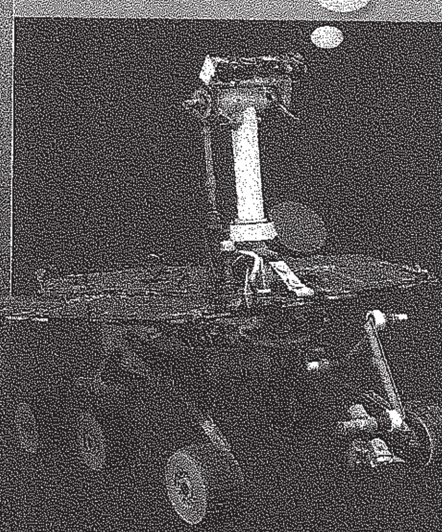
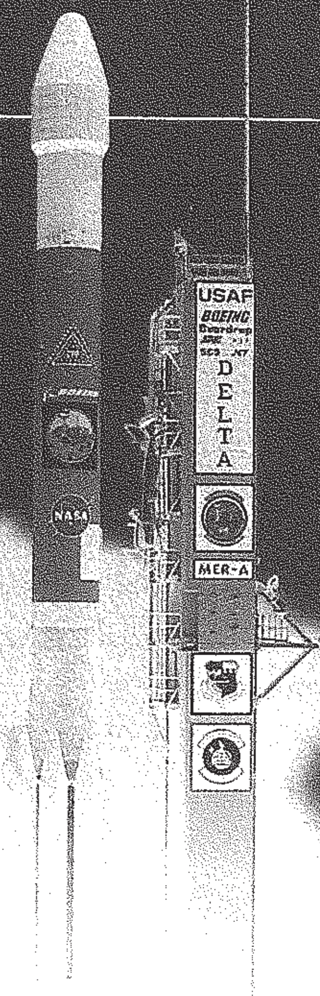
Why It Matters

How did I get to Mars?

LET'S GO to Mars!

How did an understanding of forces help to send a rover to Mars and safely land it there?





1 The first force you need is an unbalanced force to oppose Earth's gravity. A huge booster rocket produces nearly 900,000 N of force that accelerates the rocket upward.

2 After the booster rocket falls away, smaller rockets in the second stage fire. The rockets change the direction of the vehicle's motion and put it in orbit around Earth.

3 The third-stage rocket firing produces enough force to reach "escape velocity." Earth's gravity can no longer pull it back down. We're on our way!

▶ What forces act on the rocket while it's at rest on Earth's surface? Are they balanced or unbalanced?

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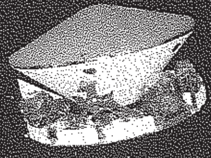
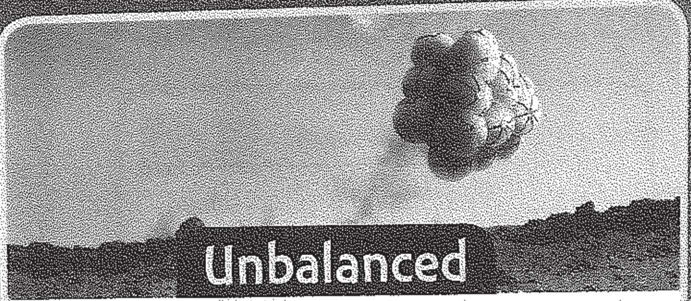


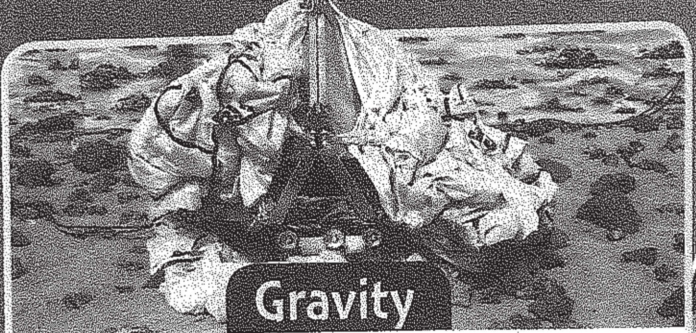
Balanced

▶ At what points during the Rover's trip to Mars are the forces on it balanced?



Unbalanced

▶ What unbalanced forces are acting on the Rover as it lands on Mars?



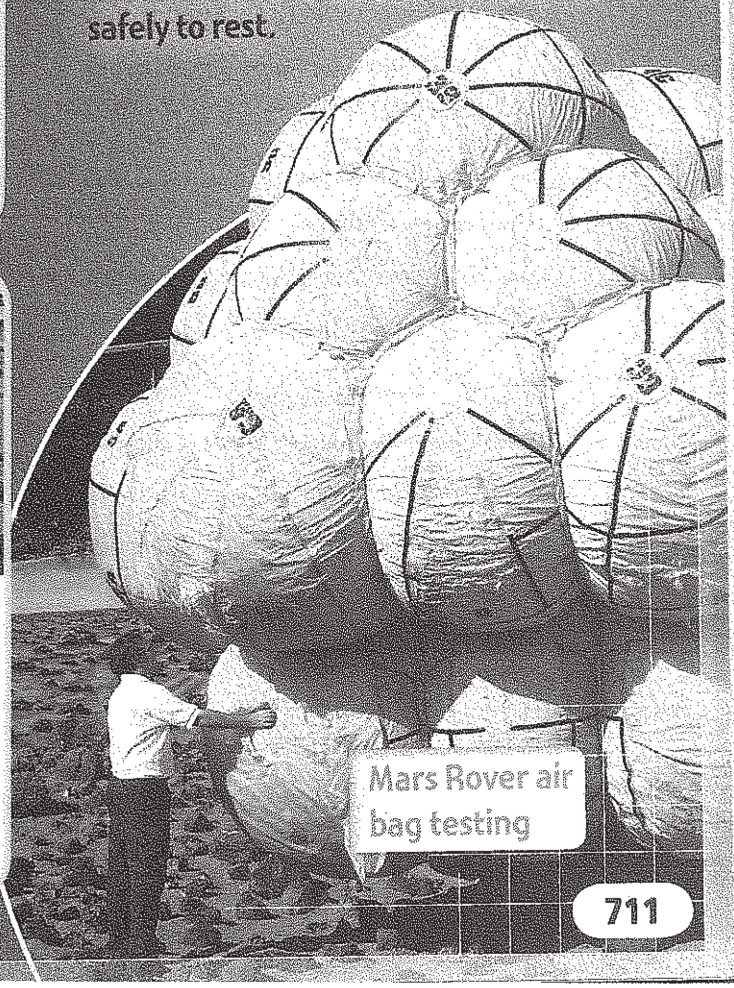
Gravity

▶ Use forces to explain why the Rover required a parachute and "air bags."

During much of the time it takes the spacecraft to travel to Mars, it travels at a constant velocity. The forces acting on the spacecraft are balanced, so its motion does not change.

Tiny rockets occasionally fire to keep the spacecraft on course. During these times, the forces are unbalanced.

As the spacecraft approaches Mars, gravitational attraction begins to accelerate it toward the surface. Like a person jumping from a plane, the Rover detaches from the spacecraft. Parachutes open to slow its fall. Then a big ball inflates around the Rover. When the Rover hits the surface of Mars, it bounces around until it comes safely to rest.



