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.

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?

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.

MATERIALS

For one setup:

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

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

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:

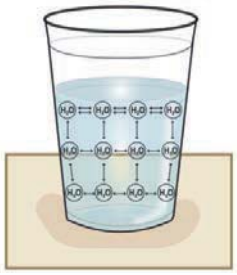
- Make a prediction: what will happen when you try to pull the bag from the trash can? Why?
- What happens when you try to pull the trash bag out of the can? Is it different when you change the position of the trash can or the direction in which you are pulling?
- What kind of force stops you from pulling 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

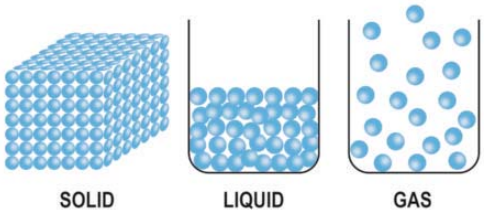
What's happening in this Activity?

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.