Name____________________

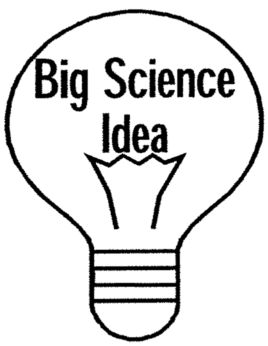
Forces

When you ride a bike, your foot **pushes** against the pedal. The push makes the wheels of the bike move.

When you drop something, it is **pulled** to the ground by gravity.

A **PUSH** or a **PULL** is a **FORCE**. So, a good definition for ***force*** *is a push or pull in a particular direction.*

Forces affect how objects move. They may cause motion; they may also slow, stop, or change the direction of motion of an object that is already moving.

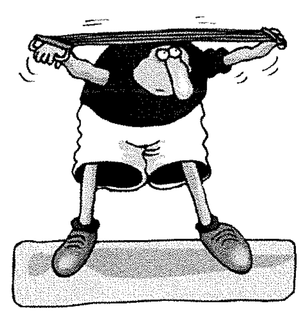


Forces can affect motion in several ways:

→ They can make objects start moving
→ They can make objects move faster
→ They can make objects move slower
→ They can make objects stop moving
→ They can make objects change direction
→ They can make objects change shape

Since force cause changes in the **speed** or **direction** of an object, we can say that forces cause changes in **velocity**, so.... **Forces cause acceleration**!

FORCE FACTS:



→ Forces are measured in Newtons (N)
→ Forces usually act in pairs
→ Forces act in a particular direction
→ Forces usually cannot be seen, but their effects can

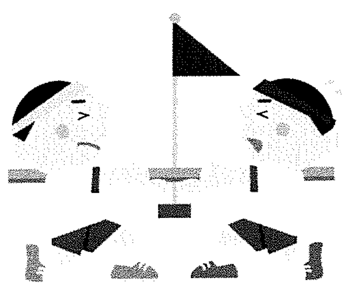
More than one force can act on an object at a time. The forces can push or pull in any direction. What happens to the object when the forces act depends on two things:

→ How strong the forces are
→ The direction of the forces

When more than one force acts on an object, the forces combine to form a **net force**. The combination of all the forces acting on an object is the net force.

Forces may work together or they may be opposite forces.

Two or more opposite forces are **balanced forces** if their effects cancel each other and they **do not cause a change in an object's motion**. If two forces of equal strength act on an object in opposite directions, the forces will cancel, resulting in a net force of zero and no movement.



If the effects of the forces don't cancel each other, if one force is stronger than others, the forces are **unbalanced forces**. **Unbalanced forces cause a change in motion**; speed and/or direction.

When two forces act in the **same direction** on an object, the net force is equal to the **sum** of the two forces.

When two unequal forces act in **opposite directions** on an object, the net force is the **difference** of the two forces

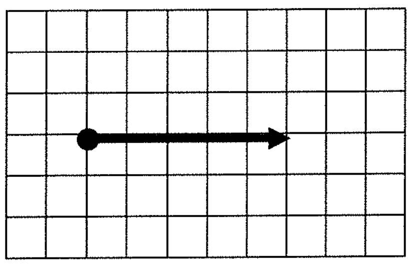
The final force and its direction are called a **resultant**.

SHOWING FORCES:

A force can be shown with a **vector**. A vector is a line with an arrow. It begins with a dot.

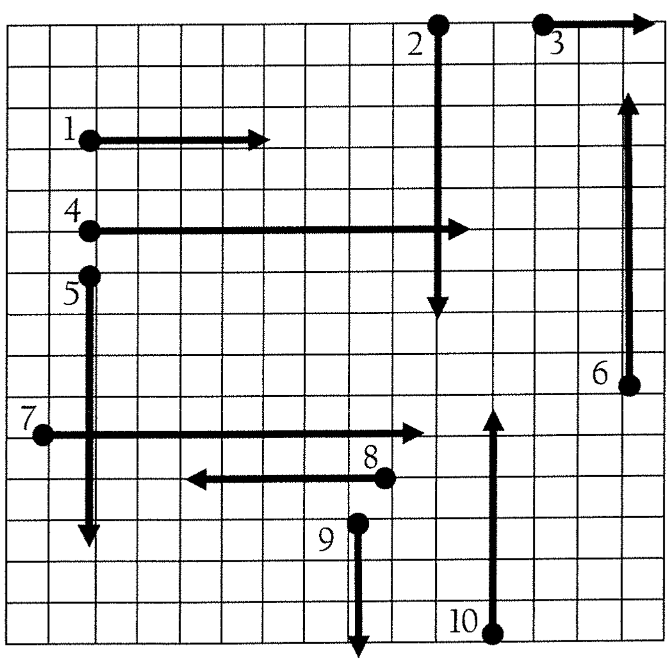
→ The dot shows where the force begins
→ The length of the arrow shows the amount of force
→ The arrows shows the direction of the force

Example:



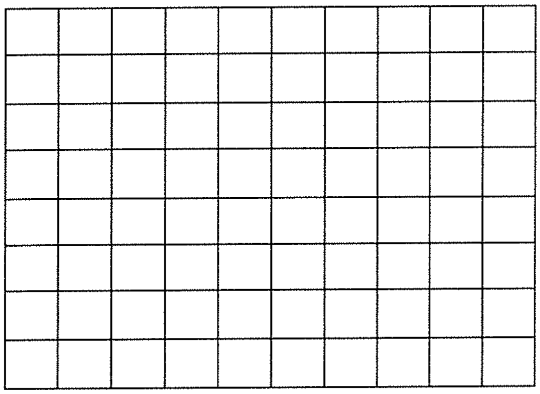
Each square represents force of ONE NEWTON.
This vector shows a 5 n force to the right.

Fill in the chart on the right with the information found in the figure on the left. Each square represents 1 n of force.

