

Lesson 4: Blast Off!

Grade Level: 4 (3-5)

Lesson #: 4 of 6

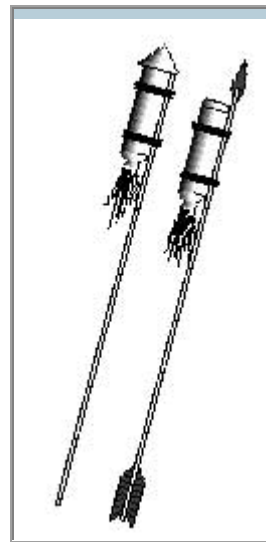
Time Required: 15 minutes

Lesson Dependency: Newton Gets Me Moving

Keywords: Newton, motion, rocket, thrust, fuel, chemical reaction, gas, pressure, action, force, oxidizer, propellant, space, energy

Summary: Rockets need a lot of thrust to get into space. In this lesson, students learn how rocket thrust is generated with propellant. The two types of propellants are discussed and relation to their use on rockets is investigated. Students learn why engineers need to know the different properties of propellants.

Engineering Connection: Engineers use powerful propellants in order to launch a rocket into space. When these propellants burn, hot gas is expelled out the nozzle causing the rocket to move forward. In order to achieve the necessary speeds, engineers must understand the chemical properties of the different propellants. Factors such as weight, efficiency, controllability and safety are all things engineers must keep in mind when choosing a propellant. Individual propellants are better for different tasks, and it is the job of the engineer to choose which and how much of a propellant to use.



Ancient Chinese fire-arrows
Copyright © NASA Quest,
<http://quest.arc.nasa.gov/space/teachers/rockets/history.html>

Learning Objectives

After this lesson, students should be able to:

- Use Newton's third law of motion to explain how a rocket launches.
- Explain the difference between propellant and fuel.
- Describe how weight of fuel affects the ability to get a rocket into space.
- Explain why engineers need to know the properties of different propellants.

Introduction/Motivation

Have you ever seen a real rocket being launched? If you have, I bet you noticed a lot of fire and smoke. Why was that happening? Imagine how hot it would be if you were standing close to the launch pad! Do you remember how a rocket moves? (Refer to Lesson 2: Newton Gets Me Moving.) That's right, the rocket moves by shooting mass (hot gas) from the vehicle at a high velocity or speed. Whose law was this? (Answer: Newton's third law of motion) What does Newton's third law say? Remember, it states that for every *action* there is an equal and opposite *reaction*. So, when the rocket shoots mass (hot gas) out in one direction, the rocket actually moves away in the opposite direction! The direction it moves in is a result of *thrust*.

Launching a rocket into space requires a lot of energy. That energy comes from something called *propellant*. Did you know that a car uses propellant? A car burns gasoline and air in its engine so that the car can travel down the road. Rockets and cars are similar in this way, but a rocket has to

travel 62 miles above the Earth to reach space at a speed of 25,000 miles per hour. How does it do it?

In order to design Tess' rocket, her engineering team (that's you!) needs to understand what sort of propellant to use, how propellants work and finally, how much to use. Propellant is a little bit different from fuel in that propellant contains both *fuel* and *oxidizer*.

Let's start with the oxidizer. What chemical does the word oxidizer resemble? (Answer: oxygen) What does fire need in order to burn? (Demonstration: Light a candle in front of the class and ask the students what are the ways that we could put the flame out? Place a larger glass on top of the candle cutting off air supply to it. Students should realize that the fire needs something in the air in order to burn. Answer: oxygen.) That is correct: fire needs oxygen to burn. What does oxidizer mean, then? It is a substance that supplies oxygen in order to burn a fuel.

So now that you know about an oxidizer, let's learn about the propellant? Propellant is generally what we think of as fuel. In the case of the candle, what is the fuel? (Answer: wax) What types of fuel can you list? (Possible answers: gasoline, natural gas, propane, kerosene, wood, coal, wax, etc. In order to get some answers, ask students about appliances and vehicles in their house and how they think they run?) These are all examples of fuels. Which ones are examples of liquid fuel? (Possible answers: gasoline, kerosene, etc.) Which ones are examples of solid fuel? (Possible answers: wood, coal, wax, etc.)

Choosing an appropriate fuel for Tess' rocket is very important. What factors would affect our choice? (Answer: Weight and rate of burning are perhaps the most important factors.) Weight is incredibly important because fuel weighs a lot. And, we have to launch the rocket with all the fuel attached to it. Additionally, we have to have enough fuel to get Tess, the rocket and the satellites all the way into space!

Ideally, any rocket — including Tess' — is approximately 90% propellants, 4% tanks, engines, fins, etc. and 6% payload (spacecraft, satellites and astronauts). That is a lot of propellants. Basically, that means that the weight of the propellant, the tanks and the payload must add up to 100%. Let's try a short mental math exercise. If Tess' satellite weighs 6 tons, and the tanks, engines, and body of the rocket weigh 4 tons, how many tons would the propellants weigh? (Answer: $6 + 4 = 10$. Then, $100 - 10 = 90$. The answer is 90 tons. The total of all of them is 100 tons). How about another one: if the total rocket weighs 100 pounds (it's a small rocket), how much of that weight should be propellant? (Answer: 90% of 100 pounds is 90 pounds - because we already know that 90% of the total weight is propellant.) How about the payload and tanks together? (Answer: 100 pounds - 90 pounds is 10 pounds. Together, the payload and tanks should weigh 10 pounds.)

Now that we have a basic concept of propellants and their importance in getting Tess and her cargo into space, we can learn more about how propellants work and how rocket thrust is generated. Are you ready, engineers? We're ready for launch!

Lesson Background & Concepts for Teachers

Rockets are able to travel into space because of a force called *thrust*. How is thrust generated? The answer is *propellant*. When rocket propellant is burned, hot gases expand very quickly through a nozzle. These hot gases are then forced out the back of the rocket which produces an equal and opposite direction upward due to Newton's third law of motion.

What exactly is propellant and how does it work? Propellant is made up of a fuel and an oxidizer. There are two types of propellant used in chemical rockets: liquid and solid.

Liquid Propellant

Liquid propellant is composed of liquid fuel and oxidizer. Rockets use many different combinations of these two substances. One example of liquid propellant is liquid hydrogen with liquid oxygen. The large, orange external fuel tank on NASA's Space Shuttle holds both of these two chemicals (see Figure 2).

You cannot see it from the outside, but the chemicals are separated from one another until launch time. Then during the launch procedure, the chemicals flow through a bunch of pipes and valves until they reach a chamber where they are burned. The burning of this propellant creates a high pressure and high velocity gas. This gas travels through an exit nozzle which makes the gas move even faster. The faster the gas can leave the nozzle, the more thrust the rocket will have.

The liquid propellant on the Space Shuttle is used to fire the three main engines on the orbiter. These main engines can move in a specified order to control the direction of the Shuttle. Liquid propellant is good to use because it can provide a lot of thrust. Also, rockets using liquid propellant can be quickly shut down should there be a problem — an extremely important safety feature. However, because of how complex they are, these types of chemical rockets can be very expensive to design and build. This is why other rockets use a different type of propellant, called *solid* propellant.

Solid Propellant

Many people do not think of fuel as being solid. However, there are many ordinary examples of solid fuel all around you, such as wood and coal. Even candle wax is a solid fuel. Energy is slowly released as the wax melts and is consumed by the flame. Solid propellant that is used in rockets utilizes substances that are a bit more complex and burn at a much faster rate, but the idea is still the same. The most famous solid rockets are the two white solid rocket boosters (SRBs) that are attached to the orange external tank on the Space Shuttle (remember, the orange external tank uses liquid propellant. The solid fuel used in the SRBs is atomized aluminum, and the oxidizer is ammonium perchlorate.

Solid propellant rockets may have a hole drilled through the center that is shaped like a circle or star (or other possibly complicated shape). The interior shape of the hollowed out core is an important factor in determining a rocket's performance. The amount of propellant exposed to burning flames is called surface area. An increase in surface area will increase thrust but will reduce burn-time since the propellant is being consumed faster. Typically, solid rockets will start out having a large propellant surface area because rockets need the greatest amount of thrust to get off the ground. After the propellant has burned for some time, the surface area will decrease since the required thrust is less. For example, a star configuration would accomplish this necessary surface area change over time in that as the propellant burns, the star will eventually become circular and the surface area will be less. The SRBs on the Space Shuttle actually use an 11-point star configuration.



