Level H High | Grades 9-12

Exploring Newton's Laws of Motion with Bottle Rockets

Photo courtesy of NASA

ACTIVITY: EXPLORING NEWTON'S LAWS OF MOTION WITH BOTTLE ROCKETS

Big Idea

Newton's Second and Third Laws of Motion play a part in how a rocket lifts off. As a rocket burns fuel, a hot gas is created and forced out of the back of the rocket. As the gas is expelled, the rocket is propelled with equal force in the opposite direction, once the force exceeds the weight of the rocket. Students will apply Newton's Laws to design, test, redesign, and retest rockets to optimize the distance a rocket travels from launch.

Guiding Question

How do Newton's Second and Third Laws of Motion explain the launch of a water rocket and how can that knowledge be used to improve the distance over which the rocket travels?

Materials Gathered by Teacher (enough for 6 groups):

1. 20-oz.(medium sized) soda bottle (1 per group, plus 1-2 extra, lids discarded)
2. Potato chip can (1 per group, plus 1-2 extra)
3. Wire coat hanger, straightened (1 per group)
4. Scissors (1 pair per group)
5. Jugs or pitchers of water (1 per group)
6. Safety goggles (2 pair per group)
7. Measuring tape or meter stick (1 per group, optional)
8. Paper (1 per group)
9. Pencil (1 per group)
10. Water

Materials Provided in the EITC Kit:

1. Bicycle pump (1 per group)
2. Needle attachment for bike pump (1 per group)
3. Cork (1 per group)
4. Duct tape (1 roll per kit)

Set Up

Communicate with the teacher at least one week before your scheduled classroom visit about the materials needed for this activity. Inform the teacher that this activity will require indoor and outdoor work spaces. For the indoor portion of this visit, desks should be arranged so students can alternate between small-group work and all-class discussions and demonstrations.

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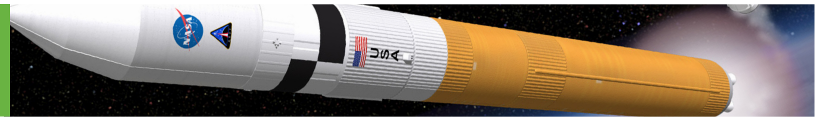

For the outdoor portion of this experience, ask the teacher to preselect a launch area that will be available during your classroom visit. The launch area will require enough space for groups to launch side by side with a few feet between each group and with a clear space of at least 50 feet in front of the groups. An athletic field is ideal. The launch portion of this activity should not be done inside.

Introduction

Teacher introduces the engineer/classroom visitor.

Setting the Stage

- Show the introductory video.
- Tell them who you are, what you do, and what it's like to work in your career.
- Tell them a story about how you got interested in engineering/your career or something that happened in your work that was really exciting—something that truly made a difference in your life.
- Show the activity PowerPoint presentation, as appropriate.

Hands-on Activity

Briefly discuss how Newton's Second and Third Laws of Motion apply to rocket launches.

Ask: Who has heard of Newton's Laws of Motion? What is Newton's Second Law of Motion? (The greater the mass of an object, the more force is needed to accelerate that object.) What is Newton's Third Law of Motion? (For every action there is an equal and opposite reaction.) Discuss how those laws apply to a rocket launch. Make sure students understand that as a rocket burns fuel, a hot gas is created and forced out of the back of the rocket. As the gas is expelled, the rocket is propelled with equal force in the opposite direction (Newton's Third Law), once the force exceeds the weight of the rocket (Newton's Second Law).

Prepare the water rockets.

Explain that students will create a water rocket and experiment with different levels of fuel (water) to propel it. Divide students into four to five groups. Have each group gather all of the materials they will need to complete this activity from the front of the room.

Have students create the rocket "launch pad" by cutting the bottom off the potato chip can so that the remaining part of the can is about 7 inches tall and the top end of the soda bottle sticks out the bottom when it is placed in the potato chip can. Then have students bend the top 1/3 of the wire and tape the wire to the outside of the can so that about half the wire (the unbent part) extends past the end of the can.

Have students insert the needle pump attachment into the cork so that it goes all the way through the cork and sticks out slightly from the other end. Have them remove the needle pump attachment, leaving behind a premade hole in the cork. Have students attach the needle pump attachment to the bicycle pump.

Set up the launch site and give safety and launch instructions.

