Wizards of Wright

Lesson: Rocketry - Testing Thrust with Paper Rockets

Use WOW! Lesson Intro to begin.

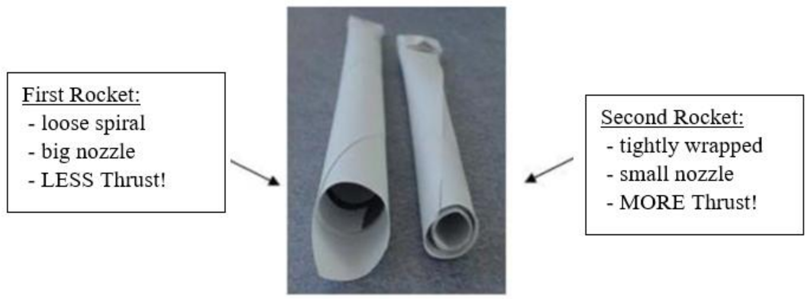
Background Info for Wizards:	Engineers must know about thrust in order to design successful rockets. And, they must understand Newton's laws of motion as well as how exhaust behaves in order to calculate the thrust needed for a rocket to reach its destination. How engineers design the shapes of rocket nozzles is very important to the performance and thrust of rockets. The nozzle size and shape effects how fast the exhaust leaves the rocket as well as how much pressure it has.
Materials:	Each student needs: - 1 piece of letter-sized paper (8.5 x 11 inches), cut in half, resulting in 2 half-sized pieces each measuring 8.5 × 5.5 inches *(The teacher will have been asked to prep this before you get there.)* - 1 pencil - 1 drinking straw (with no wrapper) - 1 cotton ball For the entire class to share: - scissors - target pictures of each of the nine planets - tape measure - Scotch tape provided in several dispensers - masking tape or string, to mark a starting line
Lesson Time: 60 minutes	Introduction: 5-7 minutes Guided Lesson: 3 minutes Student Activity Introduction: 5 minutes Student Activity Directions: 10 – 15 minutes Student Activity: 20 minutes Conclusion: 10 minutes
Learning Targets:	- Compare and contrast airplanes and rockets and explain why airplanes cannot travel into space. - Describe thrust and what factors can affect it.

	- Identify some factors that engineers must consider when designing real rockets, including safety.
Introduction for Students: 5-7 minutes	**Ask the students:** Can an airplane fly into space? No. **Ask the students:** But, do you know why. Airplanes need air to fly, and there is no air in space. - Airplanes have propellers, angled blades that push air—like a fan does. - Airplanes also have wings that use air to help them stay in flight. With no air in space, rockets can't use propellers or wings. So, how do engineers get rockets into space? - Rockets that fly into space are very heavy and require something powerful to "push" them. Engineers design rocket engines to do just that. The push that a rocket engine provides is called thrust. **Ask students if they have studied Newton's Laws yet. If so, what was his 3rd Law?** (If not explain just this concept.) The third law says that for every action (force) there is an equal and opposite reaction (force). That means that as the rocket engine pushes hot gases out of the rocket, the rocket propels or pushes forward into space. That forward push is called thrust. (show graphic of space shuttle pics) So, is getting a rocket into space just as simple as the third law sounds? Nope. Rockets are big and heavy! It takes a huge force to launch rockets into space. **Engineers must consider three main things when designing rockets that can be launched into space include: thrust, weight and control.** Thrust directly relates to Newton's third law, which tells us how rockets move—by pushing out mass in one direction to move in the opposite direction. In some rockets, the **thrust** comes from pushing out hot gases that come from burning fuel. When the engines fire, it boosts the rocket upward against the Earth's gravity, and at the same time the explosion of fuel generates a force within the bottom of the rocket. How do you think **weight** affects a rocket? The heavier the rocket weighs, the more thrust it needs to take off. Lastly, engineers have to work on rocket **control** to get a rocket to move in the right direction. Control is important for getting the rocket past the Earth's