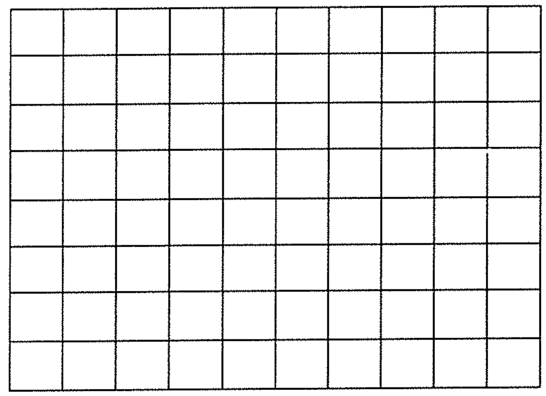


	Force (n)	Direction (right, left, up, down)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

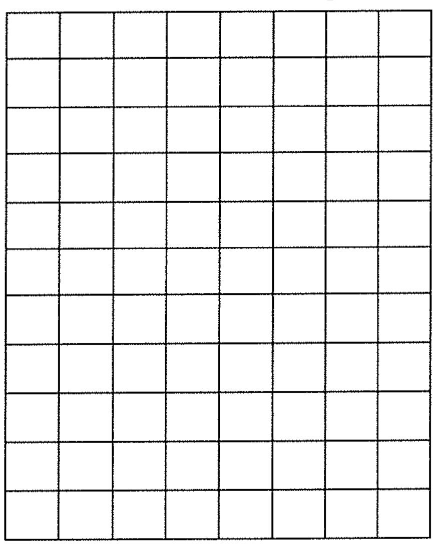
Draw each vector on the chart below. Start at the dot. Each square represents one n of force.



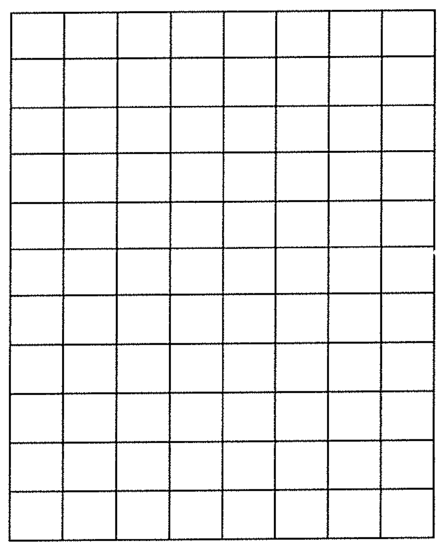
7 n force to the right



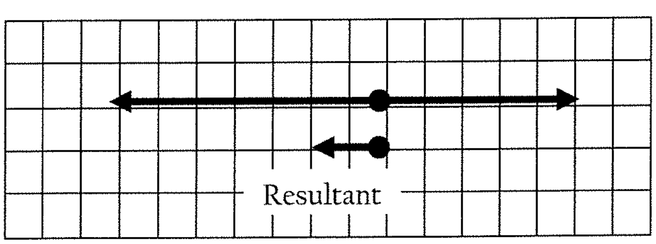
5 n force to the left



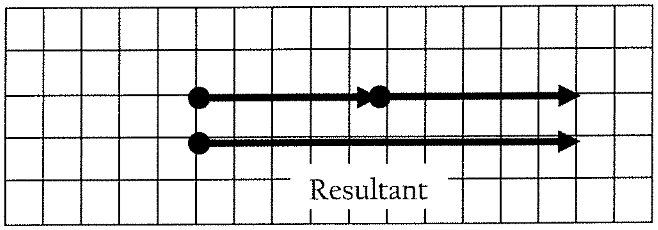
10 n upward force



3 n downward force

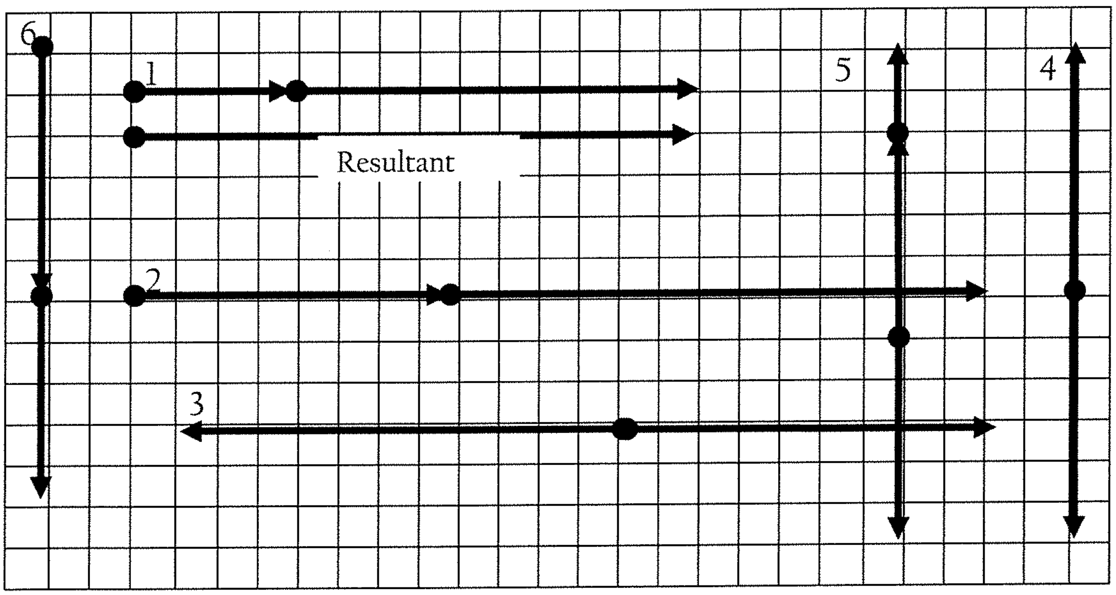


The figure to the left shows two opposite forces.
There is a 5 kg force to the right and a 7 n force to the left. Subtract 5 from 7.
The resultant is a 2 n force to the left.
The resultant vector is shown



This figure shows two forces in the same direction.
They are both 5 n forces.
Add 5 and 5.
The resultant is a 10 n force to the right.

Six sets of vectors are shown below. Draw the resultant vector next to each set. Start at the dot. One has been for you.



Use the above information to fill the chart:

	Total number of forces	Amount of force (n)	Direction (right, left, up, down)	Resultant	Movement? (yes, no)
1					
2					
3					
4					
5					
6					

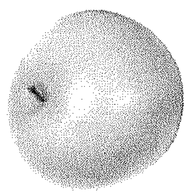
Non-Contact Forces

What are forces?

Pushes and Pulls

A **force** is a push or a pull that acts on an object. A force can make an object speed up, slow down, or change its direction.

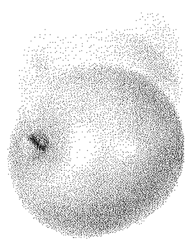
Forces have magnitude and direction. The magnitude of a force is how strong the force is. It is measured in units called newtons (N). The direction of a force tells which way the force is pushing or pulling. If you hold an apple in your hand, it exerts a downward force with a magnitude of about 1 newton.



An apple falls because gravity pulls it downward.

