Background Information for the Teacher:


Isaac Newton’s three laws of motion and the law of gravity that explain motions are observed on Earth and in space. In the case of rockets, the action is the force produced by the expulsion of gas, smoke and flames from the nozzle end of a rocket engine. The reaction force propels the rocket in the opposite direction. Newton’s laws of motion explain just about everything you need to know about rockets.

Newton’s third law deals with actions and reactions. Stated simply, the law says "for every action, there is an equal and opposite reaction." The statement of this law is deceptively easy. However, the key to grasping this law correctly is to understand action-reaction pairs. Pair means two, so only two objects are in an action-reaction pair. Action is the result of a force. Release air from an inflated balloon. The air shoots out the nozzle. That is an action. Reaction is related to action. When the air rushes out of the balloon, the balloon shoots the other way—reaction!

What causes action and reaction to occur? The action and reaction in Newton's third law are forces. If you recall from our previous lessons, force was defined as a “push” or “pull” on an object. To take this concept further, you should also add that force is an agent of change. The application of a force to a body (one that is free to move) changes the body's state of motion, that is, it changes its velocity (the speed of something in a given direction). "If you insist upon a precise definition of force, you will never get it!" (Richard P. Feynman, Robert B. Leighton, and Matthew Sands, The Feynman Lectures on Physics, Addison-Wesley, Reading, MA, Vol. 1, 1964, p. 2 – 4). In the case of rockets, however, burning rocket propellants that expand explosively usually exerts force.

Unbalanced force refers to the sum total or net force exerted on an object. The forces on a coffee cup sitting on desk, for example, are in balance. Gravity is exerting a downward force on the cup. At the same time, the structure of the desk exerts an upward force, preventing the cup from falling. The forces are in balance. Reach over and pick up the cup. In doing so, you unbalance the forces on the cup. The weight you feel is the force of gravity acting on the mass of the cup. To move the cup upward you have to exert a force greater than the force of gravity and the muscle force you are exerting are in balance.
Background Information for the Teacher, Continued…

Let’s look at an example of Newton’s action-reaction law: The Sun’s gravitational force acting on Earth is an *action* and the Earth's gravitational force acting on the Sun would be considered a *reaction*. Earth’s gravitational force on the Sun and the Sun's gravitational force on Earth is an action-reaction pair.

*Gravity* is the force holding the universe together. There is a gravitational force between any two objects in the universe, so it is called *universal gravitation*. Gravity pulls you down because there is a gravitational force between you and the earth as well as between you and the Sun and even, between you and the person sitting next to you. You don’t fall to the sun because it is too far way for its gravitational force to be strong. You don’t fall toward the people sitting next to you because they are less massive than Earth.

What happens when you're standing still on a skateboard and then suddenly step off? The force of stepping off the board pushes your skateboard (and you) in the other direction. The same force occurs when you step off a boat onto a pier. Unless the boat is held in some way, it moves in the opposite direction.

You can also demonstrate this using *Newton’s Cradle*. This apparatus consists of steel balls suspended on a frame. When the ball on one end is pulled back and then let go, it swings into the other balls. The ball on the opposite end then swings up with an equal force to the first ball, as shown in the illustration on the right. The force of the first ball causes an equal and opposite reaction in the ball at the other end.

**Fun Fact:** Action/reaction force pairs also make it possible for birds to fly. The wings of a bird push air downward (action). In turn, the air pushes the bird upward with an equal force (reaction).
**Activity Overview:** Students construct a “rocket” from a balloon propelled along a guide string. They use this model to learn about Newton's Third Law of Motion, examining the effect of different forces on the motion of the rocket.

**Learning Objective:** Students will demonstrate practical applications of Newton's Laws of Motion by using the model of the balloon to understand the different forces that act on the rocket. They will also collect data from the experiment and graph the results.

**Science Process Skills:** Observing, Measuring, Predicting, and Investigating

**Estimated Time Required:** Day 1 =50 minutes, Day 2 =50 minutes

---

**Teacher Preparation:**
- Make sure you have all the materials ready for your students in advance.
- Assemble students in teams of four
- Choose appropriate locations for students to set up the experiment
- Give each team the listed materials and the Data Sheets
- Technology Activity= *Newton’s Laws App, Isaac Newton App*

**Materials:**
- Plastic Drinking Straw
- Tape
- Ruler
- Fishing line or smooth string
- Long, tube-shaped balloon
- Skateboard
- Basketball
- Data Sheets
- Literature Book: *TECHNOLOGY: How today's technology really works* by Clive Gifford
- Literature Book: *Isaac Newton’s Laws of Motion* by Andrea Gianopoulos

---

**What You Do!**

1. **[Day 1]** Engage students by asking them the following question:
   - What happens when you fill a balloon with air and then release it? How does the balloon move?
   - Has anyone ever stepped forward off a skateboard suddenly? What happened?
   - What do you think happens if a person were to step off a boat onto a pier? In which direction does the boat seem to move?