Mars Rover air bag testing

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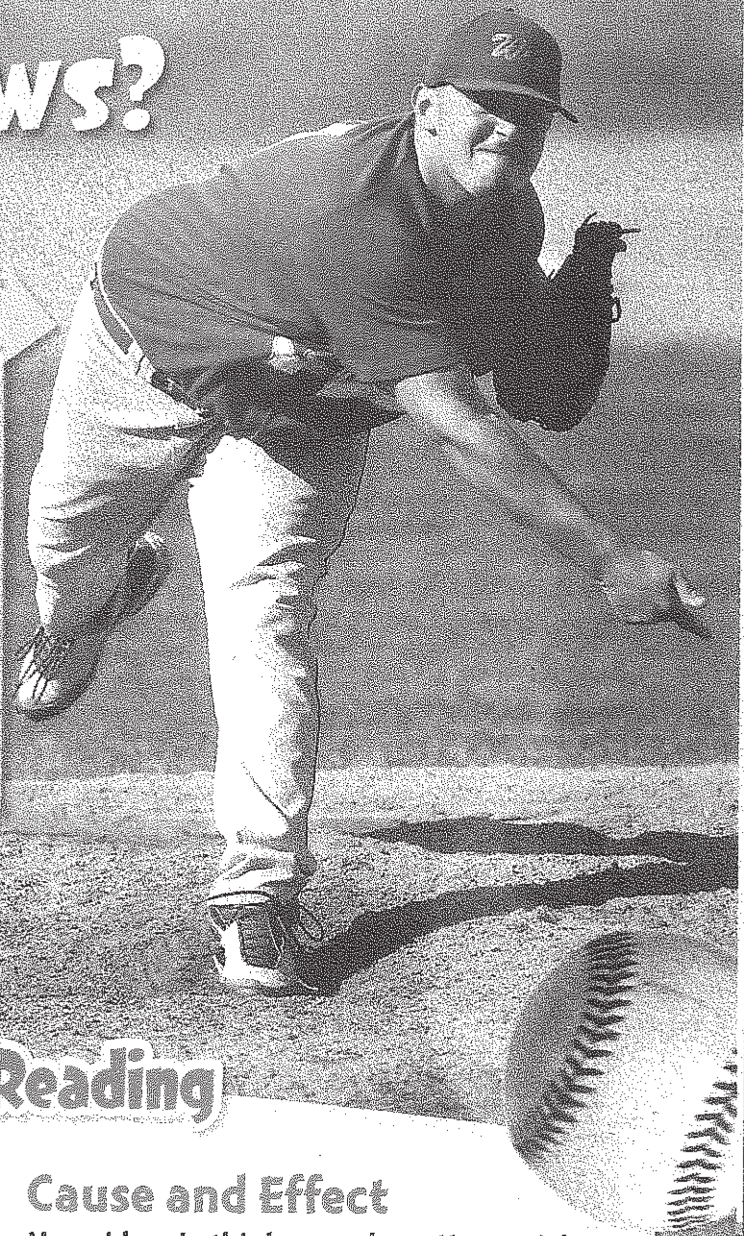
Lesson 4

Essential Question

What Are Newton's Laws?



Engage Your Brain!

Look for the answer to the following question in this lesson and record it here.

How does a baseball obey Newton's laws?

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Active Reading

Lesson Vocabulary

List each term. As you learn about each one, make notes in the Interactive Glossary.

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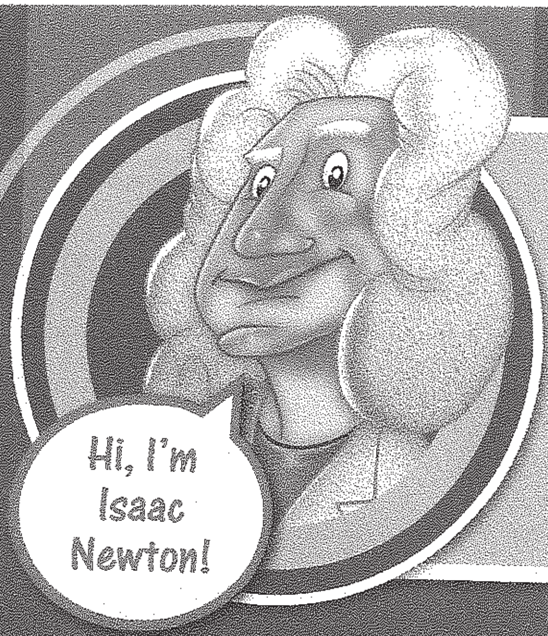
Cause and Effect

Many ideas in this lesson about Newton's laws of motion are related by cause and effect. A cause is the reason something happens. An effect is what happens as a result of a cause. Active readers look for effects by asking themselves, What happened? They look for causes by asking, Why did it happen?

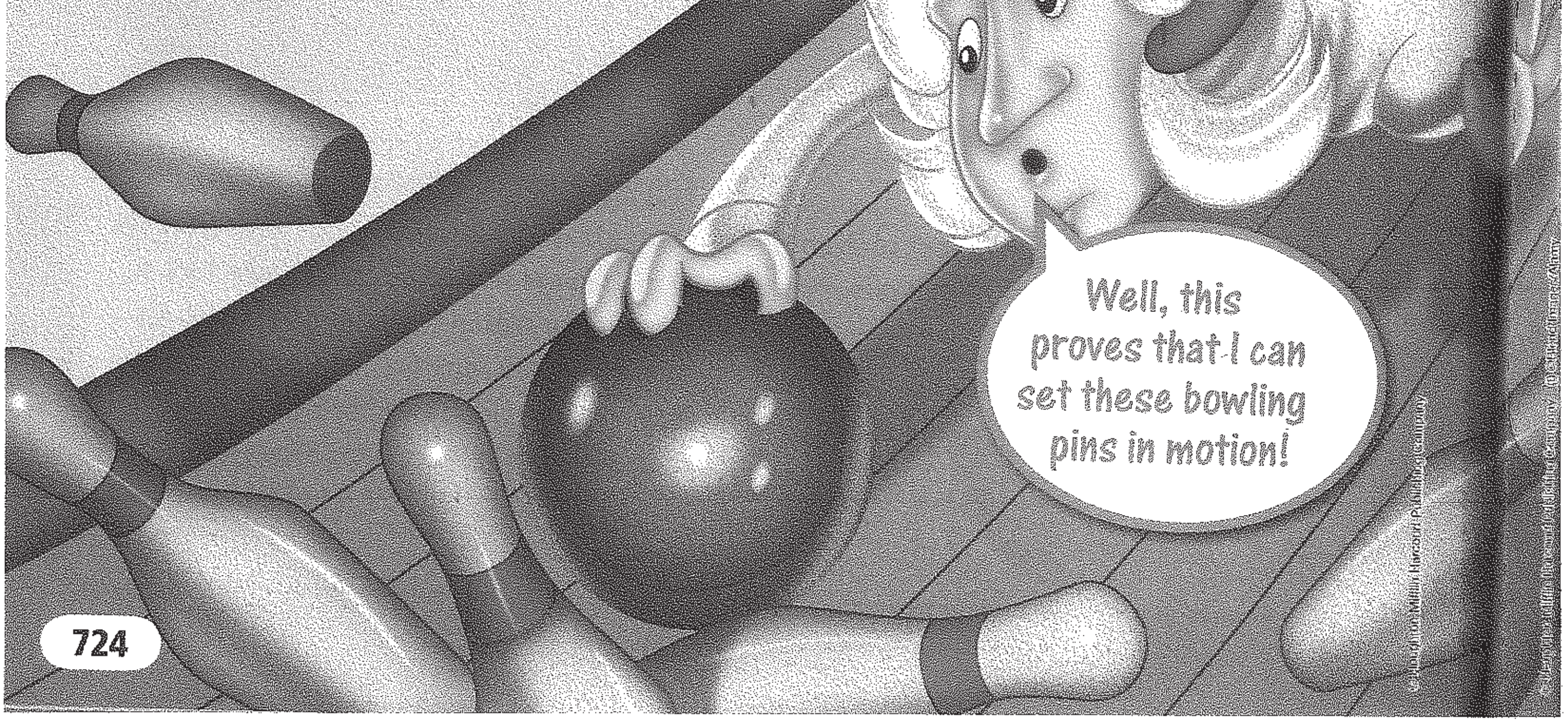


Newton's First Law of Motion

In the 1600s, Isaac Newton discovered some laws that still apply to the things you do, see, and feel every day.

Active Reading As you read the next page, **circle** words that identify what Newton said caused an object to accelerate.

Newton did experiments to understand how objects behave in nature. He wanted to know more about what causes an object to start moving or to change the way it moves.



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Newton's First Law

Newton's first law of motion says that an object will stay in uniform motion unless a net force acts on the object. Without that force, an object at rest will stay at rest. An object in motion will keep the same speed and direction. For example, a marble will stay still on the floor unless you push it. If the marble is already moving, it will continue to move at a constant speed in a straight line until a force acts on it.

