Fifth Edition

YOU BE THE CHEMIST™

ACTIVITY GUIDES

Hands-on Science for Grade K-8 Students

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Forces & Interactions

Background

Activity Guides:

GRASPING FOR AIR | ANTIGRAVITY WATER | BALLOON ROCKETS | MAGNETIC METALS | PUFFED RICE FLEAS

Introduction to Forces

Chemistry is the study of matter, its properties, and the changes it undergoes. **Matter** is anything that has mass and takes up space. Matter exists in many different shapes, sizes, and forms. We interact with matter around us constantly, whether that means bouncing a basketball or boiling water to make tea. One way that we interact with matter is by exerting force. A **force** is any kind of push or pull on an object. Any interaction that changes the movement of an object is a force.

Think about bouncing a basketball: the ball falls to the ground because of the force you exert by pushing it with your hand, as well as the force of gravity pulling it down to Earth. When the ball bounces off the ground, the ground exerts a force on the ball to make it change direction and start going up.

Properties of Forces

There are many different types of forces—some that we can see, and some that we cannot. **Contact forces** happen between objects that are touching each other. Pushing a basketball with your hand is a contact force. Some other examples of contact forces are friction and air resistance. **Non-contact forces** happen between objects that are not physically touching each other—they act from a distance. Gravity pulling a basketball to the ground is a non-contact force. Magnetism is another type of non-contact force.

Every force has a specific direction and strength. For example, you can bounce a basketball, pass it to someone else, or shoot it up at a basket. These forces have different directions. You will probably throw the ball harder when you are passing to someone far away than when you are passing to someone near you. These forces have different strengths. When a force is stronger, its push or pull is bigger, which makes an object speed up or slow down more quickly compared to a weaker force on the same object. We often draw forces using arrows to show direction and strength. The size of the arrow represents the strength of the force.

Force, Mass, and Motion

Compare a tiny jet plane to a large commercial airplane with lots of passengers. If both planes are going the same speed and landing in similar locations, should their brakes exert the same amount of force to allow each of them to stop? Probably not—since the jet plane is smaller, it takes less force to make it stop in the same amount of time.

Weights about 12,500 lbs.

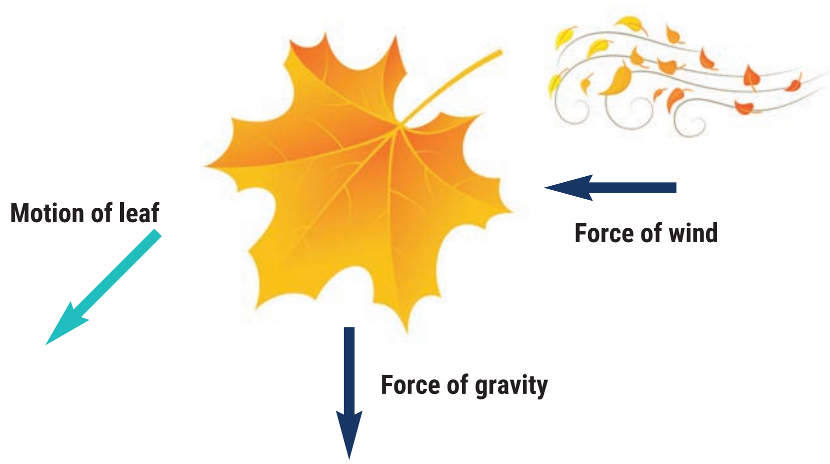
Weights about 900,000 lbs.

The amount of force needed to change the motion of an object is related to the mass of the object. **Mass** is a measurement of how much matter is present in something. Mass is similar to the weight of an object—when weight increases, mass also increases. The more mass an object has, the harder it is to change the object's motion.

Sometimes the way an object moves is determined by more than one force acting upon it. The way an object moves depends on the sum of all these forces together. Think of a game of tug of war. Each team exerts a force on the rope, pulling it in their direction. The way the rope moves is the sum of these forces.

In tug of war, the two forces on the rope are in exact opposite directions. This isn't always the case. Think of a leaf falling from a tree.

There is a force of gravity pulling the leaf downwards. There also might be force from the wind pushing it to the side. The direction that the leaf moves comes from both these forces together—it moves down and to the side .



The relationship between force, mass, and change in motion comes from Sir Isaac Newton, who was an English mathematician, astronomer, theologian, and physicist. In 1666, Newton started wondering about the way that objects move after he watched an apple fall from a tree. He discovered that the change in an object's motion depends on two things: the forces acting on that object, and the object's mass. This is called **Newton's Second Law**, and we can write it out as an equation:

$$F = m \times a$$

All of forces acting on an object = (the object's mass) × (the object's acceleration)

Acceleration means change in speed and direction. The equation can be written out to help us find acceleration based on force and mass:

$$\text{Acceleration} = \text{Force} \div \text{Mass}$$

Force and Energy

Force is also related to energy. Energy is the ability to move an object by applying a force. You are able to use force and throw a basketball because you have energy stored in your body. There are many different types of energy, including the energy of motion, potential or stored energy, and energy related to temperature. Light, heat, sound, and electricity all have energy. These types of energy can exert force to make the particles in an object move, even if we can't see it. Learn more about all of these from the Energy section of the Activity Guides.

Let's try some experiments so you can see different types of forces in action!

Notes

ENGAGE YOUR STUDENTS

Before beginning any of these activities, use the following ideas to engage your students in learning about forces:

- Start by asking students what kind of things can make an object move. Have one student hold a soft object, like a stuffed animal, and then throw it to another student. Why did the object move? Then hold the object in the air and drop it. Why did the object fall to the ground? For each of these movements, was it the result of something pushing on the object, or pulling on the object?
- Bring your class outside to explore forces on the playground. Why do students slide down from the top of a slide to the bottom of a slide? Why does it take energy to climb up the monkey bars? Is it harder to climb up with a backpack on?
- Have one student show that they can push a chair across the floor. Then ask students to try and push a heavy table across the floor. Does it take more students? Why is it harder? You can also do this experiment more slowly by asking students to lift a bag of coins. Continue adding coins to make the bag heavier. Why does this change how hard it is to lift the bag?
- Have students think about opening a door to illustrate forces that push versus forces that pull. What is different about when the door opens away from you, compared to when the door opens toward you? Do you interact with the door in the same way? How is the force that you exert on the door different?
- Illustrate the force of air motion through a competition. Have two students stand side by side at the edge of a table. Ball up two pieces of paper and put one in front of each student. Which student can get the ball of paper over the other side of the table first without touching it? You can also give students small objects to throw at their ball of paper.
- Use a balloon to show the air pressure inside of a plastic bottle. Put an un-inflated balloon inside of a plastic bottle so that the opening to the balloon is around the mouth of the bottle. Have students try blowing up the balloon inside the bottle. Why can't they do it? How can they change the setup so that the balloon will inflate? Use a nail or other sharp object to poke a hole in the bottom of the plastic bottle. Do they think the balloon will be able to inflate now? Why?
- Show students that you can make a marshmallow inflate inside a bottle. Put a marshmallow in a hard, plastic bottle with a small opening. Stick a straw in the opening, and put tape or playdough around the straw so that it is completely sealed, and the straw is the only way for air to get in or out. Ask students to predict what will happen to the marshmallow when you start sucking air out of the bottle. Suck in from the straw to remove air from inside the bottle, making sure to cover the top of the straw between breaths. What do students notice? Why does the marshmallow inflate?

Notes

Grasping for Air

Section **FORCES & INTERACTIONS**

Estimated Time Setup: 5 minutes; Procedure: 5 minutes

OVERVIEW

Students squeeze out all of the air between a trash bag and a trash can, and then attempt to pull the bag out to understand how air pressure can exert force.

We can demonstrate the force that a gas exerts on its container by creating a difference in air pressure between two areas. In this activity, students create an area between the trash bag and trash can where there are very few gas particles, which will act as a vacuum. Students then test whether they can increase the volume of this area and experience the force of air pressure from outside of the bag.