Figure 2. NASA's Space Shuttle Discovery
Copyright © National Aeronautics and Space
Administration, <http://www.nasa.gov/centers/kennedy/shuttleoperations/orbiters/discovery-info.html>

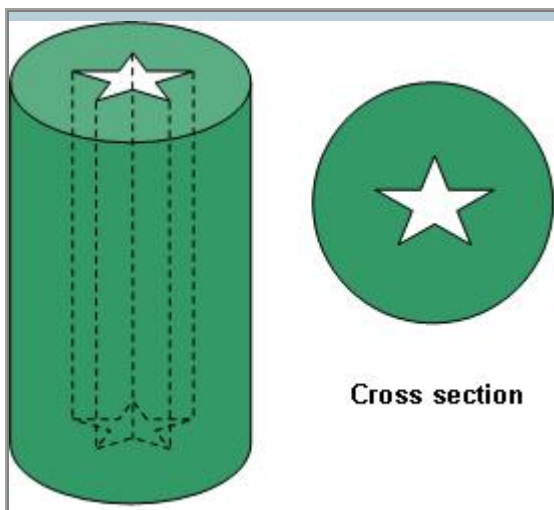


Figure 3. Solid rocket with star configuration.
 Copyright © Image created by Luke Simmons, University
 of Colorado at Boulder, 2004.

Solid propellant rockets are relatively simple. Unfortunately, once a solid rocket is ignited, it will consume all of its propellant without any option to turn it off. Therefore, if anything goes wrong, this can potentially pose a dangerous situation. Because of this, the SRBs are the last component to be turned on before launch so that if anything goes wrong before then, the mission can be aborted.

Thrust for a rocket continues as long as its engines have propellant that can be burned. Furthermore, the mass of the rocket changes during flight. Its mass is the sum of all its parts, including engines, fuel tanks, payload, control system and propellant. By far, the largest part of the rocket's mass is its propellant (note: earlier in this lesson, we learned that the propellant accounts for 90% of the weight of the rocket). This mass constantly changes as the engines burn and eject the propellant — ultimately decreasing the rocket's mass during flight. The

acceleration of the rocket will increase as its mass decreases due to Newton's second law of motion, which states that the force of an object is equal to its mass times its acceleration.. A rocket is accelerating fastest when its propellant is almost gone. Newton's second law of motion can be restated as such when explaining rockets: the greater the mass of propellant ejected, combined with the speed with which it is ejected from the engine, then the greater the thrust force which pushes the rocket in the opposite direction.

Simulating Rocket Launches

Did you know that fireworks that shoot up into the air are actually rockets? Gunpowder is often used in fireworks as a solid propellant. You could launch a model rocket into the air with gunpowder to simulate a real rocket launch. A safer alternative, however, is to use the energy stored in an antacid tablet (such as Alka-Seltzer®), which contains aspirin, sodium bicarbonate (NaHCO_3) and citric acid ($\text{C}_6\text{H}_8\text{O}_7$). When the tablet is dissolved in water (or some other liquid), a chemical reaction occurs between the sodium bicarbonate and the citric acid: the hydrogen ions (H^+) and carbonate ions (CO_3^{2-}) are freed to collide and react in the solution. The products of the reaction are carbon dioxide (CO_2) gas and water. The carbon dioxide can be seen as bubbles in the gas. If you find a way to capture the carbon dioxide created, you can release this pressure and use it to create thrust.

Vocabulary/Definitions

- Gas:** a collection of molecules with enough energy to remain isolated and free floating (as opposed to liquids and solids where particles group together).
- Chemical Reaction:** A process where one type of substance is chemically converted to another substance involving an exchange of energy.
- Pressure:** Results from collisions of gas molecules with a surface. It is defined as force/area, which is measured in units of lb/in² (psi) or N/m² (Pa).
- Fuel:** Something consumed to produce energy.
- Oxidizer:** A substance that supplies oxygen in order to burn a fuel.
- Thrust:** The forward-directed force of a jet or rocket engine as a reaction to the ejection of exhaust gases.
- Surface Area:** The amount of exposed or outer material of any object.

Associated Activities

- Fuel Mystery Dis-Solved! - In this activity, students discover how solid fuels are consumed and what variables affect the rate of reaction.
- Aqua-Thrusters! - In this activity, students investigate how solid fuels produce thrust by constructing a rocket powered boat.
- Pop Rockets - Students will launch a paper rocket using solid fuel in this activity.

Lesson Closure

In this lesson, we learned that a rocket can be launched into space by expelling propellant in the opposite direction. Which law is this? That's right, Newton's third law of motion! Newton's second law tells us that force equals mass times acceleration. So, we know that the larger the amount of propellant and the faster it is pushed out the back of the rocket, the more thrust the rocket will have. Also, we learned that rockets could use either liquid propellant or solid propellant. Propellants are made up of a fuel and an oxidizer. Can you tell me what an oxidizer is? (Answer: something that gives oxygen to be burned) Different fuels are able to provide different amounts of energy at different rates, and it is the job of engineers to find fuels that provide the most energy for the rocket. This means that engineers have to also think about the weight and cost of the fuel as well.

In order for Tess to be able to explore space and to carry the satellites that will be part of the rocket cargo for use to communicate with her mother, Maya, her rocket needs to successfully make it into space. Since you all, as the engineering team, now understand propellants and how they work, you know one more important factor behind engineering Tess' rocket.

Assessment

Pre-Lesson Assessment

Discussion Question: Solicit, integrate and summarize student responses.

- Ask the students if candy lasts longer when you chew it or just suck on it. (Answer: Sucking lasts longer. If you chew it into many pieces you have actually increased the candy's surface area, and your saliva will dissolve it faster!) Do you get more candy if you chew it up? (Answer: No, it is the same amount of candy. It just does not last as long.) These are important concepts to understand for learning about solid fuel.
- Shake up a can of soda pop. Open the can over the sink or outdoors. Ask the students what happened to cause the pop to explode. (Answer: The drink is carbonated with carbon dioxide gas. The gas is usually dissolved into the liquid because the can is pressurized. When you shake the can, some of the gas is no longer dissolved and bubbles form on the sides and bottom of the can. When you open the can, the undissolved gas bubbles try to escape and push liquid out in the process since it is in the way.)

Post-Introduction Assessment

Question/Answer: Ask the students questions and have them raise their hands to respond. Write their answers on the board.

1. Does launching a rocket into space require energy? (Answer: yes)
2. What material is used to generate thrust in a rocket? (Answer: propellant)
3. What are the two types of propellant? (Answer: liquid and solid)
4. What is the difference between a propellant and fuel? (Answer: Propellants are made up of a fuel and an oxidizer.)
5. What is used as propellant in cars? (Answer: Gasoline and air: gasoline is the fuel and air is the oxidizer.)
6. Why do engineers need to know the properties of different propellants? (Answer: Engineers need to know about the properties of propellants in order to launch a rocket successfully into space.)

Class Discussion: Show pictures or video clips of rocket launches (from NASA's website at <http://search.nasa.gov/nasasearch/search/search.jsp?nasalInclude=launch+video+clips> or from v2Rocket.com at http://www.v2rocket.com/start/others/aud_vid.html). In groups of 2-3, have students discuss what powers a rocket. (Note: fire and fuel are popular answers.) Fire is the result of fuel burning, but how exactly does the fuel store and release energy? (Answer: Fuel stores chemical energy which is released when the fuel burns, causing an expansion of gases and a pressure increase. These gases are expelled out of the back of the rocket very quickly through a nozzle which makes the rocket move in the opposite direction because of Newton's third law of motion).

Lesson Summary Assessment

Mental Math/Pairs Check: Have students work in pairs to answer following questions.

Ideally, any rocket, is approximately 90% propellants; 4% tanks, engines, fins, etc.; and 6% payload (spacecraft, satellites and astronauts). Think of a pie graph when picturing the distribution; the biggest chunk is propellants.

- If a satellite weighs 5 tons, and the tanks, engines, and body of the rocket weigh 5 tons, how many tons would the propellants weigh? (Answer: $5 + 5 = 10$ tons. $100 - 10 = 90$ tons. The answer is 90 tons.)
- Challenge: If the total rocket weighs 200 tons, how much of that weight should be propellant? (Answer: 90% of 100 tons = 90 tons, so 90% of 200 tons = 180 tons. The answer is 180 tons.)

