Straw Rockets

Build and launch a rocket using common classroom materials! This activity is a great demonstration of momentum exchange and aerodynamic forces.

Suggested grade level: 3-4

Activity length: 40 – 60 minutes

Required materials: Drinking straws, paper, tape, clay

Relevant topics: Forces, pressure, momentum

Purdue Space Day, an educational outreach program of Purdue University's Department of Aeronautical and Astronautical Engineering, organizes the largest free STEM advocacy children's event in the Midwest, as well as myriad year-round outreach events throughout the surrounding metropolitan area. These activity write-ups are provided free of charge as an extension of Purdue Space Day's STEM programming.

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Questions? Comments? Contact Purdue Space Day via email at psd@purdue.edu. We'd love to hear your feedback to help us improve our activities and write-ups.

Activity Summary

Students construct small rockets from drinking straws, paper, and modeling clay. Rockets can be launched either with straws or with a commercially-available launcher

Key Concepts: Momentum, Pressure, Aerodynamic Forces

NGSS Summary: The key concepts of this activity align with Next Generation Science Standards (NGSS) Disciplinary Core Ideas for third-grade science education. Specifically, they meet the following Physical Sciences standards:

- 3-PS2.A – Forces and Motion
- 3-PS2.B – Types of Interactions

This activity also connects to the following standards for Engineering, Technology, and Applications of Science:

- ETS1.A – Defining and Delimiting an Engineering Problem
- ETS1.B – Developing Possible Solutions
- ETS1.C – Optimizing the Design Solution

Learning Objectives

Students will be able to explain the concept of momentum through the use of real-world examples.

Students will be able to relate changes in momentum to forces and vice versa using examples.

Students will be able to explain how rockets use momentum to fly.

Students will be able to describe how objects feel forces due to air flowing past them.

Scientific Background

Rockets work by expelling hot exhaust gases out of a nozzle. These gases exert a pressure on the rocket to push it forward, and pushing the weight of the gases backwards propels the rocket via the conservation of momentum. An easier way of thinking about the concept is this: to change the direction in which something is travelling, we have to exert a force on it. Think of catching a speeding baseball. To stop the baseball, you have to push back on it to bring it to a halt. You can feel this force in your hands and your arm as you catch the ball. Now, if you want to throw the ball back in the direction it came from, you have to exert even more of a force – first you have to stop the ball, and then you have to speed it up in the other direction. Either way, to change the ball's motion, you have to exert a force – a push – on it.

A rocket works based on this same idea. Inside a rocket engine, we have a bunch of hot gases from burning the rocket's fuel. We can push these gases out of the back of the rocket by exerting a force on them (this force comes from the high-pressure combustion process of the fuel). We are effectively changing the motion of these gases because they start out at rest and end up moving away from the rocket. Just like throwing a ball in the example above, this means that we are exerting a force on the gases, because this is the only way to change their motion.

Since we are pushing the gases down, the gases must also be pushing the rocket up – this is a direct consequence of Newton's third law of motion, which states that every action, or force, has an equal and opposite reaction. So the rocket pushes the gases down, and the gases push the rocket up. Note that this is different from the most common explanation of rockets, which is that the rocket "pushes" itself upwards by exerting a force on the air around it using its exhaust gases. This is not entirely untrue, but it muddles the line between pressure forces and momentum forces. This explanation describes pressure thrust – the force which a rocket feels due to the differential pressure of the gases at its base. If the rocket exhaust is at a higher pressure than the surrounding air, then the rocket feels an additional force from the greater pressure. However, if the exhaust is at the same pressure or a lesser pressure than the ambient air, it will feel zero or even negative thrust from the pressure – which is why this simplistic explanation of rockets is not ideal. The predominant force which rockets feel comes from the momentum exchange process described above.

Straw rockets work in the same way as full-sized rockets, except that instead of hot exhaust gases, we use pressurized air provided from a ground source (the launcher). The launcher shoots a jet of air out of the launch tube. This jet of air travels up into the rocket, but since the rocket is sealed at the top by the nosecone, the air is deflected down and around the sides of the rocket. Once again, we are changing the motion of this air – it is stopped on its way up and sent racing back in the other direction, just like catching and throwing a ball. Since the direction of motion of the air changes, we know that we are exerting a force on it, and since the rocket exerts a force on the air, the air must exert a force on the rocket. Thus the rocket feels a thrust upwards and flies off of the stand.

Another engineering concept illustrated by the straw rocket is aerodynamic stability. The addition of fins to the rockets helps ensure stability – i.e. a flight in a predictable, controlled trajectory. The reasoning behind this is pretty straightforward – as air flows over the rocket, it exerts a force on anything which it touches – a pressure force caused by the air ramming into the surfaces of the rocket (we call this “dynamic pressure”). The parts of the rocket with the most area feel the strongest forces, because there is more surface for the air to push against. By adding fins to a rocket, we are increasing the area at the rear/bottom end of it; this means that if the rocket starts to waver off-course, the wind flowing past will hit its fins and straighten it out. A good way to think about this is to imagine a weathervane. Weathervanes have a tail with lots of area and a pointier tip, just like a rocket. When the wind blows, the bigger tail feels a greater force and swings around, aiming the smaller nose into the wind. Fins on a rocket work the same way.