MATERIALS

For one setup:

- 1 small plastic trash can
- 1 clean plastic trash bag
- Duct tape

INQUIRY QUESTIONS

Getting Started:

- What is air made of?

Learning More:

- How does air pressure vary based on volume and number of gas particles?

Diving Deeper:

- What is a vacuum and how does pressure maintain it?

ACTIVITY NOTES

This activity is good for:

- Individuals
- Pairs
- Small groups
- Demonstrations
- Concept introduction

Safety Tips and Reminders:

- Ensure the trash can and bag used are new and/or clean.
- Review the Safety First section in the Resource Guide for additional information

CONTENT TOPICS

This activity covers the following content topics: states of matter, properties of matter, forces, gas particles, pressure, volume

This activity can be extended to discuss: contact forces, force-interaction pairs, ideal gas laws, collision theory, kinetic energy, transfer of energy

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **5-PS1-1:** Develop a model to describe that matter is made of particles too small to be seen.

Fun Fact #1

Vacuums exist, but none are perfect. A perfect vacuum would have nothing in it at all. Outer space is considered to be a partial vacuum. While the space between the planets and stars seems empty, it still has heat, light, sound, and cosmic radiation.

ENGAGE

Use the following ideas to engage your students in learning about forces:

- Challenge your students: what do they think will happen when the bag is pulled from the can? Ask them to draw or write their hypothesis in their own words and share with a peer. Then ask them to try the activity and see if their hypothesis was correct. Why or why not?
- Use a balloon to show the air pressure inside of a plastic bottle. Put an un-inflated balloon inside of a plastic bottle so that the opening to the balloon is around the mouth of the bottle. Have students try blowing up the balloon inside the bottle. Why can't they do it? How can they change the setup so that the balloon will inflate? Use a nail or other sharp object to poke a hole in the bottom of the plastic bottle. Do they think the balloon will be able to inflate now? Why?

See more ideas for engagement in the Forces & Interactions Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

EXPLORE

Procedure:

1. Place a trash bag inside of a trash can.
2. Reach inside the bag and push it against the trash can, starting from the bottom, so that all the air is squeezed out. The bag should be flat against the can all the way around.
3. Fold the top of the bag over the rim of the trash can and tape seal it with duct tape. Make sure the bag is totally sealed so no air can come in or out.
4. Reach into the can and try to pull the bag out. Try doing this by grabbing different parts of the trash bag and angling the can different ways.

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

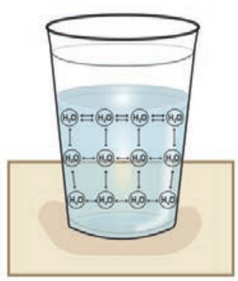
- Make a prediction: what will happen when you try to pull the bag from the trash can? Why?
- What happens when you try to pull the trash bag out of the can? Is it different when you change the position of the trash can or the direction in which you are pulling?
- What kind of force stops you from pulling out the bag? Is it a push or a pull force? What direction does the force point?
- How does the air pressure between the bag and the wall change when you pull the trash bag out?
- Draw a diagram showing the space between the trash bag and the trash can, and the air outside of the trash bag. Fill it in with air particles. Which space has a higher concentration of air particles?

EXPLAIN

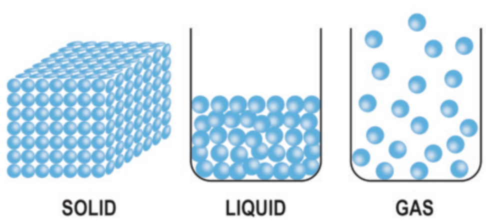
What's happening in this Activity?

First review the Forces & Interactions Background section to gain a deeper understanding of the scientific principles behind this activity.

All of the matter around us is made up of tiny particles. These particles can be **atoms** (the smallest particle of an element that retains the element's chemical properties) or **compounds** (made up of two or more elements that are chemically combined in a defined ratio). If you zoomed in on a glass of water, down to the microscopic level, you would see that it is made up of smaller particles. For example, in one glass of water there are millions of H_2O molecules. Water, H_2O, is a compound that is made from two hydrogen atoms and one oxygen atom.



The smaller particles that make up an object are in constant, random motion. The amount of motion depends on an important physical property: **state of matter**. Three of the major states of matter are solid, liquid, and gas. In a **solid**, particles are locked in place and only vibrate slightly. Solid particles are more tightly packed than liquid or gas particles. In a **liquid**, particles are in constant motion and can move more than particles in a solid. Particles have the most movement when they are in a **gas**.



Gases have no definite volume and no definite shape. A gas will expand to fill the shape of its container and will change in volume depending on that container. Gas particles have weaker attractions between them than solid or liquid particles, which allows them to move quickly in random directions and over larger distances. Gases can compress and drastically change their volume, but they always take up space.

As the particles in a gas move around randomly, they collide with each other and with the walls of their container. These collisions exert a force. A **force** is any kind of push or pull on an object. The gas particles push out on the walls of their container every time they collide with it. This is called gas pressure. **Pressure** is the amount of force on a surface with a specific area.

For example, when you blow up a balloon you are filling it with gas particles. When more gas particles are added to the inside of the balloon, more particles collide with the walls of the balloon and exert force. While the force of a single gas particle collision is too small to notice, the total force created by all the gas particle collisions within the balloon is significant. This force makes the balloon expand. The force exerted by gas particles is a **contact force** because, even though we can't see it, the gas particles and container walls are physically touching.

Notes

EXPLAIN continued

The air around us is a mixture of gases, which are constantly moving and colliding with objects in our world. The air is 78% nitrogen (N_2), 21% oxygen (O_2), and the other one percent is made up of argon (Ar), carbon dioxide (CO_2), and a mix of other gases. Air pressure, or atmospheric pressure, is the force exerted on a surface by the weight of air above that surface. Air pressure is the gas pressure of the air around us. The average air pressure at sea level is about 14.7 pounds per square inch. That's almost 15 pounds of air pushing on every inch of our bodies at all times! Fortunately, we are so used to the force of air particles colliding with our bodies that we don't even notice it.

A trash can is subject to air pressure from the air both outside and inside the can. The air pressure inside and outside of the trash can is equal at the start of this activity. When you put a trash bag into the can, there might be air between the trash bag and the trash can. As you push the bag flat against the sides of the can, you squeeze those air particles out, so a smaller amount is left. Once you tape the trash bag to the trash can, no additional air particles can get in between the bag and the trash can.

Since there are very few air particles left between the bag and the trash can, there is not much gas pressure in this space to push the bag away from the can. There is a greater amount of gas pressure outside of the bag, pushing the bag closer to the trash can wall.

When you try to pull the bag out of the trash can, you are trying to increase the amount of space between the bag and the can. However, there are millions of more air particles outside of the bag, colliding with the bag and pushing back towards the can, than there are between the bag and the can pushing the bag out. As the amount of space between the bag and can increases, the air pressure in that space decreases. This means that the air pressure on the other side of the bag is greater than the air pressure between the bag and the can. As a result, you can't pull the bag out of the trash can. The more you pull, the greater the air pressure pushes in the opposite direction. The space between the bag and the trash can is like a vacuum.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • States of matter • Gases and their properties	**For more advanced students, emphasize the following concepts:** • Particle movement in gas pressure • Contact and non-contact forces

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Conduct the experiment in a similar manner but use a glass cup and small plastic sandwich bag instead. Tape the sides of the bag against the cup.
- Poke a hole in the trash bag. Does that make a difference as you attempt this activity? Why?
- Try the opposite action first. Fill the trash bag with air and tie it so the air cannot escape. Then try to push the air-filled bag into the trash can. You can also blow up the bag with air and quickly seal it to the mouth of the trash can. Have students try to push the bag into the trash can. Discuss that the air pressure inside the trash can is preventing them from pushing the bag inside. There is already something inside the can—air takes up space! (Again, you can use a cup and a small plastic sandwich bag instead of the trash bag and trash can for this activity as well.)
- Based on this experiment, can students explain how suction cups work? Have students experiment with suction cups and discuss any similarities or differences to the experiment they already did. Can they create a diagram that shows where the air particles and forces are acting as a suction cup is used? What makes the suction cup 'stick' to a surface?