Toss-a-Question: Ask students to independently think of an answer to each of the questions below and write it on a half sheet of paper. Have students wad up and toss the paper to another team member who then adds his/her answer. After all students have written down ideas, have them toss the paper wad to another student, who then reads the answers aloud to the class. Discuss answers with the class.

- Can any material be a fuel? (Answer: No, only materials that react with something and cause a change in energy of its particles can be a fuel.)
- How is pressure created in a rocket engine? (Answer: A reaction takes place that gives particles more energy causing them to move more and take up more space which increases the pressure.)
- How does the amount of surface area affect the rate at which fuel burns? (Hint: Remind students to think about the piece of candy example from the Pre-Assessment section.) (Answer: More surface area means a faster reaction; less surface area produces a slower burn.)

Lesson Extension Activities

- Go to NASA's website (<http://search.nasa.gov/nasasearch/search/search.jsp?nasalInclude=launch+video+clips>) and download a movie clip of any shuttle launch to see it!
- *Class debate:* Have students work in groups of four. Two students will argue in favor of solid propellant on the latest NASA rocket to Mars; the other two will argue in favor of liquid propellant. Have students report back to the entire class on how they feel their debate went and if they formed an agreement.
- Have students investigate other methods of propulsion — instead of chemical rockets, such as ion and nuclear rockets.
- Have students research the difference between a jet engine and a chemical rocket engine.

Activity 4a: Fuel Mystery Dis-Solved!

Grade Level: 4 (3-5)

Group Size: 2

Time Required: 50 minutes

Activity Dependency: None

Expendable Cost Per Group: US \$1

Keywords: chemical reaction, fuel, surface area, temperature, rockets, space, propellant, energy

Summary: In this activity, students investigate the simulated use of solid rocket fuel by using an antacid tablet. Students observe the effect that surface area and temperature has on chemical reactions. Also, students compare the reaction time using two different reactants: water and vinegar. Finally, students report their results using a bar graph.

Engineering Connection: An engineer must understand chemical reactions when designing a rocket propellant. Safety, amount of thrust and amount of heat are all important considerations to rocket performance. Also, engineers must know and understand the properties of fuel so that they can design rockets that effectively maximize their fuel consumption.



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6399 USA. All rights reserved.

Learning Objectives

After this activity, students should be able to:

- Describe how temperature and surface area exposure affect the rate at which fuel is consumed.
- Explain why engineers want to know about the properties of a fuel when designing rockets.
- Create a bar graph of result data.

Materials List

Each group needs:

- 3 solid halves and 3 crushed halves of antacid tablets (e.g., Alka-Seltzer™. Do NOT use Tums™ tablets.)
- 1 clear plastic cup
- 1 stopwatch or clock with a second hand
- Enough vinegar to fill the provided, clear cup
- 2 pair of safety glasses/goggles

To share with the entire class:

- Access to a sink to get and dispose of tap water

For class demonstration:

- 1 tablespoon baking soda
- ¼ c. vinegar
- 1 clear cup or bowl

Introduction/Motivation

Have you ever mixed baking soda together with vinegar? What happens? (Mix the two ingredients in a clear bowl or cup for students to observe the reaction.) These two substances form a chemical reaction when they are mixed together, causing carbon dioxide to be produced. That is why you see a lot of fizzing and bubbling. A similar reaction occurs when you drop an antacid tablet in a cup of water. Pretty cool!

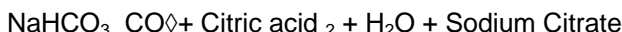
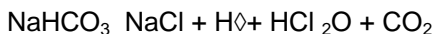
So, how does this relate to rockets? Some rockets use solid fuel propellant to generate *thrust*. What is thrust? Thrust is the forward motion of a rocket engine as a reaction to gas being ejected from it. That is how the rocket gets into space. Remember Newton's third law of motion? (The third law states that for every *action* there is an equal and opposite *reaction*.) The chemical reaction is set off in solid fuel rockets by lighting them on fire! Did we have to light the baking soda on fire to get it to work? No. Some of the factors that affect a chemical reaction are the same whether you have to light the fuel on fire or not. .

When rocket fuel is burning, a chemical reaction is occurring. An engineer must understand this reaction when designing a rocket. In order to get Tess and her cargo into space safely, it is very important to understand that chemical reactions are not only very useful, but if not done with proper understanding, they can be potentially dangerous also. How the different chemicals react affect how much thrust will be created, as well as how much pressure and heat will be created. The condition under which the chemical reaction occurs also affects its outcomes. This information is critical to you all as Tess' engineering team when trying to decide how much propellant is needed, how strong the rocket has to be, and how much heat shielding the rocket needs (burning fuel can be hot!). Today, we will perform an experiment that will allow us to see what affects chemical reactions. This will help us design the best rocket to get our cargo into space.

Procedure

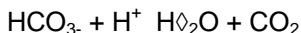
Chemical Reaction Background

The chemical reaction that occurs in the body with an antacid tablet is as follows:



The sodium bicarbonate (NaHCO₃) in the alka-seltzer tablet reacts with the hydrogen chloride (HCl) acid in the stomach to neutralize it, producing carbon dioxide (CO₂) as a byproduct.

Essentially, what is happening in these reactions (with vinegar and water) is that a proton (H⁺) is being freed up by being in a liquid solution, as is HCO₃⁻ from the sodium bicarbonate and is described by the following chemical equation:



Before the Activity

1. Remove antacid tablets from packaging and break them in half (see Figure 1).
2. Prepare crushed tablets.
3. Clean up any white powder that has been spilled, as it may be mistaken for many other illegal or dangerous substances.

With the Students

1. Each group should be given one cup filled with cold tap water.
2. Give each group a solid half tablet of antacid. (Note: Antacid tablets should be given out only as needed so that the instructor knows that all tablets are accounted for and used appropriately in the experiment.)
3. Have one student start the stopwatch as another student puts the half tablet of antacid into the cup of water.
4. Have the students stop the stopwatch when the tablet is completely dissolved and they no longer hear/see the fizz.
5. Allow students to record their time and make observations on the Fuel Analysis Worksheet before continuing.
6. Have the students empty out their cup into the sink and fill it back up with cold tap water. They should refill their cup with the same amount of water as they had before.
7. Give each group a crushed half tablet of antacid.
8. Repeat steps 3-5.
9. Have the students empty out their cup in the sink again. This time, have them fill it up with hot water, to the same level that they had previously filled their cup with cold water. Have them repeat the experiment again for each of a solid half tablet and a crushed half tablet. Have them record their results on the Fuel Analysis Worksheet.
10. Have the students empty out their cup in the sink again. This time, have them fill it up with vinegar, to the same level as they filled the water. Have them repeat the experiment two times again, using each of a solid half tablet and a crushed half tablet. Have them record their results on the Fuel Analysis Worksheet.
11. Have the students complete the Fuel Analysis Worksheet by making a bar graph of their results and answering the final question.

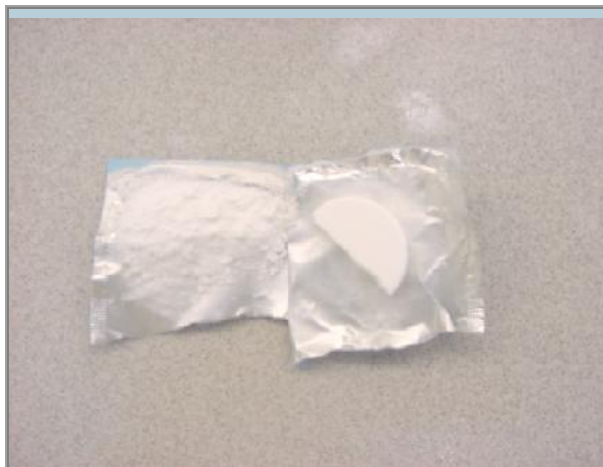


Figure 1. Antacid tablet.
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Attachments

- Fuel Analysis Sheet - 3rd Grade
- Fuel analysis sheet - 4th-5th Grade

Assessment

Pre-Activity Assessment

Prediction: Of the scenarios listed below, have the students predict which will dissolve faster; have them record their predictions on the board.

- Solid antacid tablet versus crushed antacid tablet;
- Antacid in hot water versus cold water; or
- Antacid tablet in water versus vinegar.

