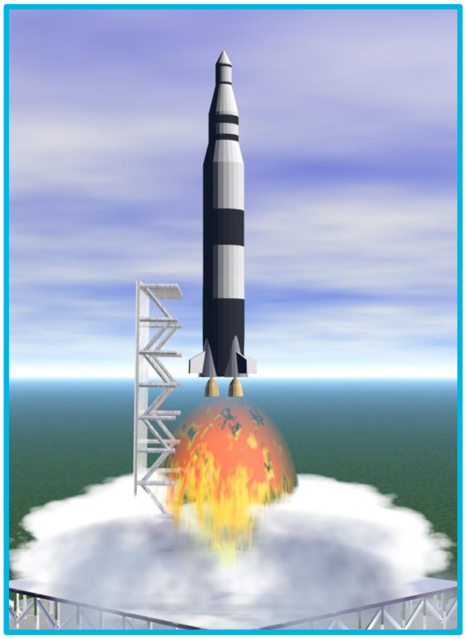
IEEE Lesson Plan:

Water Rocket Launch

Lesson Focus

Lesson focuses on aerospace engineering and how space flight has been achieved from an engineering vantage point. Student teams build and launch a rocket made out of a soda bottle and powered with an air pump and consider the forces on a rocket, Newton's Laws, and other principles and challenges of actual space vehicle launch. Teams design their structure on paper, learn about aerospace engineering, launch their rocket, and share observations with their class.



Lesson Synopsis

The "Water Rocket Launch" lesson explores rocketry and the principals of space flight. Students work in teams with teacher supervision and construct and launch a rocket from a soda bottle and everyday materials that is powered by an air pump. They observe their own achievements and challenges, as well as those of other student teams, complete a reflection sheet, and present their experiences to the class.

Age Levels

8-18

Objectives

- Learn about aerospace engineering.
- Learn about engineering design and redesign.
- Learn about space flight.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- aerospace engineering
- engineering design
- space flight
- teamwork

Lesson Activities

Students explore how engineers have developed rockets over the years, and learn about the principals of rocketry. They work in teams to construct and launch a rocket made from a soda bottle that launches with an air pump under teacher supervision. The students compare their accomplishments and challenges with those of other student teams, complete a reflection sheet, and present to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Timeline of Rocket History (http://history.msfc.nasa.gov/rocketry/)
- NASA Beginners Guide to Rockets (www.grc.nasa.gov/WWW/K-12/rocket/bgmr.html)
- Water Rocket Launcher (www.nasa.gov/pdf/153405main_Rockets_Water_Rocket_Launcher.pdf)

Recommended Reading

- Rockets and Missiles: The Life Story of a Technology (ISBN: 978-0801887925)
- Rocket Propulsion Elements (ISBN: 978-1118753651)
- Firing a Rocket (ISBN: 978-1549688683)
- "A Pictorial History of Rockets" (www.nasa.gov/pdf/153410main_Rockets_History.pdf)
- Soda-Pop Rockets: 20 Sensational Rockets to Make from Plastic Bottles (ISBN: 978-1556529603)

Optional Writing Activity

- Write an essay or a paragraph describing an example of rockets might be used to help society in peaceful times.

Safety Notes

- This is an outside activity.
- This exercise should only be done under the supervision of a qualified teacher.
- Safety glasses should be worn at all times.
- Since a quantity of water will be sprayed over the floor, it is suggested that old clothes or rain coats be worn by the test crew.
- Observing students should stand safely back from launch site.

Related Lesson

- TryEngineering.org offers a lesson incorporating traditional rockets called "Blast Off"

For Teachers:
Teacher Resource

- **Lesson Goal**

The "Water Rocket Launch" lesson explores rocketry and the principals of space flight. Students work in teams with teacher supervision and construct and launch a rocket from a soda bottle and everyday materials that is powered by an air pump. They observe their own achievements and challenges, as well as those of other student teams, complete a reflection sheet, and present their experiences to the class.

- **Lesson Objectives**
  - Learn about aerospace engineering.
  - Learn about engineering design and redesign.
  - Learn about space flight.
  - Learn how engineering can help solve society's challenges.
  - Learn about teamwork and problem solving.

