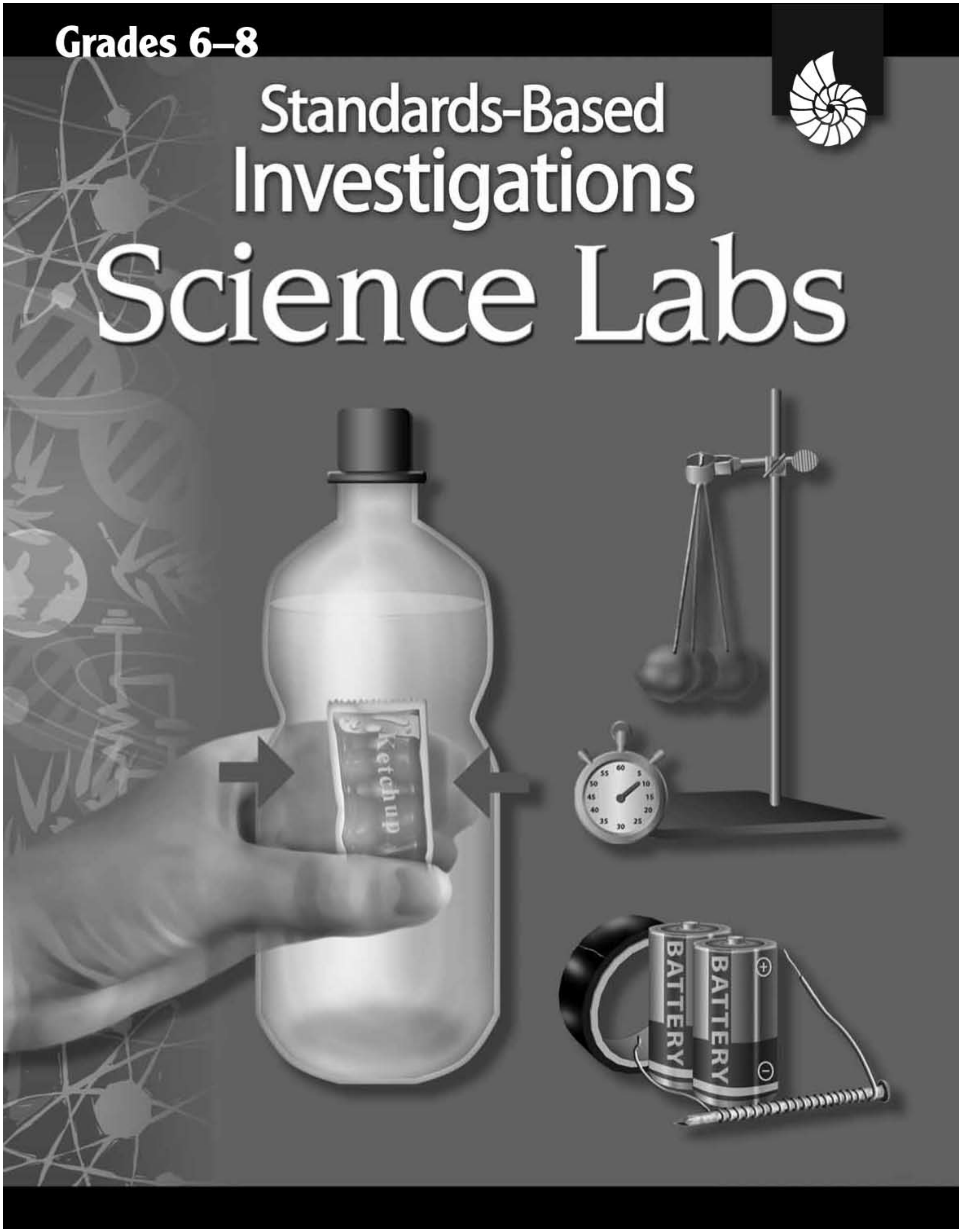

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SHELL EDUCATION

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How to Teach Forces and Motion

So What Are Forces?

Forces are behind everything that is happening around us. Forces make things happen.

You probably think this subject is difficult. You are quite right to fear getting too deeply into it because when you do, you will have to suspend your disbelief and your trust in common sense. Forces just don't behave as we would expect them to. Teaching forces is not easy!

Take these examples. Which of them would you think are true?

