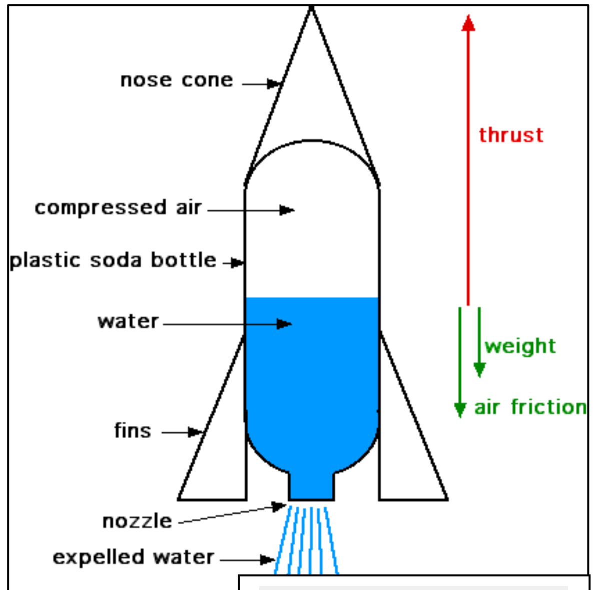
Water Rockets
Application of Newton's Laws of Motion

Background

A water rocket is a chamber, usually a 2-liter soft drink bottle, partially filled with water. Air is forced inside with a pump. When the rocket is released, the pressurized air forces water out the nozzle (pour spout). The bottle launches itself in the opposite direction. The bottle usually has a nose cone for streamlining and fins for stability.



Courtesy of Classical Mechanics - Physics Stack Exchange

Water rockets are easily capable of 100-meter-high flights, but advanced hobbyists have combined bottles and staged bottles for flights over 300 meters high.

Water bottle rockets are ideal for teaching Newton's laws of motion. The launch of the rocket easily demonstrates Newton's third law. Students can see the water shooting out of the nozzle (action) and see the rocket streak into the sky (reaction). *Example:*
Newton's third law says that for every action there is an equal and opposite reaction, so like the picture on the right shows, as water rushes out (weight), thrusts is produced as a reaction.

Students can also experiment with different pressure levels inside the chamber and different amounts of water. The rocket will not fly very high if it is filled only with air. The air will quickly rush out during the launch, but its mass is very low. Consequently, the thrust produced is also low (Newton's second law). By placing water in the bottle, the air has to force the water out first before it can leave the bottle. The water increases the mass expelled by the rocket, thereby increasing the thrust. *Example:*
Mass and Acceleration are needed to create force, so the water's mass and the rate at which the pressurized air is pushing the water out produces the force that will push the rocket upwards. (F = M x A)

Like all rockets, the flight performance of water bottle rockets is strongly influenced by the rocket's design and the care taken in its construction. Beveling the leading and trailing edges of fins allows them to slice through the air more cleanly. Straight-mounted fins produce little friction or drag with the air. A small amount of ballast weight inside the nose cone helps balance the rocket. This moves the center of mass of the rocket forward while still leaving a large fin surface area at the rear. In flight, the 116 rocket design acts like a weather vane, with the nose cone pointed up and the fins down.

Related Physics topics: inertia, aerodynamic forces, center of gravity, center of pressure, trajectory

Investigation ACTIVITY

Overall Objective

The teacher plans to bring the concepts learned in physics class to life through the experience of building and launching rockets. Students investigate how a rocket design affects its flight at launch.

The purpose of this lesson is to apply Newton's Laws of Motion and other physics concepts to alter the flight time and height of a water rocket. Students will also identify the forces acting on the rocket at different phases of the trajectory. The students will also gain teamwork experience.

PROBLEM:
What change to the water rocket will make it fly higher than the control or Teacher's rocket and at the same time increase the flight time of the rocket? What force(s) are acting on the rocket throughout its trajectory?