Activity Embedded Assessment

Worksheet/Pairs Check: Have students work individually or in pairs on the Fuel Analysis Worksheet. After students finish the worksheet, have them compare answers with a peer or another pair, giving all students time to finish the worksheet.

Post-Activity Assessment

Prediction Analysis: Have students compare their initial predictions with their test results, as recorded on the worksheets. Ask the students to explain why they think the tablet dissolved faster when they are crushed or in hot water.

Numbered Heads: Have the students on each team number off so that each member has a different number. Ask the students a question (give them a time frame for solving it, if desired). The members of each team should work together to answer the question. Everyone on the team must know the answer. Call a number at random. Students with that number should raise their hands to give the answer. If students do not know the answers, allow the teams time to work a little longer. Ask the students:

- Does a crushed antacid tablet dissolve faster than a solid tablet in a liquid? (Answer: Yes, crushed tablet dissolves faster.)
- Why does more surface area (crushed tablet) decrease the time it takes for the tablet to dissolve? (Answer: More surface area means more molecules of the antacid can react with the liquid molecules immediately.)
- How are antacid tablets related to solid rocket fuel? (Answer: Both contain stored energy. When a chemical reaction is started, this energy is released and can be used.)
- Does an antacid tablet dissolve faster in hot or cold water? (Answer: Hot; it has more energy to react with the antacid.)
- Why do you think hot water increases the rate of reaction? (Answer: Warm water moves faster than cold water. It has more energy in the form of water molecules that vibrate and move around faster than those in cold water. These faster moving warm water molecules find and react with antacid molecules much quicker than cold water molecules.)
- Should an engineer design a dishwasher to use solid blocks of soap or powdered soap if they want the soap to mix with the water quickly? (Answer: Powder, since it has more surface area.)
- Which cleans dishes better, hot or cold water? (Answer: Hot water because the extra energy of motion makes the hot water particles mix with the soap faster! Although unrelated to chemical reactions, the heat also softens the food making it easier to remove.)

Activity Extensions

Have the students repeat the experiment at a number of different liquid temperatures. Have them record the temperature with a thermometer and make a new graph of the results.

Have the students repeat the experiment with antacid tablets cut into thirds, quarters, fifths, etc. Have them graph the new results.

Have students try different brands of antacids to determine if there are any differences in the results.

Safety Issues

Remind students not to put the antacid tablets (crushed or solid) in their mouths; if a student eats a solid tablet they could become very sick.

Make sure the students wear safety glasses when putting the antacid into the water.

Hand out antacid only as necessary; do not give each group a "supply" in advance.

Troubleshooting Tips

In order to effectively use half tablets of antacid in both solid and powder form, this method of preparation can be used:

1. Use scissors to cut a two-tablet packet down the middle (between the two whole tablets).
2. Carefully, tear open each of the foil antacid packets and remove both tablets. Break them in half as evenly as possible.
3. Place $\frac{1}{2}$ of each tablet back into its foil packet.
4. Fold over the open end of one of the packets, hold it shut and use a blunt object to crush the half tablet in the packet (this takes some practice but works well). Repeat for the other tablet.
5. Now you should have two crushed half tablets nicely contained in their packets and two solid half tablets set aside.

Name: _____ Date: _____

Fuel Mystery Dis-Solved Activity – Fuel Analysis Worksheet – 3rd Grade

Test 1 – Solid Tablet with Cold Water

What happened to the fuel? _____

What happened to the water? _____

Time: _____

Test 2 – Crushed Tablet with Cold Water

What happened to the fuel? _____

What happened to the water? _____

Time: _____

Test 3 – Solid Tablet with Hot Water

What happened to the fuel? _____

What happened to the water? _____

Time: _____

Test 4 – Crushed Tablet with Hot Water

What happened to the fuel? _____

What happened to the water? _____

Time: _____

Test 5 – Solid Tablet with Vinegar

What happened to the fuel? _____

What happened to the water? _____

Time: _____

Name: _____ Date: _____

Test 6 – Crushed Tablet with Vinegar

What happened to the fuel? _____

What happened to the water? _____

Time: _____

Make a bar graph of your results!

Color in the boxes from left to right until you have reached your recorded time.

Test 1: Solid/cold												
Test 2: crush/cold												
Test 3: Solid/hot												
Test 4: Crush/hot												
Test 5: Solid/vinegar												
Test 6: Crush/vinegar												
	10sec	20sec	30sec	40sec	50sec	1 min	1 min 10sec	1 min 20sec	1 min 30sec	1 min 40sec	1 min 50sec	2 min

Time

Final Question

How would stirring the water affect the dissolving antacid? Why would engineers need to know this?

Name: _____ Date: _____

Fuel Mystery Dis-Solved Activity – Fuel Analysis Worksheet – 4th-5th Grade

Test 1 – Solid Tablet with Cold Water

Fuel observations: _____

Water observations: _____

Time for reaction to complete (in minutes and seconds): _____

Test 2 – Crushed Tablet with Cold Water

Fuel observations: _____

Water observations: _____

Time for reaction to complete (in minutes and seconds): _____

Test 3 – Solid Tablet with Hot Water

Fuel observations: _____

Water observations: _____

Time for reaction to complete (in minutes and seconds): _____

Test 4 – Crushed Tablet with Hot Water

Fuel observations: _____

Water observations: _____

Time for reaction to complete (in minutes and seconds): _____

Test 5 – Solid Tablet with Vinegar

Fuel observations: _____

Vinegar observations: _____

Time for reaction to complete (in minutes and seconds): _____

Name: _____ Date: _____

Test 6 – Crushed Tablet with Vinegar

Fuel observations: _____

Vinegar observations: _____

Time for reaction to complete (in minutes and seconds): _____

Make a bar graph of your results!

Color in the boxes from left to right until you've reached your recorded time.

Test 1: Solid/cold												
Test 2: crush/cold												
Test 3: Solid/hot												
Test 4: Crush/hot												
Test 5: Solid/vinegar												
Test 6: Crush/vinegar												
	10sec	20sec	30sec	40sec	50sec	1 min	1 min 10sec	1 min 20sec	1 min 30sec	1 min 40sec	1 min 50sec	2 min

Time

Final Question

How would stirring the liquid affect the dissolving antacid? Describe how stirring would affect the “fuel,” and predict whether the antacid would dissolve faster or slower. Why would an engineer want to know this about rocket fuel?

Activity 4b: Aqua-Thrusters!

Grade Level: 4 (3-5)

Group Size: 2

Time Required: 50 minutes

Activity Dependency: None

Expendable Cost Per Group: US\$.50

Keywords: fuel, thrust, surface area, chemical reaction, boat, rocket, Newton, energy, motion, antacid, Alka Seltzer®

Summary: In this activity, students construct their own rocket-powered boat called an "aqua-thruster." These aqua-thrusters will be made from a film canister and will use carbon dioxide gas — produced from a chemical reaction between an antacid tablet and water — to propel it. Students observe the effect that surface area of this simulated solid rocket fuel has on thrust.

Engineering Connection: Engineers design powerful propellants in order to launch a rocket into space. In order to design the propellant properly and with enough thrust, they must understand the chemical properties of the different propellants. Factors such as weight of propellant must also be considered for flight in space as well as air flight.



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98052-6399 USA. All rights reserved.

Learning Objectives

After this activity, students should be able to:

- Explain that thrust can be created by a chemical reaction and what affects it.
- Compare the motion of a model rocket-boat to a rocket designed to travel in space.
- Describe some of the factors that engineers consider when choosing propellants for rocket design.

Materials List

Each group needs:

- 1 solid half and 1 crushed half of an antacid tablet (e.g., Alka-Seltzer™. Note: do not use Tums™.)
- 1 film canister. (Note: Film canisters are readily available at no charge from camera shops and stores where film is processed, such as grocery stores, Target, Costco, etc. These businesses recycle the canisters and are often willing to donate them for educational use. Most of the canisters they have will be the solid black ones (see Figure 1, center canister). These are good for this activity. The elliptical-shaped canister is used for Advantix® film (see Figure 1, left canister) work too.



Figure 1. Film canisters
Copyright © Photograph taken by Jeff White, University of Colorado at Boulder, 2003.

