SIEMENS STEM DAY | Science Technology Engineering Math

SIEMENS STEM DAY ACTIVITY

STOMP ROCKETS

REAL-WORLD SCIENCE TOPICS

- An exploration of conservation of momentum applied to rockets.
- An exploration of the relationship between the launching angle and distance travelled by a rocket.
- An exploration of the factors that affect the distance travelled by a rocket.

ADDRESSES NGSS

LEVEL OF DIFFICULTY

4

OVERVIEW

In this activity, students will construct and launch stomp rockets. Students will learn about the concepts of conservation of momentum, thrust, controlling variables, and recording data.

TOPIC

Stomp Rockets

OBJECTIVE

Students will gain an understanding of performing a controlled experiment and how different variables affect the distance travelled by a stomp rocket.

MATERIALS NEEDED FOR STUDENT ACTIVITY

Materials Needed for Each Team of 3–4 Students:

- 6 feet of one-half inch PVC pipe
- one one-half inch 90° elbow connector
- one four-way, one-half inch PVC fitting
- two one-half inch PVC end caps
- one empty 2-liter soda bottle with a cap (it's a good idea to have some extra bottles on hand)
- duct tape
- 4" x 10" piece of cardstock or poster board
- styrofoam plate
- saran wrap
- measuring tape
- protractor

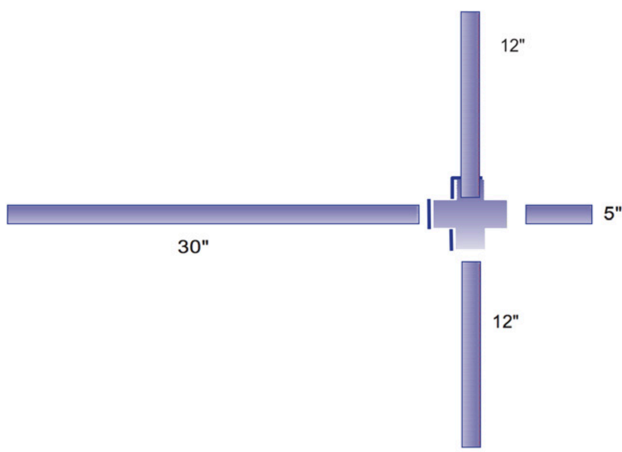
- strong, quick drying glue—a hot glue gun works well, one for the whole class is sufficient

TEACHER PREPARATION

Ask students to bring in 2-liter soda bottles (with the cap). Calculate how many teams of 3–4 students you will have in your class. Each team will need one rocket launcher and one rocket. Obtain the materials needed for each team. You will be constructing the rocket launcher for each team. If you have enough class time, you can have each team build their own launcher.

1. Ask your hardware store to cut each 6ft piece of PVC pipe into 5 pieces for you. (If you have a hacksaw, you can easily do it yourself.) The measurements do not need to be exact.

2. Connect the two 12" pieces, the 5" piece and the 30" piece together with the 4-way connector.



3. Put end caps on the two 12" pieces.
4. Connect the 13" piece and the 5" piece together with the 90°elbow.
5. Insert the free end of the 30" pipe into the soda bottle. Wrap the connection several times with duct tape to seal the area.

Find a location to conduct the experiment. If it is not windy, the experiment can be done on an athletic field. The gymnasium is an indoor option.

NGSS THREE-DIMENSIONS

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Apply scientific ideas or principles to design an object, tool, process, or system.	**PS2.A: Forces and Motion** Objects pull or push each other when they collide or are connected. Pushes and pulls can have different strengths and directions. Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it. An object sliding on a surface or sitting on a slope experiences a pull due to friction on the object due to the surface that opposes the object's motion.	**Stability and Change** Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

1. **Warm-up Activity:** Ask the class, "what makes a rocket, a rocket?" Most people envision a tall, thin, cylindrical vehicle that is launched into space. Have the class generate a list of types of rockets they have heard of or seen. Answers may include space shuttles, sounding rockets, water rockets, stomp rockets, and compressed air rockets.

