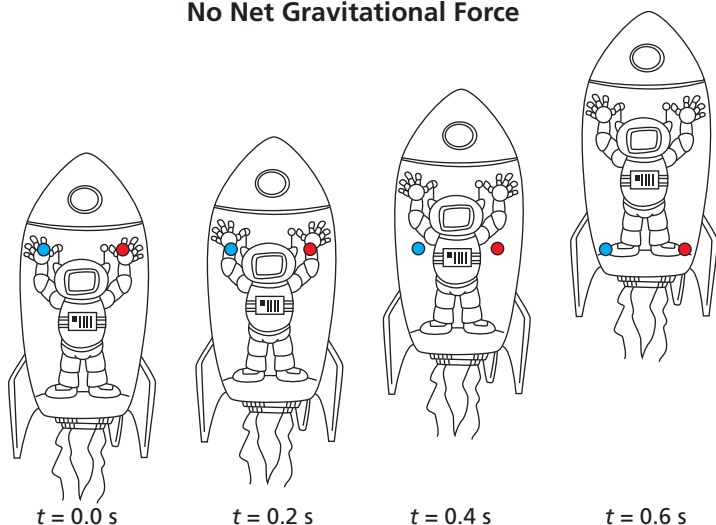
a) What does the astronaut in the rocket ship see?

b) How does the astronaut explain this?

c) What would the astronaut measure for the acceleration of the massive red ball and the less massive blue ball?

4. You have the ability to see that the rocket is accelerating up.

a) How do you explain the balls' positions after each 0.2 s?

b) How do you explain the rocket's positions after each 0.2 s?

5. Can you think of an experiment that the student in the room or the astronaut in the rocket could perform to determine if gravity is pulling the ball down or if the rocket is accelerating up?

What Do You Think Now?

At the beginning of this section, you were asked the following:

• **Does your weight change when you are riding on a roller coaster?**

• **If you were sitting on a bathroom scale, would the scale give different readings at different places on the roller coaster?**

Revise your answers to these questions using what you have learned about apparent weight and acceleration. Discuss your revisions with other students in your group.

Physics
Essential Questions

What does it mean?

Force, mass, and acceleration are key concepts in the study of motion. Explain what F_{net} means, what m means, and what a means.

How do you know?

In physics, you use reliable instruments to verify your sense perceptions. In your investigation, how did you use a spring scale to explore the way you feel on a roller coaster as it goes up and down?

Why do you believe?

Connects with Other Physics Content	Fits with Big Ideas in Science	Meets Physics Requirements
Forces and motion	✱ Change and constancy	Experimental evidence is consistent with models and theories

✱ General principles of science allow you to learn new things about a situation. Newton's second law, $F_{net} = ma$, says that if an object is not accelerating, then the net force on the object must be 0. How was Newton's second law able to help explain weight changes as you accelerate up and down?

Why should you care?

Force, mass, and acceleration are important in all kinds of motion. How will what you learned about force and acceleration in this section help you with your challenge?

Reflecting on the Section and the Challenge

A ride in an elevator is a lot like a ride in a roller coaster. Roller coasters, like elevators, accelerate up or down. However, the elevator moves at too slow a pace and with too little acceleration to provide a great deal of excitement. In a roller coaster, these accelerations are much greater and they are what make a roller-coaster ride thrilling. At the locations where these accelerations occur, people feel as if they weigh more or less. When you design your roller coaster, you may want to take into consideration how large an acceleration your sample population would enjoy.

Physics to Go

1. Objects near the surface of Earth accelerate at a rate of 9.8 m/s every second if gravity is the only significant force acting on them. Based on this information, how fast will an object be going after it has fallen from rest after each of the following lengths of time?
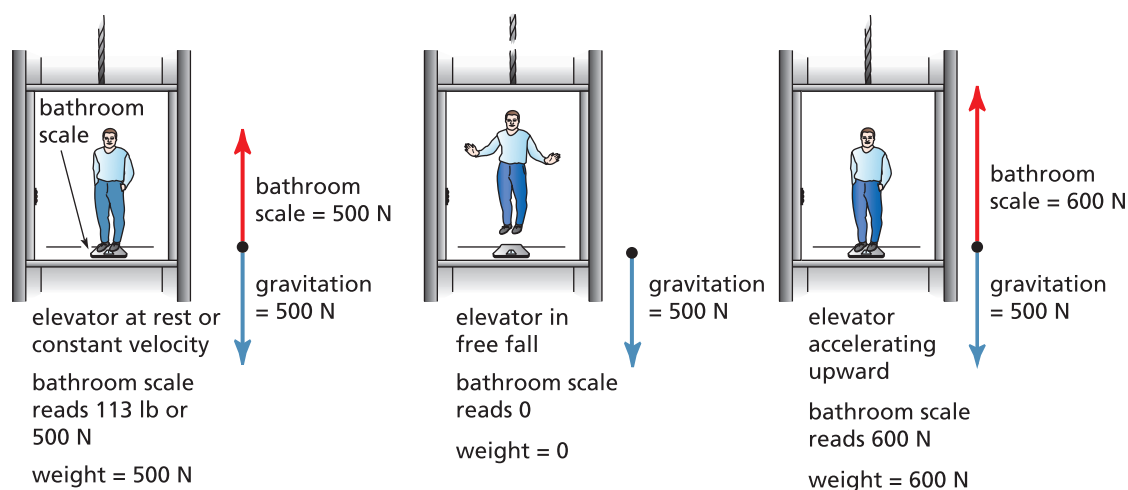
   a) 2 s   b) 5 s   c) 10 s