Gravity

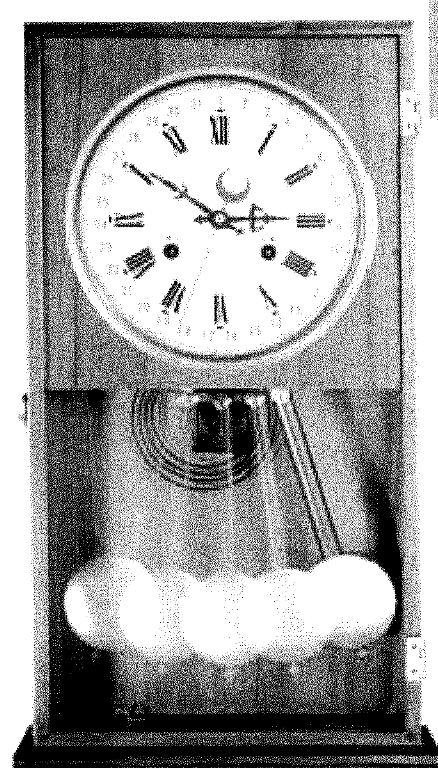
Every object in the universe pulls on every other one. This pull is called gravity. But only the gravity of a large object such as Earth is strong enough to be felt. Earth's gravity pulls all objects toward it, without even touching them. Pendulums swing, apples fall, and satellites stay in orbit because of the pull of Earth's gravity.



Gravity makes the velocity of the apple increase as it falls.

Weight is the amount of gravitational force between an object and Earth. It depends on the mass of the object and the Earth's mass. It also depends on how far above Earth the object is. You weigh a bit less when you fly in an airplane high above Earth. Your weight would be different on other planets. This is because other planets have different masses, so they pull with different amounts of gravitational force. The chart shows how much an object that weighs 100 newtons on Earth would weigh on other planets.

Planet	Weight (in newtons)
Earth	100
Mercury	38
Venus	91
Mars	38
Pluto	7
Jupiter	253



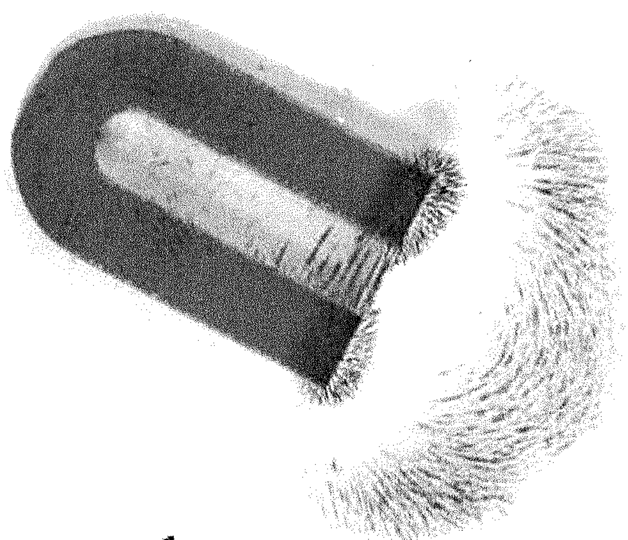
Gravity is what makes a pendulum swing downward. The pendulum then swings upward until gravity stops it. Then, as gravity pulls it back down, it swings in the other direction.

Magnetism and Electricity

Magnetism is a force that pushes and pulls objects. The force is strongest at the poles of a magnet. All magnets have a north pole and a south pole. Magnets pull strongly on objects made of iron, cobalt, and nickel. The force of a magnet also works on other magnets. The north pole of one magnet will attract, or pull on, the south pole of another. Two poles that are the same will push each other away.

Electric forces act between objects that have electrical charges. All atoms have electrons, which are negatively charged, and protons, which are positively charged. An object is negatively charged if it gains electrons. It is positively charged if it loses electrons. If you rub silk and glass together, electrons move from the glass to the silk. This gives the glass a positive charge and the silk a negative charge.

All objects with electrical charges push or pull on each other. It is similar to the way magnets work. Objects with opposite charges pull toward each other. Objects with the same charge push away from each other.



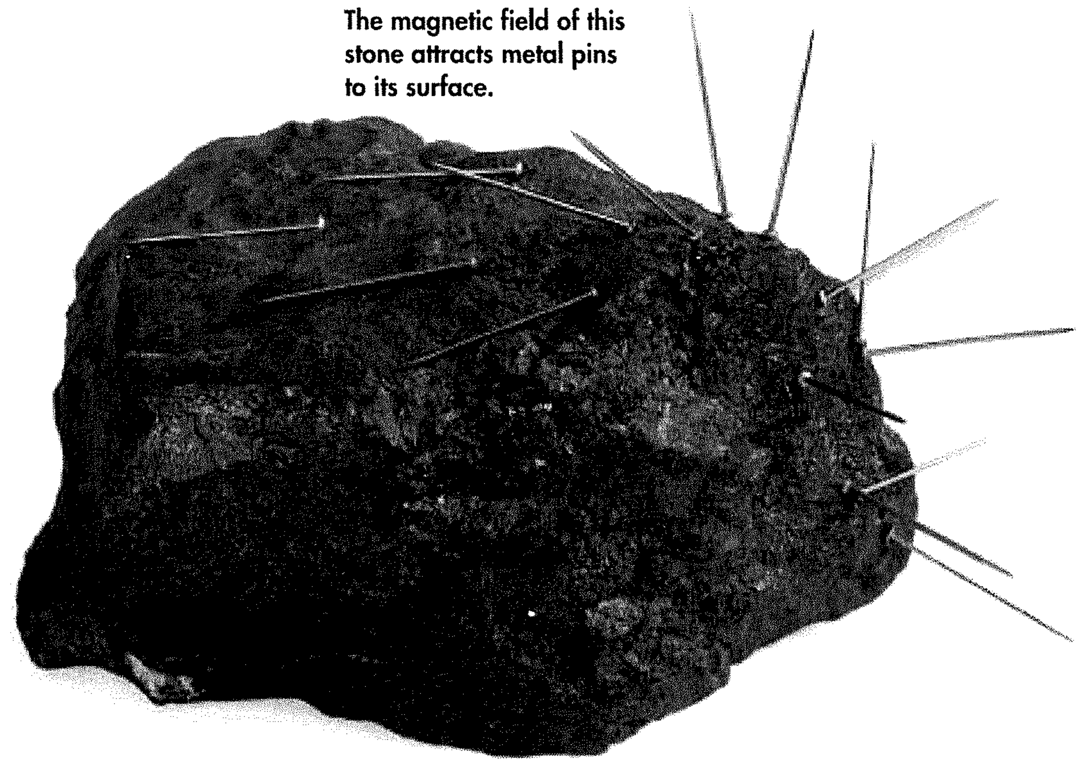
The force of the magnet pulls bits of iron toward it.

Gravity, Electricity, and Magnetism

Magnetic and electric forces can act even if the objects do not touch. All these forces get stronger as the objects get closer to each other.