	atmosphere safely. Engineers must specifically design rockets to be balanced and stable while flying.
Guided Lesson: 3 minutes	In order to create a successful rocket, an engineering team must understand thrust and know how much force (push) it is creating. What do you think could affect the thrust of a rocket? Perhaps a bigger engine? Yes, but that would change the weight too. There's something else that engineers can do to affect thrust as well. How an engineer designs the shape of the rocket nozzle is very important to the performance and thrust of the rocket. A nozzle is a device designed to control the direction of a fluid flow. Think of the nozzle that we can add to the end of our garden hoses. It can control the speed, the force/pressure, and the direction of the water. The size and shape of the nozzle effects how fast the exhaust will leave the rocket as well as how much pressure it will have. (show graphic of space shuttle pics) **You must design a nozzle that will create enough thrust to launch the rocket into space.** Today, we are going to design two paper rockets with different nozzle shapes. We will show how the different sized nozzles affect thrust.
Student Activity Introduction: 5 minutes	After building our rockets, you will use your own mouth as the rocket engine. (Demonstrate) By blowing air out of your mouth, you can launch your paper rockets into the air. Do you see what I have on the end of my rocket? Why do you think the cotton ball has been added? Engineers have to take safety into consideration when designing rockets. We will add a soft cotton ball to the front of the rocket to protect its landing. - Students will investigate the effect that thrust has on rocket flight. - Students will make two paper rockets that they can launch themselves by blowing through a drinking straw. - These straw rockets will differ in diameter, enabling students to see how rockets with smaller exit nozzles provide more thrust. - Students will compare the distances traveled by their two straw rockets after predicting where they will land.

	- Since each student has a slightly different rocket and launching technique, they also observe which factors contribute to thrust and performance.
Student Activity Directions: 10 - 15 minutes	Hand out materials. Have samples available. Students will make 2 rockets. Make sure they understand that the directions are different. Have students follow your directions to make the first rocket. Work together. When everyone is ready, have them follow your directions to make the second rocket. (Do not give them both sets of directions at the same time.) 1. Have students wrap one half-sheet of paper around a pencil, starting from the eraser end and working up to the graphite tip. When wrapping, spiral the paper to make a cone shape, it helps to hold it tighter at the eraser end and wrap upward.  2. Have students tape the paper tube near each end so it keeps its shape. 3. Then remove the pencil. 4. Check the final length of paper tubing to make sure it is at least a few centimeters shorter than the straws; otherwise, students will have nothing to hold onto for the launch. 5. If necessary, use scissors to cut the paper tube shorter. 6. Have students pinch and fold the smaller end of the tube over and tape it so it is airtight. This end is the "nose" of the rocket. 7. Have students tape a cotton ball to the nose of each rocket. To prevent the cotton from falling off, place the tape over the top of the cotton ball (that is, not wrapped inside/out and placed underneath the cotton ball as it sits on the nose of the paper tubing). Note: Some cotton balls are big enough to pull apart; only use as much cotton as necessary to provide some protective padding. 8. Have students write their names on their rockets. Have them label it as Rocket #1. 9. Have students make their second rocket. Take another half-sheet paper and wrap it tightly around a pencil - without spiraling into a cone shape -

to make a tight paper tube that is more even in diameter along the length of the tube.



Rocket #1 - A spiraled, cone-shaped paper tube with a large opening has not been rolled up very tight. The loose spiral has a big nozzle which equals less thrust.

Rocket #2 - A similar rolled paper tube, but with a smaller opening was rolled much tighter without being spiraled. This tightly wrapped tube has a small nozzle which equals more thrust.

10. Again, be sure the final length is a few centimeters shorter than the straws to leave available some length of the straw to hold onto for the launch.
    Note: If students have trouble wrapping this tube, assure them that a slight cone-shape is acceptable as long as the tube is tighter than their first designs.

11. If necessary, use scissors to cut the paper tube shorter.

12. Have students pinch and fold the smaller end of the tube over and tape it so it is airtight. This end is the "nose" of the rocket.

13. Have students tape a cotton ball to the nose of each rocket. To prevent the cotton from falling off, place the tape over the top of the cotton ball (that is, not wrapped inside/out and placed underneath the cotton ball as it sits on the nose of the paper tubing).
    Note: Some cotton balls are big enough to pull apart; only use as much cotton as necessary to provide some protective padding.