   Ask students what each rocket launch has in common. A material is ejected from the back of the rocket while the rocket moves forward. Rockets use the idea of conservation of momentum. Ask students what it means to have momentum. Students will probably know an object needs to be moving in order to have momentum. The mass of an object multiplied by its velocity is its momentum. For today's activity, simply stress:

   The more mass a moving object has, the more momentum it has. The faster an object is moving, the more momentum it has.

   Conservation of momentum says that when the material gains momentum out the back of the rocket, the rocket gains momentum forward. They gain equal amounts of momentum in opposite directions. For example, blow up a balloon and release it. The air gains momentum in one direction, while the balloon gains momentum in the opposite direction. Two students standing on skateboards can push off of each other. Again, one student gains momentum in one direction, while the other gains momentum in the opposite direction. This is easy to demonstrate if you have two skateboards.

   Thrust refers to the force given to the rocket for propulsion. Thrust is related to the momentum of the matter leaving the back of the rocket. This matter is usually exhaust gases from burning fuel. For the rockets you are building today, the matter is air.

   If you want to increase the thrust given to a rocket, you need to increase the momentum of the material ejected from the rocket. Ask the class two ways to increase the momentum of the ejected material. You could increase its mass or its velocity.

A water rocket ejects water out the back of the rocket. What advantage does a water rocket have over an air rocket? Water has more mass than air. The mass of the water helps it to have a big change of momentum, and therefore gives the rocket a big change in momentum.

The hot gases leaving a NASA rocket are very light but they are moving very fast. This gives them a lot of momentum, even though they are not massive.

2. Divide the class into groups of three to four students. Explain to students that they will be constructing and launching stomp rockets. Each group will work together to explore the relationship between the angle of the launch and the horizontal distance travelled by the rocket.

3. Make copies and distribute the Make Me a Rocket and STEP ON IT! Student Handout. Students can use this handout to record the results of their trials.

   It's time to make the rocket.

   - Roll the poster board into a tube that is slightly wider than the PVC pipe so it can glide easily on and off the launcher. Use duct tape to secure it.
   - Glue the soda bottle cap onto one end of the rocket. Take a piece of saran wrap and mash it into a ball. Tape the ball of saran wrap to the bottle cap. Ask students what is the purpose of making the end of the rocket soft and rounded. This will make the rocket safer and give the rocket a softer landing, and therefore increase its lifetime.
   - Cut three triangles out of a styrofoam plate and glue them onto the rocket for the fins. Each team can decide the size and placement of their triangles. Ask the class what benefit they think the fins will provide.

4. Inform the class that if you are investigating the relationship between the launching angle of the rocket and the distance travelled, other variables that affect the distance must be kept the same. Students will quickly realize that they need to stomp on the bottle the exact same way each time, so that the thrust given to the rocket is consistent. Let each group figure out how they will keep the thrust as consistent as possible. Note: Be sure to tell students to step in the middle of the bottle rather than the end. This will help the bottle last longer.

5. Give students time to come up with their own procedures. Ultimately, students will need to follow the following basic procedure:

   - Use the protractor to set the launcher at a specific angle. The elbow connector can be rotated so that the rocket points at any angle.
   - Launch the rocket at that specific angle and measure the horizontal distance travelled (in meters) with a measuring tape. Repeat two more times for the same angle. Average the three distances for each trial. Record all data in the table provided.
   - Repeat steps 1 and 2 at several other angles.
   - Note: Help students come to the realization that they should do multiple trials for each angle.

6. Go have fun launching rockets and taking measurements! Once all groups have collected their data, the students would certainly enjoy a contest to see whose rocket can go the farthest!

7. **Wrap-up Activity:** Lead the class in a guided discussion of the results of this activity. Ask them to describe what they found about the relationship between launching angle and distance traveled. Explain that in an ideal situation, the distance traveled would increase as the angle increases from 0 degrees to 45 degrees. In theory, 45 degrees results in the longest distance traveled. As the angle increases from 45 degrees to 90 degrees, the distance decreases. Ask students why they did not obtain the "ideal" results. What real life variables affected their results? Help the class conclude that variation in thrust and air resistance affected their results. As hard as they try, they aren't able to keep the thrust exactly the same in each launch. Ask the class for ideas as to how the rocket could be modified to have a consistent thrust. Dropping an object onto the bottle from a certain height for each trial, is one idea. Air resistance also plays a major role. For which trials do they think air resistance plays the largest role? The longer the rocket is in the air, the more time air resistance acts on it. Therefore, the larger angles are affected the most by air resistance.

