

Rocket Activity

3...2...1...PUFF!

Objective

Students will learn about rocket stability as they construct and fly small paper rockets.

Description

Students will construct small “indoor” paper rockets, determine their flight stability, and launch them by blowing air through a drinking straw.

Materials

Sheet of 8.5 x 11 paper (white or colored)
Cellophane tape
Scissors
Ruler
Meter stick or tape measure
Fat, round pencil or dowel (see tips, p. 43)
Eye protection
Drinking straws
Copy of the *Ares I* paper rocket plans

National Science Content Standards

Unifying Concepts and Processes

- Evidence, models, and explanation

Science as Inquiry

- Abilities necessary to do scientific inquiry

Physical Science

- Position and motion of objects
- Motions and forces

Science and Technology

- Abilities of technological design

National Mathematics Content Standards

- Number and Operations
- Geometry
- Measurement
- Data Analysis and Probability

National Mathematics Process Standards

- Connections
- Representations

Management

Hold on to the straws until students have completed their rockets and tested them for stability. Select a clear space for the launches. Depending upon student lung power, rockets may fly 7-10 meters. Be sure students wear eye protection. Although the rockets have little mass, the pointed nose cones could injure eyes. Make sure students understand that the rockets are not to be launched toward anyone.

Background

Rocket stability is an important issue for rocket scientists. The success of a space launch depends upon “pinpoint” accuracy. If a future *Ares I* rocket arrives in space in the wrong orbit, it may not have enough fuel or supplies to make

rendezvousing with the International Space Station possible. The crew would have to return to Earth and “chalk off” a failed mission.

Stability means making sure the rocket follows a smooth path in flight. If it wobbles, the ride will be rough and extra fuel will be burned to get back on course. If it tumbles, it’s time to push the destruct button! An unstable rocket is dangerous.

Fortunately, it is relatively easy to ensure stability if two things are kept in mind. These two things are *center of mass* and *center of pressure*.

Center of mass (COM) is easy to demonstrate. It is the balance point of a rocket. Think of it like balancing a meter stick on an outstretched finger. If the stick rests horizontally, the COM is directly over your finger. If the COM is to the right of your finger, the stick will tip to the right. If to the left of your finger, the stick will tip to the left.

An object, tossed into the air, rotates around its COM. Rockets also try to rotate around their COM while in flight. If this rotation is allowed to happen, the rocket becomes unstable. This is where Center of pressure (COP) comes to the rescue.

COP is a balance point too but it has to do with the pressure exerted on the rocket surface by air molecules striking the surface as the rocket flies through the air. Like COM, there is a midpoint for the flight pressure on the rocket body. This is the COP. For a stable rocket, the COP is located to the rear of the rockets and the COM is to the front. To understand why the rocket is stable, let’s take a look at a couple of devices that also depend upon the placement of COM and COP.

A weather vane pivots on a vertical axle when the wind blows. One end of the vane is pointed and the other end has a broad surface. When the wind blows, the broad end of the vane catches more air (more air pressure) and is blown down wind. The narrow end of the vane has less pressure exerted on it and points into the wind.

One end of an arrow is long, narrow, and pointed while the other end has large feathers (or modern plastic fins). In flight, greater air

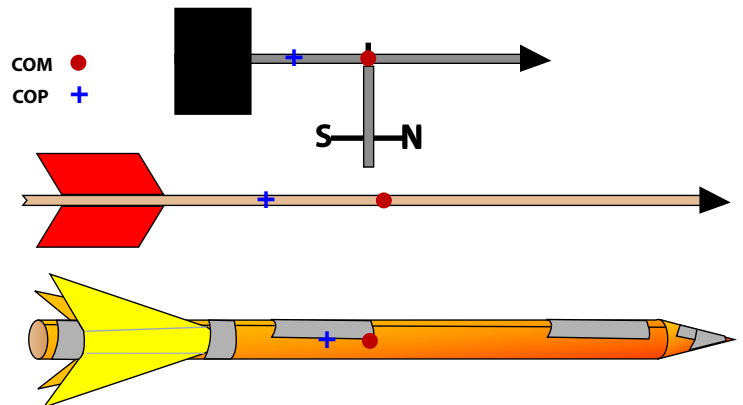
pressure is exerted on the feathers than on the narrow end. This keeps the arrow from tumbling around its COM and on course to its target.