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

Air pressure varies with altitude. At higher elevations, the air pressure is lower than at sea level. When you fly in a plane or travel up a mountain, your ears may "pop." As you travel higher in the atmosphere, outside air pressure decreases. As a result, the air pressure exerted by the air trapped in your inner ear is no longer balanced with the air pressure outside. The trapped air will begin to push outward toward the lower pressure area, which can cause discomfort. The pressure can equalize when some air from your inner ear escapes through the Eustachian tubes, the small channel in each ear that connects the inner ear to the throat. When they open, you feel the pressure release—the "pop." You can hear this change because it is happening in your ear. However, before the pop, you may notice that your hearing ability decreases. The buildup of pressure inside your ear makes it more difficult to transmit sound.

Likewise, as you descend, the atmospheric pressure increases, but your inner ear is still at the lower pressure. Now, the extra pressure from the outside air pushes into your ear. Eventually, the pressure will equalize again, but many people don't wait for the pressure to balance naturally. Instead, they close their mouth, hold their nose, and "blow." Since the air from their lungs has nowhere else to go, it is forced into the inner ear through the Eustachian tubes, "popping" their ears.

Careers in Chemistry

- A number of medical procedures employ the science of air pressure to create suction. Devices such as aspirators, ventilators, and syringes all use air pressure and forces to move fluids into or out of the body. Medical professionals need to understand how forces determine the flow of particles, so they can provide life-saving treatments to their patients or develop innovative tools for use worldwide .
- CPR (cardiopulmonary resuscitation) is an emergency procedure used to continue the circulation of blood and air when a person has suffered from cardiac arrest or another form of trauma. Medical professionals or trained bystanders administer a series of chest compressions to push blood through the body, and artificial ventilation through rescue breaths that push air into the body .

EVALUATE

- Ask each student to draw a model of what is happening in the experiment, including labels and air particles. They should draw the experiment before it starts, as the bag is being put into the trash can, once it is sealed, and what happens when someone tries to pull the bag. They can add arrows to show the forces, including air pressure and any other pushes or pulls. Once they finish their model, they should show it to a peer for review and feedback. They can then make changes before handing in a final copy.
- Ask students to write what they learned from this experiment in their own words. They should use new vocabulary and terms introduced in the lesson.
- Pose a different scenario: what would happen in this experiment if the bag is not taped against the bin? Ask students to explain if the results would be different and why.

Antigravity Water

Section **FORCES & INTERACTIONS**

Estimated Time Setup: 5 minutes; Procedure: 5-10 minutes

OVERVIEW

Students will observe how water can remain suspended in an inverted cup.

In this activity, students place a paper plate over a cup of water and then carefully turn the system upside down. The water remains in the cup and seems to defy gravity – even after the student lets go of the paper plate!

INQUIRY QUESTIONS

Getting Started:
- What forces are acting on the objects around us?

Learning More:
- How can forces – such as air pressure, cohesion, and adhesion – cause water to remain in an inverted cup?

Diving Deeper:
- What are unique physical and chemical properties of water, and how might they explain how water can seem to defy gravity?

CONTENT TOPICS

This activity covers the following content topics: air pressure, forces, properties of gases, properties of liquids, water

This activity can be extended to discuss: surface tension, cohesion, adhesion, Newton's laws, ideal gas laws, kinetic energy

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:
- **3-PS2-1:** Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.
- **5-PS1-1:** Develop a model to describe that matter is made of particles too small to be seen.
- **MS-PS2-2:** Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MATERIALS

For one setup:
- Clear glass or plastic cup
- Paper plate (large enough to completely cover the rim of the cup)
- Large bowl or dish to catch falling water (or do the activity over a sink)

Optional materials:
- Dawn® Ultra dishwashing liquid soap

ACTIVITY NOTES

This activity is good for:
- Demonstrations
- Small groups
- Pairs

Safety Tips and Reminders:
- If the experiment is done incorrectly it can lead to some spills! We recommend trying the activity over a bin, sink, or towel until you feel comfortable with it.
- Review the Safety First section in the Resource Guide for additional information

ENGAGE

Use the following ideas to engage your students in learning about forces:

- For exciting experiments like this, sometimes the best way to engage students is through a demonstration! Can they guess what will happen? Can they think of how the water stays in place when the cup is turned upside down? You can also try one cup with water, and one with added Dawn® Ultra dishwashing liquid soap. Because soap acts a surfactant and disrupts the surface tension of water, the plate will not stay in place when the cup is turned upside down!
- Start by challenging students to brainstorm and test ways to make water stay in an upside-down cup. Can they come up with a solution?
- What makes water unique? Have students brainstorm in small groups, then share out with the class. You can prompt students with questions about where water is found, how abundant it is, how we use it, its chemical properties, physical properties, and more. After making the list, inform students that the activity will demonstrate some interesting properties of water, and will teach them more about forces.

See more ideas for engagement in the Forces & Interactions Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

Fun Fact #1

Cohesion and adhesion are seen all around us! On a rainy day, you might notice that rain doesn't leak through your umbrella, even though it's made of fabric! That's because adhesion and cohesion keep the water molecules from seeping through the pores in the fabric.

EXPLORE

Procedure:

1. Fill a cup roughly halfway with water
2. Wet the rim of the cup slightly by dipping your finger in water and running around the cup's edge.
3. Place the plate over the cup so it covers the entire rim.
4. Place one hand on the plate and hold it against the cup's rim and place your other hand on the cup.
5. Keep your hands in place and carefully invert the cup while holding the plate against the rim (which is now facing down). If you are using a plastic cup, be careful to not squeeze it in this process!
6. Without squeezing the cup, hold the cup in place and slowly remove your hand from the plate.

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Describe the physical properties of water.
- Describe some chemical properties of water.
- Draw a water molecule. What do you know about this molecule and its behavior?
- When you initially invert the cup, what do you notice? Does any water escape? Does any air get into the cup? Are there any other observations you can note?
- What do you predict will happen when you remove your hand from the bottom of the cup? Will the water fall or stay in place?
- What happens when you squeeze the cup after you have removed your hand? Does that change whether the water falls or not?
- Explain your results. Why do you think the water remained in the cup or fell from the cup?

EXPLAIN

What's happening in this Activity?

First review the Forces & Interactions Background section to gain a deeper understanding of the scientific principles behind this activity.

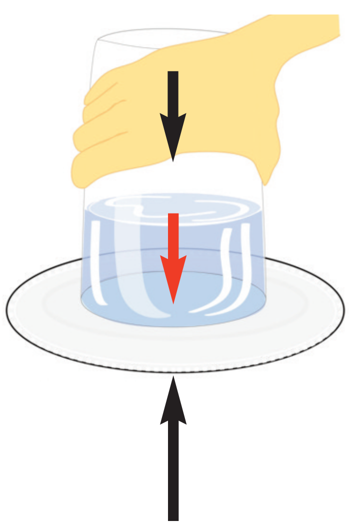
A force is any kind of push or pull on an object. The way an object moves is not determined by just one force. At any time, there are many different forces acting on one object, such as the force of gravity pulling an object down towards Earth, or the force from a gust of wind. The way an object moves depends on the sum of all these forces together. Think of a game of tug of war: each team exerts a force on the rope, pulling it in opposite directions. If the teams are pulling with the exact same force, the rope does not move at all: the forces cancel each other out. But if one team is pulling harder, the forces do not cancel each other out, and the rope moves in the direction of the team pulling with the most force .

In this activity, there are several forces acting on the water and paper plate that work together to keep the water and plate in place. Let's break down all the forces that make this surprising experiment possible.

The strongest force that keeps the water and the plate from falling is air pressure. **Air pressure** is the force exerted on a surface by the weight of air above that surface. Remember that everything in our world contains particles – even the air! Though we do not notice it day-to-day, the particles in the air exert pressure on everything around them. Air pressure is the result of tiny gas particles zooming around and colliding with one another and with the walls of their container. These collisions exert force on all the objects that air collides with. To understand how air pressure keeps the paper plate from falling, we need one more piece of information.