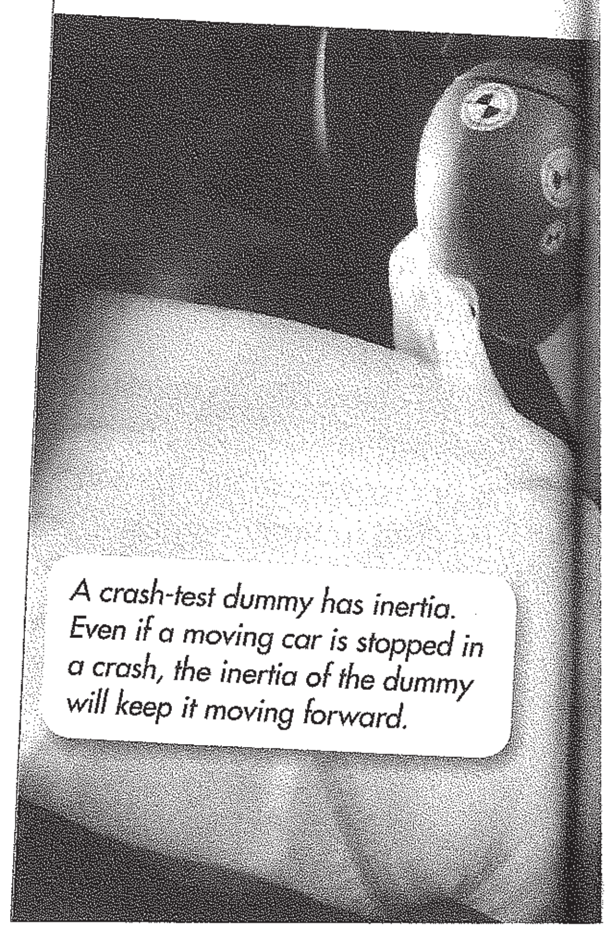
The tendency of an object to resist any change in motion is known as **inertia**. Objects with a lot of mass have more inertia than objects with less mass. Your body's inertia is what pushes you against the side of a car when the car turns. Your body tends to keep moving in a straight line when the car changes direction. The car must push you as it turns. Inertia is also what makes your body rise up from your seat when the car goes up and over a steep hill. At the top of the hill, your body tends to continue going forward as the car begins to move down the hill.

Things you push or throw eventually will stop. This is because there are other forces acting on these objects. For example, friction and air resistance will slow down a rolling marble until it stops. However, a space probe will keep moving through space because it has no friction to slow it down. Even without fuel, a space probe can travel a long distance by inertia. It only needs fuel to change direction or to slow down.

2. Main Idea and Details Read the second paragraph again. **Circle** the main idea and **underline** two details.

3. Infer Why do standing passengers fall forward when a bus stops?

4. CHALLENGE Why is fuel needed to change the speed or direction of a probe in space?

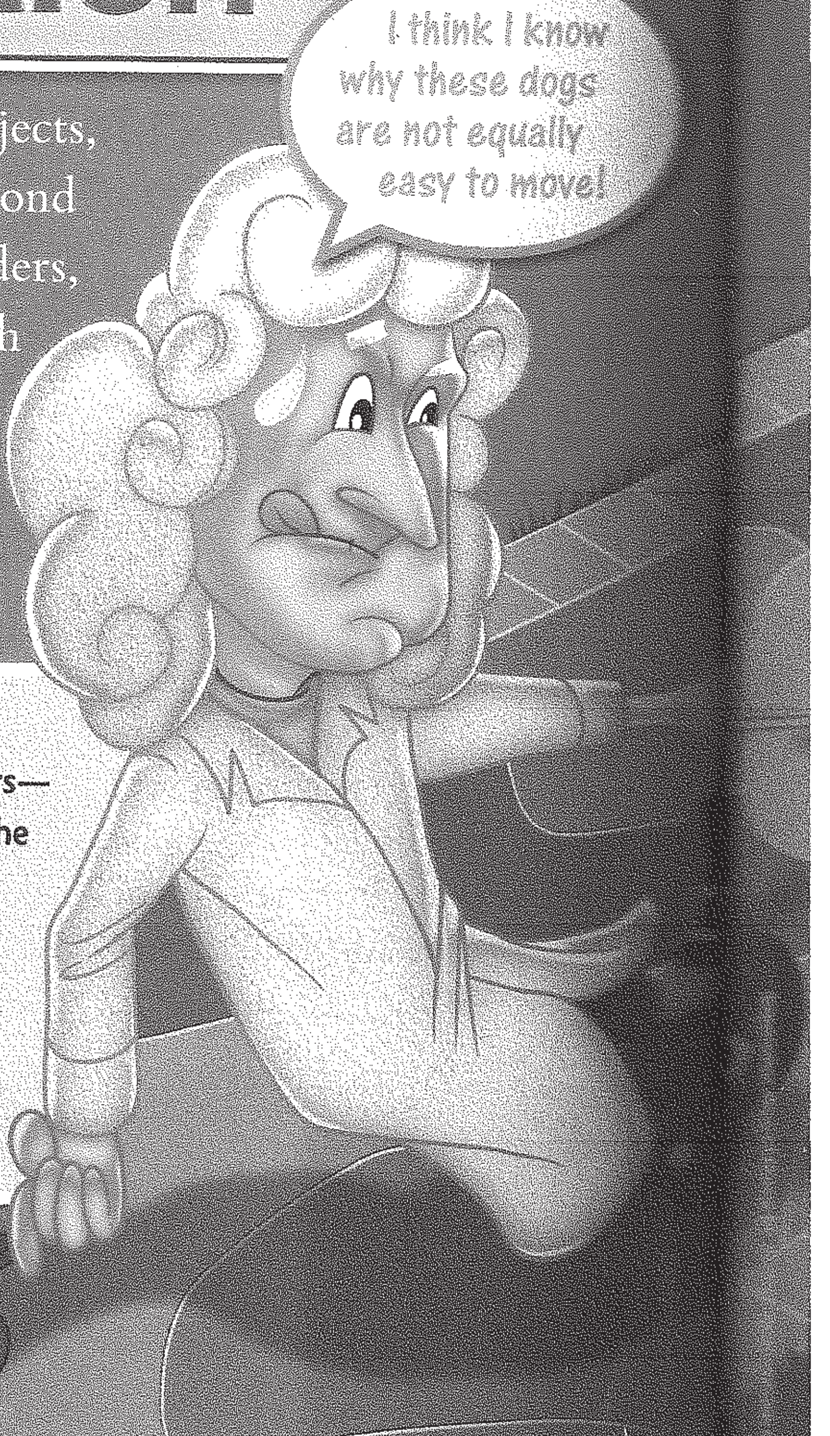


A crash-test dummy has inertia. Even if a moving car is stopped in a crash, the inertia of the dummy will keep it moving forward.

Newton's Second Law of Motion

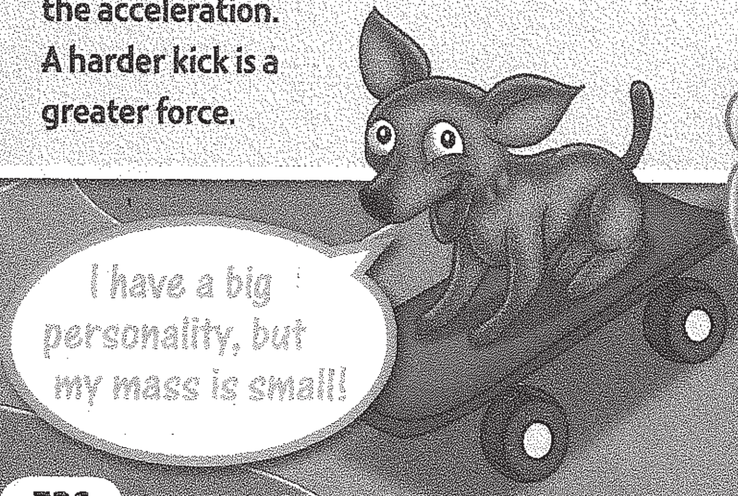
Newton's first law talks about objects, forces, and motion. Newton's second law is more specific. It also considers, How big of an object? How much force? How much motion?