In both examples, there was more surface area on one side of the COM than the other. Both devices were stable. Stability of a rocket is the same thing.

In this activity, students will build paper rockets and test them for stability using a drop test. Later activities will further explore the COM/COP concept and employ an advanced string test for rocket stability.

Procedures: First Activity

1. Demonstrate the construction technique for making paper rockets. (Refer to the diagrams on the next page.)
 - a. Cut a strip of paper for the rocket body (about 4 cm wide by 28 cm long).



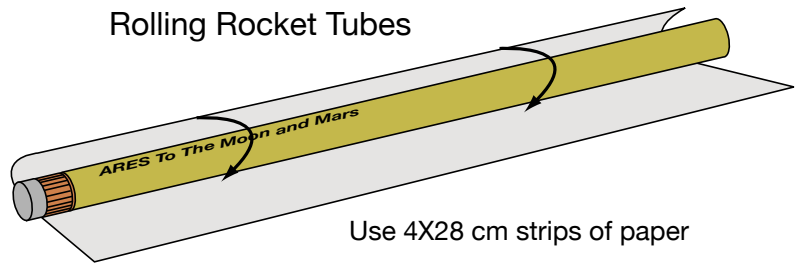
The positions of center of mass (red dot) and center of pressure (blue +) are shown for a weather vane, arrow and a rocket. The center of pressure is to the rear of the center of mass in each device. This enables them to point into the wind.

- b. Use a round pencil as a form and roll the strip around the pencil.
 - c. Tape the long seam.
 - d. Close off one end to make a nose cone.
 - e. Cut out three or four fins.
 - f. Tape the fins to the open (lower) end of the rocket. Bend them outward to space them equally.
2. After students have constructed their rockets, show them how to perform drop tests to check for stability. Hold the rocket horizontally at eye level and drop it to the floor. If the nose of the rocket hits the floor first, the rocket is stable and ready for flight.

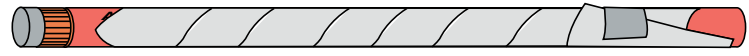
If the rocket falls horizontally or the fin end hits first, the rocket is unstable. Larger fins may be needed to stabilize the rocket. Have students perform their own stability tests and make adjustments to their rockets if needed.

3. Finally, demonstrate the launch procedure for the rocket. Stand at one end of your launch range. Insert a straw into the rocket body. Aim the rocket down range and puff strongly into the straw. Liftoff!
4. Talk over ideas for safety. Discuss wearing safety glasses. Ask students what should be done when they retrieve their rockets for another launch. (Other students should wait until the range is clear before launching.)
5. Have students improve their rocket design by holding distance trials. Students will launch their rocket three times and find the average distance the rocket travels. They will then try to improve their rocket design to get greater distance. The student data sheets outline the procedures and provide space to jot down and analyze data.

Rolling Rocket Tubes

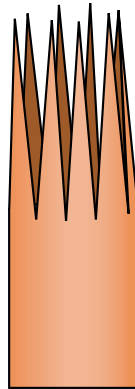


Use 4X28 cm strips of paper

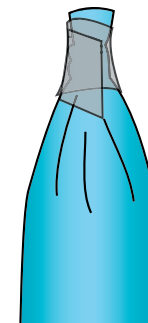
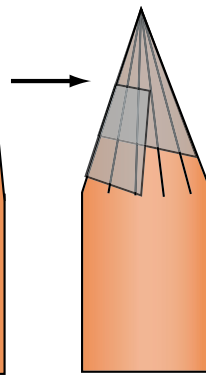


Tape and trim ends.

