# Chapter 16 Force and Motion

*Sharply curved bobsled tracks must be tilted to keep the sled on the track. What do you think might happen if the track were not tilted as steeply?*

## Learning Objectives

- Describe the effects of gravity, friction, and centripetal force.
- Explain the difference between weight and mass.
- Describe how inertia affects an object's motion.
- LAB ACTIVITY: Observe the relationship between the weight of an object and friction.
- ON-THE-JOB SCIENCE: Relate motion and inertia to stopping distances of vehicles.

## Words to Know

| | |
|---|---|
| **force** | any push or pull on an object |
| **gravity** | the force of attraction between any two objects that have mass |
| **weight** | the measure of the force of gravity on an object |
| **friction** | a force that slows motion or prevents it |
| **lubricant** | a substance that reduces friction between the moving parts of machines |
| **centripetal force** | a force that causes objects in motion to move in a curved path |
| **inertia** | the tendency of an object to stay at rest or in motion unless it is acted upon by a force |
| **motion** | a change in the position or place of an object |

# 16-1 What Is Force?

## Words to Know

| | |
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## Physics and Everyday Life

**Remember**
Physics is the scientific study of energy and how it interacts with matter.

Physics has a lot to teach us about our everyday lives. For example, knowing physics can make someone a better athlete. Physics explains why it is important to follow through when hitting a baseball. It explains why it is harder to stop a big football player than a small one.

In many of your everyday activities, you exert a **force** on something. A force is any push or pull on an object. When you throw a baseball or hit a baseball with a bat, you push it away from you. When you drag a sled, you pull it behind you. Your body pushes on a chair as you sit in it. A dog tugging on a leash pulls its owner behind it. These are all examples of force.

In many sports, you want to hit the ball as hard as possible. This means you try to give the ball as much force as you can. In golf, a ball hit hard means the ball goes farther. In tennis, a ball hit hard means the other player has to move faster to return the shot.

The longer you exert a force on something, the greater the effect of that force will be. That is why a coach will tell a player to "follow through" on a swing or stroke. By following through, the bat, racquet, or club is on the ball longer. The player exerts a force for a longer period of time. That makes the ball go faster and farther. In this chapter, you will learn about different kinds of forces and their effects on objects.

✓ **What happens when a force is exerted on something?**

## Gravity

All objects that have mass are attracted to each other. This force of attraction between any two objects that have mass is called **gravity.** The more mass an object has, the greater the force of its gravity. The Earth is a very massive object. So, its force of gravity is very great.

Gravity is the force that holds us on the ground. It pulls all matter toward the center of the Earth. The sun and moon also have a gravitational effect on the Earth. The sun's gravity keeps the Earth traveling around the sun. The moon's gravity pulls on the Earth's oceans, causing tides.

Imagine the Earth without gravity. If you let go of an apple, it would not fall. It would just float away. In fact, you would also float away. There would be nothing holding you to the ground.

The force of gravity depends on the distance between two objects. The farther apart two things are from each other, the less gravitational pull they have on each other.

✓ **What two things affect the force of gravity between two objects?**

### Science Fact

Sir Isaac Newton was the first person to explain what gravity is. After seeing an apple fall, he realized that the force that makes the apple fall is the same force that keeps the moon traveling around the sun.

## Weight

### Science Fact

A spacecraft must reach a speed of 24,800 miles (40,000 kilometers) per hour to escape the Earth's gravity.

The measure of the force of gravity on an object is its **weight.** The stronger the pull, the greater the weight is. Weight is different from mass. Mass is the amount of matter in an object. An object's mass will stay the same wherever the object is. However, the weight of an object can change. This is because the amount of gravitational pull on an object can change. For example, the moon is less massive than the Earth. If you were on the moon, there would be less gravitational pull on you than if you were on Earth. You would weigh one-sixth as much on the moon as you do on Earth.