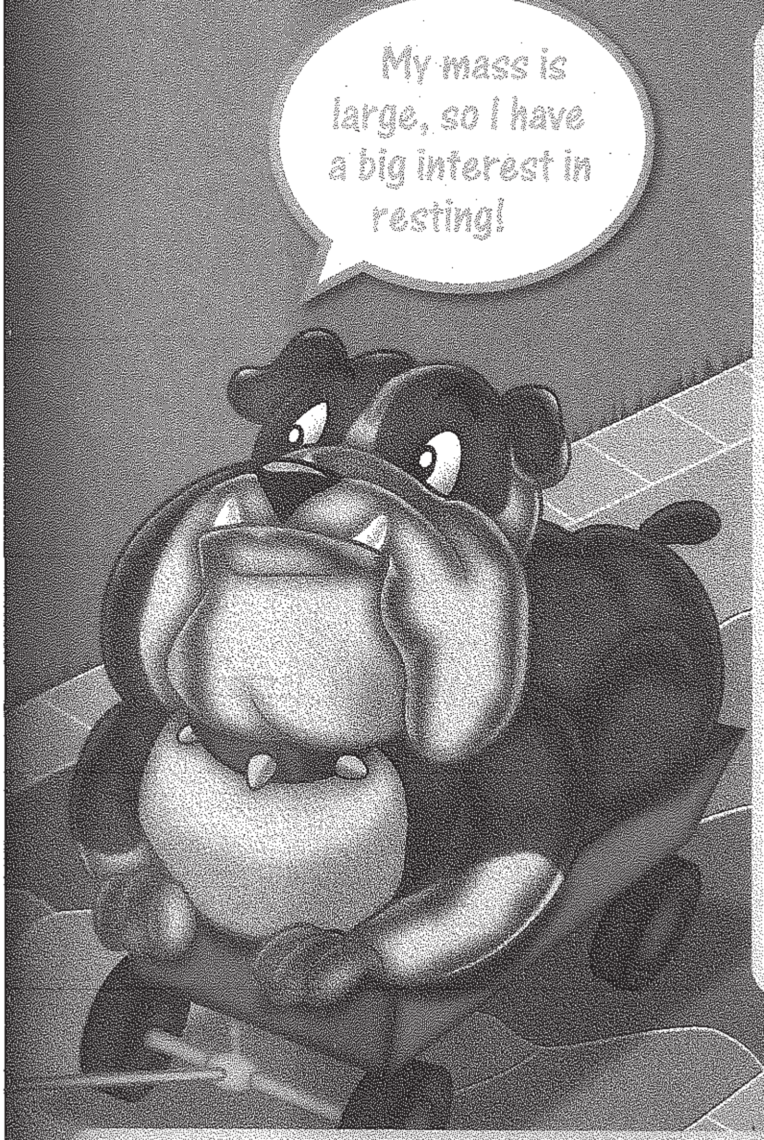
Active Reading As you read this page, **underline** two factors that affect the way an object moves.



***N**ewton's second law of motion* states that an object's acceleration depends on two factors—the amount of force applied to the object, and the object's mass. Think about how kicking a ball harder makes it move faster. In other words, the greater the applied force, the greater the acceleration.

A harder kick is a greater force.





Do the Math!

Solve Word Problems

F means *force*, *m* means *mass*, and *a* means *acceleration*.

Use Newton's second law ($F = m \times a$) to find the missing values in the equations below. Recall that the standard unit of force is the newton (N).

If a mass has a value of 1 and its acceleration is a value of 3, what is the value of the force acting on the mass?

____

A ball has a mass of 6 units. Its acceleration is 8 units. What is the value of the force that set the ball in motion?

____

The mass of an object affects how, or if, the object moves when a force is applied to it. Think of an empty shopping cart at a grocery store. How much force does it take to start it moving? Not much, right? Now imagine the cart filled with groceries. If you used the same amount of force as before, would the full cart move? Probably not. Newton's second law explains why you must use more force to move an object with a greater mass. The second law of motion can be written as an equation: Force = mass × acceleration.

The amount of force needed to turn the pinwheel would not be enough to move the blades of the wind turbine.

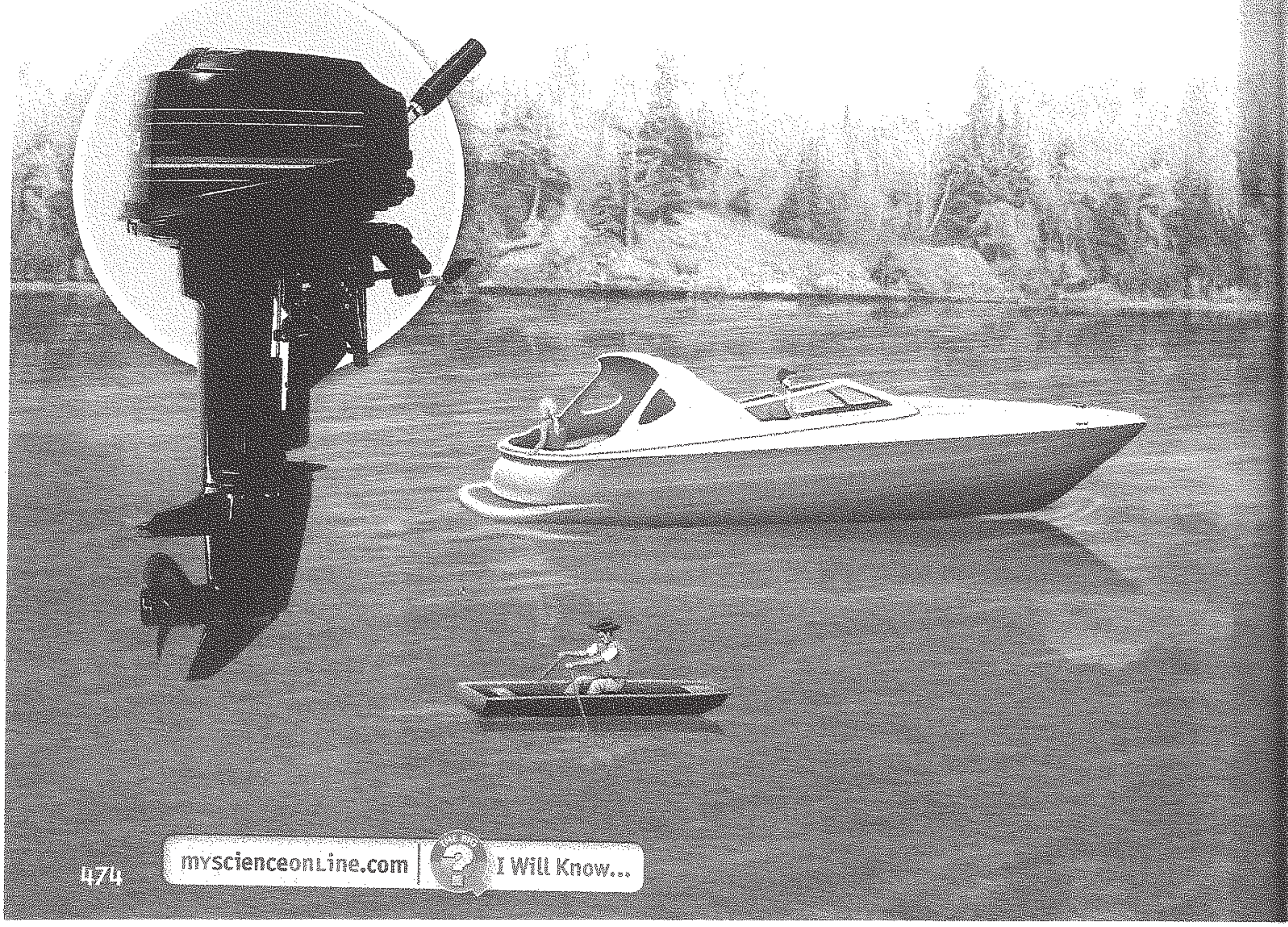
Newton's Second Law

Newton's second law of motion describes how acceleration, mass, and force are related. Force is the product of mass and acceleration. The force acting on an object can cause the object to speed up, slow down, or change direction.

Same Force, Different Masses

Newton's second law says that the greater the mass of the object, the smaller its change in motion will be for a given force. This means that the same force will cause an object with small mass to accelerate more than an object with large mass. Large masses are harder to accelerate and harder to stop. For example, the engine and brakes of a truck provide the same forces whether the truck is empty or loaded. However, the loaded truck has more mass and will accelerate more slowly. It will also take longer to stop. Truck drivers must be aware of Newton's second law in order to drive safely.

7. Compare The boats below have no engines. The engine shown can push either boat with the same force. **Circle** the boat that is more likely to experience less acceleration with this engine. Tell why.



Do the math!

Using Formulas

The formula that describes the relationship between force, mass, and acceleration is:

Force = Mass × Acceleration

This means that the stronger the force acting on an object, the more that object will accelerate. The formula is often written as follows:

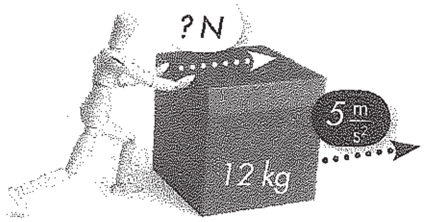
$$F = m \times a$$

The unit of force in the metric system is called a newton (N). The unit of mass in the metric system is the kilogram (kg).
The unit of acceleration is the meter per second squared ($\frac{m}{s^2}$).

$$1\ N = 1\ kg \times \frac{m}{s^2}$$

Example

A block with a mass of 12 kg is being pushed. Its acceleration is $5\ \frac{m}{s^2}$. What force is acting on the block?



