Rocket STEM

Student Handouts

Developed by:

Angela Wendel
Bradford Exempted Village Schools
750 Railroad Ave
Bradford, OH 45308

Philip Bottelier
Dayton Regional STEM School
1724 Woodman Drive
Kettering, OH 45420

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1. STUDENT HANDOUTS

The following handouts target eighth and ninth grade standards with extension for non-calculus physics, and can be modified to suit instructional needs.

1.1. ROCKET PRE/POST ASSESSMENT

_____ 1. Which is not one of Newton's laws of motion?

a. F=ma
b. For every force there is an equal and opposite force
c. $e=mc^2$
d. inertia

_____ 2. Which of Newton's laws of motion listed above is applied when a rocket orbits the Earth?

a. F=ma
b. For every force there is an equal and opposite force
c. $e=mc^2$
d. inertia

_____ 3. The blast off of a rocket is an example of which law?

a. F=ma
b. For every force there is an equal and opposite force
c. $e\text{-}mc^2$
d. inertia

_____ 4. What is the advantage of using water in a bottle rocket instead of just air?

a. Pressurized air gives too much thrust
b. Water is more dense than air so it causes the rocket to fly higher
c. People get wet during launch
d. Water allows the bottle to hold more pressure

_____ 5. What modification would increase the duration of flight of the rocket?

a. Don't use fins
b. Remove the nose cone
c. Put the fins near the top of the rocket
d. Reduce drag

_____ 6. The fins on a rocket help

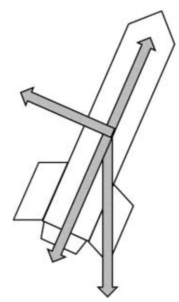
a. Increase aerodynamics
b. Stabilize flight
c. Propel the rocket
d. Steady the launch

_____ 7. Which has the least volume (assume all have the same diameter and same height)

a. Half of a sphere
b. Cylinder
c. Cone

8. Without an altimeter, how can the altitude of a rocket be calculated?

9. Identify the forces that act on a rocket.



1.2. DETERMINING EXPANSION COEFFICIENT OF FLEXFOAM-IT

The nose cones for the two liter rockets will be cast from a polyurethane foam product called FlexFoam-iT!. It is an ideal material for nose cones because it is flexible, adheres to the bottle surface, and is very durable. This material comes in two parts—generally an isocyanate and a polyol, which, when mixed together, chemically react and expand to produce mid-density foam. The expansion coefficient, the amount by which the foam expands from its original volume, is important when considering how much to use to cast your nose cone. Your task is to determine the expansion coefficient.

1.2.1. CHALLENGES

- Write a protocol (step by step instructions) on how to determine the expansion coefficient.
- Experimentally determine the expansion coefficient of the two part expanding polyurethane foam.
- Extended challenge: experimentally determine conditions that affect the expansion of the foam.

1.2.2. BACKGROUND

In your own words, describe the field of materials science and engineering.

Describe three applications of materials science that you use every day.

1.2.3. PROCEDURE

1. You will be supplied with known, equal volumes of Part A and Part B FlexFoam-iT!®X (1:1 is the appropriate ratio for this particular foam), cups, and a popsicle stick for stirring. You will also have access to most basic materials found in the lab.

2. With your group, brainstorm how to determine the expansion coefficient.
3. Choose one method and draft a list of materials that you need and the protocol (step-by-step procedure) that you plan to follow.
4. Have your protocol approved by your teacher before proceeding.

Important considerations

- Part A and Part B must be combined and stirred vigorously for 60 seconds. The reaction will start after 60 seconds and should be complete in about 5 minutes.
- Upon reacting, the foam adheres to most surfaces and will be hard to clean out (i.e., mix in a disposable container).
- Note any sources of error in the procedure that may affect the final result.

1.2.4. BRAINSTORMING

1.2.5. MATERIALS NEEDED

1.2.6. PROTOCOL

1.2.7. OBSERVATIONS

Note anything you did differently from your written protocol, any sources of error that may affect the final result, and any other observations of the reaction.

1.2.8. ANALYSIS

Write down any measurements or calculations used in determining the expansion coefficient. Expansion coefficient = volume of ending material/ volume of starting material.

Expansion coefficient of FlexFoam-iT!®X: ________

Complete the following table using expansion coefficients determined by other groups (including your group).