- 1 stopwatch or a clock with a second hand
- Small piece of construction paper, a strip of heavy tape (such as electrical tape), or a small cutout of dense foam
- To share with the entire class:
- Safety glasses (enough pairs for the largest group)
- Large sink, tub or other plastic/glass container that will hold water

Introduction/Motivation

Have you ever been in a boat before? How did it move? Did it move using a motor? How about a paddleboat? They move when you paddle the pedals with your legs. Let's think about Maya in her canoe. How does she move? She uses her own energy to move through the water with paddles. If she were on a sailboat, the wind would push her along. Do you think Maya's canoe or any other boat could be powered with a rocket? Yes, it actually can! Rockets burn propellant (a combination of fuel and oxygen) to create enough thrust to get into space. Who can tell me what thrust is? That's right, it is the forward motion of an object as a force pushes away from the object in the opposite direction.

Today, we will make a rocket-powered boat using an antacid tablet and water. The antacid and water will form a chemical reaction and produce a gas, just like the solid propellant on a real rocket would. If we capture this gas and then release it, we can create thrust. Is there any way that we can control how much thrust is generated by a propellant? (Brainstorm ideas with students.)

When propellants burn, an immense amount of pressure is created. This pressure is released through the nozzle or opening of a container. The smaller the nozzle that the chemical reaction pressure is forced through, the more thrust — or forward motion — is created. Think about a garden hose. Have you noticed that if you make the nozzle on the garden hose smaller, then the water comes out in a faster stream? This is the type of stream you use to wash your car versus the more open nozzle and slower stream you may use to water plants.

As Tess' engineering team you must have a good understanding of the chemical reaction occurring in the rocket. You must understand the different factors that affect the thrust, such as the type of propellant, the temperature, the pressure, and whether the propellant makes the

rocket move forward in a smooth or choppy motion. With all this dangerous fuel onboard, Tess' engineering team must do a good job designing the thrust system so that everyone is safe and the mission is a success. Engineers need to consider all of these things when choosing a propellant and designing the container in which the propellant will be used. Are you ready to build your rocket-boats? Let's go!

(Note: For the purpose of this activity, rocket-boat and aqua-thruster are used interchangeably.)

Procedure

Before the Activity

1. Remove antacid tablets from packaging and break them in half.
2. Prepare crushed tablets.
3. Clean up any white powder that has been spilled, as it may be mistaken for many other illegal or dangerous substances.
4. Use a pin to poke a small hole into each film canister lid. The smaller, the better, and as close to the edge as possible without hitting the seal (see Figure 3) is best.
5. Fill the LARGE sink or plastic/glass tub with water.

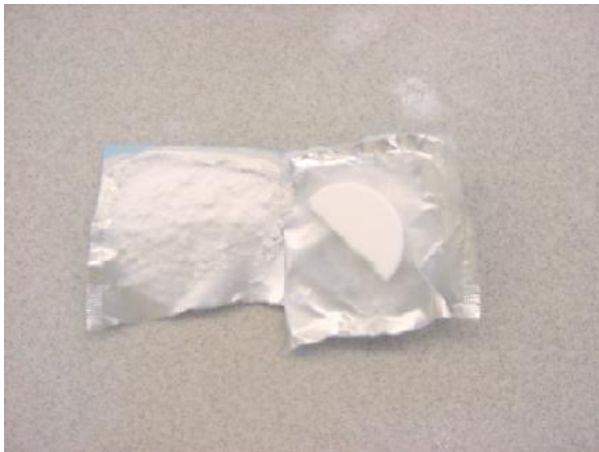


Figure 2. An antacid tablet
Copyright © Photograph taken by Jeff White, University of Colorado at Boulder, 2003.

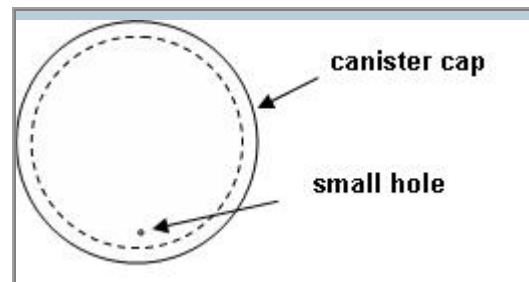


Figure 3. Canister cap with hole
Copyright © Image created by Jeff White and Luke Simmons, University of Colorado at Boulder, 2004.

With the Students

Test 1

1. Each group should be given a film canister and lid with a pinhole already poked into it.
2. Have the students make a fin or keel for their aqua-thruster. A small piece of dense foam, folded construction paper, or even tape doubled over on itself and cut to a fin shape can be used. This will help the aqua-thrusters keep their pinhole nozzles in the water, and travel straight (see Figure 4).
3. Have each student sketch their aqua-thruster on the Aqua-Thruster Worksheet and predict how long they think the thrust will last.

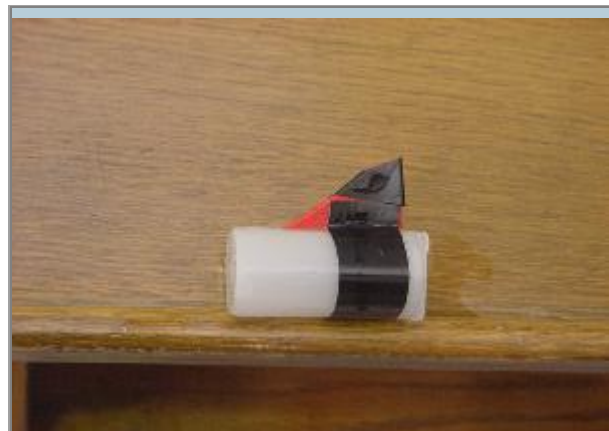


Figure 4. A rocket-boat, or aqua-thruster.
Copyright © Photograph taken by Jeff White, University of Colorado at Boulder, 2003.

4. Give each group a solid half tablet of antacid. (Note: Antacid tablets should be given out only as needed so that the instructor knows that all tablets are accounted for and used appropriately in the experiment.)
5. Have one group at a time fill their canister 3/4 full of water from the sink, drop in a solid half tablet of antacid, snap on the lid, start the stopwatch, and set it in the water. Make sure the pinhole nozzle is under water! Note: Each group that tests should wear safety glasses.
6. The students should stop the stopwatch when the thrust fully ends. Then, they should complete the Aqua Thruster Worksheet under the Test 1 section.

Test 2

1. Groups should now repeat the experiment with a crushed half tablet.
2. Have each student finish the rest of the Aqua Thruster Worksheet.



Figure 5. Aqua-thruster in sink
Copyright © Photograph taken by Jeff White, University of Colorado at Boulder, 2003.

Attachments

- Aqua Thruster Worksheet

Assessment

Pre-Activity Assessment

Brainstorming: In small groups, have the students engage in open discussion. Remind students that no idea or suggestion is "silly." All ideas should be respectfully heard. Ask the students:

- Is there any way that we can control how much thrust is generated by a propellant?
Prediction: Have students predict the following:
- Will more thrust be generated when a solid tablet or crushed tablet is used?

Activity Embedded Assessment

Worksheet: Have the students record measurements and follow along with the activity on their Aqua Thruster Worksheet. After students have finished their worksheet, have them compare answers with their peers.

Post-Activity Assessment

Question/Answer: Ask the students and discuss as a class:

1. Ask the students what is creating the thrust. (Answer: the water being expelled from the hole produces an equal and opposite force forward due to Newton's third law of motion.)
2. There was almost no water left in the canisters after the tests. Was the water turned into a gas by the reaction? (Answer: No, the water allowed the solid particles in the antacid to mix and react.)
3. Was the water pushed out of the small nozzle by the expanding gas created by the reaction? (Answer: Yes, as the mass of the water was pushed out the nozzle, a force was generated forward on the canister.)
4. Ask the students whether propellant with a larger surface area produces more or less thrust than one with less surface area. (Answer: It produces more thrust since more propellant can react more to produce more energy. Compare this to the time it takes to eat a lollipop if you lick it or break it into pieces with your teeth. More surface area by breaking the lollipop into pieces makes the lollipop dissolve faster. The same is true with a solid fuel.)
5. Ask the students whether they think more thrust will be generated when a solid tablet is used or when the tablet is crushed. (Answer: The crushed tablet will since it has more surface area.)
6. Ask students what state of matter is created when an antacid tablet is combined with water forming a chemical reaction. (Answer: a gas made of carbon dioxide)

Engineering Application: Ask the students to think about their aqua thrusters. Engineers often create prototypes or models of a design before they build the real thing. If the students were engineers who are going to design a life-sized rocket boat for use in a lake or ocean, what types of things would they have to consider for the real design? Have the students come up with a list or discussion of what they would learn more about before building the real thing. (Answers may include: the type of propellant, the temperature, the pressure, safety of the design, whether the propellant makes the boat move forward in a smooth or choppy motion, and the size or conditions in the lake or ocean.)

