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.

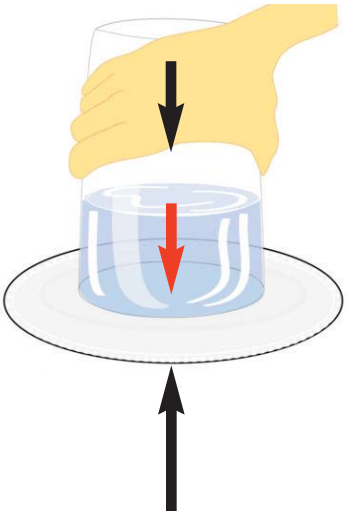
A force is any kind of push or pull on an object. The way an object moves is not determined by just one force. At any time, there are many different forces acting on one object, such as the force of gravity pulling an object down towards Earth, or the force from a gust of wind. The way an object moves 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.