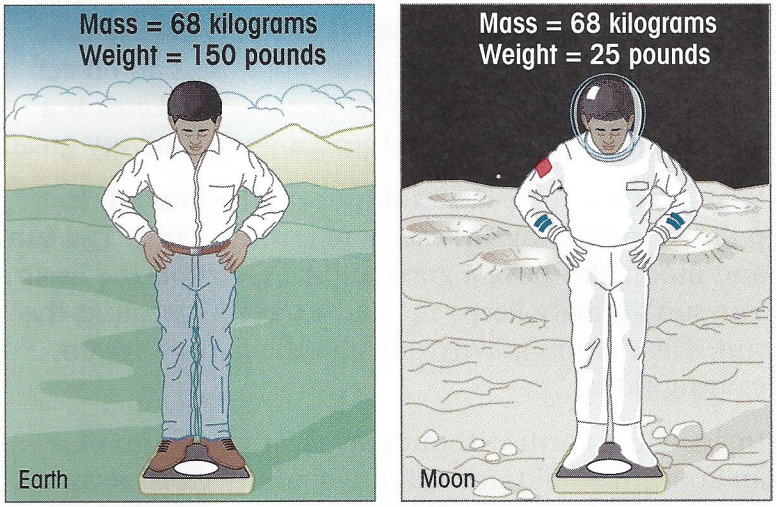


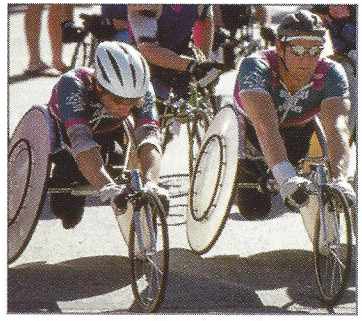

Figure 16-1 *Mass is the same on the moon as on Earth, but weight is only one-sixth as much on the moon.*

The force of gravity is slightly weaker near the equator than it is at the North and South poles. This is because the Earth bulges. It is bigger at the equator. An object on the equator is farther from the Earth's center. Therefore, it will weigh slightly less than an object near one of the poles.

✓ **How is weight different from mass?**

## Friction

Some riders wish their skateboard rides would never end. They would like to push off once and never have to push again. This would be possible if it were not for **friction.** Friction is a force that slows motion or prevents motion. Three types of friction are *rolling friction, sliding friction,* and *fluid friction.*



*To begin this marathon, these racers must overcome rolling friction.*

### Rolling Friction

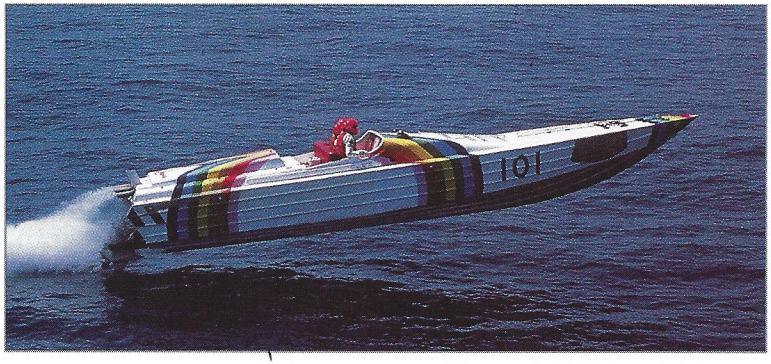
When you drive a car, you must overcome rolling friction. The car wheels roll over the road. The road slows down the rolling of the wheels. The rougher the surface, the greater the friction is. The smoother the surface, the less the friction is. For example, ice is very slippery. When a car travels on ice, there is much less friction than there is on a dry road. This is why cars often have trouble stopping on ice.

### Sliding Friction

If you try to slide across a polished floor in sneakers, you will come to a stop very quickly. However, when you slide in socks, sliding friction will stop you after a few feet. There is greater sliding friction with sneakers than with socks.

### Fluid Friction

When you row a boat, you must overcome the fluid friction in water. The boat pushes against the water. The water slows the boat's motion. A flying airplane must overcome the same type of friction in the air.




*The more friction, the more force a boat needs to exert to get started. The fastest boats only skim the water. Less contact with the water means less friction.*

Friction explains why many things break down or wear out. The friction of a fingernail scraping against a wall will eventually wear off the paint on the wall. The friction of moving parts in a car engine will wear down the parts. After a time, you will have to replace some parts.