1. Two balls the same size dropped together from the top of the Leaning Tower of Pisa will both hit the ground at the same moment, even if one is a foam ball and the other is made from lead.
2. A bullet fired horizontally across a field from a gun, and an identical bullet dropped at the same moment from the barrel, will both hit the ground simultaneously.
3. When you sit on a table, it pushes back at you with an equal and opposite force.
4. There are two forces acting on a kicked football once it is in the air—the drag of the air and the downward pull of gravity.
5. The force of gravity is pulling you downward, but you are also pulling Earth towards you with your own force of gravity.

That's right—all of them are true.

Well, almost.

Position, Velocity, and Acceleration

One of the more obscure foundations of physics is position and its derivatives velocity and acceleration. It is very easy to overlook the simple proposition that things have positions, and those positions change. However, all of forces and motion requires this foundational understanding in order to actually work.

Position

Position is where an object is. That position cannot be measured absolutely—that is, there is no position that describes where the object "really is." Instead, position can only be measured relative to other objects. The blue block is three inches from the red block. The text stops a half-inch from the edge of the page.

Velocity

Velocity is the rate at which position changes. Students will probably be familiar with the idea of speed. Velocity is speed plus a direction: not 50 kph (31 mph), but 50 kph (31 mph) due east.

Acceleration

Acceleration is the rate at which velocity changes. Students may be familiar with the word accelerate, thinking that it means "speed up." However, acceleration is any change in velocity: speeding up, slowing down, or changing direction.

Pushes and Pulls

Forces are pushes and pulls. You can't escape forces—they are around you all the time.

When you are cycling, you need to push on the pedals to move forward. The ground is pulling on your tires to slow you down. The air is pushing in your face. If you stop pedalling, the ground and the air will slow you down until you come to a stop, but their forces keep working.

Attach a trailer on the back of the bike. Now you are pulling. Your force on the trailer is a pulling force. You push the pedals; the bike pulls the trailer! Stop cycling and try sitting still. Surely no forces are acting now? In fact, the force of gravity is pulling down on you. And the ground is pushing back.

The ground? Pushing? Yes, it has to. If the ground didn't push back, you would fall to the middle of Earth. So the ground pushes on your bike, and your bike pushes on you. Good thing, too. You don't want to disappear into Earth!

Faster and Slower

You use forces when you change speed. Hop on a scooter. First, you want to accelerate. Push off with your foot. The ground is pushing back at you and you're away! Want to go faster? It's no good just thinking about it. A bit of force is needed. Foot down, push again, and again. That's better. Now you are really rolling.

Lamppost ahead. Time to slow down. Push your foot to the ground. Slowing… whoops! Bit of a mistake there. The lamppost is still coming up. Brakes on. Put foot down and push backwards. Too late. Contact. Unfortunately, the lamppost pushed back just as hard as you pushed on it. It certainly stopped you.

Changing Direction

You can't change direction without a force, either. It might be the push and pull you give to the scooter handlebars. It might be the push and pull you give to a steering wheel. It might be the twisting force you give to your leg as you jump sideways to catch a ball. (You can see the results of that force if you look at the soles of your shoes. Old shoes get a well-worn jumping-off spot.)

Isaac Newton, the great scientist, stated this as a law in 1687. He said that every object would remain still, or carry on moving in the same direction at a steady speed, unless forces acted on it. This is called Newton's first law of motion.

It doesn't matter whether it is speeding up, slowing down, or changing direction, you need forces for change! Forces make things change direction. Try bouncing a ball. It changes direction when it hits the ground or the wall. But the new direction can be predicted. Try rolling a ball against the wall and seeing which way it bounces off. What do you notice? You can predict the angle—especially if you are a good billiards player!

Two Special Forces

There are two special forces. They are also invisible. They don't need to touch an object. They can act on an object without touching it. They are magnetism and gravity.

Magnetism

Magnets exert forces. The forces act on magnetic materials. Some metals, like iron and steel, are magnetic but not all metals are magnetic. Magnetic metals can be attracted over a distance. Magnets can repel other magnets, too. They can push other magnets over a distance.

Gravity

Gravity works over a distance, as well. All objects have gravity. But for those of us on Earth, the gravitational pull of Earth is the nearest and strongest by far.

