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.

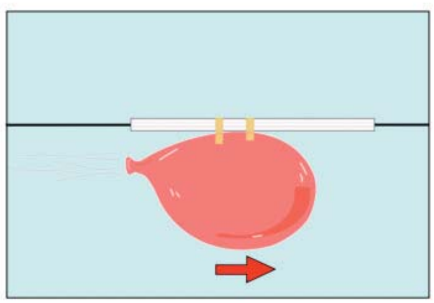
3. Students should be tasked with attempting to get a piece of cargo (e.g. a paperclip, button – anything small) from one end of the room to the other using only the materials available and the string. There are lots of different ways to do this, and one example is outlined here:

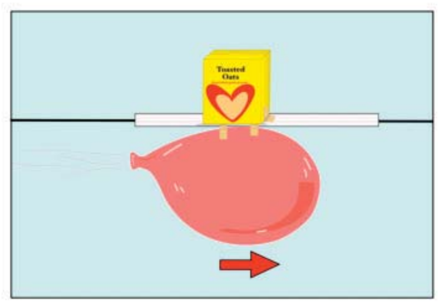
   - Untie one end of the string and put it through the piece of straw, then retie it so the straw is suspended on the string.
   - Blow up a balloon and pinch the opening so it is closed, but do not tie the end.
   - Tape the side of the balloon horizontally to the straw so the top of the balloon is facing 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.