Solve for the force, F. Use $m = 12$ kg, $a = 5\ \frac{m}{s^2}$

$F = m \times a$

$F = 12\ kg \times 5\ \frac{m}{s^2}$

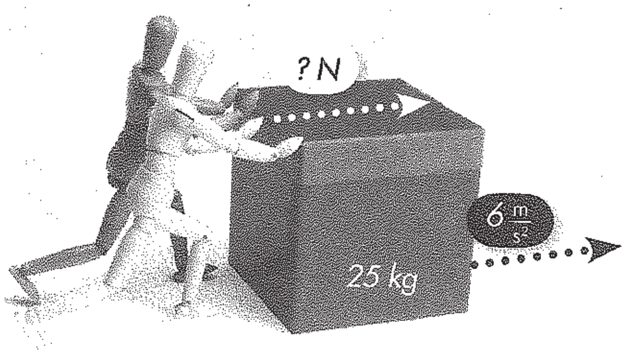
$F = 60\ kg \times \frac{m}{s^2}$

$F = 60\ N$

Think I know that $1\ kg \times \frac{m}{s^2} = 1\ N$, so $60\ kg \times \frac{m}{s^2} = 60\ N$

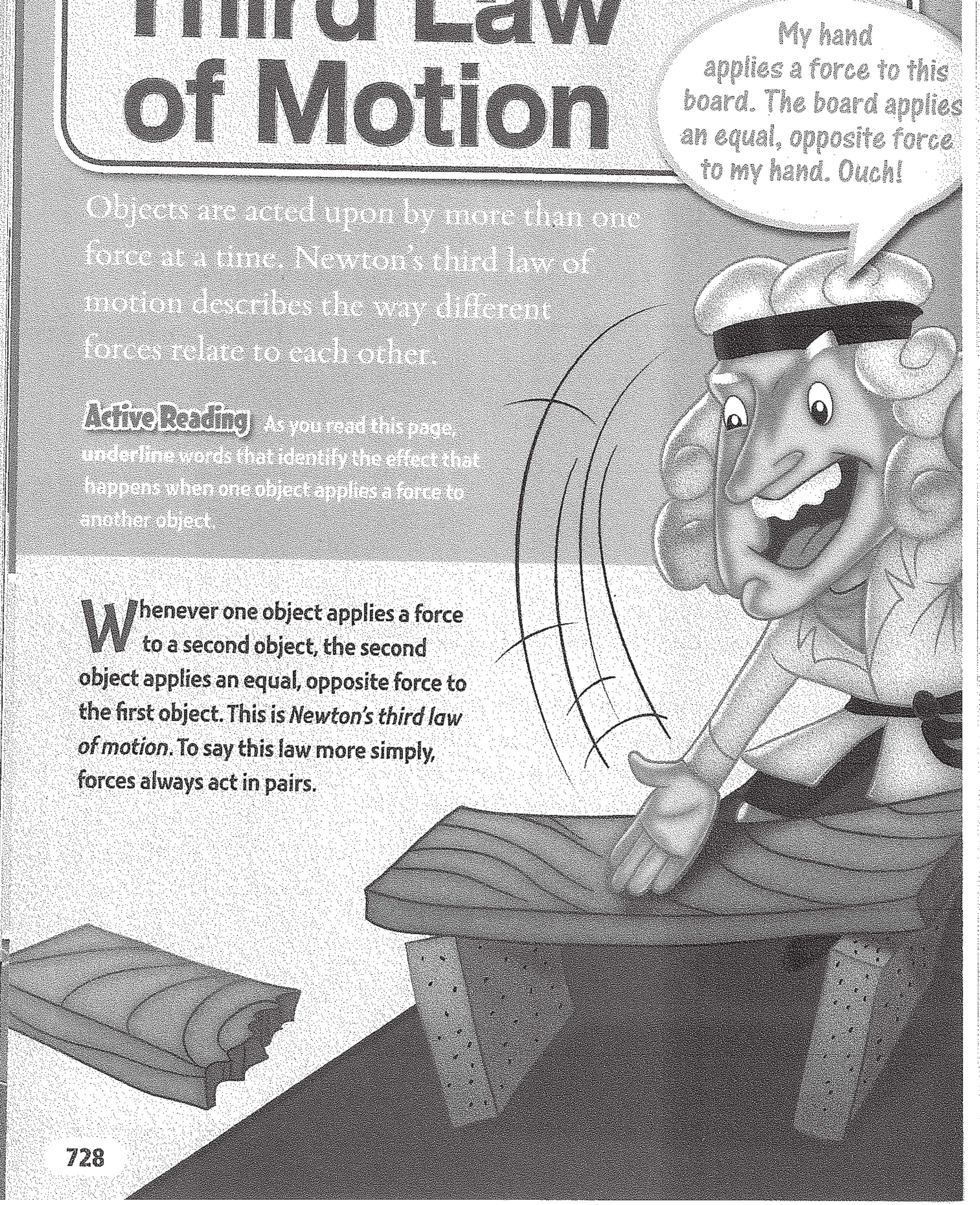
The force being applied to the block is 60 N.

1. A 25 kg block is being pushed and is accelerated at a rate of $6\ \frac{m}{s^2}$. What force is being applied to the block? Show your work.



Work Area

Newton's Third Law of Motion



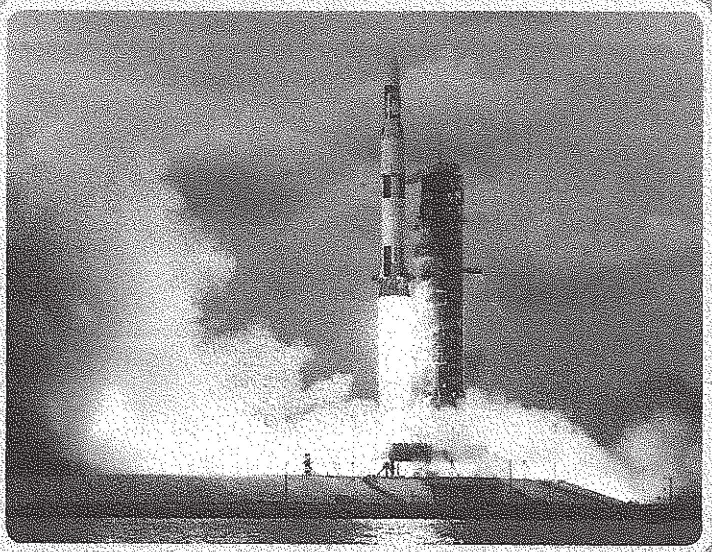
Objects are acted upon by more than one force at a time. Newton's third law of motion describes the way different forces relate to each other.

Active Reading As you read this page, **underline** words that identify the effect that happens when one object applies a force to another object.

Whenever one object applies a force to a second object, the second object applies an equal, opposite force to the first object. This is *Newton's third law of motion*. To say this law more simply, forces always act in pairs.

To better understand Newton's third law, picture two objects—your body and a wall. As you lean against the wall, your body applies a force to the wall. The wall doesn't move because it applies the same amount of force to you. Sometimes scientists use the terms *action force* and *reaction force* to refer to a pair of forces.

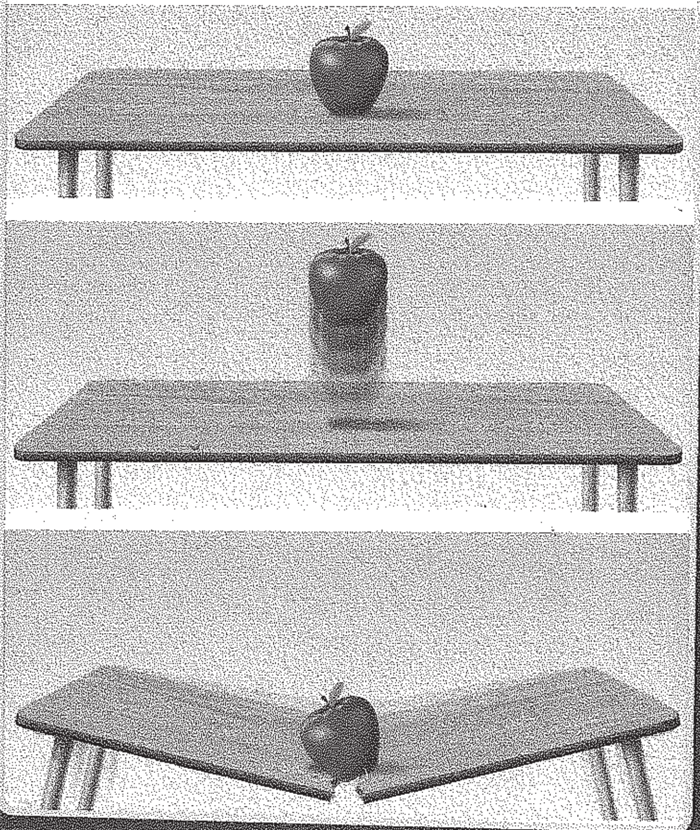
Now think about the two adjectives that Newton used to describe a pair of forces. How are action and reaction forces *equal* and *opposite*? The two forces described above are equal in size, and they are opposite in direction.