Bring the students and teacher outside to a large sports field for launch. Be sure that students bring all of their rocket supplies with them, including water, soda bottle, launch pad, bicycle pump, cork, paper, and pencil. Have groups line up side by side with a few feet between each group. Have each group push the wire of the launch pad into the ground so the launch pad is at about a 45o angle to the ground. Make certain that all the launch pads are facing the same way, away from the groups, and that there is at least 50 feet of open space in the direction the launch pads are facing.

Give safety instructions to students. Explain that two students from each group will launch the rockets, while the other students in the group will stand behind them during launch. The students launching the rockets must wear safety goggles. All groups must launch at the same time and no one should move in front of the launch pads until you call "clear."

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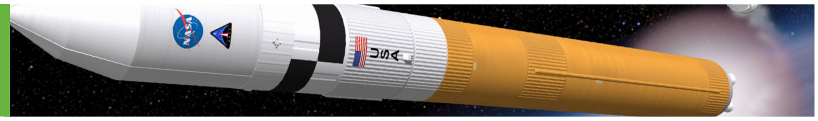


Explain students' roles. One launcher will hold the launch pad steady while the other pumps air into the bottle using the bicycle pump. Note that the students launching the rockets will get a little bit wet. Other group members will watch the rocket and note a landmark to mark the rocket's estimated maximum height after launch. They will also measure and record the distance the rocket traveled once you have given the "clear" signal. Note that, for this activity, a launch will be defined as the cork being expelled from the bottle, regardless of whether or not the bottle moves off the launch pad.

Launch the rockets.

Have students place the corks in the bottles. Then, have the launchers place the bottles in the launch pad with the cork side facing down. Have them quickly insert the needle of the bike pump into the pre-made hole in the cork and begin rapidly pumping the bike pump. Make sure all students are behind the launch pads. After 30 seconds to a minute of pumping, the rockets should launch. Once all the rockets have launched give the all-clear signal. Note that with air only, the bottle is unlikely to actually move from the launch pad. If it does travel a small distance, have the student watchers mark its height, measure the horizontal distance it traveled, and record this information.

Next, have students fill the bottles about 1/3 full of water and place the corks in the bottles. Again, have them quickly place the bottles in the launch pad, insert the needle of the bike pump, and pump rapidly. Make sure that everyone stays behind the launch pads. Note that some water may leak from the cork as they are doing this, and that is fine. Remind the student watchers to note and record a landmark to mark the height of the rocket. This time, the rockets should leave the launch pads and travel up to 40 feet.

Once all the rockets have launched, give the all-clear signal. Group members should then measure and record the distance the rockets traveled. The relative difference between the launches is what is important here, so if measuring devices are not available, students can estimate using their feet. Encourage students not to move the launch pads between launches so all launches are at approximately the same angle.

After measuring, students should reset the rockets and launch again, this time with the bottles full of water. Like the first launch, the bottle is unlikely to leave the launch pad when full of water. If it does, have students measure and record its height and distance traveled as before. Again, make sure that all groups launch at the same time and that all students stay behind the launch pads until you give the all clear.

Introduce the challenge.

After the third launch, challenge students to look at their data and determine what fuel mixture they think will result in the longest vertical and horizontal distances. Have them launch a final time with the amount of water of their choosing to see which group is best able to maximize the height and horizontal distance its rocket travels.

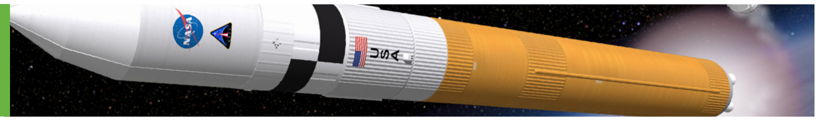
Wrap-up

Return to the classroom and discuss the experiment and challenge with students.

Ask a student volunteer to draw a curve showing generally how the distance the rocket traveled related to how much water the rocket contained.

Ask:

- *How would you describe the relationship of the amount of water to the distance the rocket traveled?* (The distance increased as the water increased up to a point and then began to decrease as the water increased.)
- *What propellant was used to propel the rocket?* (a combination of air and water)
- *The rocket didn't travel as far with just air as fuel as it did when water was mixed with the air. How can you explain this using Newton's Laws of Motion?* (Newton's Third Law of Motion says that for every action there is an equal and opposite reaction. The rocket moves forward in reaction to the propellant being expelled from the bottom of the rocket. Water has about 100 times more mass than air; therefore, the air alone didn't have as much force as it was expelled from the rocket, so the thrust wasn't as great.)