When the cup is flipped over a small amount of water escapes the cup. Look closely when you initially invert the cup and you will see a small amount of water on the plate and outside the cup. Because some of the water escaped, this means the air in the cup has to take up more space and spread out, even though the actual number of air particles inside the cup has not changed. The air particles spread out to fill the space, and when there is more space between air particles, the particles collide with each other and surrounding objects less frequently. Less collisions means less air pressure inside the cup. This means the force of the air pressure inside of the cup pushing against the cups walls, and pushing down on the water, is less than the force of outside air pressure pushing up on the plate.

Let's look at the forces that are acting on the water in the cup:



The black arrows represent the forces of air pressure pushing down on the water and up on the plate. The red arrow represents the force of gravity (the weight of the water).

Notes

EXPLAIN continued

The air in the cup is similar to a vacuum. The air pressure pushing up on the plate is so much stronger than the air pressure pushing down on the water that the plate is held to the bottom of the cup, and the water is held in the cup.

While air pressure is the main reason that the water stays in the cup, other forces based on the properties of water contribute as well. Adhesion is the force of attraction between unlike molecules, such as a water molecule and molecules that make up a plate. Adhesion in this experiment is what makes the water and plate "stick" together and what makes the water "stick" to the sides of the cup. This helps the water stay in the cup. Cohesion is the attractive force that exists between like particles in a liquid. Cohesion is especially strong between water molecules. Because of cohesion, all the water molecules in the cup tend to stick together, and therefore stay in the cup.

Adhesion and cohesion explain why it is so important in this experiment to form a full seal between the rim of the cup and the paper plate. Wetting the rim of the cup forms the initial seal. The seal is formed by forces of attraction known as adhesion and cohesion which help prevent any other air molecules from entering the cup to equalize the pressure. This is why squeezing or distorting the shape of the cup after it has been turned over causes the water to fall, because it breaks the seal formed through adhesion and cohesion.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • Properties of matter • Gases take up space • Forces – push or pull on an object	**For more advanced students, emphasize the following concepts:** • Strength and direction of forces • Air/atmospheric pressure • Gas pressure

Notes

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Try the experiment using a mason jar, lid, and piece of wire mesh screen. Cut the screen so it fits over the lid of the jar and remove the insert of the lid so when the top is screwed on only the mesh screen covers the lid. Do the experiment again but with the screen in place. But this time remove the index card or plate after the jar is inverted. What happens? What happens if you lightly touch the water pressing against the screen while it is inverted?
- Try the experiment again, but this time add Dawn® Ultra dishwashing liquid soap to the water soapy water. Can you get the experiment to work? Why or why not? (Hint: check out the Surface Tension section of the Activity Guides to learn about surfactants.)
- Try the activity with other liquids instead of water. You will find that this trick works for a number of liquids. But if you try soda pop, it will not. Why do you think that is? (Hint: think about air pressure and the carbon dioxide bubbles coming out of the drink!)
- Try the experiment again using a cup that has a small hole at the top. The hole at the top of the cup allows more air particles to enter the cup after a bit of water escapes, keeping the air pressure inside the cup the same as the air pressure outside the cup. The increased downward air pressure on the water prevents a balance of forces. Can you get the water to remain suspended? Can students explain why not?
- Compare the effect of using an index card versus a paper plate. Paper plate is heavier, but it is also sturdier and does not absorb the water like the index card does. Which works best and why? Can students find other materials that work better? What about for the cup: does it matter if a glass, plastic, Styrofoam, or paper cup is used?
- Try a soda bottle instead of a cup. Bottles have a smaller contact area than the cup, so the adhesive forces won't be as strong. Additionally, because the opening is smaller, less water will escape, and the air pressure inside will not decrease by as much. Have students make a prediction, then try the experiment and see how it differs from the original example. Can they explain why?
- Try different amounts of water. How much water is required to keep the paper plate from falling? Can you do the experiment with a full glass of water? What about with a glass that has very little water in it?
- Compare the effect of using warm water versus cold water. Does the temperature of the water make a difference?

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

A number of medical procedures employ the science of air pressure to create suction. Devices such as aspirators, ventilators, and syringes all use air pressure and forces to move fluids into or out of the body. Medical professionals need to understand how forces determine the flow of particles, so they can provide life-saving treatments to their patients or develop innovative tools for use worldwide .

Toilet plungers utilize a suction to unclog pipes. When a plunger is inserted into the toilet bowl, the rubber "cup" covers the toilet drain that leads to the pipes. The shape of the plunger cup creates a seal. Therefore, when you push down on the plunger, the air is forced out of the cup and into the pipe, increasing the air pressure in the pipe. As the plunger is pulled back, suction is created, pulling air and water from the pipe back toward the toilet drain. This quick and strong force of air and water pressure helps to loosen a clog in the pipes.

EVALUATE

- Group students and ask them to prepare a short presentation and hands-on activity for their younger peers. Find a time for these groups of students to meet with students in a younger grade level to do the activity together and explain the science behind the magic! Alternatively, they can prepare a demonstration for a younger sibling or parent as a take-home activity.
- Ask students to draw a diagram of the setup at the start, middle, and end of the experiment. See if they can add lines to represent forces (hint: larger forces should be larger lines).
- Task students with creating media (like a video, podcast, website, etc.) that shares their knowledge of air pressure. They can use new vocabulary and an example of a hands-on activity that demonstrates air pressure. Students should also incorporate examples of where air pressure is experienced in everyday life.

Careers in Chemistry

- Scientists and engineers are able to design airplanes that fly by knowing how air pressure on the winds will affect the airplane. Airplane wings are shaped to make air move faster over the top of the wing. When air moves faster, the pressure of the air decreases and the pressure on the top of the wing is less than the pressure on the bottom of the wing. The difference in pressure creates a force on the wing that lifts the wing up into the air.
- Meteorologists use air pressure to predict upcoming weather. It is measured using a barometer, which records pressures in 'bars'. High air pressures usually correlate to clear skies and cool temperatures, while low pressure usually means warmer weather, storms and rain.

Balloon Rockets

Section **FORCES & INTERACTIONS**

Estimated Time Setup: 5 minutes; Procedure: 15-30 minutes

OVERVIEW
Students will experiment with propelling a balloon across the room using air pressure.

In this activity, students create a makeshift rocket out of a balloon by inflating and increasing the air pressure inside the balloon. When the balloon is released, air rushes out and propels it forward.

INQUIRY QUESTIONS
Getting Started:
- What causes a balloon to expand?

Learning More:
- How is air pressure different inside of a balloon versus in the air around us?

Diving Deeper:
- How can the force of air pressure be manipulated to make an object move?

CONTENT TOPICS
This activity covers the following content topics: gas properties, forces, Newton's Third Law, air pressure, kinetic energy

This activity can be extended to discuss: collisions theory, contact and non-contact forces, force diagrams, ideal gas laws, effusion

NGSS CONNECTIONS
This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:
- **4-PS3-4:** Apply scientific ideas to design, test and refine device that converts energy from one form to another.
- **MS-PS2-2:** Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- **3-5-ETS1-1:** Define a simple design problem reflecting a need or want that includes specified criteria for success and constraints materials, time or cost.
- **3-5-ETS1-3:** Plan and carry out fair test in which variables are controlled and failure points are considered to identify aspect of a prototype that can be improved.

MATERIALS
For one setup:
- Balloon
- String (long enough to cover the length of the room, or at least 10 feet)
- 2 chairs or other objects that can hold an end of the string on opposite sides of a room
- Drinking straw, cut into 4 equal pieces
- Craft supplies, such as scissors, tape, and glue
- Permanent marker
- Small object to be used as cargo (paper clip, bottle cap, candy, etc.)
- Material to make lightweight cargo containers (construction paper, cereal box, etc.)