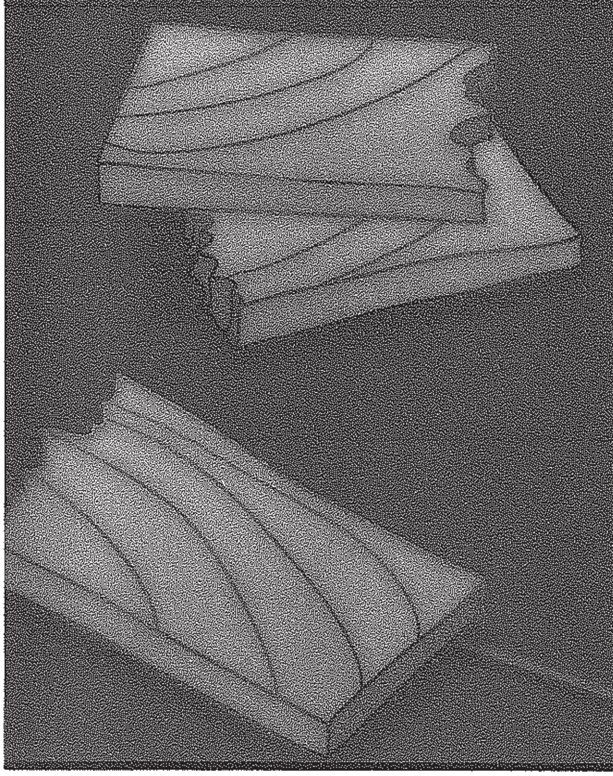


During takeoff, the rocket's thrusters push the exhaust gases downward as the gases push the rocket upward with an equal force.

Forces in Action

Look carefully at the diagrams of the apple and the table. Draw arrows to show the forces between apple and table. Make longer lines to show stronger forces.





Newton's Third Law

Newton's third law of motion states that when one object exerts a force on a second object, the second object exerts a force on the first. These forces are equal in strength and opposite in direction.

It is impossible to have one force without an equal and opposite force. For example, if you have ever ridden bumper cars, you know that when a moving car collides with a stationary car, both drivers feel the force of the collision. The driver of the stationary car feels a force and starts to move. The driver of the moving car feels an opposite force that slows the moving car.

10. Choose Suppose the girl on the left bumps the car on the right. Which girl feels a bigger bump? Explain.

Got it?

11. Explain What is needed to give a large boulder a large acceleration?

12. UNLOCK THE BIG ? Suppose a train engine is pulling ten cars. The last car becomes separated from the train. What happens to the motion of the rest of the train?

Stop! I need help with

Wait! I have a question about

Go! Now I know

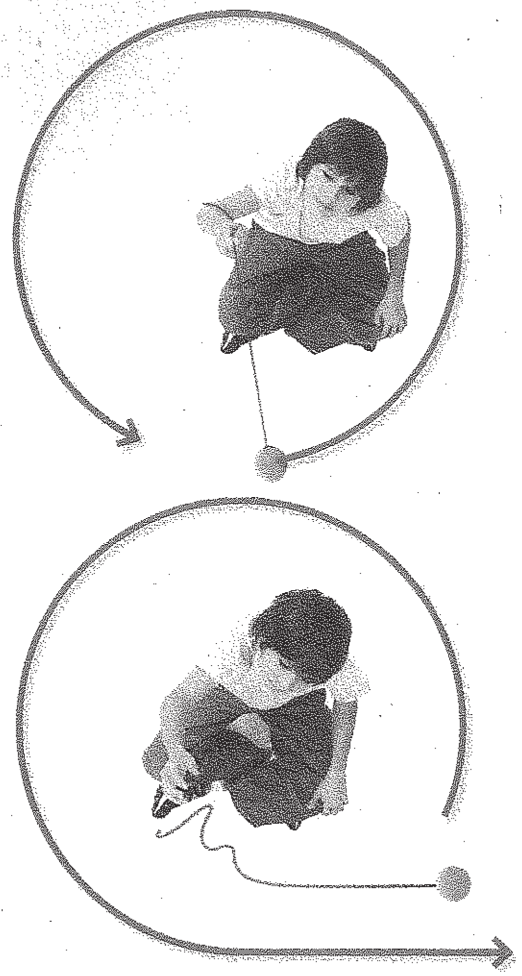
Motion in Space

You've probably seen pictures of astronauts floating with other objects inside a spacecraft. The astronauts, the objects, and the spacecraft are all in motion, and Newton's laws still apply.

Active Reading As you read the next page, **circle** the main idea. **Underline** details that add important information about the main idea.

Astronauts in orbit appear to be weightless. To understand the motion of objects in space, it's important to remember the difference between weight and mass. Remember, *mass* refers to how much matter is in an object. *Weight* refers to how much force is applied to an object by gravity.

As a person swings an object in a circular motion, you can see an example of how objects orbit Earth. The string acts like gravity, constantly pulling the object toward the center of the circular path. If the person lets go, inertia takes over; the object keeps traveling, but in a straight line. The *International Space Station* (*ISS*) shows how Newton's first law works in space. Because of inertia, the *ISS* moves forward at a contant speed. At the same time, gravity pulls the *ISS* toward Earth, so that the *ISS* constantly changes direction. As a result of these two motions, the *ISS* follows the curve of Earth's surface. What would happen if Earth's gravity did not constantly pull on the *ISS*? Inertia would cause the station to fly off into space in a straight line!



▶ Explain what two forces are acting on Isaac Newton as he floats in the *ISS*.

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Newton's laws of motion apply to objects in space, because the laws involve mass, not weight. The mass of an object is the same on Earth and in space. An object's weight can change because it is related to the force of gravity at a particular location. Astronauts feel and look weightless because of microgravity. Often mistakenly called "zero gravity," *microgravity* occurs because Earth's gravity causes the space station to fall toward Earth at a constant rate. Everything inside the space station falls at the same rate. Because the astronauts are also in free fall, they appear to float.

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What Can Change an Object's Motion?

Motion and Newton's First Law

Motion is a change in an object's position. A motionless object is at rest, or stationary. Sir Isaac Newton described several laws in 1867 that explain much about motion. His laws show how forces and motion are connected. A force is a push or pull that acts on an object.

Newton's first law of motion states that an object at rest remains at rest. An outside force must act on it to make it move. Likewise, an object in motion stays in motion. The resistance to a change in motion is called inertia.

Speed, Velocity, and Acceleration

Newton's first law explains that an outside force is needed to change an object's speed or direction. Speed is a measure of distance moved in a given amount of time.

To calculate average speed, divide the distance traveled by the time it took the object to travel that distance. You can use this formula to relate speed (s), distance (d), and time (t):

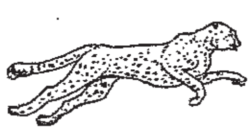
$$s = d/t$$

If a car travels 160 miles in 2 hours, the average speed is

$$s = 160\ mi/2\ h$$
$$s = 80\ mph$$

There are many other units of speed. However, they are all written as units of distance per units of time. Meters per second (m/s) is one common unit.

Top Animal Speeds

			
Cheetah 100 km/h (60 mph)	**Blue Whale** 50 km/h (30 mph)	**Peregrine Falcon** 320 km/h (200 mph)	**Dragonfly** 60 km/h (36 mph)

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Velocity is a measure of both an object's speed and its direction. If you and a friend both run at a speed of 5 mph but go in different directions, you have different velocities.

Whenever an object's speed or direction changes, its velocity changes, too. This change is called acceleration. Acceleration measures a change in speed, in direction, or both over a certain amount of time.

Newton's Second Law

Imagine you and a friend are pulling on opposite ends of a rope. You are pulling with greater force. The difference between the two forces is called net force.