Re-Design Practice: Have the students list any design or fabrication changes they would make to their rocket-boat on their Aqua Thruster Worksheet to make it work better next time.

Activity Extensions

- Have students try canister caps with different sized pinholes to see how that affects the thrust.
- Have students alter their design so they simulate a catamaran using two film canister connected together side-by-side. Have them put half-tablets in each canister and ask them to write a paragraph about what they observed.
- Have students create a mega aqua-thruster. Instead of providing them with a film canister, allow them to use a small water bottle or any other bottle with a screw-on top. See if they can generate thrust with multiple antacid tablets or baking soda and vinegar. Remind students that the weight will become an issue with these larger bottles and more propellant must be used.

Safety Issues

Remind students not to put the antacid tablets (crushed or solid) in their mouths; if a student eats a solid tablet they could become very sick.

Hand out antacid only as necessary; do not give each group a "supply" in advance.

Students should wear safety glasses when testing their aqua-thrusters.

Troubleshooting Tips

In order to effectively use half tablets of antacid in both solid and powder form, this method of preparation can be used:

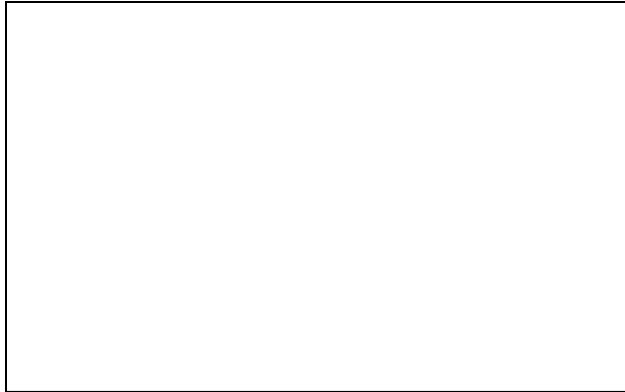
1. Use scissors to cut a two-tablet packet down the middle (between the two whole tablets).
2. Take both tablets out and break them in half as evenly as possible.
3. Place one half of each of the tablets back into its packet.
4. Hold the open end shut and use a blunt object to crush the half tablet in the packet. This takes some practice but works well. Repeat for the other tablet. Now you have two crushed half tablets nicely contained in their packets and two solid half tablets!

Name: _____ Date: _____

Aqua Thruster Activity – Aqua-Thruster Worksheet

Test 1 – Using a Solid ½ Antacid Tablet

Sketch Your Aqua-Thruster in the box below!



How long do you think the thrust will last?

Solid ½ tablet
burn time
(in seconds): _____

Examine your aqua-thruster after the test.

What is left inside? _____

Where did the water go? _____

Test 2 – Using a Crushed ½ Antacid Tablet – Safety Glasses Required!

How long do you think the thrust will last? _____

Crushed ½ tablet burn time (in seconds): _____

Did it last longer than the solid tablet? _____

Was the thrust stronger or weaker than the solid tablet? _____

Describe the THRUST produced in both tests (at least two sentences):

Descriptive hints: Powerful, medium, light, fast, slow, constant, on-off, straight, circular, random, quiet, noisy, sputtering, smooth...

Activity 4c: Pop Rockets

Grade Level: 3 (K-5)

Group Size: 1

Time Required: 50
minutes

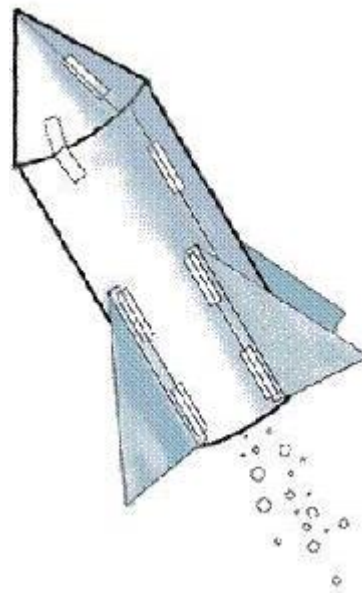
Activity Dependency:
None

Expendable Cost Per Group: US\$.50

Keywords: thrust, chemical reaction, pressure, gas, pop rocket, Alka Seltzer®, Newton, laws of motion, motion, antacid, energy

Summary: Students design and build a paper rocket around a film canister, which is used as the engine. An antacid tablet and water are put into the canister, react to form carbon dioxide gas, and act as the pop rocket's propellant. With the lid snapped on, the continuous creation of gas causes pressure to build up until the lid pops off, sending the rocket into the air. The pop rockets demonstrate Newton's third law of motion: for every action, there is an equal and opposite reaction.

Engineering Connection: Engineers design scale models of a project to determine how it will perform. When designing a rocket, engineers must develop small prototypes to test fuel properties. Does the fuel burn too high? Does the fuel create enough thrust? Prototypes of rockets help engineers discover the balance between weight and thrust that is necessary for space flight.



Copyright © National Aeronautics and Space Administration, Space Place, <http://spaceplace.jpl.nasa.gov/>

Learning Objectives

After this activity, students should be able to:

- Explain that energy needed for a rocket launch is related to the size of the rocket.
- Collect and analyze data on model rocket launch height, comparing to size or weight of the rocket.
- Describe what factors an engineer must consider when designing a rocket.

Materials List

Each student needs:

- 1 35-mm film canister (with internal snapping lid; see Figure 1)

Note: For this activity, a film canister with an internal-sealing lid must be used instead of one that snaps over the outside of the rim. These are usually white, translucent canisters - not the solid black ones. Film canisters are readily available at no charge from camera shops and stores where film is processed, such as grocery stores, Target, Costco, etc. These businesses recycle the canisters and are often willing to donate them for educational use. Most of the canisters they have will be the solid black ones which will not work for this activity. You may have to make several trips to the above locations to obtain enough of the white, translucent canisters with the internal sealing lids.

- ½ antacid tablet
- 1 sheet of paper
- 1 pair of scissors
- Cellophane tape

For the entire class to share

- Access to a sink to get and dispose of tap water
- Safety glasses/goggles (enough pairs for the largest group and instructor)
- Paper towels for cleanup
- A pitcher (to launch the rockets out of if launching inside)

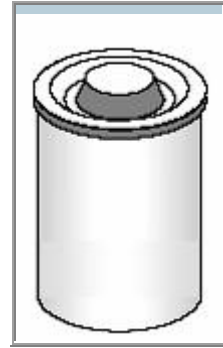


Figure 1. Film Canister with internal-sealing lid
Copyright © Image created by Jeff White, University of Colorado at Boulder, 2003.

Introduction/Motivation

Rockets are incredible machines that are designed by engineers and used to explore space. Have you ever seen a rocket or a picture of one? How do engineers get these heavy vehicles into space? Indeed, something very strong is needed to push the rocket upward into the atmosphere and into space. A rocket needs a lot of *energy* to move.

Let's think about energy. How do we have energy to move our bodies when we get out of bed in the morning or when we walk to school? We get our energy from food; essentially, food is fuel. Well, rockets use propellant, which is a mixture of fuel and an oxidizer to burn the fuel. Large rockets need to use a lot of propellant in order to create enough energy to reach space. What if we made a model rocket that was very light? Would we need as much energy as a normal rocket? No, probably not.

Antacid tablets have stored chemical energy in them, and this energy can be released when mixed with water. Although it is not much energy, it is enough to launch a small rocket made out of a film canister and paper. And, for our purposes, this particular chemical energy is also a lot safer than burning real fuel.

Engineers will build and test a model of a rocket (called a *prototype*) before they build the real thing, which aids them in creating a perfect design. When designing Tess' rocket, her engineering team must consider many things, such as the weight, cost, thrust and stability of the rocket. We can use small model rockets to test the performance before Tess spends a lot of time building an expensive full-size rocket. When an engineer tests a scale model, they know whether or not it will work without wasting time and money on a huge rocket. With a scale model, they can test the thrust and stability and make modifications in order to build the best rocket they can. This is what we are going to do today — design model rockets and find out if we can propel them high into the air using simple chemical energy created from Alka Seltzer® and water.