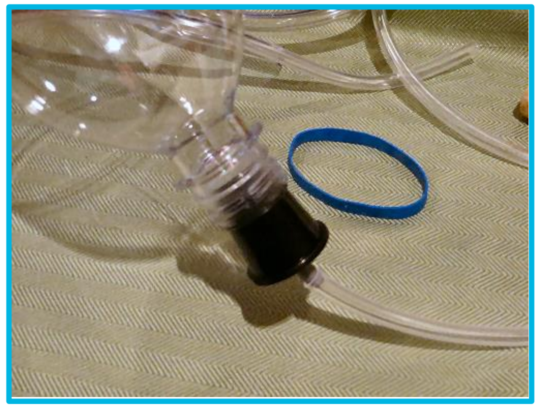
- **Materials**
  - Student Resource Sheets and Worksheets
  - Student Team Materials (if building from everyday items: empty soda bottle, cork, paper, pen, pencil; plastic tubing, bicycle tire valve, cardboard, glue, tape, rubber bands, foil, decoration materials.)
  - Kit option: Water bottle rocket kits may be purchased inexpensively (via Amazon.com, Antigravity Research at https://waterockets.com/, or through most teacher supply stores globally and might be better for younger students, or where there may be issues in drilling a hole through the required cork.
  - Classroom Materials: water source, drill (if not using a kit), bicycle tire pump, system/tools for measuring how high the rockets fly.
  - Internet access (optional) to explore www.grc.nasa.gov/WWW/K-12/rocket/ for research and to use online rocket simulator

- **Procedure**
  1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
  2. To introduce the lesson, consider asking the students how they think a rocket can fly and how engineers have to consider payload, weather, and the shape and weight of a rocket when developing a new or re-engineered rocket design.
  3. Teams of 3-4 students will consider their challenge, read about rocketry, and explore the online rocket simulator (if internet access is available)
  4. Teams next build and launch their rocket as a team, and observe the flight patterns of other rockets that are launched.
  5. For an optional challenge, require students to launch a payload with their rocket. They'll have to develop a design, add a way to hold an item such as a hardboiled egg or tennis ball on their rocket, and evaluate which design worked best.
  6. Teams reflect on the experience, and present to the class.

For Teachers:
Teacher Resource
Teacher Resources (continued)

◆ **Detailed Assembly and Launch Instructions**

If not using a kit, the procedure is as follows and should be reviewed at www.grc.nasa.gov/WWW/K-12/rocket/rktbot.html:



- Empty and clean a large plastic soda or water bottle.
- You will need to make the rocket stand up on its own upside down (cap down)…so either guide students to make "tail fins" out of cardboard that can support the weight of a bottle that is 1/4 filled with tap/still water, or make a stand for the class out of wood that will keep the rocket upright during launch. Lengths of wooden dowel held together with duct tape would suffice. For younger students, it is best to have a "launch pad" prepared by the teacher -- this will help ensure that rockets go up and not sideways.
- If you intend to do this lesson multiple times, or want to add another layer of consistency in results, consider building a launching stand for your school. A good plan is at www.nasa.gov/pdf/153405main_Rockets_Water_Rocket_Launcher.pdf. There are many options for building a launcher. Another idea is to set up a joint project with a high school class. The high schools students can design and build the launcher, and the younger students can build the rockets.
- For older students, or to provide additional challenge, after the initial launch, tell student teams that their rockets must now carry a payload (hardboiled egg, tennis ball, packs of sugar).
- Students may decorate their rockets, or, for an extra challenge, require student teams to develop a way to adapt the rocket to carry a payload. This can be done mid-way through testing the rockets to add a twist to the experience.
- Set up a connection from the bottle to a bicycle air pump.
  - You'll need to gather corks which will need to be drilled in order to insert a small plastic tube. Some "corks" are actually made from plastic now, and would be easier to drill evenly. Another alternative is to obtain one of the soft rubber plugs used as temporary stoppers in partially emptied wine bottles. (The type which can be pushed into the neck of the bottle and the air then pumped OUT with a small pump). In essence, the objective here is to somehow obtain a plug which can be tightly squeezed into the neck of the plastic bottle so that it is virtually air-tight.

For Teachers:
Teacher Resource

◆ **Detailed Assembly and Launch Instructions (continued)**

- Next obtain a small valve of the type which is used to pump up a football. Carefully drill a hole down the length of the cork. The drill used should be smaller than the diameter of the air valve, to ensure it is a really tight fit in the cork.
- For extra safety use a plastic tube (hardware store) to add some space between the bicycle pump and the rocket --- you'll need to have two valves to make this connection work. (Note: many kits come with an extension tube for safety.)