Suggested Activity Practices

- Provide students an overview of the different components of the rocket and how they are launched.
- Explain the principles of momentum conservation by explaining how force is needed to change an object’s motion, even if that “object” is just a volume of gas.
- Challenge students to think of how a bigger diameter rocket would behave (assuming that the velocity of the air in the launcher is the same between sizes, it should go higher because there is more air/momentum).
- Explain the importance of aerodynamics for fins and nosecones.

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Assessment Techniques

Students can be observed for the following signs of comprehension or learning. The level to which a student understands the fundamentals of the activity is often clear from observing their rocket construction or asking basic questions about the scientific principles of it.

- Students indicate an understanding of a rocket's fins by designing identical fins and mounting them in a logical arrangement on the rocket.
- Students are able to provide examples of momentum in real-world systems.
- Students are able to provide examples of momentum exchange processes in real-world systems.
- Students are able to explain the connection between the hot exhaust gases of a full-size rocket and the air of the water rocket.

Participant learning can also be assessed using the following pre-activity and post-activity questionnaires.

Pre-Activity Questionnaire

Draw the most important parts of a rocket.

What makes a rocket fly?

What is a force?

How do fins work?

Post-Activity Questionnaire

Draw and label the parts of your straw rocket.

How does the straw rocket fly?

What does a force do?

Did your rocket's fins keep it flying straight? If so, how did they do this?

Construction Directions

Note: These directions are provided as a sample to help educators and volunteers guide students through the process of building a stomp rocket. They should not be given or shown to the students, who should be encouraged to design their own rockets according to what they have learned about rocket propulsion. Building rockets of their own design encourages students to embrace the engineering design process and apply the scientific principles they have learned.

Materials Required:

- Construction paper
- Drinking straws (cut into 6-10 cm lengths)
- Tape
- Straw rocket launcher (available from companies such as PITSCO)*
- Small ball of modeling clay/plasticine (about 1 cm diameter)

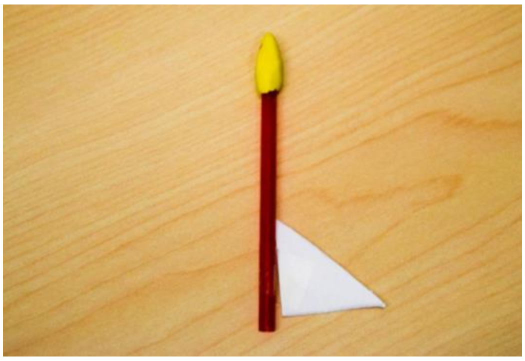
**As an alternative to a commercial straw rocket launcher, it is possible to launch the rockets by finding two sizes of straws such that the larger-diameter straw (used for the rocket) can slide over the smaller-diameter straw (used as a launcher).*

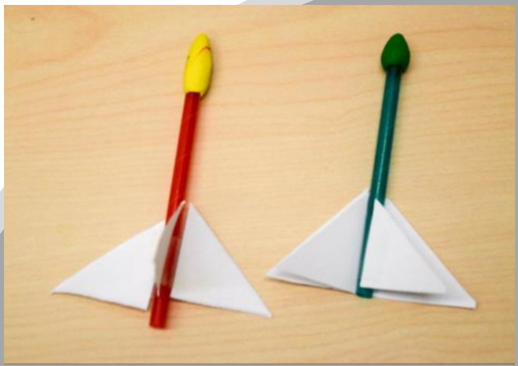
Construction:

1. Stick clay onto straw and shape into a nosecone shape (pointed, rounded, or really any shape will work). Make sure that the clay is solidly attached to the straw and makes a good seal.

2. Cut three or four fins from construction paper – they can be any shape, although small triangular fins of about 1-2 cm side length will probably work best.

3. Tape fins onto the bottom of the rocket (opposite from the nosecone), taking care to space them evenly around the rocket's circumference.





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Launch:

Place rocket onto the launcher and ensure that it can slide freely along the launch tube. Raise the piston of the launch station and drop it (do not slam it downwards) to see the rocket launch! Experiment with the angle of the launcher to see its effect on flight distance and height.

If a commercial launcher is not available, you may slide the rocket onto a smaller straw and blow swiftly through the inner straw to launch the rocket. Note that the rockets will work better with more tightly-fitting straws (provided that they can still slide freely).

Post-Launch

Discuss any observations which students were able to make about the launches. Were the any factors that made rockets go higher? Did rockets generally fly straight? Why? Encourage students to answer these questions by thinking about momentum exchange and aerodynamic stability, respectively. Ask students to think of ways they might improve their rocket, and to brainstorm possible uses for it. What could be measured, tested, or accomplished with a small rocket?

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