ACTIVITY NOTES
This activity is good for:
- Demonstrations
- Pairs
- Small groups
- Individuals

Safety Tips & Reminders:
- Make sure the string is set up in an area of the room where students will not be walking through, so they do not disturb the setup or trip!
- This experiment uses a balloon. Check to see if any students have latex allergies or if there are any restrictions on using balloons in the classroom in advance.
- Review the Safety First section in the Resource Guide for additional information

ENGAGE

Use the following ideas to engage your students in learning about forces:

- This is a great activity to conduct with the Engineering Design Process. Start with a problem in your community, such as transportation. Can the students build a device to safely transport people (or paperclips, in this case!) from one area of town to another (or one side of the room to another)? Guide them through the Engineering Design Process as they work in teams to solve this problem and find an efficient and effective mode of transportation for the community.

See more ideas for engagement in the Forces & Interactions Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

Fun Fact #1

Before the rubber or nylon balloon was invented, balloons were made from dried and inflated pig bladders and intestines!

EXPLORE

Procedure:

1. Tie one end of the string to a chair, doorknob, or any stationary object on one side of the room.

2. Tie the other end of the string to a stationary object on the other side of the room, making sure that the string can easily be untied as needed.

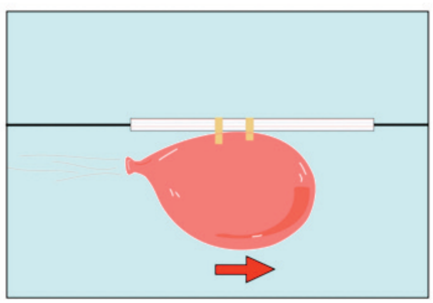
3. Students should be tasked with attempting to get a piece of cargo (e.g. a paperclip, button – anything small) from one end of the room to the other using only the materials available and the string. There are lots of different ways to do this, and one example is outlined here:

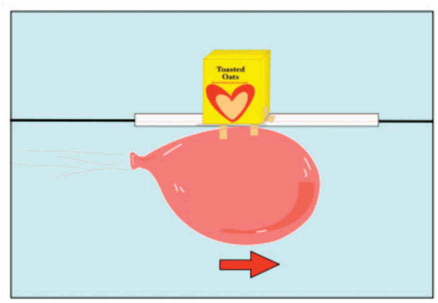
    - Untie one end of the string and put it through the piece of straw, then retie it so the straw is suspended on the string.
    - Blow up a balloon and pinch the opening so it is closed, but do not tie the end.
    - Tape the side of the balloon horizontally to the straw so the top of the balloon is facing one side of the room, and the opening of the balloon is facing the other end of the room, closest to the end of the string.
    - Pull the balloon and straw back so they are at the end of the string, which is the starting line.
    - Attach the 'cargo' to the straw.

4. Let go of the balloon opening and watch it zoom to the other end of the room, cargo in tow!

5. Use a marker to mark a spot on the string where the first trial stopped.

6. Have students create different designs or variations to make the contraption go further, faster, carry more cargo, etc.





DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Draw the setup at the start of the activity. What is the problem to solve, and what are some constraints you might face?

- What are some possible solutions? Draw some possible setups of the activity and how you may be able to get the cargo from one side of the string to the other. Can you add arrows indicating how air is moving and the motion of the balloon/straw/cargo?

- What worked and what didn't during this activity? What adjustments need to be made?

EXPLAIN

What's happening in this Activity?

First review the Forces & Interactions Background section to gain a deeper understanding of the scientific principles behind this activity.

We interact with matter around us constantly, whether that means bouncing a basketball or boiling water to make tea. One way that we interact with matter is by exerting force. A **force** is any kind of push or pull on an object. Any interaction that changes the movement of an object is a force.

When two objects interact, both objects exert a force on each other. The sum of those forces determines whether an object will move or not. For example, when you sit on a chair you are exerting a force on that chair: your weight is pushing down on the chair. But what force causes you to stay seated and not keep moving down to the ground? The chair is exerting an equal and opposite upward force on your body, which we know because you remain at rest. It is only when two forces are acting in equal and opposite directions that an object will remain at rest .

This is an example of the laws that Isaac Newton came up with almost 400 years ago. **Newton's Third Law** says that for every action, there is an equal and opposite reaction. This means that any time there is any kind of force, there is another force of equal size and strength pushing back against it. The force of the chair pushing up on your body is exactly the same strength as the force you exert on the chair.

Newton's Third Law helps to explain how rockets work. Rockets create a force acting in one direction in order to propel themselves forward. As the rocket accelerates in one direction, a force of the same magnitude is exerted in the opposite direction, pushing the rocket through the air. This force is known as **thrust**.

In this activity, the balloon moves forward as it releases gas. When you blow up a balloon you fill it with gas particles. These gas particles move around randomly and collide each other and with the walls of their container (the balloon). These collisions exert a force called **gas pressure**. As more gas particles are added to the inside of the balloon, more particles collide with the walls of the balloon and exert force, which increases gas pressure. While the force of a single gas particle is too small to notice, the total force created by all the gas particle colliding within the balloon is significant. This makes the balloon expand.

All these air particles are trapped inside of the balloon, so that the air pressure inside of the balloon builds up because the balloon can only expand so much. The particles inside the balloon are packed together more tightly than the air outside. As soon as you stop holding the balloon closed, the air inside the balloon rushes out of the small opening. But remember: there are already air particles surrounding the balloon. The air particles coming out of the balloon exert a force on the outside air particles to push them out of the way. As described in Newton's Third Law, the outside air pushes back in the opposite direction. It is this force—the equal and opposite force of the outside air, called thrust—that pushes the balloon forwards.

Think of being in a pool and pushing off the wall. As you straighten your legs, you push against the wall of the pool. You move forward because the wall pushes back. The pair of forces here is your feet pushing against the wall, and wall pushing back in the exact opposite direction.

Notes

EXPLAIN continued

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED

For younger students, emphasize the following concepts:

- Gases take up space
- Particles of matter are always in motion
- A force is any kind of push or pull
- For every action, there is an equal and opposite reaction

DIVING DEEPER

For more advanced students, emphasize the following concepts:

- Air pressure and particle collision
- Air pressure and its relation to volume
- Diffusion of gas particles
- Contact forces

Fun Fact #2

Fireworks are considered the earliest form of rockets.

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Ask students about some other things that make an object move. For example, a car, a baseball, or a runner. Can students identify the pairs of equal and opposite forces for all the movements they see around them?
- Tell your students that they need to devise a way to transport cargo across a string using only the materials you provide them. Have the students work in groups or individually to test methods. Discuss how they may accomplish this task and offer hints as needed.
- Use the lesson to practice measurement and apply calculations. Measure the distance from the start to the finish line on the string. Measure the mass of the inflated balloon. (They can use a clip to keep the balloon opening closed and then subtract the mass of the clip.) Then, time how long it takes for the balloon to move across the finish line. Students can then use these measures to calculate the rocket's force.
- Additional calculations that can be incorporated into this experiment are measurements of central tendency. As students conduct trial runs they can record the distance traveled. From this large data set they can calculate and describe the class results using mean, median, mode, and range.
- Try the activity with balloons of different shapes and sizes. Does this change the results? Or, inflate the same type of balloon to different sizes. Have students measure the circumference of the balloon with a tape measure and run multiple trials at each circumference. Students can plot their results (i.e. balloon circumference vs. distance traveled) to see if there is a connection. How can they explain their results?
- For more of a challenge, try angling the string up so the balloon rocket has to climb to reach the end! Students can try the experiment on flat, downward, and upward sloped strings to see how the angle of the string changes the results. To add some mathematical measurements, students can measure the angle or calculate the slope of each string!
- Incorporate a discussion of friction by testing different types of string: nylon, fishing line, cotton, twine, etc. Does the contraption move just as easily over each type of string? Why or why not?
- How does the balloon mass affect its movement? Do a number of trials with the same setup but add mass to the balloon rocket each trial (something like sticky tac can easily be weighed, added, and removed to any setup). For more advanced students: how would the added mass be included in a force diagram?
- If you have the space available, you can make this into a race! Set up the same number of strings as teams of students. Task each student group with designing their own unique balloon rocket (hint: use the Engineering Design Process to guide them in creating their own solution to move an object across the string), then test them all at the same time to add some fun competition to the activity!
- Does the type of material used for the "rocket" matter? How would this experiment work if a beach ball were inflated instead? What feature of a balloon makes it a good "rocket"?
- Students will notice that when the balloon is released it moves erratically. If this were a device used for transportation, that would be unsafe! Can students tweak their design so the balloon moves more smoothly? (Hint: cylindrical balloons move more smoothly across the string because the air is released in a steady stream. How can students make their balloon release air at a controlled rate?)

