Lesson 2: Lighter than Air

During this lesson students will learn the role density plays in balloon flight through building their own hot air balloons. They will work in teams with minimal instruction to learn how to navigate group collaboration, role delegation, and effective communication. By the end of this lesson students will understand that aerospace engineers still consider balloons an extremely efficient way to get heavy payloads into the Earth's upper atmosphere.

Learning Objectives

Students will

- Understand what makes a hot air balloon rise by explaining the difference in density between hot air and cool air
- Successfully test and modify design (iterate) hot air balloons to improve performance
- Build appreciation for the many different cultures that have contributed to aerospace

Materials

Hot air balloons for class

- Extension cords
- Power strips
- Timer

Per Group

- 10 sheets of tissue paper
- 2 pairs of scissors
- 1 tape dispenser
- 2 glue sticks
- 15 paper clips
- Hair dryer or hot air popcorn popper
- 2 rulers or 1 yard stick

Students will work in groups of 4–5 to construct and pilot their hot air balloons. Ensure that you have enough heat sources for each group. Make sure that groups have enough space to build and modify without running into other groups.

You have the option of making this lesson 2 hours long if your students are engaged with the building process and want to continue improving the design of their balloons.

Time

2 hours

WELCOME AND CHECK-IN (5 MINUTES)

Welcome students to class and open with a check-in question:

- What kinds of vehicles are used to become airborne?
- How long has aerospace engineering been around?
- When did aerospace engineering begin? Who were some of the first aerospace engineers?

A check-in question is a good way to transition students from their last activity into the classroom. Use one that is reflective or will be answered during the lesson.

Explain that today they are going to answer all of these questions by learning about some of the history of aerospace engineering.

PART I: HISTORY OF AEROSPACE ENGINEERING (15 MINUTES)

In this part of the lesson you want to provide a brief overview of the history of hot air balloons. The goal is for students to understand that the difference in density is what causes balloons to rise and stay in flight. It may be useful to illustrate that the design of some hot air balloons has not changed drastically over time.

The following green text is a suggested facilitator script; feel free to alter it as necessary. Consider how your students responded to the curriculum from the previous lesson and oscillate between modalities to meet the learning styles of your group. What is important is that students learn that regardless of how the design of hot air balloons may change over time, the physics behind what enables them to fly does not.

> 2,000 Years Ago
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> Unmanned sky lanterns have been documented in use as early as the third century BCE, in ancient China. These sky lanterns were used during wars to scare enemy troops. General Zhuge Liang (181–234 CE) is credited for the use of lanterns as a war tactic. The lanterns took flight by an oil lamp or waxy flammable material being lit on fire under a large paper bag.

Here is a good opportunity to test what students may already know about density. You can ask the class if anyone knows what causes the lanterns to take flight.

> The flame heats the air inside the bag, making it less dense than the air outside of the bag, which causes the bag to rise. These particular "lanterns" are some of the oldest forms of hot air balloons in history.

You should prepare a brief explanation of density for your class in case they are unfamiliar with the concept: Density is the degree of compactness of a substance.

Explain that density measures how much mass is within a specific unit of volume. To illustrate how the density of air within the balloon changes when heated, you can draw an illustration of how air particles spread out (because they are moving more quickly than cool or room-temperature particles) as they are heated. When particles are moving more quickly, they take up more space within the balloon and rise to the top of the inside of the balloon. The particles enclosed within the balloon are hotter than the particles outside, which makes the density of particles within the balloon lower. Fewer particles are now within the balloon. The difference in density between the inside and the outside of the balloon causes the balloon to rise.

If available, this would be a good opportunity to show students a video of lanterns in flight. There are many videos online of international festivals like the Loi Krathong festival in Thailand or New Year celebrations that include the releasing of lanterns into the atmosphere.