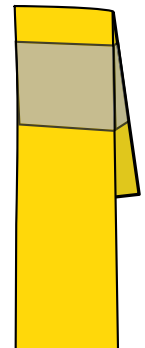
Making Nose Cones



Cut crown points and tape



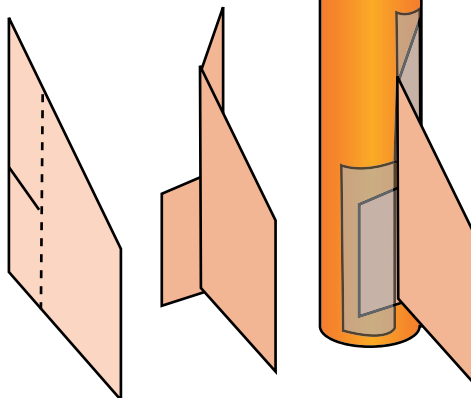
Gather end and tape



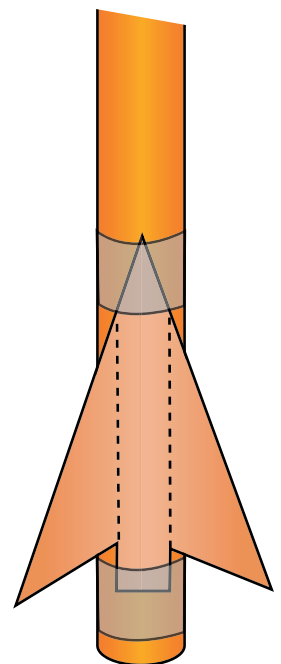
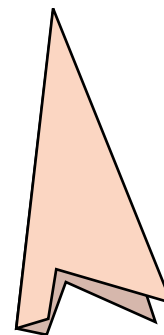
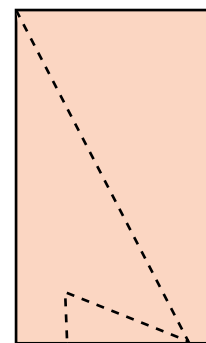
Fold end over and tape

Making and Attaching Fin

Cut tabs and spread. Tape tabs to rocket tube.



Fold paper square. Cut out fins. Spread fins and tape to rocket tube. Bend fin tips outward.



Procedure Second Activity

1. Give students *Ares I* rockets to assemble. (These rockets do not have any fins. The actual *Ares I* uses steerable rocket engines to keep the rocket stable in flight.) After forming the rocket body, the upper end of the tube is folded four times and taped.
2. Before flying these rockets, have students repeat the stability drop test.

Discussion

- *Why is the Ares I rocket stable even though it doesn't have any fins?*

Folding the paper makes that end of the rocket heavier than the other. Run a balance test with a finger. The balance point (center of mass) is far forward. The center of pressure is to the rear. This combination stabilizes the rocket for flight. The stability control for the paper version of *Ares I* is similar to the control used by the Chinese for their fire arrows (See pictorial history section.) The actual *Ares I* will employ steerable engines to maintain stability.

- *How do paper rockets work?*

Unlike traditional rockets, paper rockets do not carry their own propellants. Instead, a sharp puff through the straw momentarily fills the rocket tube with “high pressure” air. The tube directs the air back through the opening, producing an action force. The rocket launches because of the equal and opposite reaction force (Newton’s third law).

Assessment

- Have students write and illustrate a paragraph that describes their improvements to their rockets and how these improvements affected their experimental results.

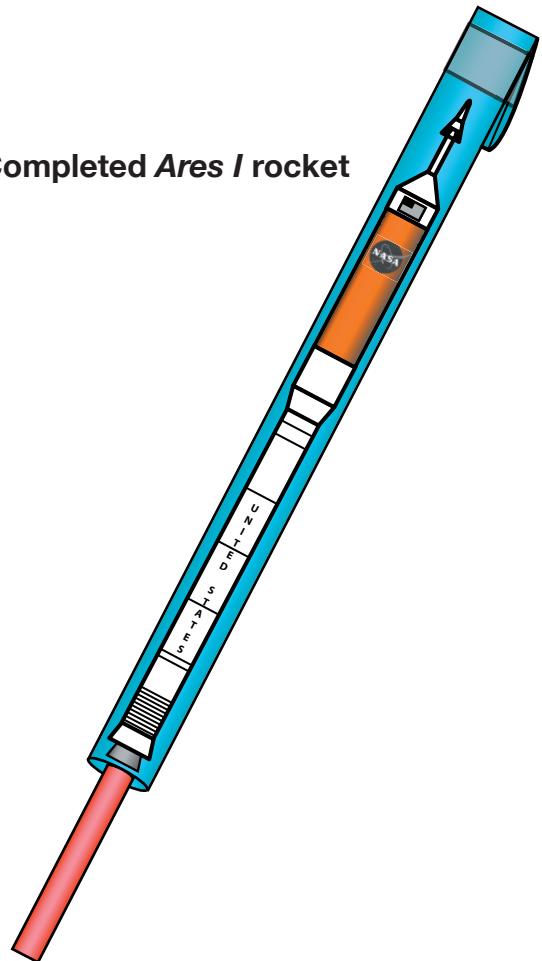
Extensions

- Have students investigate fin size and placement for its effect on flight stability. What will happen if the fins are placed at the nose end of the rocket? What will happen if the fin tips are bent pinwheel fashion? (Don’t

forget to perform drop tests before the actual flights!)