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

Jet engines work by igniting fuel, combined with compressed oxygen, inside the engine. As a result of the reaction, large amounts of gas are released quickly out of the rear of the aircraft. The extremely high acceleration of the mass of gas creates a large force. Then, as indicated by Newton's Third Law of Motion, an equal and opposite force (thrust) is created in the opposite direction of the released gas, propelling the jet forward. Fireworks are considered the earliest form of rockets.

Balloon rockets are fun toys that use the same scientific principles to launch balloons through the air! The balloons designed to be long and thin, which allows for a more controlled release of air.

Careers in Chemistry

- Aerospace and aviation engineers need a good understanding of force, movement, and thrust so they can design spaceships and aircrafts that can safely and efficiently launch through Earth's atmosphere. A process called reverse thrust has also been designed for jet engines to decelerate an aircraft for a safe and steady landing .
- Basic physics and forces explain how drones are carefully designed and engineer to glide through the air. Drones use rotors that work like powerful fans, which push down on the air, and in turn cause the air to push up on the rotor and lift the device. The speed of the rotor can be increased to create thrust, causing the device to rise through the air, or decreased to descend .

EVALUATE

- Provide students with a diagram of the activity at the beginning, middle, and end. Task them with drawing and labeling a force diagram for each stage of the activity.
- Using the same diagram, ask students to draw the gas particles at each stage in the activity. When is the gas pressure in the balloon the greatest? When is it the smallest?
- Provide students with a few diagrams or written scenarios about various setups for this activity. They can include variations like balloons inflated to different sizes, with different amounts of mass on them, the string at different angles, and more. Ask students to describe which example will go the furthest and to justify their selection using new vocabulary words they learned.

Magnetic Metals

Section **FORCES & INTERACTIONS**

Estimated Time Setup: 5 minutes; Procedure: 5-10 minutes

OVERVIEW

Students will learn about magnetism by testing whether a variety of objects are attracted to a magnet.

The force of magnetism isn't visible traveling through the air, but we can see it because it makes objects move. In this activity, students place a variety of metal items on a desk and try and attract each item with a magnet. Based on whether or not an object moves, students can tell whether or not the object has magnetic properties.

INQUIRY QUESTIONS

Getting Started:

- What objects are magnetic?

Learning More:

- What are the properties of magnets?

Diving Deeper:

- How does a magnet work?

CONTENT TOPICS

This activity covers the following content topics: physical properties of matter, properties of metals, magnetism, forces, magnetic fields, temporary magnets, permanent magnets, magnetic poles, non-contact forces

This activity can be extended to discuss: periodic table of elements, contact forces, chemical properties of matter

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **3-PS2-3:** Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

MATERIALS

For one setup:

- 1 magnet wand
    - Alternative: 1 refrigerator magnet (other types of magnets will work too), 1 wood or stiff plastic ruler, clear plastic tape
- Assorted metal objects (e.g. keys, paper clips, spoon, ball of aluminum foil, pieces of pipe cleaner, coins) and non-metal objects (e.g. toothpicks, pencils, erasers, hairbands, plastic bottle cap, ball of tape, rubber bands)

ACTIVITY NOTES

This activity is good for:

- Individuals
- Pairs
- Small groups
- Concept introduction

Safety Tips & Reminders:

- Review the Safety First section in the Resource Guide for additional information

Fun Fact **#1**

A naturally magnetic mineral commonly called lodestone was used in the past to make magnetic compass needles. The word "lode" means "lead" because the compasses were used to lead sailors home. Today, compasses have tiny bar magnets that float in liquid. The magnet naturally aligns to the earth's poles and will always point north and south!

ENGAGE

Use the following ideas to engage your students in learning about forces:

- Start by brainstorming a list of what objects are metals and what are not metals. What are the properties of metals and nonmetals? Of the metals and nonmetals discussed, which ones are magnetic? How do students know? How would they describe magnetism? What does it feel like? Look like? Sound like?
- Have students make predictions based on the objects in front of them: which will be magnetic, and which will not? Why do they think that? Now test to see if their predictions are correct!

See more ideas for engagement in the Forces & Interactions Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

Notes

EXPLORE

Procedure:

1. If you do not have a magnet wand, start by making one: use the tape to attach a magnet to a ruler so the magnet is facing away from the ruler.
2. Place all the objects in a row on a table. Ask students to predict which will be magnetic and which will not. Record all observations.
3. Test the predictions by holding a magnet over each item one-by-one.

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

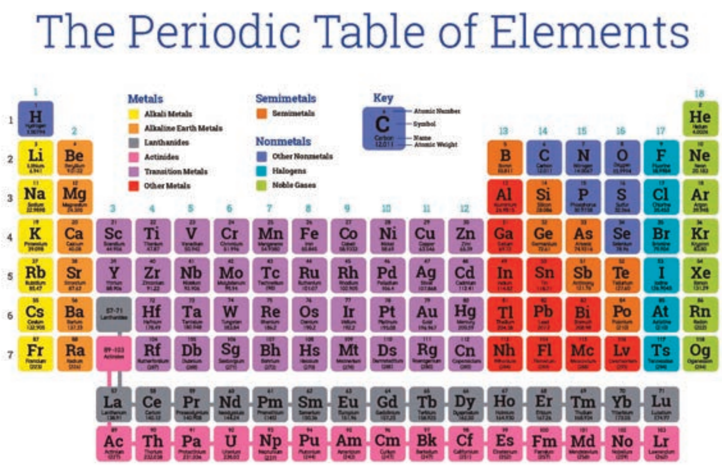
- Record the names of each item.
- What material is each item made from? How do you know? What are some physical properties of these materials?
- Note your predictions: which objects will be attracted to the magnet and which will not? Why?
- Look closely: what happens when the magnet approaches an object that it is NOT attracted to? What happens when the magnet approaches an object that it IS attracted to?
- Revisit your predictions: which objects were magnetic, and which were not? Were you correct in your predictions?
- What surprised you?
- What similarities do you note between objects that are all magnetic?
- What similarities do you note between objects that are all not magnetic?
- What differences do you note between objects that are magnetic and objects that are not magnetic?

EXPLAIN

What's happening in this Activity?

First review the Forces & Interactions Background section to gain a deeper understanding of the scientific principles behind this activity.

Chemistry is the study of matter, its properties, and the changes it undergoes. **Matter** is anything that has mass and takes up space. Matter exists in many different shapes, sizes, and forms. All matter is made up of some combination of 118 building blocks called elements, each of which is unique. **Elements** are the simplest chemical substances and cannot be broken down further through physical or chemical means. The periodic table shows all the elements that we know exist.

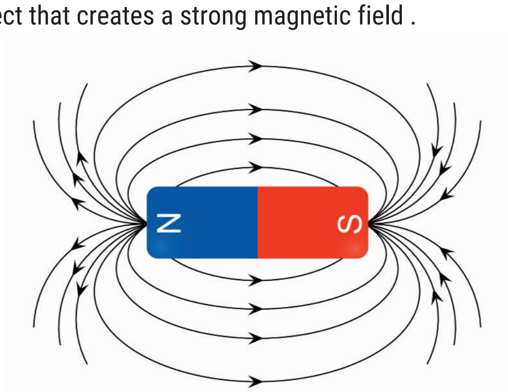


Each of these elements has unique properties. **Physical properties** are properties of a substance that can be observed or measured without changing the substance's chemical makeup, or its identity. Color, size, and conductivity are all physical properties.

One physical property that can used to identify what material a substance is made of is magnetism. **Magnetism** is a force between objects that acts at a distance through a magnetic field. A **force** is any kind of push or pull on an object. The force of magnetism can be either **attractive** and pull objects closer together, or **repulsive** and push objects farther apart .