Title: ______________________________

Student's PURPOSE: ____

PRE-LAB Question: Draw free body diagrams of a rocket showing any and all forces acting on the rocket during… a) at the instant of launch, b) on the way up, c) on the way down

Rocket DESIGN: Discuss the ideas considered and scientific reasoning behind them. Identify independent, dependent, and controlled variables

> *Each team of students will agree on a way to make their rocket different than the control rocket. They can change the fins (shape, number, width, position) or the body tube (length) or the nose cone (shape) or the mass or even the location of the center of mass. All ideas must be recorded in the lab notebook. - No parachutes are allowed!*

NOTE: Remind students they can only make one thing different than the control rocket – for example the fins or the body tube. They can't change both at the same time.

CLAIM: Hypothesis: ____

Construction Instructions and Materials: see attachments… NO PARACHUTES ARE ALLOWED for this challenge!

Launching Materials:
Student rockets, a teacher built rocket, water rocket launcher, bicycle pump with pressure gauge, ESTES Altitrack, lab notebooks, and pencil or pen

Rocket Measurements and Specifications: Draw a scaled diagram of your rocket. Label all parts and rocket measurements in lab notebook. Be specific! (ex: body & fins width, body & fins height, nose cone, mass)

Launching PROCEDURE:
The control rocket must be launch first to set the target for students to beat.

1. Place the launcher on an open field with the launch rod pointing upward.
2. Add 300 ml of water to the rocket.
3. Load the rocket on the launch rod and lock it.
4. Connect the air pump to the valve on the launcher. With the valve closed, pump up 50 psi of pressure. FOR SAFETY, students must be within 4 meters of the launcher.
5. Perform a countdown to let the "recorders" know when the rocket is about to launch.
6. As one teammate launches the rocket by pulling on the string attached to the valve, another uses the Estes Altitrack to collect the launch data for their rocket, and a third teammate records the flight time.
7. Using the data collected, calculate the maximum rocket height (apogee) – *see attached notes.*
8. Each team must follow the steps above exactly.
9. Each rocket must be launch at least twice for precision.

Sample DATA Table & Observations

Launch #	Pressure (psi)	Empty Rocket Mass (g)	Amt of water added (ml)	Rocket Mass w/ Water (g)	Flight Time (s)	Distance of Altitrack from Launcher (m)	Angle Reading from Altitrack	Calculated Maximum Height (m)
Teacher	50		300			70		
1	50		300			70		
2	50		300			70		

1. What did you observe? Describe the flight of your rocket. (Did it fly straight, wobble, drop quickly to the ground, etc?)
2. Based on your observations how stable was your rocket? Why?
3. Discuss any visible problems with the rocket flight, and how can they be corrected.

Evaluation of Data: Computations

SHOW ALL CALCULATIONS!

Conclusion

Provide reasoning that connects the evidence (data) to the claim. *How did your design affect the rocket's flight at launch according to your observations?*
Includes appropriate and sufficient scientific principles to explain why the evidence supports the claim OR recognizes alternative scientific explanations if evidence does not support the claim. Cite sources of error.

Argumentation and Interpretation of Class Data

1. Which rocket design in the class gave the greatest flight height and time flight? How does this design compare with yours? Why do you think this design worked best? Does it increases or decreases drag, increases or decreases stability?
2. Putting together everybody's data, describe what the "perfect" water rocket would be like. Be specific.

Going Further

- ❖ Hypothesize how the maximum height will be affected if more water is added? Launch your rocket with only 150ml of water instead of 300ml
- ❖ Hypothesize how the maximum height will be affected if less pressure is added? Launch your rocket using 35 psi pressure instead of 70psi
- ❖ Using Newton's 2nd and 3rd law of motion, explain your results.

Resources

- *NASA*
- *University of Nebraska Rocket Team*
- *SECME National Competition Guidelines*
- *Boy Scouts of America*