Group #	Expansion Coefficient	Method of Measurement
1		
2		
3		
4		
5		
6		
7		
8		

Average expansion coefficient: ________
*Do not include any values that were a result of a serious mistake in the procedure because they may skew the average.

How does your expansion coefficient compare to the average and those obtained by other groups?

What are at least three sources of error that may account for the differences in expansion coefficients determined among groups?

1.2.9. CONCLUSION

Using all of the above data, approximate the expansion coefficient of FlexFoam-iT! X: _______

How did you determine this (what factors did you take into account)?

1.2.10. EXTENSION

Determine the density of FlexFoam-iT! X: __________
Show your calculations here:

Materials sciences and engineering connection:
Identify a circumstance in which you would want to change a property of the foam. How would you change the property of the foam to adapt it to that circumstance?

1.3. ROCKETS

1.3.1. BACKGROUND

1. Make a timeline of at least eight events in the history of rocketry. The timeline must include events related to the first rockets, Chinese rocketry, and the Soviet Union and United States space programs. Cite the references that you used.

2. Identify the main contribution or impact that these people have had on rocketry.
   a. Archytas:

   b. Hero of Alexandria:

   c. Wan-Hu:

   d. Sir Isaac Newton:

   e. Konstantin Tsiolkovsky:

   f. Robert H. Goddard:

References:

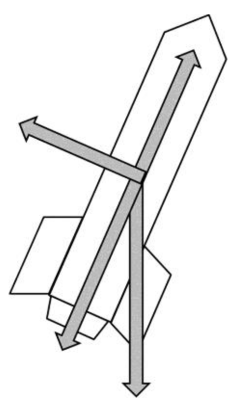
Explore the NASA Water Rocketry website to learn about rockets and how certain variables can be adjusted to increase rocket performance. Use this information or other sources to complete the following section. Cite any other sources used.

NASA Water Rocketry:
http://exploration.grc.nasa.gov/education/rocket/BottleRocket/about.htm

3. Water rockets demonstrate all three of Newton's Laws of Motion. In your own words, identify Newton's Laws of Motion and describe how rockets demonstrate each one.

Newton's Laws of Motion	**Describe how rockets demonstrate each law**
Newton's 1st Law:	
Newton's 2nd Law:	
Newton's 3rd Law:	

4. Identify the forces that act on a rocket:



5. Using Newton's Laws of Motion and the forces that act on rockets, briefly explain how rockets work.

6. Water bottle rockets are comparable to rockets used in space exploration. Identify the parts of a water bottle rocket and their functions:

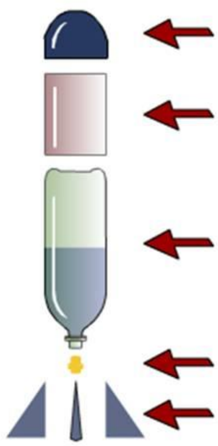


Photo credit: http://exploration.grc.nasa.gov/education/rocket/BottleRocket/Rocket_Parts_animation.html

7. Explain why using only air is not ideal to power the rocket/ why is water necessary?

8. Explain why using more water is not necessarily better for reaching the maximum height.

9. What is a characteristic of good fin configuration?

10. In what circumstances is nosecone shape extremely important?

1.3.2. ROCKET SIMULATION

Rocket Modeler III is a virtual simulator used to test variables of your water bottle rockets to optimize rocket design without having to launch actual rockets hundreds of times. Use this tool to help design your rocket.

Rocket Modeler III: http://www.grc.nasa.gov/WWW/k-12/rocket/rktsim.html

Below are the baseline variables to set up the default rocket.

- Be sure to hit Enter after adjusting any values, otherwise the changes will not occur.
- You must have all green buttons in "Mission Control" before you can launch your rocket.

Red buttons or text indicates trouble that needs attention before launch.