   Brainstorm student answers on the board. Keep these ideas on the board during the class period so you can refer back to them as you learn more about rockets and how they work.

---

**Science Vocabulary**
- Action-Reaction
- Force
- Gravity
- Newton’s Cradle
- Mass
- Unbalance Force
- Universal Gravitation
- Velocity
What You Do! Continued…

2. Start with an in-class demonstration. Have a student stand on a skateboard and throw a basketball. Invite the class to observe what happens (note: this could be dangerous; be very careful not to have the student fall). The student rolls backwards on the skateboard. Allow students time to observe and respond to the demonstration. Invite them to speculate the conditions if the skateboard were larger or smaller, or if the basketball were bigger and/or heavier, smaller and/or lighter, or if the floor were smoother/rougher. What would be the outcome?

3. Remind students that our purpose for observing this third law of motion today is mainly to understand that the motion of objects on Earth also apply to the motion of objects in Space. Our understanding of how rockets work arises from Sir Isaac Newton’s three laws of motion. It is important for engineers to understand Newton’s laws because they not only describe how rockets work they explain how everything that moves or stays still works! Tell students that this activity demonstrates all three of Newton’s laws of motion. The focus of the activity is Newton’s third law of motion, but the first and second laws are intrinsically involved with the motion of the rocket as well.

4. TechConnect= Connect your iPad Mini to the projector so the students can watch a YouTube video called Newton’s 3rd Law of Motion. Have them scroll down to the video uploaded by MacMillanSpaceCenter. Have students discuss what they observed from the action-reaction experiment as soon as they are done watching the video. Then bring the whole class back together for a discussion on Newton’s Third Law.

5. Make copies of pages 78-79 in the literature book TECHNOLOGY: How today’s technology really works by Clive Gifford. Students will be able to read about rocket propulsion and see a few pictures of how 3…2…1…Lift Off! has changed over time.

6. [Day 2] Tell students that they are going to complete an experiment similar to the one they saw on YouTube. However, a chemical compound will not be used, just simply air and a balloon. Invite students to think about why they should perform this experiment and how it relates to their understanding of physics.

7. Gather materials for this activity. Choose appropriate locations for students to set up the experiment.

8. Assemble students into teams of four to six. Make sure all teams have the listed materials. Allow teams to complete the activity a number of times while they observe and write a brief description of the experiment. Students should also use the iPad Mini to video the action – reaction activity. You may want to designate roles for students such as tester, recorder, videographer and presenter. Make sure the videographer uses the iPad Mini to capture this experiment in the making. It could make for some funny footage!
What You Do! Continued…

9. Show your students the handout Newton’s Third Law. Have them complete the written exercise. In this exercise, students will learn why action – reaction forces occur. Remind them that these forces come in pairs. You may want to read the directions aloud while students follow along.

10. **TechConnect:** Have students click on the iPad Mini app called *Newton’s Laws*. Students can click to learn about Newton’s Third Law of Physics. Feel free to use this app as it was initially introduced in the first law of motion activity. It is a good way to reinforce learned concepts.

Checking For Understanding!
While students are working on their experiments, walk around the room and them to give verbal descriptions of Newton’s Third Law. If students can tell you that air pushing is an *action* and the balloon pushing back is a *reaction*, then they understand the concept.

**Modifications**

**For Older Students:** To ensure that your students are receiving a sufficient challenge from this lesson, have them expand their visual skills by making a plot showing the distance that the balloon travelled with different air volumes. This can be one on graph paper or with a computer software package like Microsoft Excel).

**For Younger Students:** To ensure that your students are learning at the appropriate level, you may want to briefly review fractions in a visual way: $\frac{1}{2}$, $\frac{1}{4}$, $\frac{3}{4}$. Reviewing this may help them understand how much air to fill in the balloon experiment.

**TechConnect:** A great enrichment activity for the lessons on Newton’s Laws is to have the students use two iPad Mini apps: *Newton* and *Isaac Newton*. These apps give an overview of the life of Isaac Newton in a story form. The app, *Newton*, is a better choice for less advanced students because it reads like a storybook. The other app, *Isaac Newton*, would be better for more advanced students. Both apps are very informative and span through Isaac Newton’s life and give information about his achievements. Students could use these apps to write a report about Isaac Newton or create a comic book about him, like the book, *Isaac Newton’s Laws of Motion* by Andrea Gianopoulos.
Newton’s Third Law: Action - Reaction

Directions: Read the information below. Answer the questions that follow about this article.