   Ask the class if they have heard of a multi-stage rocket. A rocket having two or more engines, stacked one on top of another and firing in succession is called a multi-stage. Normally each unit, or stage, is released after completing its firing. Ask the class what is changing about the rocket during the flight. Its mass is decreasing. Remind students that momentum is the rocket's mass multiplied by its velocity. The rocket gains a certain amount of momentum from the exhaust gases, if the rocket's mass is less, that gives it more velocity.

momentum = (mass) x (velocity)

determined by exhaust gases — decreases — increases

STOMP ROCKETS EXTENSION ACTIVITY

If more time is available, students can brainstorm how to improve the design of the rocket. For example: more fins, different shaped fins, a heavier rocket, a lighter rocket, shape of the rocket, or length of the rocket. Each group can pick a factor, make a prediction, then make a new rocket to test their prediction. Afterwards, each group can share their findings with the class.

How do rockets work?

Rockets burn fuel to create a hot gas. This hot gas is forced out the back of the rocket as exhaust. The gas gains momentum in one direction, and the rocket gains momentum in the opposite direction. This provides the thrust to propel the rocket forward.

What are the two basic types of rockets?

There are two basic types of rockets: liquid fuel rockets and solid fuel rockets. Solid fuel rockets are safer and less expensive than liquid fuel rockets, but they are not as efficient. Thrust is constant and can not be adjusted once the rocket has been launched. Liquid propelled rockets have a flow of fuel, and therefore thrust can be regulated. The main engines of space shuttles use a liquid propellant.

How are rockets used by society?

The first known rockets were used in China in the 1200s as fireworks. Later, armies began using them for war. After the Soviet Union launched an Earth-orbiting artificial satellite called Sputnik I in 1957, many people and machines have been launched into space. In 1969, the United States launched the first men to land on the moon using a Saturn V rocket. Rockets are used to launch satellites and to send probes to other planets.

Satellites allow scientists to forecast the weather and allow people to communicate instantaneously around the globe. A Delta II “heavy” rocket was used to deliver the Opportunity Rover to Mars for exploration in 2003. The Mars Exploration Rovers are meant to search for and characterize a wide range of rocks and soils that hold clues to past water activity on Mars. Not all rockets are sent into space. Smaller “sounding rockets” are used for scientific research. These rockets do not orbit, but instead help to study areas of the atmosphere that are too low for satellites.

What is the purpose of the fins on the rocket?

When the air hits the fins, it pushes on them and helps keep the rocket on its intended path. They provide stability.

How do you plan to keep the thrust the same for each rocket launch of the experiment?

Possible answer: Have the same person stomp on the rocket for each trial, and start their foot from the same height each time.

What variable will you be changing for each trial?

The Launching angle of the rocket

How do you think changing your variable will affect the distance traveled by the rocket?

(Answers will vary.)

Number and describe each step in your investigation.

1. **Use the protractor to set the launcher at a specific angle.**
2. **Launch the rocket at that specific angle and measure the horizontal distance travelled (in meters) with a measuring tape.**
3. **Repeat two more times for the same angle.**
4. **Average the three distances. Record all data in the table provided.**
5. **Repeat steps 1–4 at several other angles.**

Name____ Date__________

STOMP ROCKETS

What is the purpose of the fins on the rocket?

How do you plan to keep the thrust the same for each rocket launch of the experiment?

What variable will you be changing for each trial?

How do you think changing your variable will affect the distance traveled by the rocket?

Number and describe each step in your investigation.

Record the results of your investigation in the table below.

Launching angle in degrees	Distance travelled in meters (trial 1)	Distance travelled in meters (trial 2)	Distance travelled in meters (trial 3)	Average distance travelled in meters