Magnetism is a **non-contact** force because it happens between objects that are not physically touching each other. Think about sending a message from your phone to a friend's phone through an internet connection. If you are somewhere with Wi-Fi, you are connecting to the internet through radio waves moving through the air around you. You can send a message to someone even if they are far away by using these radio waves.

In the same way that radio waves move through the air but are not visible, the force of magnetism acts over a distance by creating a magnetic field, even though we can't see it. A magnet is any object that creates a strong magnetic field .



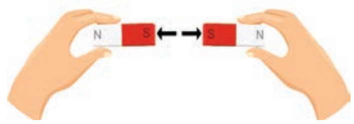
Fun Fact #2

Metal paper clips are generally made from steel wire. Steel is an alloy of iron and carbon. The iron in the paper clips causes them to be attracted to the magnet.

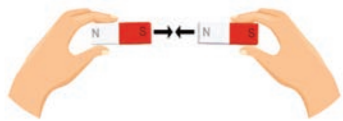
The symbol we use to represent Wi-Fi (left) is based on how we illustrate radio waves coming from a radio tower (right).

EXPLAIN continued

The two ends of a magnet, where the force is the strongest, are called its poles. Every magnet has a **north pole (N)** and a **south pole (S)**. Opposite poles are attracted to each other, and poles that are the same repel each other.



Two north poles are repelled from each other and a magnetic force pushed them apart. The same is true for two south poles.



The north pole of one magnet is attracted to the south pole of another magnet so a magnetic force pulls them together. Opposites attract !

If a material is magnetic, it will be attracted to one of the two poles of a magnet. Some metal elements have magnetic properties—these are called **ferromagnetic metals**. Iron, nickel, and cobalt are the three strongest magnetic elements.

In this activity, students test which metal objects are attracted to a refrigerator magnet. Anything that is attracted to the magnet must have some magnetic properties, and therefore must contain some ferromagnetic metal. We may not be able to see the magnetic field, but we can tell that it is there because it makes objects move.

Many of the objects you are testing might be attracted to the refrigerator magnet, but not exert any force on each other. This is because some magnetic forces are stronger than others. A **permanent magnet** creates its own magnetic field, and always has magnetic properties. The refrigerator magnet is a permanent magnet. A **temporary magnet** only acts like a magnet when something else creates a magnetic field. The objects attracted to the refrigerator magnet in this experiment are temporary magnets .

In the presence of the magnet, some objects become temporary magnets and stick to it.

When the magnet is gone, these objects don't create a magnetic field. They don't move towards each other or away from each other because they stop exerting a magnetic force.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED

For younger students, emphasize the following concepts:

- All matter is made up of building blocks called elements.
- Each element can be identified by its unique physical and chemical properties.
- Magnetism is a physical property.
- Forces can be either attractive (pulling) or repulsive (pushing).

DIVING DEEPER

For more advanced students, emphasize the following concepts:

- Magnetism is a force that acts over a distance through a magnetic field.
- Magnets have two poles. Opposite poles attract each other and like poles repel each other.
- Magnetic forces can have different strengths.
- Permanent vs. temporary magnets

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Take the experiment one step further. Use one of the objects that was attracted to the magnet and place it on the magnet for about a minute. Next, remove the object from the magnet, and see if it can attract your other magnetic objects. Metals that are magnetic can be made into temporary magnets themselves!
- Task students with finding magnets in their homes! They can take a magnet home or use it around school for a day and write their observations in a journal. What objects were magnetic? What objects were not? What surprised them? What is a question they still have?
- Tie this activity in with explorations in the Separation Techniques section of the Activity Guides. Provide a mixture that includes some magnetic items, and some nonmagnetic items, along with a variety of tools which could be used to separate them – including a bar magnet. What are the different ways a separation can be done? For ideas on what materials can be used, check out the Activity Guides "The Great Divide" and "Separating Salt and Pepper," where salt or pepper can be substituted or used in addition to magnetic sand!
- Connect this activity to a study of the periodic table of elements: which elements are magnetic? Students can do research online or in a science textbook, then present an overview of each element to their peers.

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

The earth is surrounded by an enormous magnetic field! This magnetic field is caused by the movement of molten iron in the outer core of the earth combined with heat escaping from the inner core. The magnetic north and south poles are slightly different from the geographic north and south poles. And in fact, the geographic north pole is actually the geomagnetic south pole !

Throughout your day, you use dozens of products that are made possible through magnets and magnetism. Everything from alarm systems, to MRI machines, to microphones, and car horns!

Careers in Chemistry

- Magnets and magnetic technology have been widely used in the mining industry. Powerful magnets are used to separate valuable materials from within the mine. They are also used to remove contaminants from the mined materials, such as coal.
- In rare cases, liquids can also have magnetic properties! This fascinating phenomenon is seen in ferrofluids, which are made of iron suspended in oil with a surfactant to prevent clumping. Ferrofluids are used in electronics for a variety of applications, like in hard drives to prevent debris from entering the device, and in speakers to improve quality.

Notes

EVALUATE

- Provide students with a new set of materials they did not test previously. Ask them to make informed predictions of whether each object will respond to a magnet based on their results from the original activity. They can then test their predictions and explain why they were correct or how they are revising their predictions and why.
- Ask students to reflect on their takeaways from this activity. What were they expecting? What surprised them? What are three things they learned? What three questions do they still have for further investigation? What was their favorite part of the activity? What was the most challenging? What new vocabulary did they learn today, and can they define the terms in their own words?

Fun Fact #3

Over the course of thousands of years, the geomagnetic poles of the earth flip! This means that in the past – and maybe sometime soon – our compasses directed us north to Antarctica, instead of south!

Fun Fact #4

Magnets are one of the many tools used to separate materials in the recycling process.

Puffed Rice Fleas

Section **FORCES & INTERACTIONS**

Estimated Time Setup: 5 minutes; Procedure: 5 minutes

OVERVIEW

Students will learn about the power of electric forces as a charged object is used to move other materials.

In this activity, students charge a balloon through building up static electricity. When they bring the charged balloon near a puffed rice cereal, they can see as the cereal is first attracted to – and then repelled – by the balloon. Students learn about the interplay between electron movement, forces, how they impact movement.

MATERIALS

For one setup:

- Plate
- Puffed rice cereal
- Balloon
- Charging cloths (e.g. wool, plastic wrap, carpet, etc.)

INQUIRY QUESTIONS

Getting Started:

- What happens when a charged object is brought near another object?

Learning More:

- How and why do atomic particles move?

Diving Deeper:

- How does electric force explain the movement of objects?

CONTENT TOPICS

This activity covers the following content topics: atomic structure, protons, neutrons, electrons, electric force, static electricity, charges, attractive and repulsive forces

This activity can be extended to discuss: ions, intra/intermolecular forces, ionization, Coulomb's Law

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **3-PS2-3:** Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

ACTIVITY NOTES

This activity is good for:

- Individuals
- Pairs
- Small groups
- Demonstrations

Safety Tips & Reminders:

- Beware that if it is very humid, this activity will not work as static electricity wears off quickly in moist air.
- There is no eating or drinking in the laboratory—even when we are working with normally edible materials.
- This experiment uses a balloon. Check to see if any students have latex allergies or if there are any restrictions on using balloons in the classroom in advance.
- Review the Safety First section in the Resource Guide for additional information.

Fun Fact **#1**

Static electricity occurs most often when the air is dry. This is because moist air conducts electricity, and charges that build up easily wear off.

ENGAGE

Use the following ideas to engage your students in learning about forces:

- With exciting experiments like this, sometimes the best way to engage students is to start with a demonstration of the activity and have them discuss their hypotheses.
- Start with a discussion of static electricity. Students have likely heard this term before, but can they explain what it means or where they have encountered it in the past? Ask students to describe how it happened, what it felt like, and their hypotheses about what was happening in those instances.
- You can begin with a familiar activity: charge a balloon and hold it near your (or a student's) hair. Can students explain why the hair is attracted to the balloon? What causes this? (Note: this will not work on hair that has a lot of product in it!)

