Balloon Rockets: What a drag!

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Vivify STEM

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Teachers Guide

Purpose:

The purpose of this lab is to understand the forces acting on a balloon rocket followed by how to manipulate these forces to optimize the design.

Background:

The balloon rocket is a classic science experiment, but this activity often ignores a very important force that is part of real rockets: drag! Hook students with a question: which will travel faster, a smaller or larger balloon? Students will likely be surprised that the smaller balloon actually travels faster and gets to the end of the first! Why is this happening? First, students will explore the thrust force and how this moves a balloon through the air. Next, students will be introduced to drag forces with a series of demonstrations and discussions that involve dropping objects of various sizes and weights. Students generally learn the idealized law that all objects fall at the same rate, but this ignores air resistance. These demonstrations will push their thinking and help them understand the role of drag based on the influence of surface area. Finally, the students will return to the balloon rocket activity and apply their knowledge of air resistance and thrust to optimize a balloon rocket that travels up to the ceiling!

Set up:

Balloon Rocket: Place a 10-foot string horizontal, parallel to the ground. Attach the balloon to each string by taping it to a straw threaded on the balloon. Any regular balloon will work. Make sure to stretch the balloon before blowing it up.

Helpful hints:

Here are some troubleshooting tips:

- Use a string to measure the circumference of the balloon
- Attach the string to two chairs or use a thumbtack to attach one end to the wall while a student (or a chair) holds the other end.
- Make the string at least 6 feet to make it easier to time.

Student Version

Overview: What is the relationship between the size of a balloon and the time it takes to the end of the string? How does this relate to the real forces on a rocket?

Materials

- Straight straw
- Balloon
- Tape
- String
- Measuring tape
- Scissors
- 2 chairs or something to attach the string
- Stop watch
- Paper

Procedure

Pre-Lab Procedure:

1. What are the forces acting on a *tied* balloon attached to a string? Draw a free body diagram.

2. The balloon is now untied and traveling down the balloon. What are the forces acting on the balloon as it travels down the string? Draw a free-body digram.

3. Balloon Demo: Which balloon will reach the end of the string first: the larger or smaller balloon? Explain your answer.

Part A: Impact of Balloon Size

The goal of this lab is to determine the relationship between the size of the balloon and the time it takes to reach the end of the string. Your team will conduct multiple trials of the balloon rocket experiment using different-sized balloons. The results of this lab will be useful for the final engineering design challenge.

1. Thread the straw on the string.
2. Set up the string horizontal or parallel to the ground. Make sure the string is firmly taped or tied on both ends such as tied to 2 chairs or taped to the wall. The length of the string is up to your team, but it needs to be at least 6 feet long. The length of string will stay constant in this experiment.
3. Decide as a team four different sizes of balloons to test. Record in the table below. Consider: How will you measure the circumference of the balloon? How will you make sure to blow up the balloon to the same circumference for each trial?
4. For each circumference size, record the time it takes to travel to the end of the string. Average all the times for the average time for each size. Consider: How will you record the time accurately?

Data Table

Balloon Circumference		Distance (cm)	Time (s)	Notes
	Trial 1			
	2			
	3			
			Avg:	
	Trial 1			
	2			
	3			
			Avg:	
	Trial 1			
	2			
	3			
			Avg:	
	Trial 1			
	2			
	3			

Analysis and Conclusions

1. What happened during the experiment? What challenges did you face?
2. Rank the size of the balloon with the shortest to longest time:
3. Compare results with other groups. Discuss how your results compare with other groups.
4. Why might results among groups be different?
5. How can we improve the experiment?
6. How would you explain the relationship between size and time to end of string?
7. Go back to the free-body diagram in the pre-lab Q2 activity. Does this diagram explain the relationship? Why or why not?
8. Blow up two balloons: a small and large one. What do you think will happen if you drop both balloons at the same time?

9. Why did one hit the ground first?
10. Draw the free-body digram from the pre-lab Q2 adding all forces.

Part B: Optimize a Vertical Rocket

So far, we have been doing a horizontal rocket, but real rockets go up! In our final part of the lab, we are going to use the knowledge from part A to optimize the time it takes for a balloon to travel to the ceiling!

Prior to starting, answer the following questions:

1. Draw a free body digram of a balloon rocket at the bottom of the string before releasing it.

2. Draw a free body diagram of a balloon rocket traveling on the string moving upward.

3. What should we consider about the thrust?

4. What should we consider about the drag force?

5. How can we use the previous data to optimize our results?

To complete the engineering design challenge:

1. You will have 3 tries to get the fastest time possible to reach the ceiling. Consider: how will you accurately measure the time?
2. Select the first balloon circumference. Conduct 3 trials, record the time, and calculate the average time to top.
3. Use this trial to determine if you should increase or decrease the balloon size. Select a second size of balloon, and conduct 3 trials again.
4. Repeat with a third-size balloon.
5. Compare results with other teams.
6. Extension: Add fins and/or nosecone to the balloon using paper and tape to increase the speed.

Data Table

Balloon Circumference		**Distance (cm)**	**Time (s)**	**Notes**
	Trial 1			
	2			
	3			
			Avg:	
	Trial 1			
	2			
	3			
			Avg:	
	Trial 1			
	2			
	3			

Analysis and Conclusions

1. Which size balloon traveled the fastest to the top? Compare to other teams to determine the fastest time for the class.

2. What forces were affecting the time to the top?

3. How do you optimize the balloon?

4. Real rockets have a nose cone and fins. What do you think is the purpose of these parts of a rocket?

5. How does the vertical rocket compare to the horizontal rocket?