What Are the Fundamental Forces?

You often hear the word force used in everyday conversation. For example, “Our basketball team is an awesome force!” What exactly is force? In science, force means any action that can affect the motion of an object. Like velocity and acceleration, force has both magnitude, or size, and direction.

There are four fundamental forces in nature. The four fundamental forces are gravity, the electromagnetic force, the strong nuclear force, and the weak nuclear force.

What Are the Properties of the Fundamental Forces?

Each of the four fundamental forces is similar in that they act to change the motions of objects. However, they each have different properties, and each works in a different way.

The strong and weak nuclear forces act over only short distances. These are the forces that hold atoms together. The strong and weak nuclear forces are important, but you do not experience them directly in your everyday life.

The force of gravity and electromagnetic forces are forces you feel every day. Gravity acts over long distances and pulls objects toward each other. Electromagnetic forces produce friction, magnetism, and static electricity.

### Reading Toolbox

**Compare** As you read this section, make a chart comparing the four fundamental forces. Include in your chart the relative strength of each and the effects of each.

### Reading Check

1. **Compare** How are the four fundamental forces similar?

2. **Identify** Which fundamental force acts between Earth and the moon?
FORCES OF DIFFERENT STRENGTHS

The strong nuclear force is the strongest of all the forces. The strong nuclear force holds together the protons and neutrons in the nuclei of atoms. However, it only acts over short distances. The maximum range of the strong nuclear force is about the size of an atomic nucleus.

The weak nuclear force is about ten trillion times weaker than the strong nuclear force. The weak nuclear force affects some kinds of radioactive decay.

Electromagnetic forces can act over longer distances and are about 1% of the strength of the strong nuclear force. Electromagnetic forces hold electrons near the nucleus of an atom and hold molecules together.

Gravity is the weakest of the fundamental forces. It is about $10^{40}$ times weaker than the strong nuclear force. It also works over longer distances than any of the other fundamental forces. Gravity is an important force in shaping the structure of our galaxy and the universe.

CONTACT FORCES AND FIELD FORCES

Scientists put forces into two main groups: contact forces and field forces. Contact forces require two objects to physically be in contact with each other. When you push or pull on an object, you are applying a contact force. Friction is another example of a contact force.

Field forces act over distances and do not require two objects to be in direct contact. Gravity and magnetism are examples of field forces. Field forces can attract two objects together, or push two objects apart.

<table>
<thead>
<tr>
<th>Type of Force</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact force</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>act over distances on objects that may not be touching</td>
<td>gravity, magnetism</td>
</tr>
</tbody>
</table>

How Can Forces Affect Motion?

Forces act to change the motion of an object. In most situations, several forces act on an object at once. The net force is the combination of all the forces acting on an object. An object will accelerate in the direction of the net force. An object will not accelerate if the net force is zero.
SECTION 3 Motion and Force continued

BALANCED FORCES

*Balanced forces* produce a net force of zero. Therefore, an object experiencing balanced forces will not change its motion. This means that an object at rest will remain at rest if the forces are balanced. An object in motion will remain in motion if the forces are balanced.

There are many examples of balanced forces in daily life. A light hanging from the ceiling does not move up or down. The force of tension in the cord pulls the light up. This balances the force of gravity, which pulls the light down. A car moving at a constant velocity is another example of an object affected by balanced forces.

![Image of balanced forces](image)

**FORCE**

In this picture, both people are pushing with the same force. They are pushing in opposite directions. Therefore, the forces are balanced. The couch does not move.

**ACCELERATION**

Here, the two people are pushing in the same direction. Therefore, the force is unbalanced and the couch moves. The couch moves in the direction of the net force.

UNBALANCED FORCES

When the net force acting on an object is greater than zero, the object will accelerate in the direction of the net force. Look at the image of the two students pushing a couch above. When the two students are pushing on opposite sides of the couch, the forces oppose each other. If one student pushes harder, the couch will move in the direction that student is pushing.

When the two students are pushing on the same side of the couch, the forces combine. The couch accelerates in the direction both students are pushing. What happens if one student pushes the couch west, and the other student pushes the couch north? The net force is a combination of the two forces. The couch will move in a north-west direction.

**READING CHECK**

5. **Describe** How do balanced forces affect an object’s motion?

6. **Explain** Why does the couch move in the bottom picture, but not in the top?

**LOOKING CLOSER**

6. **Explain** Why does the couch move in the bottom picture, but not in the top?