Gravity is different from electricity and magnetism in two important ways. First, you can block the forces of magnetism and electricity. All you have to do is put certain kinds of materials between the objects. But you cannot block gravity. The second difference is in the direction that the forces work. Electricity and magnetism can push or pull on objects. Gravity can only pull on objects.

The magnetic field of this stone attracts metal pins to its surface.

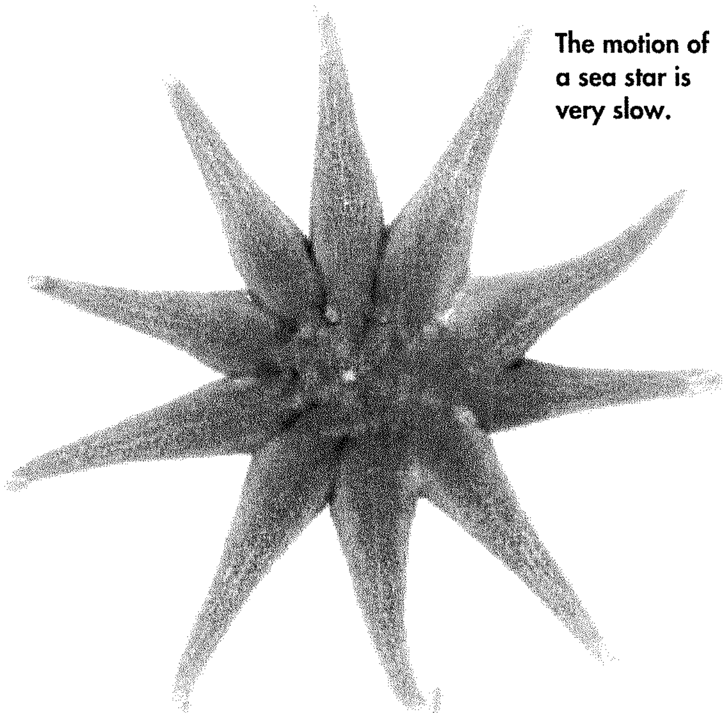


How can you describe motion?

Types of Motion

You are moving all the time. You walk around your school. You stand up from your chair. You roll over in bed. Your heart beats and your eyelids blink. Motion is also all around you.

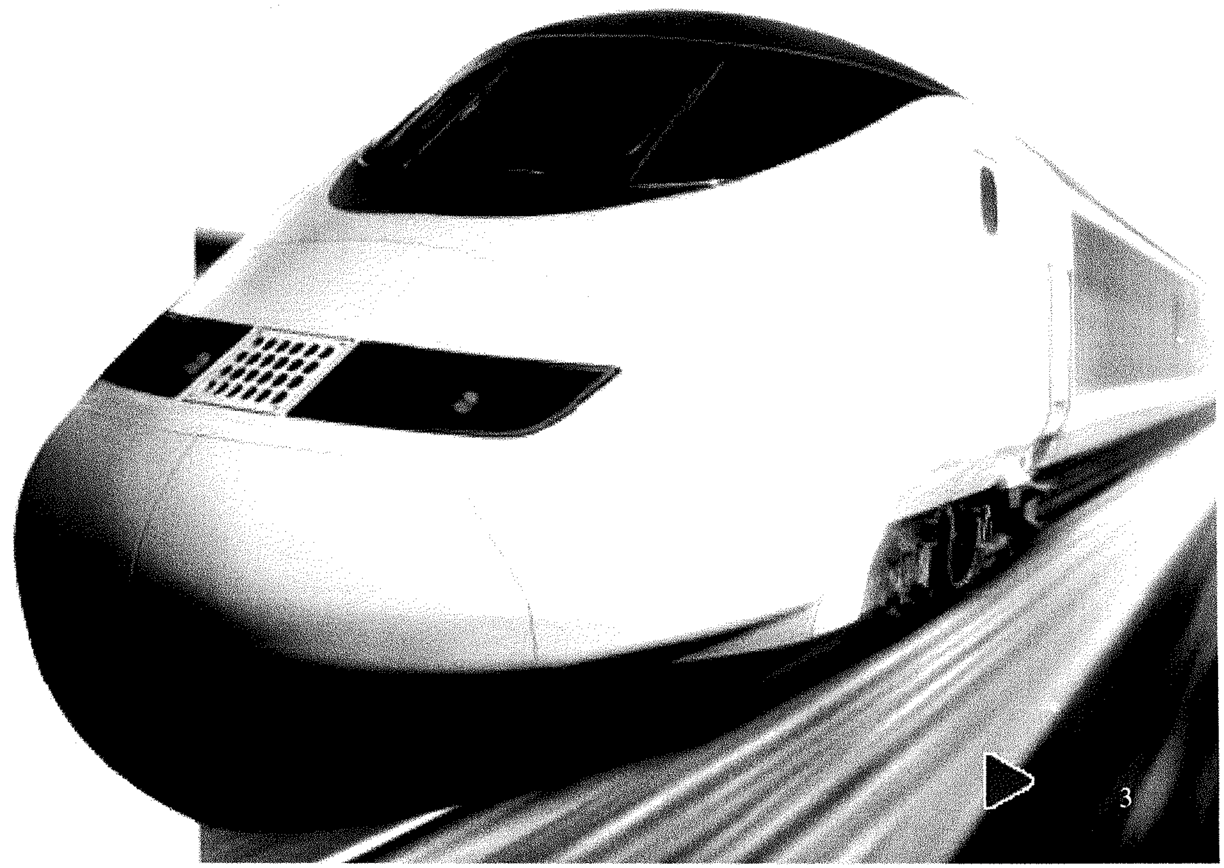
Different things move at different rates. A sea star moves very slowly. It may seem as though it is not moving at all. An airplane propeller moves so quickly that you can't even see its blades.



The motion of a sea star is very slow.

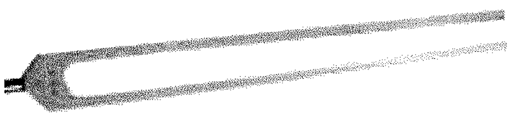
There are many different types of motion. Earth is in constant motion. It is always moving as it travels around the Sun. Cars, trucks, and buses have variable motion. They can move in many directions. They can also change their speed. A pendulum has periodic motion. It swings back and forth when it moves. A rubber band has vibrational motion. It vibrates when you pluck it.

This train has variable motion. It can speed up or slow down.