Action and Reaction
A rocket can liftoff from a launch pad only when it expels gas out of its engine. The rocket pushes on the gas, and the gas, in turn, pushes on the rocket. The whole process is very similar to riding a skateboard. Imagine that a skateboard and rider are in a state of rest (not moving). The rider pushes off the skateboard. In the third law of motion, the stepping off is called an action. The skateboard responds to that action by traveling some distance in the opposite direction. The skateboard's motion is called a reaction. When the distance traveled by the rider and the skateboard are compared, it would appear that the skateboard has had a much greater reaction than the action of the rider. This is not the case. The reason the skateboard has traveled farther is that it has less mass than the rider.

With rockets, the action is the expulsion of gas out of the engine. The reaction is the movement of the rocket in the opposite direction. To enable a rocket to lift off from the launch pad, the action, or thrust, from the engine must be greater than the weight of the rocket. In the microgravity environment of Earth orbit, however, even tiny thrusts will cause the rocket to change direction.

A rocket, in its simplest form, is a chamber enclosing a gas under pressure. A small opening at one end of the chamber allows the gas to escape, and, in so doing, provides a thrust that propels the rocket in the opposite direction. A good example of this is a balloon.

The balloon’s rubber walls compress air inside a balloon. The air pushes back so that the inward and outward forces are balanced. When the nozzle is released, air escapes and the forces become unbalanced. The action of the escaping gas propels the balloon in a rocket flight. The balloon's flight is highly erratic because it has no structures, such as fins, to stabilize it. When we think of rockets, we rarely think of balloons. Instead, our attention is drawn to the giant vehicles that carry satellites into orbit and spacecraft to the Moon and planets.
Newton’s Third Law: Action - Reaction

Directions: Answer the questions below based on the article called: Newton’s Third Law: Action-Reaction.

1. What does Newton’s Third Law of Motion state? ________________________________

2. If a skateboarder is stepping off of a skateboard and this motion of stepping forward off the skateboard causes the skateboard to roll backwards, what is the action in this scenario? What is the reaction?

__________________________________________________________________________________

__________________________________________________________________________________

3. Think about it! Would the weight of the rider have any effect on this action/reaction principle? Explain your thoughts.

__________________________________________________________________________________

4. Let’s apply the action-reaction idea to the Space Shuttle. In the picture below, label the action and reaction occurring as the Space Shuttle is launched.

5. Balloons can be very similar to rockets when it comes to the principle of action-reaction. Label the action and reaction on the balloon below.
Team Name__________________________

Directions: Read the information below. Complete the experiment and record your data then answer the following question.

Procedure:
1. With pieces of string cut to fit around the balloon, measure the circumference of the balloon with different amounts of air in it (completely full, ¼ full, ½ full, and ¾ full) and record the circumference in the table shown below.
2. Set aside the pieces of string.
3. Slide the drinking straw onto a piece of string.
4. Choose two people from your team to hold each end of the string taut and level. Place two loops of masking tape onto the straw.
5. Blow up the balloon to its maximum capacity (greatest volume). Hold tightly onto the neck of the balloon so that no air escapes, and attach the balloon to the two pieces of tape. The neck of the balloon should be parallel to the string.
6. Release the neck to let the air rush out of the balloon.
7. In the table shown below, record (a) the distance that the balloon traveled (as marked on the string) and (b) the amount of air in the balloon.
8. Repeat steps 4-7 above, filling the balloon with different amounts of air. Use the pieces of string you measured in Step one.

Analyze Data: Complete the following table.

<table>
<thead>
<tr>
<th>Amount of Air</th>
<th>Circumference (cm)</th>
<th>Diameter (cm)</th>
<th>Distance Traveled (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>¼ Full</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>½ Full</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>¾ Full</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Activity 4: Exploring Rockets
Part 1: The History of Space Travel

Modifications:

6. You Do!
   - Digitally document their experiment. Students can choose how they want to digitally document their experiment.

TechConnect:

- Satellites sent to space, and the first man in space. Students can read about the first rocket designers, the early facts that the rocket had in the investigation.

For Older Students:

- What could explain discrepancies in the data?
- Was there much variance in how high the rocket flew?
- How stable were the class' rockets when compared to one another?

For Additional Enrichment, Have

- Have your students use the iPad Mini to take video of their rocket flight and landing. Discuss the results.

Sample Questions:

- Did you experience any challenges in setting up and/or carrying out your experiment? Explain.

Think about some other examples of action – reaction forces you might have seen or experienced. List those below and draw a picture.