Procedure

Before the Activity

- Choose a wall inside or outside that students can launch next to, and mark off 10 feet at 1-foot intervals with tape or chalk.

- Remove antacid tablets from packaging and break them in half. Half tablets are sufficient enough to pop off the canister lids; too much antacid will make the lid pop off sooner, which is not desirable for this activity.

With the Students

1. Break class into groups of 3-4 students. Give each student a film canister and sheet of paper.
2. Using scissors and tape, each group should follow the Rocket Build Instructions to build a rocket. Encourage groups to experiment with different sizes. Note: Make sure students put the lid of their canister at the bottom of the rocket (i.e., the canister is inverted). Also, the canister lid should stick out from the paper a little so that the paper surrounding the rocket does not interfere with the lid either snapping on or popping off.
3. Have students put their name and any designs they want on the rocket.
4. One group at a time, students should move to the launch area to prepare to launch their rockets. *Note: students should wear safety glasses during their launch; ask students to put the safety glass/goggles on BEFORE the launch begins.* All other students should be a safe distance away from the launch area, ready to record the results on their Rocket Size/Height Worksheets.
5. Have students hold their rocket upside down, and carefully fill each canister 1/3 full of water.

NOTE: The next steps must be done quickly:

6. *One at a time*, have a student drop the ½ half tablet of antacid into their film canister. (Note: Antacid tablets should be given out only as needed so that the instructor knows that all tablets are accounted for and used appropriately in the experiment.)
7. Quickly snap the lid on tightly.
8. Very quickly place the rocket upright (which means that the film canister lid is down) into the empty pitcher or onto the flat launch site and stand back!

The rocket should pop within 1-5 seconds.

9. Ask students to note the maximum height reached by their rocket and have them record it on their Rocket Size/Height Worksheet.
10. Give the popped lid back to the student launcher and repeat steps 6-9 for each student in each group.

Assessment

Pre-Activity Assessment

Concept Inventory: Have the students attempt the attached Pop Goes the Rocket Quiz. Students should answer the first two questions on the quiz and then it put aside to complete after the activity.

Activity Embedded Assessment

Data Recording: As directed in the Procedure section, have the students decide if the rocket is small (S), medium (M) or large (L) before it is launched. Then, after each rocket is launched, the students should measure the maximum height reached by the rocket and record it on the appropriate box in their Rocket Size/Height Worksheet. Discuss any patterns in rocket size or weight versus height of the launch.

Post-Activity Assessment

Pairs Check/Concept Inventory Continued: Have students complete question 3 of the Pop Goes the Rocket Quiz (begun during pre-assessment). After students finish working individually on the quiz, have them compare answers with a peer, giving all students time to finish. Finally, go over the answers as a class.

Survey: Ask the following questions (verbal or written) to survey students about the activity:

- What makes one rocket perform better than another? (Answer: Many factors such as weight, drag, thrust (rate of gas build up), symmetry of canister, tightness of canister seal, and wind can affect a rocket's performance.)
- What is creating the thrust in our pop-rockets? (Answer: The high pressure built up from the chemical reaction of the antacid tablet and water in the canister forces the cap off and downward as the rocket moves upward — due to Newton's third law of motion.)
- If students previously performed a strawket activity from Lesson 2 of this unit, ask them to compare how these rockets are more "rocket-like" than those launched by a straw? (Answer: Like real rockets, these pop rockets carry their own fuel.)
- How are pop rockets related to real rockets? (Answer: Real rockets behave according to Newton's laws of motion just like pop rockets do. Also, solid propellant rockets have a similar process by releasing energy through a chemical reaction to generate thrust.)

Sales Pitch! Have the students pretend to be salespeople trying to sell their rocket to a manufacturer or a consumer. Have student teams create a persuasive poster or flyer, as well as a 10-minute sales pitch of their rocket design for presentation at the next class. Have them incorporate into their sales pitch where the energy is coming from to launch the rocket.

Activity Extensions

Allow students to experiment with different amounts of water and tablet sizes. Students must wear safety glasses/goggles when launching their rockets.

Have students launch for distance instead of height. Have them measure their launch angle and record their data for multiple angles.

Activity Scaling

For kindergarten and first-grade students, conduct the activity as a demonstration instead of having students individually make their own rockets. Prior to class, make several different-sized rockets with no fins and then have the students each color a fin to put on the rockets. Have students count the number of fins on each rocket. Have students count out loud to see how long it takes each rocket to "pop." Instead of using the Pop Goes the Rocket Quiz as an assessment, ask students what geometric shapes they see in the pop rockets. Then, ask for a choral response to these basic questions:

- Why does the rocket come back down when shot up? (Answer: gravity)
- Where is the energy coming from to power the rocket? (Answer: The antacid table and water reaction.)

For second-grade students, build the rockets as indicated but help them with the launching procedure, as necessary.

For fourth- and fifth-grade students, conduct the activity as is, but have them measure the mass of their rockets on a scale before launching them. Then, they should calculate the weight of their rockets according to this formula: $\text{weight} = \text{mass} \times (\text{acceleration due to gravity})$. Students should record their data on the Rocket Weight/Height Worksheet instead of the Rocket Size/Height Worksheet.

Safety Issues

Make sure students wear safety glasses/goggles while they are launching their rockets.

Ensure that students not launching are at a safe distance away from the launch area.

Remind students not to put the antacid tablets in their mouths; if a student eats an entire tablet s/he could become very sick.

Hand out antacid only as necessary; do not give each group a "supply" in advance.

Troubleshooting Tips

Common student problems when building rockets:

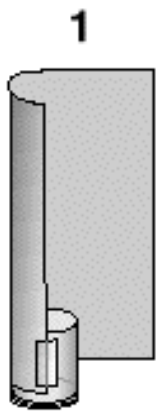
- Forgetting to tape the film canister to the rocket body.
- Failing to mount the canister with the lid end down.
- Not extending the canister far enough from the paper tube to make snapping the lid easy.

It may be easier for the students to build the rockets and then have the teacher launch them. The chemical reaction of the Alka Seltzer® and water sometimes happens too fast for small hands.

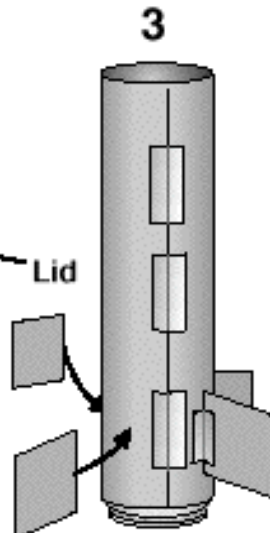
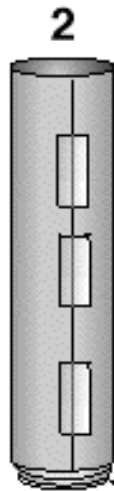
Remember to have the students stand back when the rockets are launching, so that they do not get hit with flying canister parts.

Pop Rockets Activity – Rocket Build Instructions

Instructions

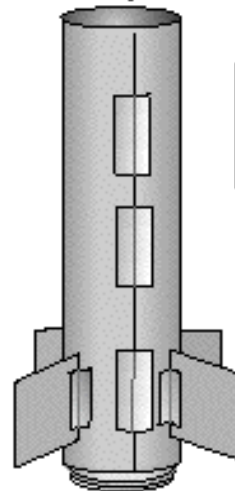


Wrap and tape a tube of paper around the film canister. The lid end of the canister goes down!

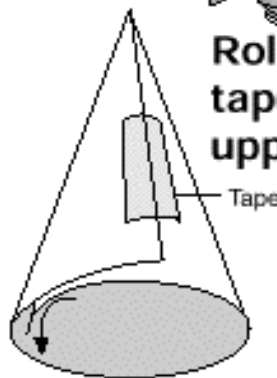
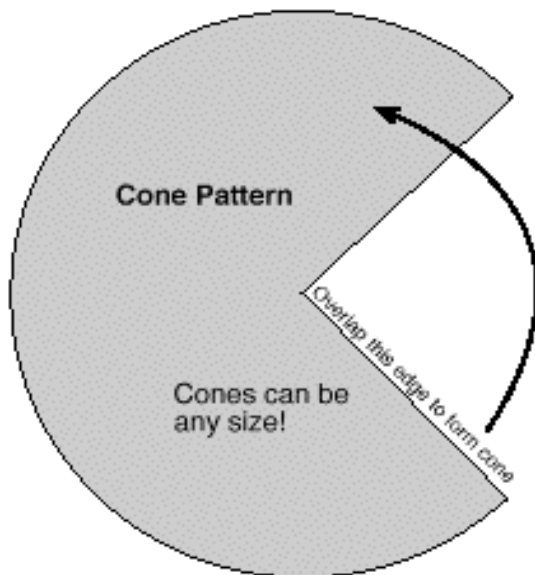


Tape fins to your rocket.