A **lubricant** is a substance that reduces friction between the moving parts of machines. Oil, grease, and graphite are all lubricants. These substances are much more slippery than metal.

In the 1600s, the Italian scientist Galileo Galilei studied falling objects. He found that light objects fall at the same speed as heavy objects unless friction in the air causes the lighter object to fall more slowly. You can try Galileo's experiment. Drop a tennis ball and a baseball from the same height and at the same time. Which of these hits the ground first? Now drop a feather and a stone. What happens this time?

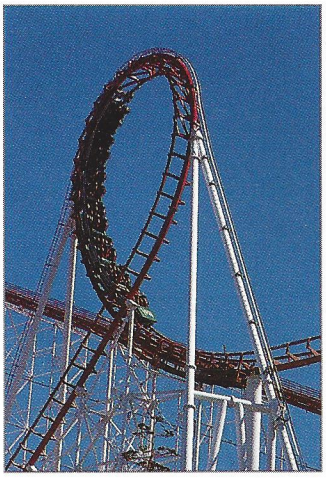
✓ **What are three types of friction?**

## Centripetal Force

One law of physics says that all moving objects travel in a straight path. However, an outside force can change that path. **Centripetal force** is an example of such a force. It causes objects in motion to move in a curved path.

When you drive a car fast around a curve, you get pressed against the car door. Your body naturally wants to continue forward in the direction it was going. The car door is acting as a centripetal force, keeping you in the path of the curve.

The tracks of many amusement park rides are examples of centripetal force. The tracks keep the cars from going out in a straight line. Centripetal force also keeps the bobsled shown on page 230 moving in a curved path.



*Centripetal force keeps the roller-coaster cars on the track.*

You can demonstrate centripetal force yourself. Tie a ball to the end of a rope. Hold onto the rope and swing the ball in a circle. This is centripetal force in action. Holding the rope creates the centripetal force that keeps the ball in its circular path.

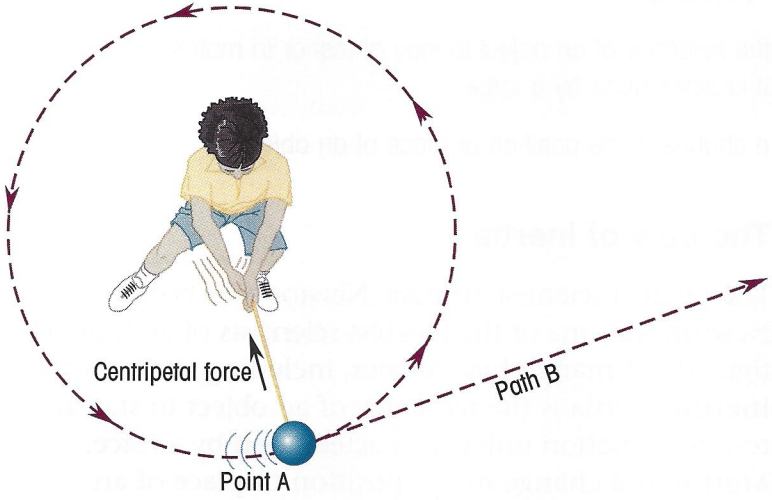



**Figure 16-2** *Centripetal force keeps the ball going in circles. If you released the rope at Point A, the ball would follow Path B. It would go straight.*

✓ **How does centripetal force affect an object in motion?**

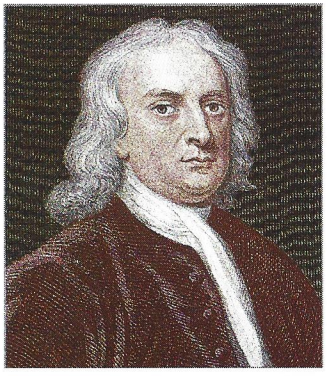
## Lesson Review

1. Does an astronaut weigh more, less, or the same on the moon as on Earth? Why?
2. What force causes a skateboarder on a flat sidewalk to come to a stop?
3. What force keeps a ball on a string moving in a circular path?
4. **CRITICAL THINKING** What would cause the gravitational pull between two objects to change? How would it change?