- *The rocket did not travel as far when it was full of water as it did when it was only partially full. How can you explain this using Newton's Laws of Motion?* (Newton's Second Law of Motion states that the greater the mass of an object, the more force is needed to accelerate that object. When the rocket was full of water, it had a greater mass than when it was less full; therefore, more force was needed to accelerate it.)

Ask: *Which rocket's launch was most effective in your group? Why?*

Ask: *Do you think scientists need to adjust the mixture of fuels used for launching spacecraft? What are some reasons they might need to make adjustments? How might the engineering process be used to do this?* (They would need to adjust for the distance the spacecraft must travel and for the mass of the spacecraft and its payload. Engineers also design different nozzles to adjust variables such as the velocity of the exhaust.)

***Be sure to collect the bicycle pumps, corks, needles, and duct tape roll and return them to the kit.**

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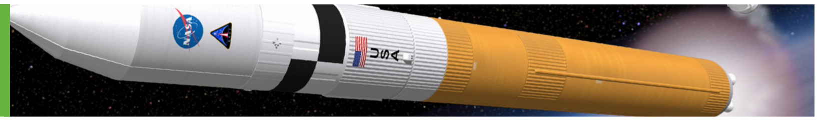

SUPPORT MATERIALS–FOR THE CLASSROOM VISITOR

Background Information

Newton's Second Law of Motion states that the greater the mass of an object, the more force is needed to accelerate that object. Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. Newton's Second and Third Laws of Motion play a part in how a rocket lifts off. As a rocket burns fuel, a hot gas is created and forced out of the back of the rocket. As the gas is expelled, the rocket is propelled with equal force in the opposite direction, once the force exceeds the weight of the rocket. Scientists have to adjust the rocket fuel and the exhaust nozzle for different missions based on the distance the spacecraft has to travel and its mass.

National Standards Alignment

- National Science Education Standard: (9-12) Standard A-1: Abilities necessary to do scientific inquiry
- National Science Education Standard: (9-12) Standard B-4: Motions and forces

Next Generation Science Standards Alignment

- Science and Engineering Practices: Constructing Explanations and Designing Solutions
- Science and Engineering Practices: Developing and Using Models

Preparation For Your Classroom Visit

Once a classroom visit has been established, check in with the host educator to make sure students are prepared and have some prior knowledge about the topic you have selected to share with the class.

An educator guide has been created for you to share with the host educator before your classroom visit. This guide includes pre- and post-visit resources and suggested activities that support the content you will be presenting during your classroom visit. Some of the information in the educator guide has been provided in the "Support Materials—For the Educator" section at the end of this document. Share the educator guide for this activity with the classroom educator as soon as you have a date for your visit. The educator guide can be found in the educator version of the Engineers in the Classroom website (www.classroomengineers.org).

Prior Knowledge

Students should be able to follow step-by-step instruction.

Students should have a working knowledge of Newton's Second and Third Laws of Motion.

Other Resources to Explore

Article: NASA–Brief History of Rockets
http://exploration.grc.nasa.gov/education/rocket/TRCRocket/history_of_rockets.html

Article: NASA–Newton's Laws of Motion
http://www.grc.nasa.gov/WWW/k-12/airplane/newton.html

Article: NASA–Rocket Thrust
http://exploration.grc.nasa.gov/education/rocket/rockth.html

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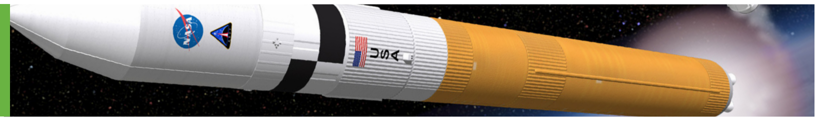

Video: NASA–Liftoff to Learning: Newton in Space
http://quest.nasa.gov/space/teachers/liftoff/newton.html

Website: Lockheed Martin
http://www.lockheedmartin.com/us/products/orion/orion-status-updates0.html

Website: TeacherTech–Newton's Laws of Motion
http://teachertech.rice.edu/Participants/louviere/Newton/