See more ideas for engagement in the Forces & Interactions Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

EXPLORE

Procedure:

1. Sprinkle several kernels of puffed rice cereal on a plate.
2. Inflate a balloon and tie the end so it is sealed.
3. Rub the balloon on a charging cloth material in one direction multiple times.
4. Slowly bring the now-charged balloon near the cereal and observe what happens.
5. Hold the balloon motionless and note any changes.
6. Try step 4 again, but this time immediately turn the balloon upside down so the kernels are on top of the balloon. Observe.

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- Before the activity starts, make a prediction: what do you think will happen when you rub the balloon, then hold it near the cereal?
- After step four, write your observations. Describe what is happening and draw a picture.
- After holding the balloon over the cereal for some time (step five), you will notice a change. Describe what happens. Why does this happen?
- After step six, do you have a revised explanation for what you observed in step five? Why or why not?

Notes

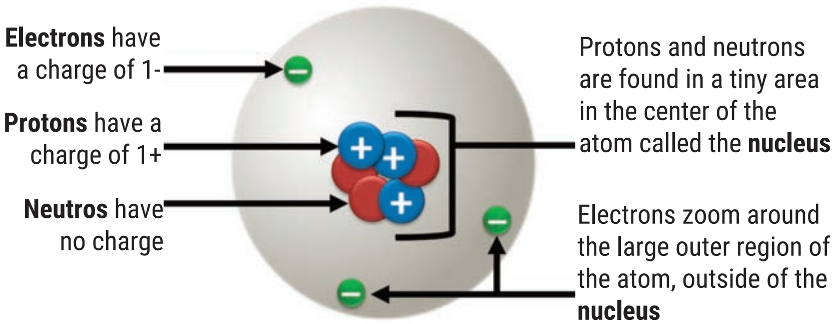
EXPLAIN

What's happening in this Activity?

First review the Forces & Interactions Background section to gain a deeper understanding of the scientific principles behind this activity.

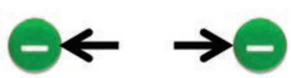
All matter is made up of some combination of 118 building blocks called elements, each of which is unique. **Elements** are the simplest chemical substances we know. An **atom** is the smallest particle of an element that retains the element's chemical properties. Every atom is made up of three parts: protons, neutrons, and electrons.

Structure of an atom

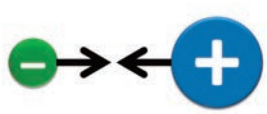


Atoms react with each other by losing, gaining, and sharing electrons. When the number of protons in an atom is the same as the number of electrons, the atom is **neutral** because the positive and negative charges are balanced. Particles that have a charge are called **ions**. If there are more electrons (−) than protons (+), the ion is negative. If there are more protons (+) than electrons (−), the ion is positive.

A **force** is any kind of push or pull on an object, and these forces happen even at the microscopic level in and between atoms. **Electrostatic force** happens when two charged objects – like electrons and protons, or two ions – interact.



Two objects with the same charge **repel** each other, and electric force pushes them apart. For example, one negatively charged electron (1−) repels another negatively charged electron (1−).



Two objects with opposite charges are **attracted** to one another, and electric force pulls them together. A proton (positive charge, 1+) is attracted to an electron (negative charge, 1−). Just like with magnets, opposites attract!

Zooming out, even large objects can have positive or negative charges based on the electrons and protons on their surface. **Static electricity** is the buildup of an electric charge on the surface of an object. Electrons are highly mobile, and easily move from one object to another. Some materials, like glass, hair, and nylon, give up electrons easily and become positively charged themselves. Other materials, like silicon and polyester, tend to draw electrons from other materials, giving them a negative charge.

Fun Fact #2

Greek philosopher Thales of Miletus was the first to discover the principle of static electricity in 585 BCE. He found that if he rubbed a piece of amber, it could pick up lightweight objects like feathers. But without the tools or knowledge to investigate this phenomenon further, it took until the late 17th century for scientists to learn more. Additionally, the Greek word for "amber" is pronounced "elektron" – which is where we get the name for the negatively charged particle today!

Notes

EXPLAIN continued

In this experiment, students rub a balloon against a cloth like wool, plastic wrap, or carpet. A balloon – which is made of nylon, latex, or rubber – tends to draw electrons from other objects. The charging cloth tends to give up electrons. When rubbed together, the cloth gives up electrons to the balloon and a negative charge builds up on the surface of the balloon.

When the balloon is brought near a neutral object, like puffed rice cereal, the electrons in the cereal repel away from the balloon and the protons in the cereal are attracted to the balloon. Electrons are more mobile and move easily in an atom. The electrons in each grain of cereal move farther away from the negatively charged balloon, but protons cannot move as much so they stay in the same place. This makes the attraction from the protons stronger than the repulsion from the electrons – which have been pushed away – giving the cereal a weak positive charge. The slightly positive cereal sticks to the balloon because of electric force.

However, overtime some of the extra negative charge from the balloon can jump from the balloon to the cereal. When this happens, the cereal becomes negatively charged. Since the cereal and the balloon now have the same charge, they repel one another, and the cereal jumps off the balloon.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • An atom is the smallest building block of matter, and is made of protons, neutrons, and electrons. • Forces can be either attractive (pulling) or repulsive (pushing). • Something can have either a positive charge, a negative charge, or no charge (neutral). • Opposite charges are attracted to each other and like charges repel each other.	**For more advanced students, emphasize the following concepts:** • Protons, neutrons, and electrons have different charges and locations in an atom. • Electrons can be transferred from one atom to another, or from one object to another. • Some atoms/objects tend to give up electrons, while others tend to accept electrons. • When charges build up on an object they create static electricity.

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- While a balloon works well for this experiment, other materials like a ruler, straw, comb, and more will work, too! Typically, insulators are good at holding a surface charge.
- Try using different materials around the room to charge the balloon. Which materials work best? Which do not work well? What factors might determine which materials most easily give away electrons and charge an object?
- Move the charged balloon toward different materials, such as small pieces of aluminum foil, rubber bands, salt, pepper, and more. Do these substances behave differently than the puffed rice. What factors might determine how strong the attraction will be?
- What happens if the balloon is placed near the cereal without charging it first? Why do you see these results?
- A fun extension is to charge a balloon, then bring it near a trickling faucet that has a steady (but small!) stream of water coming out. You will be able to see the water bend towards the balloon!
- Electric force can be used to power motion! Try charging a balloon and see if you can move a soda can, bubbles, another balloon, and more! Students can set up a race and run multiple trials to find the fastest way to move an object across the room.

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

If you rub your shoes on a carpet, your body may collect extra electrons. These electrons will remain on your body until they can be released. When you touch certain objects, you will feel a shock, which is a release of excess electrons when there is a charge difference between objects. In the case of rubbing your shoes then touching something like a doorknob, you have a negative charge and the doorknob has a positive charge, which is equalized to neutral through a shock!

Careers in Chemistry

- Concepts of electric force are employed in a variety of everyday objects. Examples include laser printers, copy machines, and air cleaners. These tools rely on the buildup of electric charge to more precisely direct fine particles, like dust or ink, to the appropriate areas.
- Have you ever noticed a metal pole sitting atop a large building? Originally developed by Benjamin Franklin, lightning rods designed to safely divert lightning and high volumes of electric charge safely into the ground.

Lightning is caused by the difference in charges, either within a cloud or between a cloud and the ground below.

Notes

EVALUATE

- Provide students with a variety of diagrams showing atomic structures, with protons, neutrons, and electrons clearly marked. Ask them whether for each example, if the atom would be positively charge, negatively charged, or neutral, and why? If a negatively charged balloon was brought near each atom, what would happen and why?
- Students can draw a "before, during, and after" picture of this activity. Be sure to label the materials and note charges for each frame. Students should explain how charges or object move throughout the investigation.
- Ask students to recall a moment where they experienced static electricity. They should write the story using their new vocabulary words and explaining how electron movement and forces resulted in their "shocking" experience.