Ready for flight



Roll a cone of paper and tape it to the rocket's upper end.



Source: www.spacesociety.org/spaceexpress/Curriculum/film_canisters.html

Name: _____ Date: _____

Pop Rockets Activity – Rocket Size/Height Worksheet

10 feet									
9 feet									
8 feet									
7 feet									
6 feet									
5 feet									
4 feet									
3 feet									
2 feet									
1 foot									
0 feet									
	Launch 1 ↑	Launch 2 ↑	Launch 3 ↑	Launch 4 ↑	Launch 5 ↑	Launch 6 ↑	Launch 7 ↑	Launch 8 ↑	Most Common letter for each height row

Instructions

1. For each launch, determine the size of the rocket to be launched: small (**S**), medium (**M**), or large (**L**).
2. Once the rocket is launched, determine how high it flew.
3. Write down the letter (**S**, **M** or **L**) in the box at the point the launch column and height row intersect.
4. Once eight launches have taken place, look at each height row and see which letter reached that height the most. Write this letter in the final column. If there is a tie, write down both letters in the final column. Is there a pattern? _____

Name: _____ Date: _____

Pop Rockets Activity – Rocket Weight/Height Worksheet

10 feet									
9 feet									
8 feet									
7 feet									
6 feet									
5 feet									
4 feet									
3 feet									
2 feet									
1 foot									
0 feet									
	Launch 1 ↑	Launch 2 ↑	Launch 3 ↑	Launch 4 ↑	Launch 5 ↑	Launch 6 ↑	Launch 7 ↑	Launch 8 ↑	Average weight for each height row.

Instructions

1. For each launch, determine the weight of the rocket to be launched in grams.
2. Once the rocket is launched, determine how high it flew.
3. Write the weight in the box at point where the launch column and height row intersect.
4. Once eight launches have taken place, look at each height row and calculate the average weight for that height (add all the weight values in that row and then divide that number by the number of launches, normally eight). Write this number in the final column. Is there a pattern? _____

Pop Rockets Activity – Pop Goes the Rocket Quiz

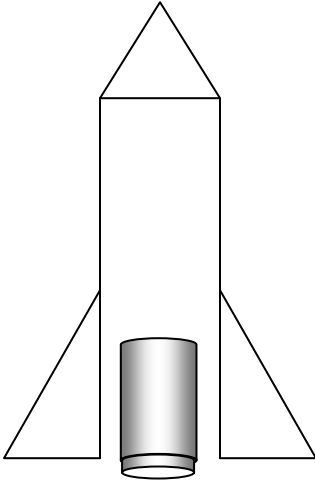
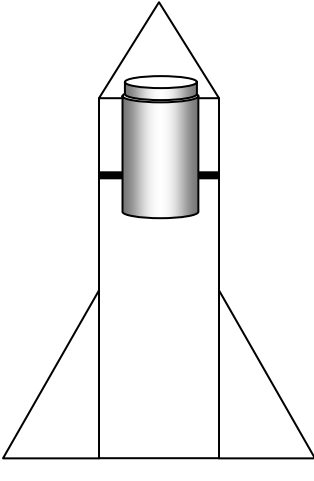
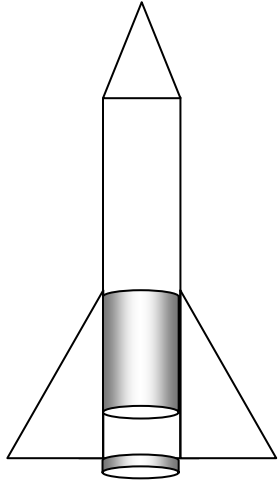
1. Circle True or False:

True or False: When you put Alka-Seltzer® in water it explodes.

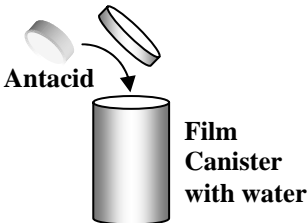


True or False: If you do not change the amount of fuel, and make a rocket longer, it will fly higher.

True or False: Tape has no weight so you can put as much on as you like.

2. Which of these rockets will NOT lift off?

<input type="checkbox"/> This one won't!	<input type="checkbox"/> This one won't!	<input type="checkbox"/> This one won't!
		
Engineers forgot to attach the pop engine to the structure	Engineers attached the pop engine to the top	Unable to secure lid to pop engine (pop engine mounted too high)

3. If a piece of antacid (like Alka-Seltzer®) is put into a film canister with water and the lid is snapped on, what will happen and why?

 <p>Antacid</p> <p>Film Canister with water</p>	<p>Snap!</p> 	 <p>?</p>
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Pop Rockets Activity – Pop Goes the Rocket Quiz

Answers

1. Circle True or False:

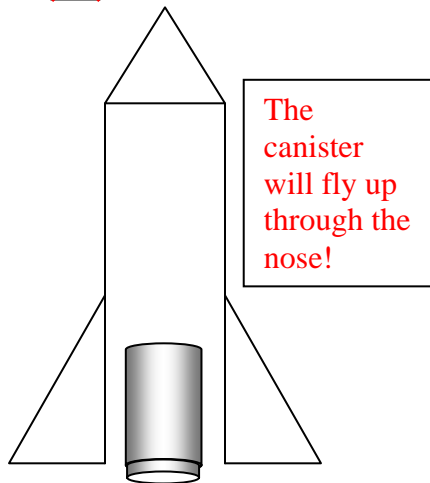
True or **False**: When you put Alka-Seltzer® in water it explodes.

True or **False**: If you do not change the amount of fuel, and make a rocket longer, it will fly higher.

True or **False**: Tape has no weight so you can put as much on as you like.

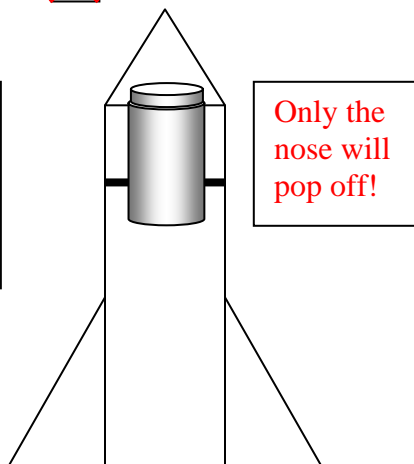
2. Which of these rockets will NOT lift off?

This one won't!



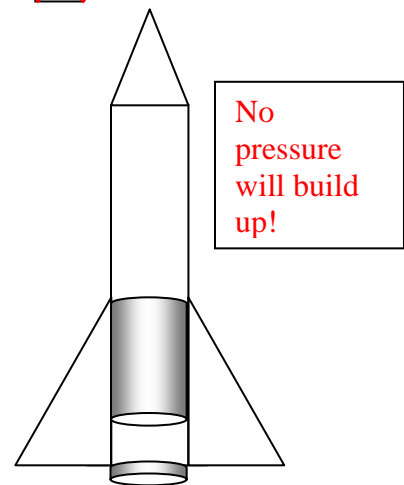
Engineers forgot to attach the pop engine to the structure

This one won't!



Engineers attached the pop engine to the top

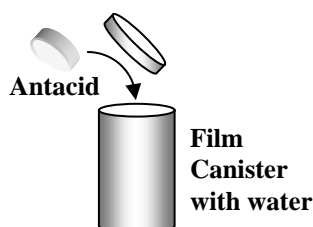
This one won't!



Unable to secure lid to pop engine (pop engine mounted too high)

3. If a piece of antacid (like Alka-Seltzer®) is put into a film canister with water and the lid is snapped on, what will happen and why?

The antacid and water react and form a gas. As more and more gas is created, pressure builds up in the canister and pushes against the lid. The pressure finally becomes strong enough to "POP" the lid off!



Snap!