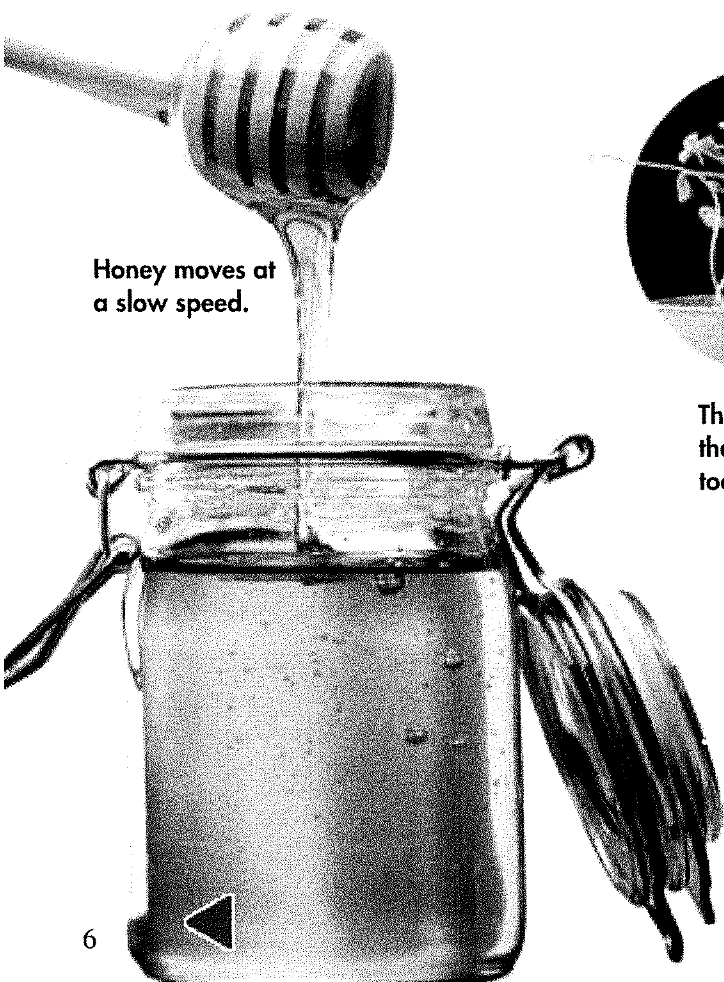


How Fast Things Move

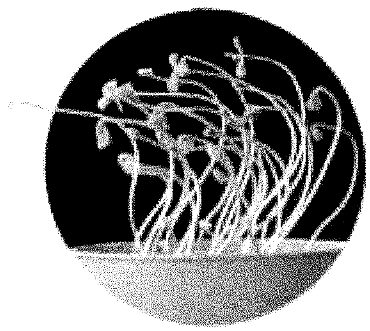
Speed is how fast an object changes its position. Speed can be fast. A jet plane moves fast. Speed can be slow. Honey moves slowly. Some things have such a slow speed that you can't see them move!



The arms of a tuning fork move very fast.



Honey moves at a slow speed.



The motion of these flowers is too slow to see.

Constant Speed

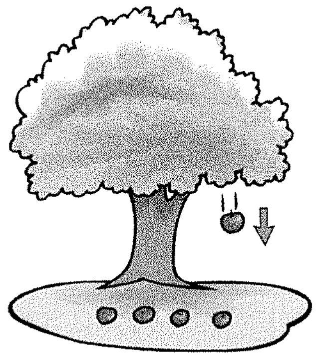
Objects can move at a constant speed. This means that they do not change how fast or slow they move.

They are always changing position. The rate at which they change position stays the same.

Variable Speed

Bumper cars move at a variable speed. An object moving at a variable speed changes speed as it moves. Bumper cars can speed up, slow down, or stop.

The Laws of Motion

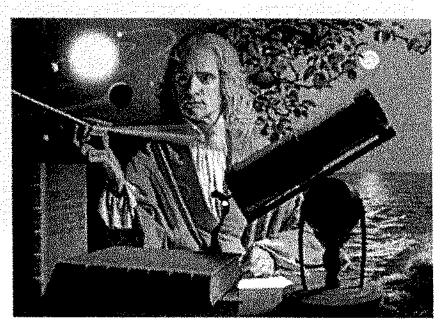


Much of what we know about motion comes from scientists who lived hundreds of years ago. They conducted tests on moving objects. British scientist Isaac Newton discovered **gravity**, the invisible force that causes things to fall toward the ground. You may have heard that he was sitting under a tree one day when a falling apple hit him on the head. The story goes that this accident led him to discover gravity.

Isaac wasn't really hit on the head by a falling apple. That's just a myth. But over time, he observed that objects always fall down toward the ground. And that led him to discover gravity.

SIR ISAAC NEWTON (1642–1727)

Isaac Newton lived on a farm in England. Instead of farming, he chose to study math and science in London. At age 27, Isaac did experiments with light. He was the first to suggest that light was actually made up of all the colors of the rainbow. He is now one of the most famous scientists of all time!

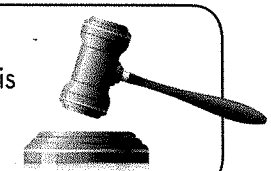


Newton's First Law of Motion

Isaac Newton is known for his three laws of motion, which explain how things move. The first part of the first law says that an object at rest will remain at rest unless a force acts upon it. For example, your bike will stay parked where it is unless something moves it.

Word Wise

In government, a *law* is a rule that people must obey. In science, a law is a statement that explains how things always work in the physical world.



The second part of this law states that an object in motion will continue moving in the same way unless a new force changes the motion. It will keep moving at the same speed and in the same direction. So your moving bike will continue moving at the same speed and in the same direction until you pedal faster, coast, brake, or turn.

Why is it important to wear a seat belt? Think about Newton's first law of motion.

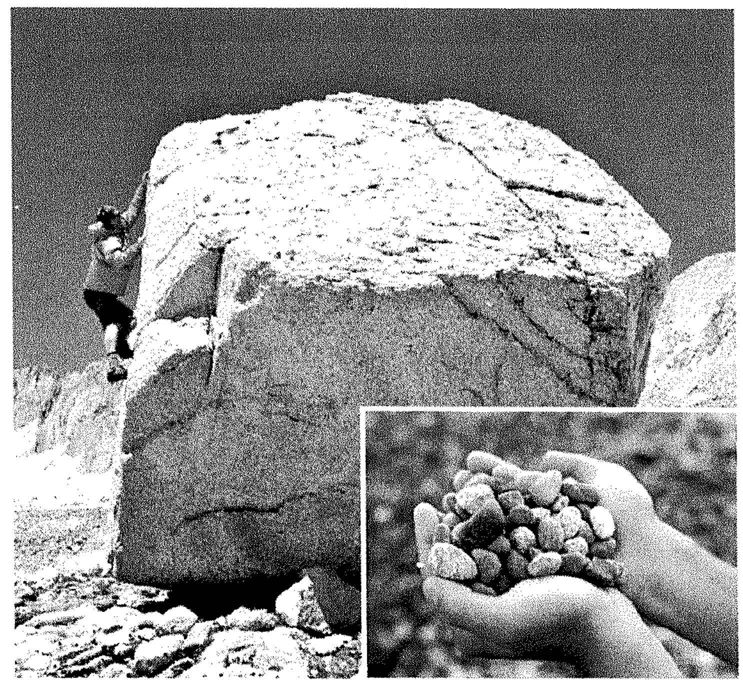
Every object, at rest or in motion, has **inertia**. Inertia is what makes an object keep doing what it is already doing. An object at rest will remain at rest unless a force moves it. An object in motion will remain in motion unless a force stops it. Newton's first law of motion is sometimes called the Law of Inertia.