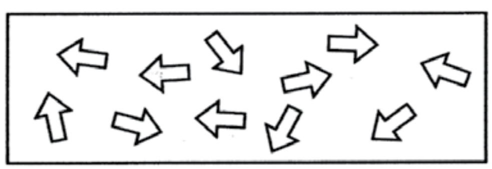
Earth's gravity holds us on the planet. If you drop something, it will always fall downward. Earth's gravity pulls it down.

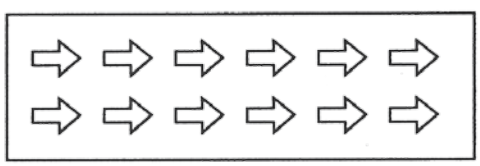
Is Magnetism Magic?

Magnets are magical and mysterious—a sure winner with students. They are also excellent subjects for investigations. All you need are a few well-chosen questions.

How Is a Magnet Made?

A material like iron is made up of countless tiny bits, all of them magnets. Usually, these little bits are facing randomly, like people crowded into a room. When the iron is made magnetic, all the magnetic bits face the same way. It's as if you open a window at one end of the room, and everyone turns to face it.



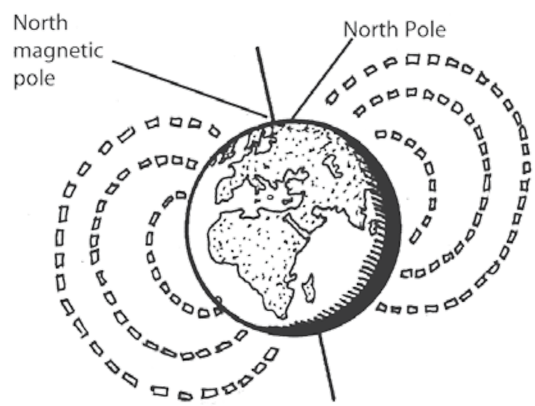


But heat a magnet, give it a good bashing, or let little Jimmy drop it on the classroom floor a few times, and all the magnetic bits will end up facing randomly again. Your magnet is weakened or destroyed. It's a good idea to put your magnets away with "keepers." These bridge the ends or poles of a pair of magnets and ensure that the magnetic force is circled and enclosed. Your magnets will last a lot longer if you do this!

Earth Is a Magnet

Four hundred years ago, a scientist named William Gilbert made a dramatic suggestion. He had looked at the way magnets turned to face north-south. This would happen, he argued, if Earth itself were a huge magnet.

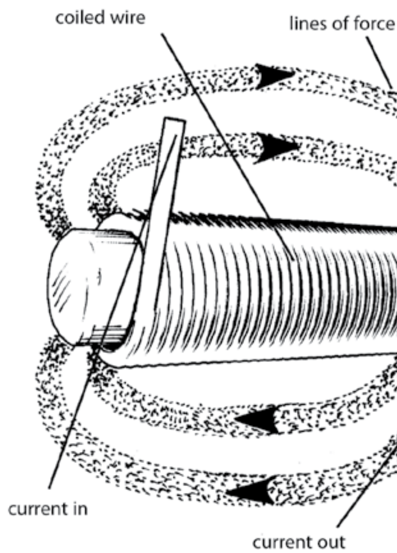
He was right. Around every magnet there is an area, a field, where the invisible force of magnetism is operating. Earth has its own magnetic field. It has poles, just like any other magnet, which are not quite in the same places as the true north and south of Earth.



Electromagnets

The connection between electricity and magnetism was discovered in a classroom. In 1820, Hans Christian Oersted was teaching about electricity when he brought a magnetic compass close to the wire. To his amazement, the compass needle moved suddenly to line up with the wire. He realized that the electricity through the wire was making its own magnetic field.

There is a magnetic field around any wire that carries an electric current. Electromagnets have this wire coiled around a metal core. Electromagnets are magnets that can be switched on and off. When they are off, they are just iron bars inside a coil of insulated wire. When they are switched on, they become powerful magnets that can lift scrap metal, ring doorbells, and pull a steel splinter from your eye.



Can a Magnet Make Electricity?

Electricity plus magnetism produces movement. And movement plus magnetism will produce electricity. If electricity flows through a wire, it produces magnetism and can move a magnet. And the reverse is true. If you move a magnet near a wire, then you generate electricity. You are doing just this if you have a dynamo-powered light on your bike. As you cycle along, you are providing the movement, and the moving magnets in the dynamo generate electricity for the bulb.