# 16-2 Inertia and Motion

## Words to Know

| | |
|---|---|
| **inertia** | the tendency of an object to stay at rest or in motion unless it is acted upon by a force |
| **motion** | a change in the position or place of an object |



*Sir Isaac Newton*

## The Law of Inertia

The English scientist Sir Isaac Newton was born in 1642. Newton was one of the greatest scientists of all time. He figured out many physical laws, including the law of **inertia.** Inertia is the tendency of an object to stay at rest or in motion unless it is acted upon by a force. **Motion** is a change in the position or place of an object. Rest is a complete lack of motion.

An object at rest will stay at rest forever unless a force moves it. An object in motion will stay in motion forever unless a force stops it.


*When the car stops suddenly, inertia makes this dummy keep moving forward. Seat belts and air bags supply the forces needed to stop the dummy's forward motion.*

Inertia is a property of all matter. The greater the mass of an object, the greater the inertia is. A big football player running down a field has greater inertia than a small player. It will take a stronger force to stop the bigger player.

✓ **What does the law of inertia say about an object?**

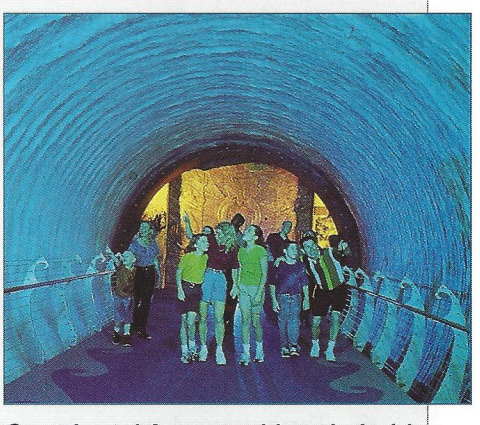
## Lesson Review

1. Who figured out the law of inertia?
2. What will stop an object in motion?
3. **CRITICAL THINKING** Why does it take a stronger force to stop a bus than it does to stop a small car?

## On the Cutting Edge

### TECHNOLOGY IN THEME PARKS

At many theme parks, technology is used to create new and different rides. At one park in Florida, visitors walk through a tunnel of swirling water. Forty high-powered jets shoot water at 100 miles (160 kilometers) per hour up and around the curved walls of the tunnel. The water is held against the sides of the tunnel by centripetal force and the inertia of the water. You can actually put your hand into the water stream to feel the force of the moving water.



*Centripetal force and inertia hold the water against the tunnel walls.*

Another new ride will combine a Ferris wheel and a roller coaster. The Ferris wheel cab will be attached to a loop of roller-coaster track. As the Ferris wheel spins, gravity will pull the cabs around the loops for a more thrilling ride.

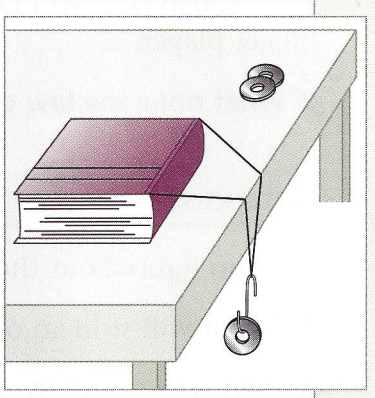
**CRITICAL THINKING** What force must be overcome to keep the water on the tunnel ceiling from crashing down on visitors?

# LAB ACTIVITY
## Weight and Friction

### BACKGROUND
Different surfaces cause different amounts of friction. The force needed to move an object depends on the object and the surface it moves across.