An object has inertia whether it is at rest or in motion. In either case, a force must overcome that inertia. The force may create motion, stop it, or change its direction.

Newton's Second Law of Motion

Mass is the amount of matter in an object. Newton's second law of motion deals with mass and motion. It explains that an object's motion depends upon its mass and the amount of force needed to move that mass.

Why is it easier to move a small rock than a boulder? Since a boulder has much more mass than a small rock, much more force is needed to overcome the boulder's inertia. Much less force is needed to make small rocks move, stop, or change direction.



This train has a large mass and a high speed, so it has a lot of momentum. It would take a very strong force to slow or stop this train!

This law of motion also deals with speed. Speed measures how far something travels in a certain amount of time. The faster an object moves, the more force is needed to stop it.

Think about a locomotive speeding down a track. It has a lot of mass and speed. So a great deal of force will be needed to overcome the inertia of the train's motion and make it stop.

Momentum is the amount of force in a moving object. The more speed and mass a moving object has, the more momentum it has. A small, slow scooter can stop much faster than a massive, fast train can.

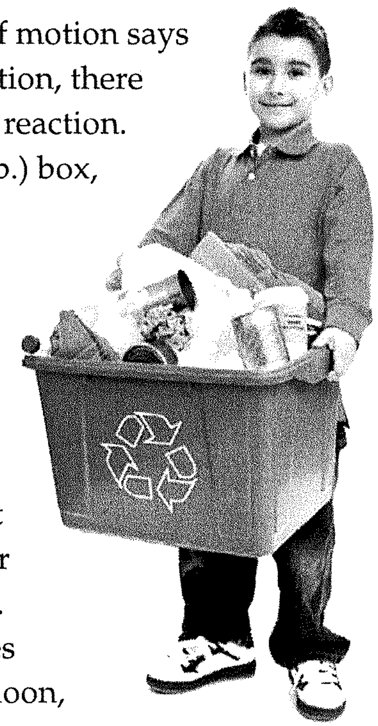
Word Wise

Velocity describes an object's speed in a certain direction. Scientists calculate momentum by using this formula:

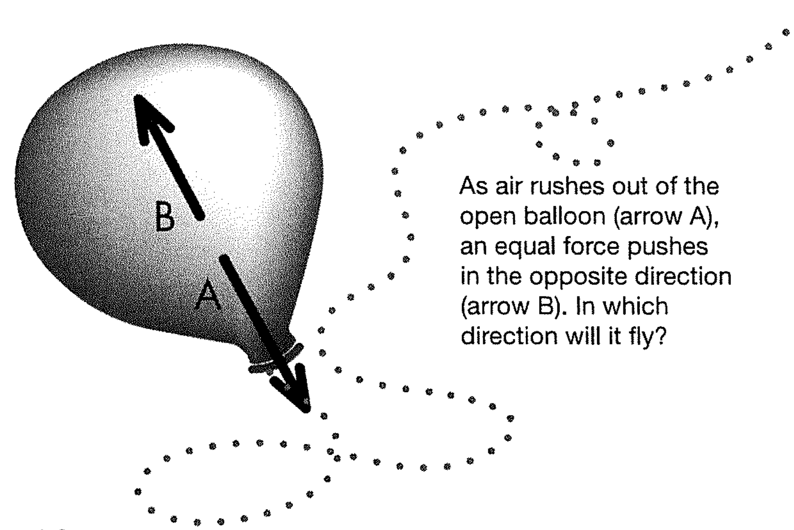
MASS x VELOCITY = MOMENTUM

Newton's Third Law of Motion

Newton's third law of motion says that for every force or action, there is an equal and opposite reaction. So, if you lift a 9 kg (20 lb.) box, the box pulls down with an equal force of 9 kg (20 lbs.) in the opposite direction.



This law explains why a balloon full of air goes flying when you let it go without tying it. Air rushes out the open end. An opposite force pushes on the far end of the balloon, making it fly.



As air rushes out of the open balloon (arrow A), an equal force pushes in the opposite direction (arrow B). In which direction will it fly?

Types of Forces

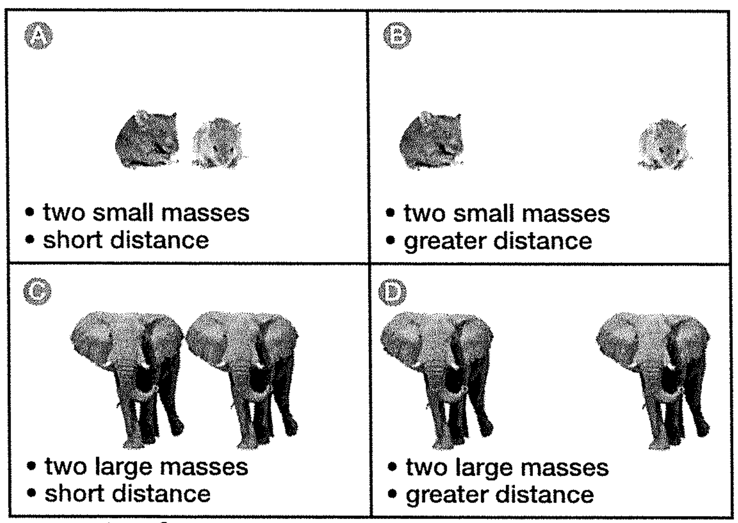
You've learned that people, machines, and nature can all provide a force. Here are three more forces you should be familiar with.

Gravity

Isaac Newton observed that all objects pull on each other due to gravity. His findings became known as the Universal Law of Gravity. The pull of gravity depends on the mass of the objects and the **distance** between them. Greater masses have a stronger pull. If they move farther apart, the pull between them gets weaker.

