Experimenting With Forces

Reflect

Have you heard the story about Isaac Newton and the apple? Newton was a scientist who lived about 300 years ago. He made many important discoveries about how and why things move. The apple story goes like this: One day Newton was sitting under an apple tree, when an apple fell and hit him on the head. He used this observation to make hypotheses about why the apple fell. He went on to understand how the force of **gravity** works.

gravity: the attraction between all objects that have mass; objects with greater mass have greater gravity

This is sort of a science fairytale. The true story seems to be that Newton was walking through an apple orchard one day, when he started thinking about how things fall. He especially wondered why apples always fall straight down and why they speed up as they fall. After some time, this led to his discovery of the scientific laws that explain the force of gravity.

Gravity is just one of many forces we experience every day. But exactly what *is* a force?

What is a force? What are some examples?

Do not confuse force with energy, work, or power. A *force* is a push or a pull. Certain forces only push or only pull. Other forces can do both. For example, the force of gravity is always a pull, never a push. Here are some other examples of everyday forces:

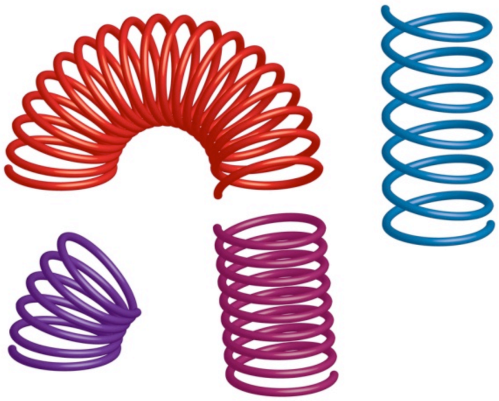
- **Magnetic Force:** This is the force between two magnets or between a magnet and certain metals such as iron. The two ends (or poles) of a magnet are called the north pole and the south pole. Magnetic force pulls the north pole of one magnet toward the south pole of another magnet. Two north or two south poles push each other away.

- **Electrostatic Force:** This force has to do with the charge an object carries. All matter is made up of particles. If there are more negative particles in an object, the object has a negative charge. If there are more positive particles in an object, the object has a positive charge. If objects have opposite charges, they are attracted to each other. This attractive force is known as an electrostatic force. If objects both have the same charge, they *repel* (or push away from) each other.

- **The Force of Friction:** This is a force that slows things down. Have you noticed that things that are rolling or sliding or otherwise in motion eventually slow down and stop? If no other forces are involved, moving objects on Earth slow down because of friction. The cause of friction is the rubbing together of two surfaces. The rougher the surfaces, the greater the force of friction.

- **Mechanical Force:** Machines like cars can supply mechanical forces. Animals and people can also supply mechanical forces. In any case, a source of **energy** is necessary. Think about walking or riding a bike. Mechanical forces can help you move! The force of feet pushing on the pedals of a bicycle, the force of a hammerhead on a nail, and the force of a canoe paddle on water are all examples of mechanical forces.

energy: the ability to do work



- **Spring Force:** Some things change shape when force is applied to them. A lump of modeling clay and a balloon both change shape when you squeeze them. However, the modeling clay keeps the new shape it was squeezed into. The balloon returns to its original shape when the force is removed. The force that returns the balloon to its original shape is called *spring force*. Some other things that can exert spring force are rubber bands, fishing poles, and (of course) springs.

What do you think?

How are gravitational, magnetic, and electrostatic forces different from mechanical, frictional, and spring forces? (Here's a hint: Which forces can act on objects at a distance—that is, without touching?)

How can forces change an object's movement, shape, or position?

Isaac Newton discovered more than just the laws of gravity. He also explained how force is related to *motion*, or the movements of objects. Newton explained force and motion in three simple laws.

- **Newton's first law:** Things don't change their motion unless a force acts on them. This means that things that aren't moving stay put, and things that are in motion keep on moving at the same speed in a straight line.

Look out!

You have probably noticed that moving objects always seem to slow down and stop. Many people would say that this is because the force that set the object in motion has worn off. Other people would say that nothing moves unless a force is acting on it all the time. Both are wrong!

Objects in motion stop because the force of friction acts on them. Friction acts in the direction opposite to the direction of motion. Objects in motion have energy of motion, which is called *kinetic energy*. Friction changes that energy of movement to heat energy. When all the kinetic energy has been changed to heat energy, the object stops. Sometimes you can feel the heat caused by friction. The warmth you feel when you rub your hands together is caused by friction. Only when an object is moving through empty space will it continue to move without slowing down. That is why Earth never stops circling around the Sun. Earth doesn't experience any friction because there are no particles in empty space!