Newton's second law of motion states that an object accelerates, or changes its motion, only when an unbalanced force acts on it. The law can be written as a formula.

$$F = ma$$

F is the applied net force, m is the mass of the object, and a is the amount of acceleration. Force is measured in a unit called the newton (N). One newton is the force required to accelerate a mass of 1 kg at 1 m/s per second.

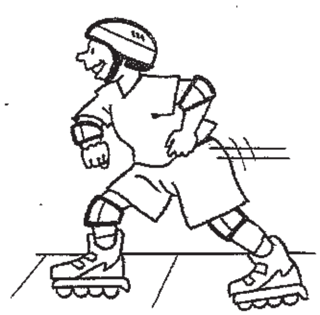
Gravity

Gravity is a force that causes objects with mass to be attracted, or pulled, toward one another. Gravity is a noncontact force because it acts on an object without touching it. According to Newton, gravity increases with the masses of two objects. As the objects get farther apart, gravity pulls with weaker force. Earth's mass is much greater than the mass of any object, so gravity pulls all objects toward Earth.

Friction

Friction is a force that resists motion of one surface across another surface. Friction is a contact force because objects or surfaces touch one another. Friction is usually greater between rough surfaces than smooth ones.

In the picture, the slowing force of friction happens between the ground and the skate wheels. If the skater uses his brakes, friction increases. He will stop sooner. Air resistance, or drag, will also help slow down the skater. This kind of friction resists motion through air.



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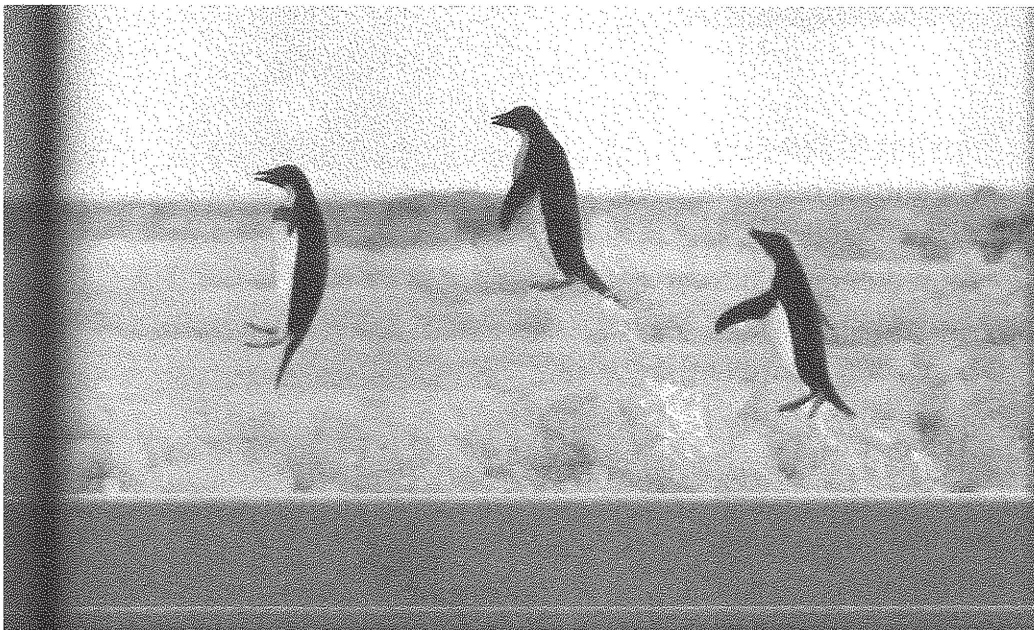
ENERGY



I will know what potential and kinetic energy are. I will know the different forms of energy into which energy can change.

Words to Know

energy
potential energy
kinetic energy

Energy

The word *energy* has different meanings. In science, **energy** is the ability to do work or cause a change. Energy can change an object's motion, color, shape, temperature, or other characteristics.

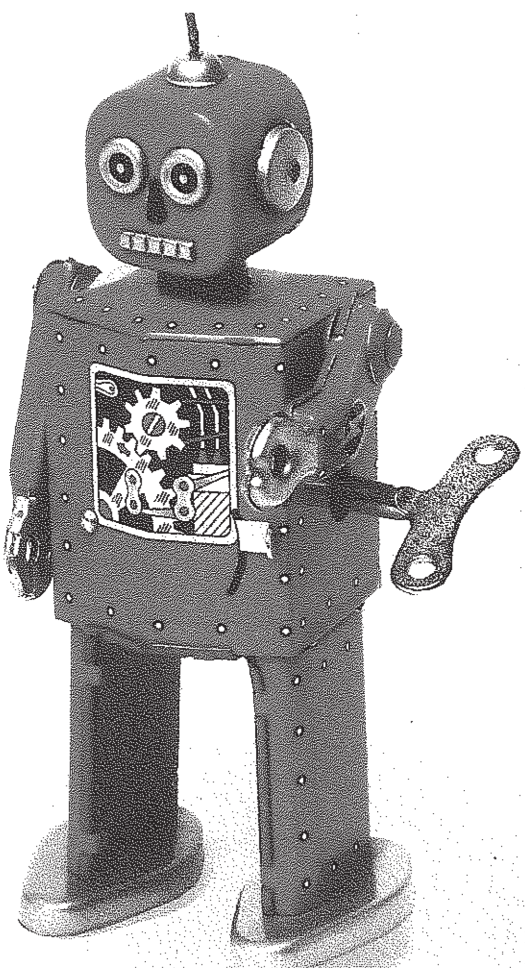
A jumping penguin has energy. Some of the energy is due to the penguin's motion, and some is due to its high position during the jump. The sum of the energy due to the motion of an object and the energy stored in the object due to the object's position is called mechanical energy.

Energy cannot be made or destroyed, but it can change form and it can move from one object to another. For example, the energy that a windup toy has when it begins to move does not disappear when the toy stops moving. The energy simply changes into other forms.

1. **Cause and Effect** Complete the graphic organizer below. List one cause and one effect found in the paragraphs above.

Cause	Effect

This windup toy uses energy to move. After its energy is used, more energy can be added to the toy by turning the key.



Potential Energy

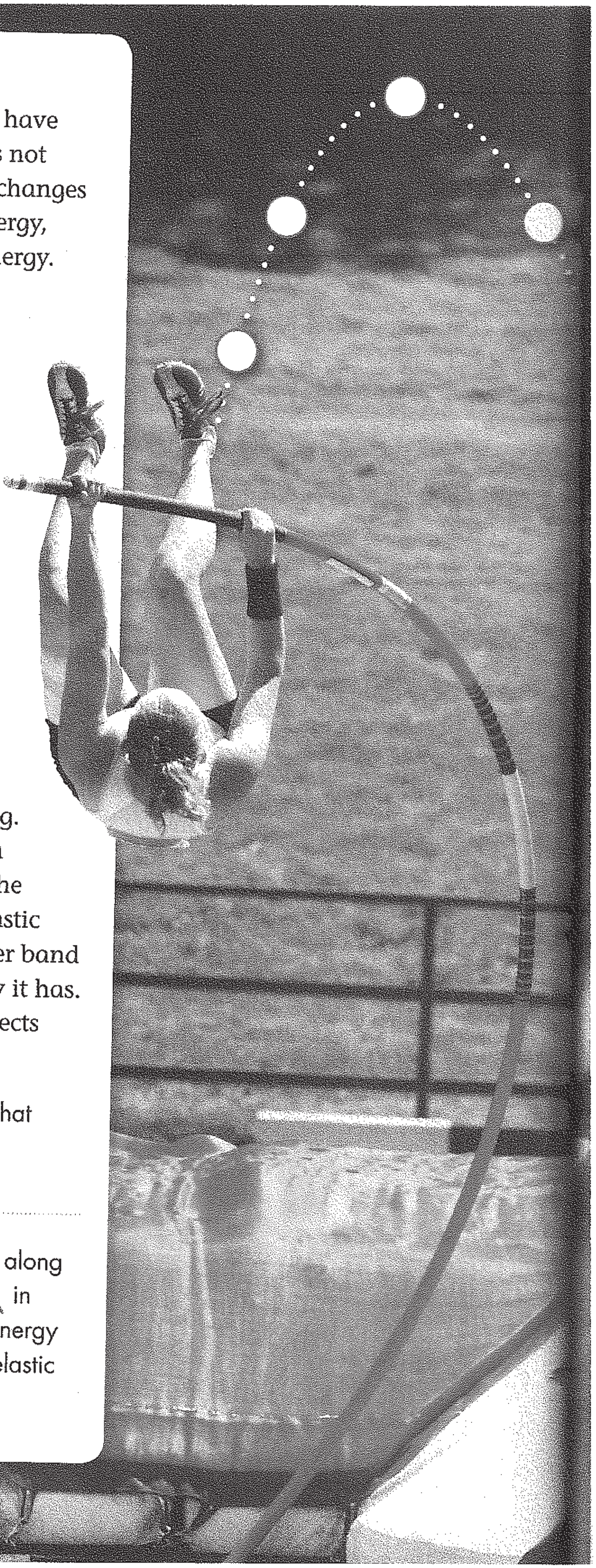
An object does not need to be moving to have energy. **Potential energy** is energy that is not causing any changes now but could cause changes in the future. Potential energy, or stored energy, and kinetic energy make up mechanical energy.