This was Michael Faraday's shattering discovery. Without this form of electricity generation, only batteries would provide our electricity. His invention changed the world. Electricity generators contain magnets. When you make the magnets move using a steam turbine, moving water, or the power of the wind, you generate electricity.

Gravity and the Apple Tree

We all dream that we could be as clever as the great scientist Sir Isaac Newton." If only an apple fell on my head," we think, "it would rattle my brain. I could have some brilliant ideas like him."

Bad news. The apple never fell on Newton's head.

Thousands of artists have drawn the apple conking poor old Isaac, and a light bulb lighting up. Idea! Now I can explain gravity.

Sadly, it wasn't like that. As Newton explained to a friend, he was walking in an orchard, puzzling over the problem of gravity, when an apple fell." Why does that apple fall downwards?" he thought. "Why does everything fall downward? It's as if there is a force pulling everything towards the center of Earth."

And there is. That force is gravity. It pulls everything towards the center of Earth. Everything has a force of gravity. The bigger it is, the bigger the force. But the biggest, nearest thing to you is Earth. Without gravity, nothing would stay on planet Earth that wasn't nailed down.

Earth's gravity is pulling down on us all the time. We call that pull your weight. You have weight because Earth's gravity is pulling down on your mass. The mass is the stuff you are made from. Your mass stays the same, wherever you are. But your weight can change.

If you went to another planet, the pull of gravity would change. If that planet were bigger than Earth, the pull would be stronger. If it were smaller than Earth, the pull would be weaker.

How to Teach Forces and Motion *(cont.)*

Can Heavy Things Fall Slowly?

Everyone finds it very hard to believe that light and heavy things, dropped together, can hit the ground together. Even when you've seen it, you may not believe it! Earth pulls harder on things of greater mass, and you might expect them to fall faster. But their greater mass means they're harder to get moving (just compare pushing a bicycle with push starting a car) and these two just about cancel each other out. Whatever the mass, objects fall at the same speed.

The exception, of course, is where one object has a greater surface area than another, catching the wind. A sheet of paper will float to the ground more slowly than a wadded-up ball; a feather will fall much more slowly than a hammer. The Moon astronauts graphically demonstrated what happens without the slowing effects of the air. A feather on the airless Moon dropped at the same speed as a hammer.

Balanced Forces

You can't see the forces acting on a football. They're invisible. One is the force of gravity. Gravity is pulling the ball down towards the center of Earth. So why doesn't the ball go down? Something is stopping it. The ground is pushing back on the ball. Gravity and the push of the ground are in balance. The ball stays where it is! When two forces are in balance, an object stays still. A space rocket on the launch pad has two forces acting on it—that of gravity pulling it down, and that of the launch pad pushing it up. These forces are in balance, and the rocket stays still. Until the engines start....

Floating and Sinking

Some objects float in liquids. Some sink. Some objects can be made to float, or they can be made to sink.

Objects float when they are lighter than the liquid. Even heavy objects can be made to float, as long as they are filled with air. The air makes them lighter than the liquid. When things are lighter than the liquid, the upthrust of the liquid holds them up. Gravity pulls down. The liquid pushes up. The two forces are in balance. The object stays still. It floats.

A floating object is in balance. The force of gravity is balanced by the upthrust of the liquid. As long as the object isn't too dense—when the force of gravity will exceed the upthrust of the liquid and the object will sink—the object will float, the forces on it nicely balanced.

When Are Forces Unbalanced?

When forces are unbalanced, things move. Take that space rocket. It is blasting off at John F. Kennedy Space Center. It is being held back by gravity, but gravity is a weak force compared to the tremendous thrust of the rocket engines. Because the forces are unbalanced, the rocket climbs into the sky.

When forces are unbalanced, things change shape. When you squeeze some modeling clay, the modeling clay pushes back. But if the modeling clay pushed back as hard as you squeezed, you could never change its shape.

How Tall Can I Build It?

Name ________________________

What You Need:

- blocks
- paper
- tape
- ruler

What To Do:

1. Use blocks to build a tall tower. How do you stop it from toppling over?

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2. Next you will build the tallest free-standing tower you can, using only folded paper and tape. Sketch your tower plans. Write down ideas on how to make it as tall as possible.

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3. Build your tower. How high did your tower reach? ________________

Next Question

What would change if you used different materials, such as heavy cardboard? What wouldn't change?

Notebook Reflection

What worked according to plan? What didn't work? What tricks did you discover halfway through?