Classroom Management Tips

1. Consult the educator prior to the class period so your classroom management approach aligns with the management plan, routines, and procedures the educator already has in place. When relevant, discuss learning needs or behavioral challenges of specific students.
2. Establishing a culture of mutual respect and trust is key. At the beginning of the class period, tell students about yourself and why you are there. Discuss a clear and concise set of expectations that are phrased positively.
3. Complete any necessary setup prior to the start of the class period. Be well-prepared and organized so you can keep things moving. "Down time" can lead to a loss of student attention.
4. Help yourself stay on track with the activity and its objectives by using a timing device and notecard to guide you. The notecard could include a brief outline of the activity, key concepts/vocabulary, and questions to facilitate discussion. Use a timing device to stay on schedule. You could even enlist the help of one or more students to be your "timekeepers."
5. If you do lose students' attention, use existing strategies the teacher has in place to "bring them back" to the task at hand. Examples include interactive clapping, counting, hand-raising, and other forms of nonverbal communication.
6. Moving around the classroom, varying the tone and volume of your voice, enlisting volunteers to assist you, and calling on students to answer questions and share their ideas can help keep students engaged and focused. Avoid lecturing and talking at students without any interaction, especially for more than a few minutes at a time.
7. Avoid open-ended questions that encourage students to share their own experiences in a story-like manner. This can use up valuable time and distract students from the task at hand.
8. Seek teacher assistance in grouping students. Groups could be predetermined based on specific criteria, i.e. student learning and communication styles, ability to self-direct, and collaboration skills. During group work, be sure to circulate around the room, engage students with questions, and use proximity control to keep students on track.
9. Be yourself and have fun! If you are enjoying yourself and engaging with the students and the activity, then they will do the same.

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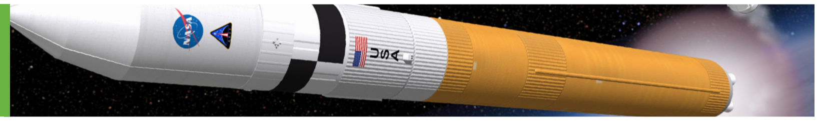

SUPPORT MATERIALS—FOR THE EDUCATOR

Tips

- Let students know in advance that they may get a little wet during the rocket launch.
- Set up cones or other visual aids to keep other students from walking into the rocket launch area.

Pre-Visit Resources and Activities

- Use the following resources to review Newton's Laws of Motion with students:
  - Simpler explanation: TeacherTech– Newton's Laws of Motion
    http://teachertech.rice.edu/Participants/louviere/Newton/
  - Intermediate explanation: NASA–Liftoff to Learning: Newton in Space
    http://quest.nasa.gov/space/teachers/liftoff/newton.html
  - Advanced explanation: NASA–Newton's Laws of Motion
    http://www.grc.nasa.gov/WWW/k-12/airplane/newton.html
- Pre-teach relevant vocabulary: Newton's Second Law of Motion, Newton's Third Law of Motion, propellant

Post-Visit Resources and Activities

- Have students brainstorm other changes they could make to optimize the rocket's distance and height, such as applying a nose cone, using a different type of bottle, etc. Have students make one change at a time and test the results.
- Learn more about rockets and find possible extension activities here: NASA–Brief History of Rockets
  http://exploration.grc.nasa.gov/education/rocket/TRCRocket/history_of_rockets.html
- Have students build more advanced rockets using these resources:
  - Article: Science in School–Sky-high science: building rockets at school
    http://www.scienceinschool.org/2012/issue22/rockets
  - Article: Make Zine: Hydrogen-Oxygen Bottle Rocket
    http://makezine.com/projects/hydrogen-oxygen-bottle-rocket/
- Review relevant vocabulary/concepts: Newton's Second Law of Motion, Newton's Third Law of Motion, propellant

For Further Exploration

- Article: NASA–Newton's Laws of Motion
  http://www.grc.nasa.gov/WWW/k-12/airplane/newton.html
- Article: NASA–Brief History of Rockets
  http://exploration.grc.nasa.gov/education/rocket/TRCRocket/history_of_rockets.html
- Article: NASA–Rocket Thrust
  http://exploration.grc.nasa.gov/education/rocket/rockth.html
- Video: NASA–Liftoff to Learning: Newton in Space
  http://quest.nasa.gov/space/teachers/liftoff/newton.html
- Website: Lockheed Martin
  http://www.lockheedmartin.com/us/products/orion/orion-status-updates0.html
- Website: TeacherTech–Newton's Laws of Motion
  http://teachertech.rice.edu/Participants/louviere/Newton/