- **Newton's second law:** If a force continues to act on an object, it will move faster and faster. This increasing speed is called *acceleration.* The greater the force, the greater will be the acceleration. The greater the **mass** of the object, the smaller will be the acceleration. A force can also cause a moving object to slow down. This is called *negative acceleration.* Sound familiar? We just saw that friction causes moving objects to have negative acceleration.

mass: the amount of "stuff" in an object

Discover Science: What are meteors?

atmosphere: the air that surrounds Earth

Meteors, which we sometimes call "shooting stars," are bits of rock flying through space that enter Earth's **atmosphere**. We see meteors because friction with the air causes them to burn up. How is the flight of a meteor related to Newton's first and second laws? When a meteor is far from Earth, it is moving at a constant speed in a straight line. Space is very nearly empty, so no friction or other forces are acting on the meteor. This agrees with Newton's first law. When the meteor gets close to Earth, the pull of Earth's gravity causes it to accelerate. When it enters the atmosphere, it slows down because the force of friction is pushing in the other direction. This process speeding up and slowing down agrees with Newton's second law.

- **Newton's third law:** For every action there is an equal and opposite reaction. This means that forces always occur in pairs. When a force acts on an object, the object pushes back in the opposite direction with the same amount of force.

In some cases, it is easy to see the third law in action. Your feet push down on the floor with a force that is equal to your weight. The floor doesn't move because it is pushing up on the bottoms of your feet with an equal force. Picture two people facing each other while standing on skateboards. They reach out and touch hands, and one person gives a push. Both skateboards move backward even though only one person exerted a force. That is because when one person exerted a force, he created an equal and opposite force, or reaction.

<u>How could you create an investigation to test the effect of force on matter?</u>
We have already described an investigation you could carry out to study Newton's third law using two skateboards. Now we will see how we can investigate the first and second laws.

TRY NOW

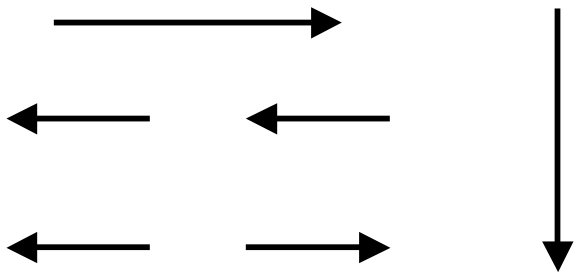
All you need for this experiment is a board about two meters long; a chair; a smooth, flat stone or small block of wood; and an ice cube.

1. Begin in a room with a carpeted floor. Prop one end of the board up on the chair and rest the other end on the carpet. Make the slope steep enough so the stone will slide down easily. Release the stone from the top of the slope, and measure how far it slides across the floor.
2. Repeat the experiment in a room with a smooth floor (wood, linoleum, or tile). Keep the slope the same, and release the stone from the same height. Measure how far the stone slides across the floor.
3. Finally, release an ice cube from the same spot and measure how far it slides across the smooth floor. (Be sure to clean up any water that melts.) Compare the distances the objects slid in the three trials.

The only thing that changed in the three trials was the force of friction. In each case, the friction acted in the direction opposite to the motion and caused negative acceleration. Which type of floor caused the greatest force of friction? Which object caused the greatest force of friction? By comparing friction and distance you should be able to conclude what would happen if there were no forces acting on a sliding object. How does this experiment agree with Newton's first and second laws?

What Do You Know?

Sometimes arrows are used to show forces. The point of the arrow shows which way the force is pushing, and the length of the arrow shows how strong the force is. The arrows below show six different forces.



The long arrows are twice as long as the short arrows. This means the long arrows represent forces twice as strong. Arrange the arrows around the two balls, below, so the forces cause one ball to accelerate downward in a straight line and the other ball to stay where it is without moving. Use each arrow once and only once, and use all arrows. Do not change the directions or lengths of the arrows.

When you finish, arrange the arrows around the balls in other ways. How does each set of forces affect the motion of the balls?

Connecting with your child

Acceleration Caused by the Force of Gravity
This experiment will demonstrate one aspect of Newton's second law of motion.

This falling apple must be accelerating because the pictures were taken at equal time intervals.

For this investigation you will need the following:

- a stopwatch
- a ladder or a structure that allows you to drop an object from a variety of heights
- a small, dense object that is easy to see, like a ball bearing or golf ball

The procedure involves dropping the object from various heights and measuring the time the object takes to fall. One person will drop the object, and the other person will measure the fall time with the stopwatch. Be careful to choose a place where no one can be injured by the falling object.

Careful comparison of the times will illustrate that the constant force of gravity exerted on the object causes it to accelerate. If the falling speed were constant, doubling the height would double the falling time; however, because the object is accelerating, the falling time only increases by about 50%.

Some questions you may wish to discuss include:

- What if you had used a feather for the object you dropped? How would the results be different? Why?
- One person jumps from an airplane and falls 30 meters before opening the parachute. Another person travels downward 30 meters in an elevator.
    - How is the motion of the two people different as they travel 30 meters?
    - How are the forces acting on the two people different?
    - How is what they feel different?
- Compare the motion of a ball thrown 10 meters into the air to the motion of a ball dropped from 10 meters.
    - How is the motion of the two balls different as they travel 10 meters?
    - How are the forces acting on the two balls different?