◈ Blast Off! Fill the bottle ¼ full with tap/still water and place it in a vertical position in its launchpad. Connect a bicycle pump to the air valve and start pumping GENTLY. Eventually, the pressure of air in the bottle should be sufficient to expel the cork from the bottle. The water in the bottle will then significantly slow down the outgoing flow of air thus giving time for the rocket to rise to a reasonable height. The actual height will partly depend on the weight of water in the bottle and the tightness of fit of the cork in the neck of the bottle. You can try using more or less water to adjust height of the rocket. Make sure you launch in an open area and keep student back from the launching rocket. You may get wet so ponchos or towels are recommended!

◆ **Safety Notes**

- This outdoor lesson is intended for students who are under the continual supervision of a responsible teacher or teacher team with prior experience with rocket launch kits.
- Be sure to follow your school's safety guidelines at all times.
- Observing students should stay back from launch pad.
- Extend the tube from the bicycle pump to the rocket as far as possible.
- Never stand over a rocket when it is launching.

◆ **Time Needed**

Two to four 45 minute sessions.

For Teachers:
Student Worksheet:

◆ Engineering Teamwork and Planning

You are part of a team of engineers given the challenge of building a model rocket using a soda or water bottle that will be attached to a bicycle air pump which will be the source of propulsion or energy. You can either make your rocket from everyday materials or use a kit that is provided to you. Either way, your goal is to have your rocket shoot up the highest and the straightest within your class. You'll research ideas online (if you have internet access), learn about rocket design and flight, and work as a team to construct and test your rocket. You'll consider the results of other teams, complete a reflection sheet, and share your experiences with the class.

◆ Research Phase

Read the materials provided to you by your teacher. If you have access to the internet, also visit www.grc.nasa.gov/WWW/K-12/rocket/ for additional research and to use the online rocket simulator, RocketModeler III.

◆ Planning and Design Phase

On a separate piece of paper draw a detailed diagram of how your rocket will look when completed and estimate how high you believe your rocket with travel. You'll need to design a base to hold your rocket before launch. Include a list of materials you will need and consider the weight you are adding to your base bottle.

If you have been given the challenge of adding a payload to your rocket, you'll need to design a way to have the bottle hold the item(s) you are launching into space. Payloads cannot be held inside the bottle.

◆ Build and Launch

As a team, build your rocket -- but always under the supervision of your teacher! You'll then test the rocket. Be sure to observe how high and how straight the rockets built by other teams go.

◆ Estimate Results

As a team, estimate how high your rocket will fly in the box below:

For Teachers:
Student Worksheet:

◆ **Reflection**
Complete the reflection questions below:

1. How did the height you estimated your rocket would reach compare with the actual estimated height?

2. What do you think might have caused any differences in the height you achieved?

3. Did your rocket launch straight up? If not, why do you think it veered off course?

4. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

5. Did you adjust your model rocket at all? How? Do you think this helped or hindered your results?

For Teachers:
Student Worksheet:

◆ **Reflection (continued)**
Complete the reflection questions below:

6. How do you think the rocket would have behaved differently if it were launched in a weightless atmosphere?

7. What safety measures do you think engineers consider when launching a real rocket? Consider the location of most launch sites as part of your answer.

8. When engineers are designing a rocket which will carry people in addition to cargo, how do you think the rocket will change in terms of structural design, functionality, and features?

9. Do you think rocket designs will change a great deal over the next ten years? How?

10. What tradeoffs do engineers have to make when considering the space/weight of fuel vs. the weight of cargo?

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:
- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry
As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of the activities, all students should develop an understanding of
- Properties of objects and materials
- Position and motion of objects

CONTENT STANDARD E: Science and Technology
As a result of activities, all students should develop
- Abilities of technological design
- Understanding about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives
As a result of activities, all students should develop understanding of
- Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science
As a result of activities, all students should develop understanding of
- Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry
As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of their activities, all students should develop an understanding of
- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

CONTENT STANDARD E: Science and Technology
As a result of activities in grades 5-8, all students should develop
- Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives
As a result of activities, all students should develop understanding of
- Risks and benefits
- Science and technology in society

For Teachers:
Alignment to Curriculum Frameworks

◆ National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor
- History of science

◆ National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Chemical reactions
- Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

◆ Next Generation Science Standards Grades 3-5 (Ages 8-11)

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 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.

Energy

Students who demonstrate understanding can:

- 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

◆ Next Generation Science Standards Grades 3-5 (Ages 8-11)

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

For Teachers:
Alignment to Curriculum Frameworks

◆Next Generation Science Standards Grades 3-5 (Ages 8-11)

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆Next Generation Science Standards - Grades 6-8 (Ages 11-14)

Motion and Stability: Forces and Interactions

- 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.

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.

Technology and Society

- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.