Gravitational Potential Energy

One kind of potential energy depends on the position of an object relative to Earth. This kind is called gravitational potential energy. For example, as a pole-vaulter reaches the top of her jump, she gains potential energy relative to the ground. The higher she goes, the more potential energy she has. She loses potential energy as she falls. The potential energy does not disappear. It just changes form.

Elastic Potential Energy

Another type of potential energy is elastic potential energy. This is the energy of a stretched rubber band or a compressed spring. This type of potential energy is present when things are bent or stretched. It is present in the pole-vaulter's pole. When the pole bends, elastic potential energy increases. The more a rubber band is stretched, the more elastic potential energy it has. This energy can also cause the motion of objects to change.



2. Infer What clues from this picture tell you that the pole-vaulter has potential energy?

....

3. Draw Look at the circles marking positions along the pole-vaulter's possible path. Write an X in the circle where her gravitational potential energy is highest. Fill in the circle where the pole's elastic potential energy is highest.

Kinetic Energy

Mechanical energy is the sum of the potential, or stored, and kinetic energies of an object. **Kinetic energy** is the energy due to motion. The amount of kinetic energy in a moving object depends on its speed and its mass.

The faster an object moves, the more kinetic energy it has. Think about a carpenter using a hammer to drive a nail into wood. When the carpenter swings the hammer slowly, the hammer has a small amount of kinetic energy. It does not have the energy to move a nail very much. When the carpenter swings the hammer quickly, it has more kinetic energy. It can push a nail farther into the wood with just one hit.

Similarly, the more mass a moving object has, the more kinetic energy it has. For example, a moving beach ball has kinetic energy. If the beach ball hits a sand castle, it might knock down a castle wall. A basketball has more mass than a beach ball. What would happen if a basketball, rolling at the same speed as the beach ball, hit the sand castle? Since the basketball has more mass, it has more energy. It might flatten the whole castle!

Potential energy can change into kinetic energy. As the pole-vaulter on the previous page falls, her potential energy becomes kinetic energy. She moves faster and faster.

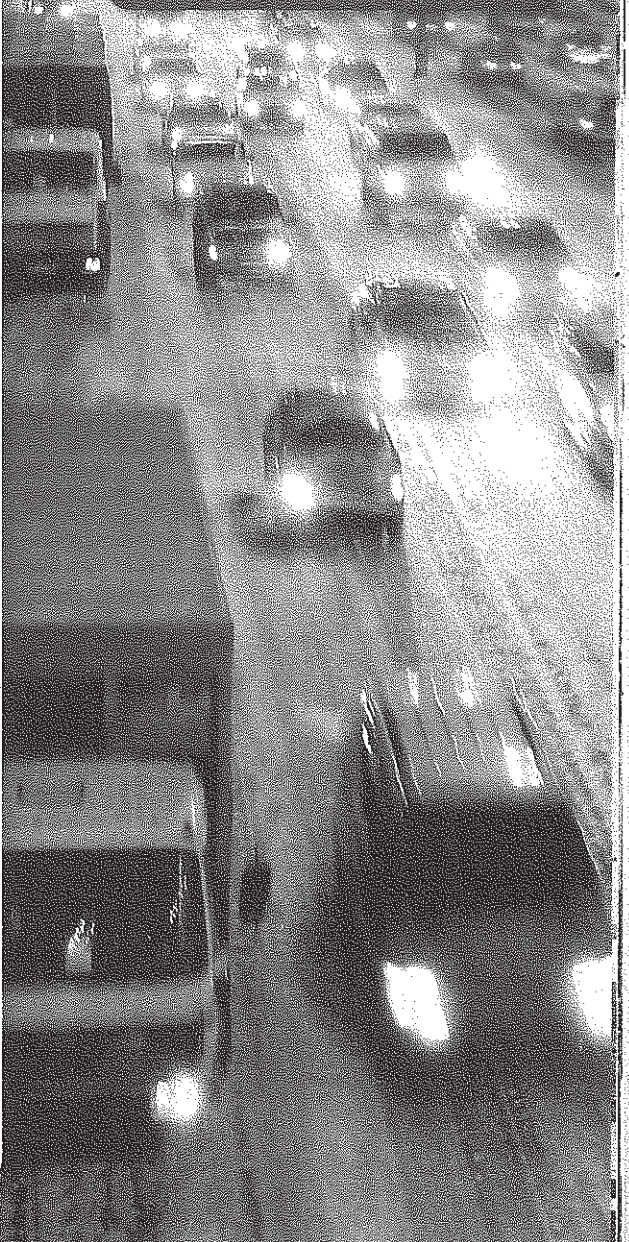
Kinetic energy and potential energy can be present in the same object at the same time. For example, an airplane has potential energy because of its altitude and kinetic energy because it is moving forward.

4. **Draw Conclusions** **Underline** the facts in the third paragraph that support the conclusion that a basketball has more energy than a beach ball.

5. CHALLENGE If all the traffic is moving at the same speed, which vehicles do you think have the most kinetic energy?

Lightning Lab

Rubber-Band Release
Wear safety goggles. Stretch a rubber band as if to shoot it, but do not let it go. The energy in the stretched rubber band is potential energy. Aim the rubber band at a blank wall and let it go. How did the energy of the rubber band change?



Name________________________________

Force and Motion Vocabulary

Acceleration – A change in the speed or direction of an object/change in velocity

Action (force) – A force exerted on an object

Air Pressure – The weight of the air pushing on objects

Air Resistance – The force created in the opposite direction of the way an object is traveling by the air around the object

Balanced Forces – forces that are equal and opposite, such that no change occurs in the motion of the object. They cancel each other out.

Centripetal Force – The Force that keeps an object moving in a circular path. (swinging water in a bucket & the water stays in)

Collision – Two or more object hit, resulting in exchange or transformation of energy

Contact Force – A force that must directly touch another object to move (Friction, air)

Direction - the line along which anything lies, faces, moves

Drag – A force that works in the opposite direction of a moving object; it catches on anything sticking out and slows the object down. (like friction, but increases with speed)

Electrical Forces – Forces that act between objects that are electrically charged.

Energy – An action, power, or force that affects what matter is and does.

Force – Something that can cause a change in motion or change in shape of an object; Measured in Newtons (N)

Friction – A force that opposes motion.

Gravity – The force of attraction between any two objects

Inertia – The property by which an object tends to remain at rest or remains in a straight-line motion unless acted upon by another force. (Newton's 1st Law)

Kinetic Energy – The energy possessed by an object because of its motion

Lift – The force that directly opposes the flight of an airplane

Magnetic Force –The power that pulls material together

Mass – The force of gravity pulled on an object – more weight = more mass.

Matter – Anything that has mass and takes up space

Microgravity – Almost weightless condition (like being in-orbit)

Momentum – Force or speed of movement

Motion – The change in an object's position over time

Newton – The unit of force.

Newton's first law of motion – inertia: an object at rest tends to stay at rest and an object in motion, tends to stay in motion, unless acted on by an unbalanced force Ex: Your toy car won't move unless you push it.)

Newton's second law of motion – Force = mass x acceleration: Ex: It takes more force to move a heavy object.

Newton's third law of motion – For every action, there is an opposite and equal reaction. Ex: If I jump off a raft, the raft will float in the opposite direction

Non-contact Force – a force that acts at a distance and doesn't need two objects to touch to make it move. (gravity, magnetic forces)

Opposite - Having a position on the other or further side of something.

Potential Energy – Stored Energy

Pull – A force that moves toward you

Push – A force that moves away from you

Unbalanced Force – Forces that cause a change in motion. One force is stronger than another.

Reaction (force) – The opposite direction of an action force. The force exerted by an object experiencing an action force.

Speed – The distance traveled by an object divided by the time it took to travel that distance.

Spring Scale – An instrument used to measure force

Velocity – A measure of the speed and direction of an object's motion.