14. Have students write their names on their rockets. Have them label it as Rocket #2.

	<u>Troubleshooting Tips</u> It is a good idea to have some extra rockets in case someone's gets crushed during the activity. (If you have quick students, that finish early, they could build a few extras for you.) The tape used to secure the cotton balls should be fairly long so they are adhered properly. Make sure kids are not holding onto the bottom of the rocket when they blow through the straw!
Prepping the Room:	As the students are finishing their rockets… Mark a starting line on the floor with tape or string. Lay out the planet targets on the floor beyond the starting line. (Layout distance: Earth – launching point, Mercury – 2.5 feet, Venus – 1 foot, Mars – 2 feet, Jupiter – 5 feet, Saturn – 10 feet, Uranus – 15 feet, Neptune – 20 feet, Pluto – 25 feet)
Student Activity: 20 minutes	Create launching groups of 3-5. Rockets should not be launched while the previous student is retrieving her/his rocket. Specifically, rockets should not be launched at another person! 1. Have each student launch Rocket #1 from the Earth. 2. To do this, have students insert their straws into their rockets - holding onto the straw, not the paper part - aim at a planet, and blow. They should probably practice a few times to get the hang of it. 3. First launch. 4. After retrieving their rocket, direct students to answer the three worksheet questions for their first launch. 5. Each student can have a second attempt, after everyone has had their first attempt. Repeat all of the steps with Rocket #2.
Conclusion: 10 minutes	Today, we learned more about rockets and how they are different from airplanes. Who can remember why rockets are different than airplanes? (Answer: Airplanes need air to fly; in space, rockets must fly without air.) How do engineers get rockets into space? Which law was that? (Answer: Newton's third law of motion.)

	From Newton's third law, we know that objects can be moved in one direction by ejecting mass in the opposite direction. Who remembers three things that engineers must consider when designing rockets that will be launched into space? (Answer: Thrust, weight and control.) What is thrust? (Answer: Thrust is the force on a rocket that moves it in a forward direction. In some rockets, the thrust comes from pushing out hot gases from burning fuel.) What made one rocket perform better than another? (Answer: Many factors, including: mass, acceleration, nozzle shape, body shape, air leaks, launch angle, and friction between the straw and paper cone.) Could you change the nozzle (the tail end) any other way to get more thrust? (Answer: Use a smaller diameter straw and tighter paper wrap while blowing as hard as before. Another idea is to plug the back with something so the air pressure builds up before launch and then "pull the plug.") We learned the importance of rocket thrust, weight and control. Now we can use what we have learned to understand how engineers design real rockets!

Info for sharing if the students ask:

Explaining the Science behind the nozzle size.

To get more thrust out of slow-moving rockets (such as paper rockets), the exit "nozzle" must be as small as possible to make the air accelerate faster.

Because it is a gas, air can be compressed and an air compressor, a pump, uses a large force to compress the air. When the air is released, it generally blows out very hard and very fast. When air moves relatively slowly through a tube that is decreasing in diameter, it does not compress. Under these conditions, not enough force is exerted on the air to make it squeeze together. Instead, the air speeds up. An example is water flowing through a garden hose. If you place your thumb over the end of the hose to partially block the water from exiting, the water sprays out much faster than if you let it flow without blockage. When the water has nowhere to go, its only option is to speed up.

This is different for real rockets because they usually travel faster than the speed of sound and when air moves this fast, it becomes compressible. This explains the bell shape for rocket nozzles. In order for the hot gases to then speed up, the shape of the nozzle must be bigger.

<u>How heavy are rockets?</u> The weight of one solid rocket booster of the space shuttle (it has two total) is 1,252,000 pounds, including the propellant!

<u>Weight distribution of a rocket is also important.</u>
The point where a rocket's weight is equally balanced is called its center of gravity (CG).

Use a ruler or meter stick to show the center of gravity. Balance either one horizontally on your finger placed directly in the center. Have students try different places on the ruler. It doesn't balance. All of the weight on one side has to be equal to all of the weight on the other side.

<u>Explaining control.</u>

If you pick up a football and throw it without the proper grip and technique, it wobbles through the air and is difficult for someone on the receiving end to catch. A quarterback spirals a football so that it completes a controlled pass, making it easy for a receiver to decide where to place his hands.

Blow up a balloon, and then let it go. An untied balloon will fly all over the place when we let it go. Why? Because it has no control.

The opening is flexible and the round shape of the balloon means it can rotate in any direction as it pushes through the air.

Obviously, it is necessary to control a rocket in the atmosphere before it reaches space. Can you imagine a launched rocket or space shuttle doing what that balloon just did? Imagine being the astronaut inside.

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