2. Objects near the surface of the Moon accelerate at a rate of 1.6 m/s every second. Based on this information, how fast will an object be going after it has fallen from rest after each of the following lengths of time?

   a) 2 s   b) 5 s   c) 10 s

3. The vector diagram on the right shows a block of wood that can move up and down. The red vector represents the force pushing up on the block. The blue vector represents the weight of the block.

   a) Could the block be at rest?

   b) Could the block be moving up at a constant speed?

   c) Could the block be accelerating down?

   d) If you wrote "no" for any of the above questions, sketch a force diagram for that description.

4. Complete the table on the right in your log. Some responses are provided in the table.

5. A student weighs 140 lb. On an elevator, the person is surprised to find that the scale only reads 137 lb for a few moments. Describe the motion of the elevator.

6. A person in an elevator at rest weighs 600 N. The elevator is about to move from the second floor to the fifth floor. When it first starts to move, what will the passenger observe about the weight indicated by a bathroom scale on which the passenger is standing?

7. An elevator at the top floor begins to descend with an acceleration of 1.5 m/s². A person is standing on a bathroom scale in the elevator.

   a) Will the bathroom scale's reading increase or decrease once the elevator starts?

   b) What will a bathroom scale read if a 50-kg person is standing on the scale during the acceleration?
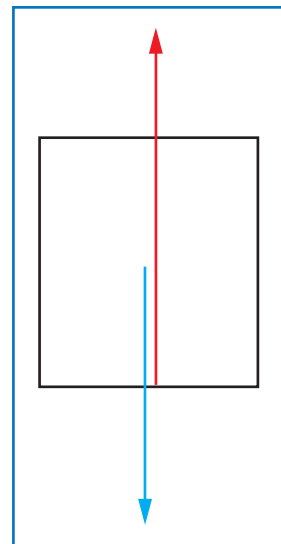
	Acceleration (up, down, zero)	Scale reading (larger, smaller, equal to weight)
A. Elevator at rest on top floor	zero	equal
B. Elevator starts moving down		
C. Elevator moves down at constant speed		
D. Elevator comes to rest on bottom floor		
E. Elevator is at rest at bottom floor		
F. Elevator begins to move up	up	larger
G. Elevator moves up at constant speed		
H. Elevator comes to rest on top floor		
I. Elevator at rest on top floor	zero	equal

8. A 50-kg student is on a scale in the elevator.

  a) What will be the scale reading when the elevator is at rest?

  b) What will be the scale reading when the elevator accelerates up at a rate of 2 m/s^2?

  c) What will be the scale reading as the elevator travels up at a constant speed?

9. Explain the meanings of the three sketches below. Specifically, why is there a different scale reading for the same student in each elevator?

bathroom scale

elevator at rest or constant velocity

bathroom scale reads 113 lb or 500 N

weight = 500 N

bathroom scale = 500 N

gravitation = 500 N

elevator in free fall

bathroom scale reads 0

weight = 0

gravitation = 500 N

bathroom scale = 600 N

gravitation = 500 N

elevator accelerating upward

bathroom scale reads 600 N

weight = 600 N

10. *Preparing for the Chapter Challenge*

Think about the group of people for whom you are designing your roller coaster. What amount of acceleration would they find exciting? How much acceleration would be safe for them? In your log, record which parts of the Terminator Express you would modify and why.

Inquiring Further

Apparent weight on elevators

Use a digital camera or video camera and record some bathroom scale readings while riding in an elevator. Go with an adult to a place where there is an elevator that moves up and down several floors. Take photographs of the readings of the bathroom scale on which you are standing while the elevator starts, moves steadily and then stops. Illustrate as many of the results described in this section as possible.

Visit interactive Web sites on apparent weight changes in elevators and explore what happens to your weight as you ride an elevator in a tall building. Write notes about your findings and draw vector diagrams to represent the interaction of the forces of gravity pulling you down and the scale pushing you up as you accelerate or ride at a steady speed in the elevator.