Select Units:	**Metric**	
Select Type of Rocket:	**Water**	
Design		
BODY		
Select "No Fairing"		
FINS		
Select	1/16 Balsa	Thickness and material of the fins.
Number:	3	Number of fins.
Geometry:	Trapezoidal	Shape of the fins.
Locate cm:	0	Distance of fins relative to the nozzle.
Length cm:	15	Length of fins.
Width cm:	7.5	Width of fins.
L.E. Ang:	45	Leading edge angle-- top angle of the fin.
T.E. Ang:	0	Trailing edge angle—the lower angle of the fin.
NOSE		
Select	Solid Foam	Material of nosecone.
Shape:	Elliptic	Shape of nosecone.
Length cm:	12.7	Length of nosecone from base to tip.
Diam cm:	10.16	Diameter of nosecone (same as a 2L bottle)
Ballast g:	482	Additional weight in the nose (e.g. parachute)
Click **GO**		
Fuel		
Vol cc:	0	The volume of water added.
Pressure kPa:	275	The pressure of air added.
Diam cm:	2.125	Diameter of the mouth of a 2L bottle.
Length cm:	15.2	The length of the launch tube.
Click **GO**		
Click **Pad**		
Click **GO**		
Click **Launch**		
Click **Fire**		
Record the **Maximum** Height of the default rocket: _________ meters		

You will now test Nose Cone Length and Fuel Volume to optimize the rocket design to reach maximum flight height (apogee). Remember to only test one variable at a time—do not change any other parameters. You will choose a third variable to test.

Before testing each variable in the simulation, write a hypothesis relevant to how the variable will affect flight height. Complete all tables and graphs (remember titles and axes labels). Either accept or reject the hypothesis after testing and make a conclusion.

1.3.2.1. VARIABLE: NOSE CONE LENGTH

Hypothesis:

Data:

Nose cone Length (cm)	Maximum Height (m)
5.0	
10.0	
12.7 (control)	
15.0	

Conclusion:

1.3.2.2. VARIABLE: FUEL VOLUME

Hypothesis:

Data:

Water Volume (cc)	Maximum Height (m)
0 (control)	
250	
500	
750	
1000	
1250	
1500	
1750	
2000	

Conclusion:

1.3.2.3. VARIABLE:

Hypothesis:

Data:

Conclusion:

1.3.3. ROCKET DESIGN & BUILD

Based on the simulations, design and build your rocket.

Plan

Nose cone (shape, length):

Fins (number, shape, length, width):

Fuel volume (to be added at launch):

Other:

1.3.4. ROCKET STABILITY

For stable flight, the center of pressure (cp) of a rocket must be below its center of gravity (cg), relative to the direction of flight. In your own words, define cp and cg and answer the following questions.

1. Center of pressure (cp):

2. Center of gravity (cg):

3. What would happen if the cp was above the cg?

4. How could you move the cg toward the nose of the rocket?

5. How could you move the cp toward the tail of the rocket?

The center of gravity and center of pressure of an object, like a large rocket, can be calculated, but it usually requires some calculus. For small objects, such as your rocket, these points can be found mechanically.

- ☐ To find the **center of gravity** of your rocket, balance the rocket using a string or an edge (similar to balancing a pencil on your finger). The point at which the rocket is balanced is the center of gravity. With a black Sharpie, draw a dot on your rocket at this point and label it "cg."

- ☐ To find the **center of pressure** of your rocket, trace an outline of your rocket on a piece of poster board and cut out the shape. Hang the cut out shape with a string and tape, and determine the point at which it balances. The point at which the rocket is balanced is the center of pressure. Draw a dot on the rocket silhouette and on your rocket at this point and label it "cp."

- ☐ Check: is the cg of your rocket above its cp, relative to the direction of flight?

- ☐ Final Stability Test: **The Swing Test**
  1. Tie and tape a 2.5 meter string around the rocket at the center of gravity
  2. Swing the rocket in a circle around you
  3. After a few revolutions, if the nose points in the direction of rotation, the rocket is stable, and the cg is above the cp. If the rocket wobbles or the tail points in the direction of rotation, the rocket is unstable, and the cg is below the cp.

Observations:

  4. If the rocket is unstable, increase the stability by raising the cg or lowering the cp, find the new cg and cp, and repeat the swing test.

Adjustments made, if necessary:

FINAL ROCKET SPECIFICATIONS			
Total mass (g):		Nose cone shape:	
Total length (cm):		Nose cone length (cm):	
Width (cm):		Nose cone mass (g):	
Fin shape:		Number of fins:	
Center of Mass (cm) (measured from nozzle of rocket; cm):			
Center of Pressure (cp) (measured from nozzle of rocket; cm):			
Distance between cm and cp (cm):			
Did your rocket pass the String Test?			