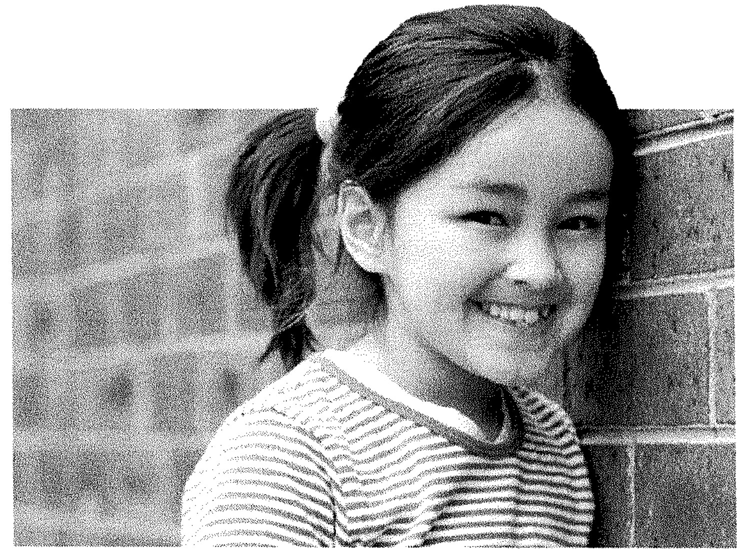
MASS, DISTANCE, AND GRAVITY

In which situation is the gravitational pull strongest?
In which situation is the gravitational pull weakest?



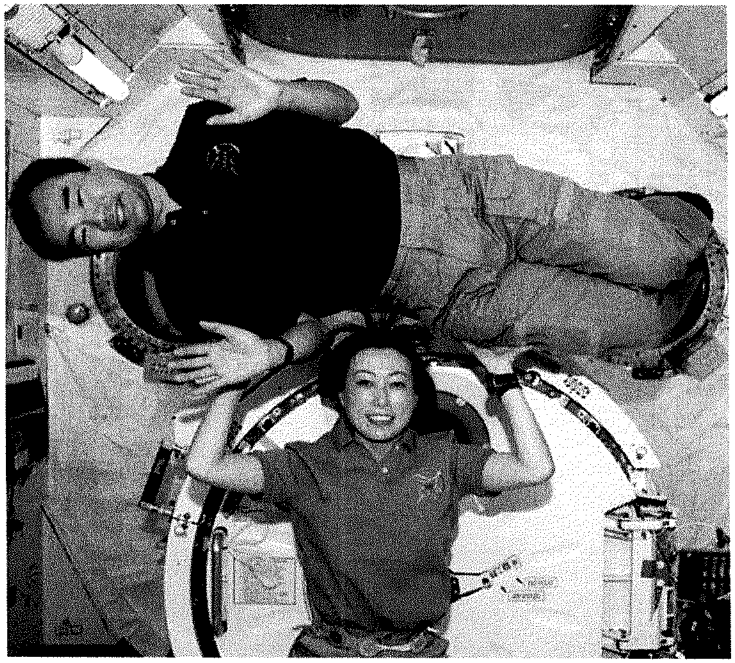
Strongest: C; Weakest: B

Imagine standing next to a tall building. Both you and the building have mass, so you both exert a gravitational pull. The building has much more mass, so it pulls on you much more than you pull on it.



However, both you and the building are standing on Earth. Planet Earth is far more massive than either you or the building. So Earth exerts a much stronger gravitational pull on you and the building than you and the building exert on each other.

On Earth, an object's mass is measured as **weight**. The greater the mass of an object, the more the force of Earth's gravity pulls on it, and the more it weighs.



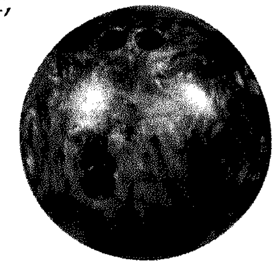
If you were in space, twice as far from the center of Earth as you are now, the pull of gravity would be only one-quarter as strong. You would still have the same mass, but you would weigh only one-quarter of what you weigh on Earth.

Now let's move from Earth to the Sun. The Sun has much more mass than anything else in our solar system. It exerts enough gravitational pull to keep all the planets from flying off into space. Instead, they orbit the Sun.

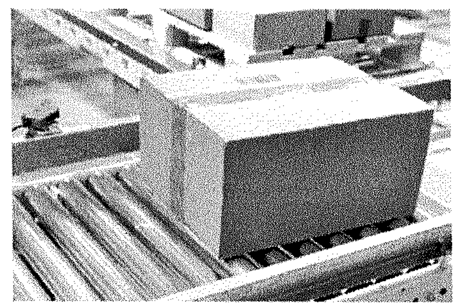
Remember, distance is also important. While the Sun exerts more gravitational pull than Earth, you are much closer to Earth than to the Sun. So Earth's gravity keeps you from getting pulled up to the Sun!

Friction

Friction is an invisible force that both slows down moving things and heats them up. One kind of friction you know well is *sliding friction.* When you rub your hands together, they create sliding friction. This friction produces heat energy, causing your skin to warm up.

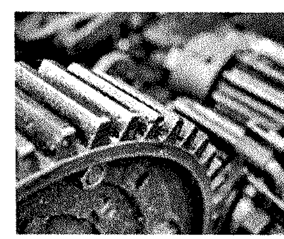


A rolling bowling ball has another kind of friction—*rolling friction.* Rolling friction will slow down a moving object, but not as much as sliding friction does. Placing rollers under a box makes it easier to move. Rolling reduces friction.



Do You Know?

Rough surfaces exert more friction against each other than smooth surfaces do. Putting a lubricant such as oil or grease between two surfaces will reduce friction.



..LESSON..
64

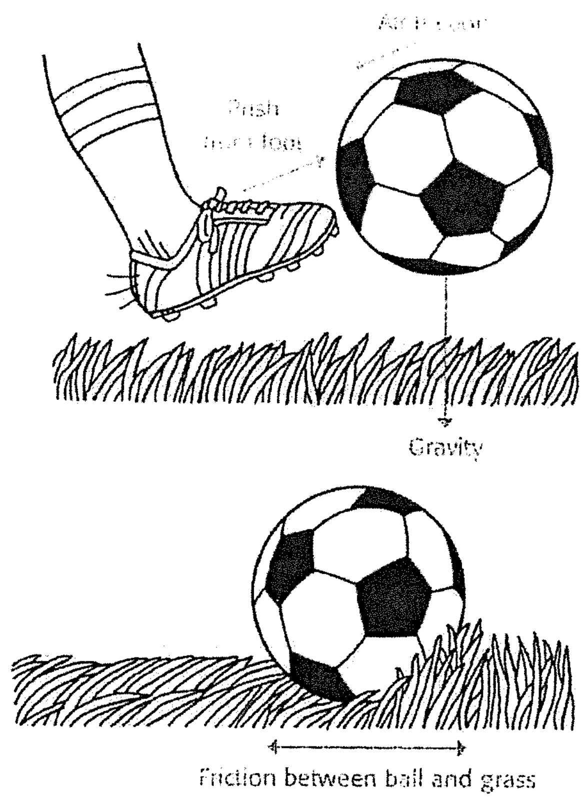
Inertia

How do objects start moving?