200 Years Ago

On September 19, 1783, one of the first hot air balloon flights with passengers launched. This hot air balloon was constructed of paper and cloth by the Montgolfier brothers in Versailles, France. To inflate the craft they burned a combination of straw, chopped wool, and dried horse manure underneath the balloon. As the straw burned it released heat that helped the balloon float. The wool and manure made lots of smoke and helped keep the burning flame low, which lessened the risk of setting the balloon on fire. The brothers were too nervous to try out their invention themselves so they sent a sheep, a duck, and a rooster in a gondola—which is the basket underneath the balloon—to see what would happen. The balloon floated up into the sky, traveled about 2 miles, and landed safely eight minutes later.

To gauge retention, you can ask students what differences and similarities they noticed between the lanterns and balloons and how they think the designs could be improved. This will help transition students into thinking about how they can build their own balloons.

Let the students know that all of the animals survived and none were harmed during this flight. Print out an artist's rendering of one of these early flights and project it at the front of the classroom or have a rendering for each student to look at while you tell them the history.

PART II: YOUR OWN ENGINEERING (60 MINUTES)

Explain to students that they will be working in groups of 4–5 to design, build, and fly their own hot air balloons. They will not receive detailed instructions and are encouraged to troubleshoot and solve problems as a team. Ideally you will have a heat source for each group. If you have a limited number of heat sources, groups can rotate between using the heat source, designing, and redesigning. Students will need time to launch balloons, so keep the class on task to ensure that each group has an opportunity to launch at least once.

Save time by preparing workstations and materials before class begins so students can jump right into the activity.

You can choose to construct your own hot air balloon to model what students should build, or if you want to make this activity more challenging, do not show students a physical example before they start building.

If you choose to build an example, create an elementary hot air balloon using as few materials as possible so students have a chance to mimic your design. There are many different designs that you can choose from; we recommend a simple balloon constructed of 5 sheets of tissue paper.

Allow students to look at your model for no more than 2 minutes. They can draw sketches of your model or take notes, but explain that you will put it away after 2 minutes.

If you decide to encourage students to build without referencing a model, explain that students can utilize any of the materials at their workstation and should think about the weight, size, and design of their balloon during construction. If they finish one balloon they may have time to build another or improve upon their initial design to test how different construction materials affect their balloon.

Students may grow frustrated with asymmetrical proportions affecting their balloon's flight path or struggle with construction, so be prepared to coach them through the design process if you decide to allow students to build without a visual aid.

For groups that finish quickly, you can instruct them to improve the design of their balloon so that it stays airborne for a longer period of time.

PART III: THE SCIENCE BEHIND YOUR FLIGHT (20 MINUTES)

After each group has had time attempting to fly a balloon, gather the class for discussion.

> Let's make sure you understand the science behind your flight! When energy is added to a molecule, in this case heat, the molecule moves more quickly, which makes it take up more space. So fewer hot, active molecules can fit inside the balloon per square unit than outside the balloon. Fewer molecules is another way to say less dense. The air inside the balloon is less dense than the air outside the balloon. The less-dense air rises and fills the balloon. As the air inside the balloon continues to rise, the balloon and gondola also rise.

This is very simplified, but as an introduction to air density this definition will work for the time being. Ask the groups what worked and didn't work in their flights and designs and why.

PART IV: HOW IS THIS TECHNOLOGY USED? (20 MINUTES)

As a conclusion for this lesson you can tell the class that hot air balloons are widely used and incredibly efficient tools for exploring the Earth's lower atmosphere. If you have access to a computer or a projector, showing a video of hot air balloons being used as research tools will help illustrate how this technology is still widely used. NASA's hot air balloon launches illustrate how the relative design of balloons has stayed the same while new technology is incorporated into data collection to utilize research balloons in revolutionary ways.

Guiding Discussion Questions

- Hot air balloons appear to be a relaxing form of transportation, but are they efficient? Is it reasonable to carry all that fuel to burn to heat the air?
- Are there other ways we can get a balloon to rise?
- Are hot air balloons useful? If yes, how and what are they used for?
- Why can't we use cool air to make balloons rise?
- What do you think would happen if the shape of the balloon was longer or wider?
- Hot air balloons are an efficient tool for exploring which part of the Earth's atmosphere?
- Why are hot air balloons efficient tools for exploring the Earth's lower atmosphere?