- Hold a rocket flight contest. See whose rocket flies the furthest or whose rocket is the most accurate (make a target).
- In a gym or other room with a high ceiling, launch rockets straight up next to a wall. Have other students estimate the altitudes reached by the rockets. Count the number of concrete blocks the rocket reached and multiply by the height of one block.
- Place a target at the far end of the launch range. An empty box makes a good target and rockets that land within the box are a “bull’s eye.”

Completed *Ares I* rocket



Tip Segments of a 1/4” or 3/8” dowel can be substituted for fat pencils. Cut the dowels slightly longer than the paper strips. The extra length makes rolling the tubes easier.

Paper Rocket Test Report

Name: _____

1. Launch your rocket three times at the same launch angle. Each time, measure how far it flew. Record your measurements in the data sheet below under the space labeled "Rocket 1." Calculate the average distance for the three flights.
2. *What can you do to improve the distance your rocket travels? Can you think of any improvements for your rocket?* Design and build a new rocket. Predict how far it will fly. Record your answer below in the space labeled "Rocket 2." Launch your second rocket three times and measure its distance. Record your data below. What is the difference between your predicted and actual distance? Did Rocket 2 fly farther than Rocket 1? Write your answers below.
3. *Did your changes in the rocket improve its flight?* Design and build a third rocket. Fly it the same way you did for Rockets 1 and 2. Did Rocket 3 fly farther than Rocket 2?
4. On the back of this paper, write a short paragraph describing the improvements you made to your rockets, how well they flew, and what you can conclude from your experiments. Draw pictures to illustrate how each rocket looked.

<p>ROCKET 1 Flight Distance (in cm)</p> <table style="margin-left: auto; margin-right: auto;"> <tr> <td style="padding: 2px;">Flight 1</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> <tr> <td style="padding: 2px;">Flight 2</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> <tr> <td style="padding: 2px;">Flight 3</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> <tr> <td style="padding: 2px;">Average Distance</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> </table>	Flight 1		Flight 2		Flight 3		Average Distance		<p>Make notes about the flights here.</p>
Flight 1									
Flight 2									
Flight 3									
Average Distance									

<p>ROCKET 2 Flight Distance (in cm)</p> <table style="margin-left: auto; margin-right: auto;"> <tr> <td style="padding: 2px;">Distance Prediction</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> <td style="padding: 2px;">Flight 1</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> <tr> <td style="padding: 2px;">Difference between your prediction and the average flight distance</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> <td style="padding: 2px;">Flight 2</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> <tr> <td></td> <td></td> <td style="padding: 2px;">Flight 3</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> <tr> <td></td> <td></td> <td style="padding: 2px;">Average Distance</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> </table>	Distance Prediction		Flight 1		Difference between your prediction and the average flight distance		Flight 2				Flight 3				Average Distance		<p>Make notes about the flights here.</p>
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<p>ROCKET 3 Flight Distance (in cm)</p> <table style="margin-left: auto; margin-right: auto;"> <tr> <td style="padding: 2px;">Distance Prediction</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> <td style="padding: 2px;">Flight 1</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> <tr> <td style="padding: 2px;">Difference between your prediction and the average flight distance</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> <td style="padding: 2px;">Flight 2</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> <tr> <td></td> <td></td> <td style="padding: 2px;">Flight 3</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> <tr> <td></td> <td></td> <td style="padding: 2px;">Average Distance</td> <td style="width: 50px; height: 25px; border: 1px solid black;"></td> </tr> </table>	Distance Prediction		Flight 1		Difference between your prediction and the average flight distance		Flight 2				Flight 3				Average Distance		<p>Make notes about the flights here.</p>
Distance Prediction		Flight 1															
Difference between your prediction and the average flight distance		Flight 2															
		Flight 3															
		Average Distance															

Ares / Paper Rocket Patterns

Fold 1	Fold 1	Fold 1	Fold 1
Fold 2	Fold 2	Fold 2	Fold 2
Fold 3	Fold 3	Fold 3	Fold 3
Fold 4	Fold 4	Fold 4	Fold 4