Sketch of completed rocket:

FLIGHT DAY DATA		
Date:	Time:	Location:
Weather conditions:		
Wind speed (mph):	Wind direction:	Temperature (^{o}C):
Launch angle:	Fuel (H_2O) volume (mL):	Pressure (psi):
Flight trajectory observation:		
Observation Site 1 Dist. from launch (m): Time of flight (s): Height (m) of observer: Angle of apogee:	Observation Site 2 Dist. from launch (m): Time of flight (s): Height (m) of observer: Angle of apogee:	Observation Site 3 Dist. from launch (m): Time of flight (s): Height (m) of observer: Angle of apogee:
Evaluation of rocket performance:		

1.3.5. DATA ANALYSIS AND CONCLUSIONS

The following handouts provide questions for students on calculating velocity and acceleration, as well as height.

1.3.5.1. VELOCITY AND ACCELERATION

Rocket velocity and acceleration can be calculated using physics video analysis software or any media player capable of frame-by-frame analysis.

1. Use the video of the rocket launch to create a distance vs time graph of the launch.

2. Calculate the average velocity of the rocket at launch.

3. Calculate the maximum velocity of the rocket at launch.

4. Calculate the average acceleration of the rocket at launch.

5. Use the maximum velocity of the rocket at launch (initial velocity) to calculate how high the rocket went. Compare to the actual maximum height of your rocket. What do you think accounts for the difference?

6. Use the actual maximum height of the rocket to calculate the final velocity of the rocket before it hits the ground.

7. Knowing that the initial velocity of the ascent and the final velocity of the descent should be equal in magnitude, which do you think is a more accurate representation of the actual velocity: the initial velocity calculated from the video or the final velocity calculated by using the maximum height. Explain why?

1.3.5.2. ROCKET HEIGHT

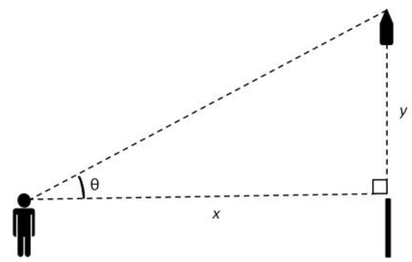
Rocket height can be measured by an altimeter or calculated using trigonometry or time. Using the launch data and the methods below, calculate the maximum height of the rocket.

Trigonometry

Trigonometry is a branch of mathematics that studies the relationships among lengths and angles of triangles. For example the tangent of an angle is the ratio between the sides of a triangle that are opposite and adjacent to that angle. Therefore, because you know how far away you were from the launch, and the angle of the rocket at its maximum height relative to you, you can calculate the height at which the rocket flew.

You will use the equation $y = x(\tan \theta)$; where:

- y = height
- x = distance between student and launcher
- θ = measured angle



Enter the data from your rocket's flight into the first two empty columns and calculate the height for each of the observations recorded for your rocket's flight.

Observation	x Distance from launch (m)	θ Angle observed	tan θ	x(tanθ) This is the height!
1				
2				
3				
			Average height (m)	

Time

Objects, such as your rocket, that are falling due only to the force of gravity are said to be in free fall. Because all free falling objects on Earth accelerate downward at a rate of 9.8 m/s^2, we can use the time the rocket fell to calculate from how high it fell, assuming no air resistance.

You will use the equation $y = \frac{1}{2} gt^2$; where:

- y = height
- g = 9.8 m/s^2
- t = time (in seconds) that the rocket fell from maximum height to the ground

Observation	**t** **Time observed (s)**	**t^2** **Time squared**	**g** **Acceleration due to gravity**	**$\frac{1}{2} gt^2$** **This is the height!**
1				
2			**9.8 m/s^2**	
3				
			Average height (m)	

1. Based on your analysis, how high did your rocket fly?

2. If you used more than one method to calculate height, how do the heights compare? What are at least two reasons you think contribute to this difference?

3. Explain which method you think is more accurate.

4. How did your rocket fly compared to other groups' rockets? What is at least one reason you think accounted for the differences?

1.4. LAUNCH LOG

Launch Site	
Weather Conditions	
Temperature	

Date	
Wind Direction	
Wind Speed (mph)	

Time Launched	Launch #	Group #	Fuel (H2O) amount (mL)	Launch pressure (psi)	Launch angle	Notes

1.5. DATA LOG

Observation Site #	
Distance from Launch Site	
Direction from Launch Site	

Date	
Time	

Launch #	Name of Observer	Angle Measured at Apogee	Name of Timer	Time (seconds)	Notes