### PURPOSE
You will measure and compare the amount of force needed to move objects across different surfaces.

### MATERIALS
paper, pen, 18-inch piece of string, book, large paper clip, large metal washers, masking tape, waxed paper, sandpaper, long pencils



*You need to add washers, one at a time, until the book starts to move.*

### WHAT TO DO
1. Copy the chart to the right.
2. Tie the ends of the string to make a loop. Put the loop over the front cover of the book.
3. Place the book on a table about 4 inches from the edge. Let the loop of the string hang over the edge of the table.
4. Straighten the paper clip to form an S-shape. Hang the paper clip from the string.
5. Put a washer on the paper clip. Add washers one at a time until the book begins to move. Record the number of washers needed to move the book.
6. Tape waxed paper to the table top. Repeat Steps 3 to 5.
7. Tape sandpaper to the table top. Repeat Steps 3 to 5.
8. Repeat Steps 3 to 5, placing some pencils under the book.

| Surface | Number of Washers |
|---|---|
| Table top | |
| Waxed paper | |
| Sandpaper | |
| Pencils | |

### DRAW CONCLUSIONS
- How do the amounts of friction caused by the different surfaces compare?
- What can you conclude about how surface friction affects the force needed to move something?

# ON-THE-JOB SCIENCE
## Truck Driver

Connie Alfaro is a long-distance truck driver. Her 18-wheeler carries things between Chicago and New York. She might carry food, medical supplies, or furniture. Connie drives her truck on highways. She knows that the huge mass of her truck gives it a lot of inertia at 55 or 60 miles an hour. She must think about the truck's mass, its speed, and the weather to drive safely. She knows the faster she goes, the longer it takes to stop the truck. If she must stop suddenly, she must allow herself enough room to stop safely.

*Connie must think about her truck's mass and speed to stop safely.*

**Study the chart and answer the questions.**

**Stopping Distances for Vehicles on Dry Roads**

| Speed (miles per hour) | Car Stopping Distance | Truck Stopping Distance |
|---|---|---|
| 40 | 125 feet | 200 feet |
| 50 | 185 feet | 305 feet |
| 60 | 240 feet | 430 feet |

1. At 50 miles per hour, how far will a car travel before it is able to stop?
2. At 50 miles per hour, how far will a truck travel before it is able to stop?
3. Why does a truck take a greater distance to stop than a car does?

**Critical Thinking**

Connie will make four stops on her trip from Chicago to New York. At each stop, she will pick up a load of furniture to deliver to New York. The truck's speed and the weather conditions are the same at each stop. At which stop will her stopping distance be the longest? Why?

Chapter

# 16 Review

## Summary

A force is any push or pull on an object. Forces affect our movements every day.

**Lesson 16.1**

Gravity is a force that pulls all matter toward the center of the Earth. The amount of gravitational pull on an object can change its weight. Friction is a force that resists motion. Centripetal force causes objects in motion to move in a curved path.

**Lesson 16.2**

Motion causes a change in the position or place of an object. Inertia is responsible for the tendency of an object to stay at rest or in motion, unless acted on by a force.

## Vocabulary Review

centripetal force
force
friction
gravity
inertia
lubricant
motion
weight

**Complete each sentence with a term from the list.**

1. A _____ must be exerted on an object at rest to cause it to move.
2. The force that causes a ball to fall to the ground is _____.
3. A change in the position or place of an object is _____.
4. The measure of the force of gravity on your body is your _____.
5. The force that slows motion or prevents it is _____.
6. The force that causes objects in motion to move in a curved path is _____.
7. The tendency of an object at rest to stay at rest unless it is acted upon by a force is _____.
8. A substance that reduces friction between the moving parts of machines is a _____.

## Chapter Quiz

**Write your answers on a separate sheet of paper.**

1. What is one example of a pulling force?
2. What is one example of a pushing force?
3. What force causes rivers to run downhill?
4. What is the difference between weight and mass?
5. What force are people using when they put sand or gravel on icy roads in the winter?
6. What type of friction must you overcome when you ice skate?
7. What force keeps a roller-coaster car on the track?
8. When you wear a seat belt, you are being protected from possible harm by what force?
9. What has greater inertia, a large car or a small car moving at the same speed? Why?
10. If someone is playing in a baseball game, what are three forces or laws of motion that could affect the game?

**Test Tip**

As you read quiz questions, look for key words, such as *force, inertia,* and *motion.* Try to remember where these appeared in the chapter to help you answer the questions.

## Research Project

Research the work of Sir Isaac Newton in a reference book or on the Internet. Describe his three laws of motion. Then write an example of each of his three laws in everyday life.