**Critical Thinking**

7. **Infer** An object moves at a constant speed along a circular path. Is the object experiencing balanced or unbalanced forces? Explain your answer.
What Is the Force of Friction?

Friction is a force that opposes the relative motion between two objects in contact. Friction results from electromagnetic forces. It occurs as a result of the interactions between atoms on the surfaces of two objects. The rougher the surfaces, the greater the friction between them.

Friction can produce heat when surfaces rub together. For example, you can warm your hands on a cool morning by rubbing them together. The heat from friction can cause a match to light, as shown in the figure below.

![Friction producing heat](image)

Even surfaces that look or feel smooth are rough at the molecular level. Interactions between atoms and molecules produce friction even between smooth surfaces.

TYPES OF FRICTION

There are two main types of friction: kinetic friction and static friction. **Kinetic friction** is the friction between two moving surfaces. There are two main types of kinetic friction: sliding friction and rolling friction. **Sliding friction** occurs when two objects slide past each other. **Rolling friction** occurs when a round object rolls over a flat surface.

In most cases, rolling friction is less than sliding friction. This is why it is easier to push a chair on wheels across a floor than a chair without wheels.

**Static friction** is the friction between two surfaces that are not sliding past each other. Forces act between molecules on the surface of two objects, holding them together. Static friction is usually greater than kinetic friction. Therefore, in most cases, it takes a greater force to start an object moving than to keep it moving.
How Does Friction Impact Everyday Life?

Friction allows you to hold a pencil and use it to write on a piece of paper. Friction even keeps you from slipping when you walk.

Friction between the tires of a car and the road allows a car to move. As the wheels of a car turn, they push against the road. As a result, the road pushes forward on the car. The force pushing the car forward must be greater than the friction that opposes the motion of the car. Due to friction, a constant force must be applied to keep the car moving. Friction also keeps cars from moving when parked.

The car’s engine produces a forward force. Friction resists this force. When the forward force balances the force of friction, the car’s motion does not change. The car moves at a constant speed.

If the forward force is greater than the force of friction, the car’s motion changes. The car accelerates forward.

The force of gravity pulls the truck down the hill. Friction between the truck’s wheels and the road resists the force of gravity. When the force of friction is equal to the force of gravity, the truck’s motion does not change. The truck does not move.

INCREASING AND DECREASING FRICTION

Sometimes, people need to decrease the friction between surfaces. For example, car engines have many moving parts. If there is too much friction between these parts, the engine can become too hot. Therefore, people add oil to their engines. Oil is a lubricant. It reduces the friction between surfaces.

Sometimes, people need to increase the friction between surfaces. For example, people in cold climates may put sand on icy roads and sidewalks. The sand increases friction between the ground and people or cars moving on it.

Talk About It

Discuss With a partner or in a small group, identify 10 different examples of how friction affects your everyday life. For each example, talk about whether friction makes things easier or more difficult.

LOOKING CLOSER

11. Apply Concepts What would happen to the truck in the bottom picture if the force of gravity were larger than the force of friction?

12. Define What is a lubricant?
Section 3 Review

SECTION VOCABULARY

<table>
<thead>
<tr>
<th>force</th>
<th>an action exerted on a body in order to change the body's state of rest or motion; force has magnitude and direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>friction</td>
<td>a force that opposes motion between two surfaces that are in contact</td>
</tr>
<tr>
<td>kinetic friction</td>
<td>the force that opposes the movement of two surfaces that are in contact and are moving over each other</td>
</tr>
<tr>
<td>static friction</td>
<td>the force that resists the initiation of sliding motion between two surfaces that are in contact and at rest</td>
</tr>
</tbody>
</table>

1. **Compare**  What is the difference between kinetic friction and static friction?

2. **Describe**  Fill in the table below for the relative strengths of the three remaining fundamental forces. List the forces from strongest to weakest. Indicate the relative strength of each force.

<table>
<thead>
<tr>
<th>Fundamental Force</th>
<th>Approximate Relative Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong nuclear force</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 : ten trillion</td>
</tr>
</tbody>
</table>

3. **Describe**  What happens to an object when an unbalanced force acts on it?

4. **Apply Concepts**  A cyclist peddling at a constant rate sees the finish line and speeds up to finish the race sooner. Explain when the forces between the cyclist and the ground are balanced and when they are unbalanced.

5. **Explain**  Why is it easier to move a chair with wheels across a floor than a chair without wheels?