The tendency of an object to resist a change in motion is called **inertia.** Because of inertia, an object will not start or stop moving unless an outside force acts on it.

A soccer ball sitting in the middle of a field will not start moving unless a force acts on it. If someone kicks the ball, it will fly up into the air. But the ball will not stay in the air forever. Gravity pulls the ball toward Earth. Friction between the ball and air molecules slows the ball's forward motion. Eventually, the ball falls to the ground and rolls for awhile. Friction between the ball and the grass finally makes the ball stop moving.

An object's inertia is related to its mass. The more mass an object has, the more inertia it has. A big truck has more inertia than a car. It is harder to get a truck moving, and harder to stop it.



Forces act to change the motion of a soccer ball.

Show What You Know

1. What do you have to do to an object to make it start moving?

____

____

2. What makes a moving object stop moving?

____

____

The Basics of Force & Motion

A **force** is a push or a pull. Much of what we know about forces and their resulting motions comes from the ideas of Sir Isaac Newton. A mathematician and scientist, Newton lived in England during the 1600s. He published his observations and theories about force and motion in 1687. Even though Newton's document is now hundreds of years old, the three "laws" he presented are still the foundation of modern physics. To explore force and motion, we need to understand Newton's three laws and be able to identify them in the world around us.

Newton's First Law of Motion

- **An object at rest tends to stay at rest, and an object in motion tends to stay in motion, unless acted upon by an outside, unbalanced force.**

Newton's First Law basically argues that objects—whether they are staying still or moving—tend to keep on doing what they're doing until something interferes. When we put something down, it tends to stay in that spot until someone or something moves it. The second part of this law—that a moving object will stay in motion—is more difficult to grasp. It's hard to picture an object in motion forever since moving objects always seem to slow down at some point.

When objects slow down or stop moving, it's always due to an outside force, like friction or air resistance. **Friction** occurs when two objects rub against each other. As a skier moves over the snow, the contact between the skis and the snow creates **sliding friction**. An object (like a skateboard) rolling over a surface creates **rolling friction**.

Newton's First Law is also called the "law of inertia." **Inertia** is another word to describe an object's tendency to stay in motion or at rest unless an outside force interferes.

Balanced and Unbalanced Forces

Newton's First Law of Motion assumes that the forces acting on the object are **balanced**. When a book is at rest on a table, the force of gravity pushing down on the book is equal to the force of the desk pushing up. The forces acting on the book are balanced, so the book stays put. The same is true of objects in motion. If the forces acting on a moving object are balanced, and no other outside forces interfere, the object would keep on moving forever.

Unbalanced forces cause a change in position or motion. If two people are arm wrestling and both exert the exact same amount of force, their arms will be deadlocked in the same spot. The balanced forces cancel each other out, causing a state of **equilibrium** where there is no motion or change. As soon as one person exerts more force, the forces become unbalanced. Unbalanced forces always result in motion. In the case of the arm wrestling, the stronger arm will overtake the weaker arm and push it down.

Once an object is set into motion, we can measure how fast it travels and calculate its **speed**. We can also calculate the **velocity**, which describes the speed and direction of a moving object. If the moving object travels at the same, unchanging velocity, it has a **constant** speed. A change in velocity (speeding up) causes **acceleration**.

Newton's Second Law of Motion

- **Acceleration of an object depends on the force and mass.**

While Newton's First Law describes how objects behave when forces are balanced, his second law is about what happens when two forces are unbalanced. Newton's Second Law says that once an object is set in motion, its acceleration will depend on two things: force and mass. In fact, this law of motion is often expressed as an equation: **Force equals mass times acceleration** (F = ma).

Force and acceleration are proportional to each other—the amount of force is equal to the amount of acceleration. The greater the force exerted on an object, the more it will accelerate. For example, the harder you kick a ball, the farther and faster it will travel.

The opposite is true of mass. The more mass an object has, the less it will accelerate. If you kick a tennis ball and a bowling ball with the same amount of force, the heavy bowling ball is going to move slower and go a shorter distance than the tennis ball. A heavier object requires more force to set it in motion.

Newton's Third Law of Motion

- **For every action, there is a reaction that is equal in magnitude and opposite in direction.**

Forces always occur in pairs, and Newton's Third Law of Motion helps us understand the relationship between pairs of forces. Every time a force, or action, occurs, it causes a reaction. We can describe the reaction in terms of its strength, or magnitude, and also its direction.

The magnitude of the action is equal to the magnitude of the reaction. For example, if you toss a pebble into the water, it's going to create a small ripple or splash. If you hurl a large boulder at the water, the splash is going to be bigger. The force of the action and reaction always match up.

While an action and its reaction are equal in magnitude, they are opposite in direction. The rock plunges down into the water, but the water splashes up. When you throw or shoot something forward, the recoil of the force pushes you backward. Every time a force acts on an object, it causes a reaction force in the opposite direction.

Kinetic & Potential Energy

Energy is the ability to do work. An object doesn't have to be in motion to possess energy. **Potential energy** is energy that's stored in an object. (In fact, it's also referred to as **stored energy**.) An object's position or circumstances give it potential energy. A spring on the bottom of a pogo stick has **potential energy** when someone is standing on the pogo stick. The coil of the spring compresses when pressure is applied, storing up energy that will later be released. The more height and mass an object has, the more gravitational potential energy it has.

Once an object is in motion, it has **kinetic energy**. When the spring compresses and releases, the kinetic energy of the spring pushes the pogo stick and its rider up into the air. When the person jumps on the pogo stick and the spring compresses again, more potential energy is stored in the spring. When the spring releases, the kinetic energy of the spring pushes the rider up once again.

Imagine a rocket is being launched from the earth. Hot gases are pushed out from the bottom of the rocket as the rocket is pushed upward. The force of the gases pushing against the surface of the earth is equal and opposite to the force with which the rocket moves upward. The motion of the rocket can be explained by Newton's third law, **for every action there is an equal and opposite reaction.** In other words, *when one object exerts a force on another object, the second object exerts a force of equal strength in the opposite direction on the first object.*

Fill in the table:

Law	Description/Definition	Everyday Example
1st Law of Motion		
2nd Law of Motion		
3rd Law of Motion		