Hot Air and Gas Ballooning

Session Time: Four, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Appreciate the rich, global history of aviation/aerospace and the historical factors that necessitated rapid industry development and expansion. (EU1)

Understand the importance of professionalism, ethics, and dedication as they relate to all aviation/aerospace operations. (EU4)

Appreciate the global nature of the modern aviation/aerospace industry and embrace the discovery and inclusion of cultures outside the learner's typical experience. (EU7)

ESSENTIAL QUESTIONS

1. How did balloons spur innovation in aviation?
2. What impact have balloons made in our history?
3. What roles do buoyancy and density play in balloon flight?

LEARNING GOALS

Students Will Know

- Scientific concepts that affect balloon flight
- How a hot air balloon is built and piloted
- Practical purposes for balloons today

Students Will Be Able To

- *Explain* the science behind the flight of hot air and gas balloons (DOK-L2)
- *Recognize* the impact balloons have had on the history of flight and innovation. (DOK-L1)

ASSESSMENT EVIDENCE

Warm-up
Students will write two to four sentences discussing their experience with observing hot air balloons, including details about how hot air balloons are generally used today.

Formative Assessment
Students will discuss if it's possible for helium balloons to lift them off the ground and then attempt the calculation.

Summative Assessment
Students will explain the scientific concepts for why their hot air balloon was able to fly and also identify factors that may have influenced their balloon's flight.

LESSON PREPARATION

MATERIALS/RESOURCES

- Hot Air and Gas Ballooning Presentation
- Hot Air and Gas Ballooning Student Notes
- Hot Air and Gas Ballooning Teacher Notes
- Hot Air and Gas Ballooning Teaching Aid

Density Demonstration Activity

- Large clear tank or tub filled with water
- Pairs of sinking and floating objects
  - Two cans of soda–regular and diet
  - Orange with peel and orange peel only
  - Two bowling balls–one more than 12 lbs and one less than 10 lbs

Hot Air Balloon Activity (per group)

- 13 sheets of tissue paper (approximately 20” x 30”) (bright, mixed colors preferred)
- Glue stick
- Scissors
- Straight edge (yard or meter stick works best)
- Marker (any dark color)
- Large bowl with smooth, rounded bottom and sides
- Masking tape or duct tape

Materials (per class)

- Masking tape or duct tape
- Camp stove with propane fuel converter and one section of metal heating duct to hold over camp stove
- Fire extinguisher
- Heat protection for hands
- Optional heat sources
  - Metal ice bucket or small metal garbage can with 3-4 cans of Sterno or similar gel fuel
    - Should be large enough to hold multiple cans of gel fuel
    - Sides should be more than 6 inches high
  - Hot air popcorn popper
  - Hair dryer set on low speed with high heat

SAFETY

- Actively supervise students during the lab or activity. Be ready to offer guidance in situations where safety could be compromised.
- Review fire safety with students prior to activities that involve the use of heat.

LESSON SUMMARY

Lesson 1: Hot Air and Gas Ballooning

The first session will begin by students sharing their observations of hot air balloons flying overhead and how they think hot air balloons are generally used today. Next, students will answer the question: “How many helium balloons would it take to lift yourself off the ground?” Students will discuss if it is possible then work in pairs to do the actual calculation and solve the problem.

Demonstrate the concept of density with a hands-on activity that will help students determine why some objects sink and others float. Through a class discussion, students will learn how balloons fly by applying the concepts of density and buoyancy. In addition, students will learn about the parts of a balloon and how a pilot operates them. Students will watch a video about some of the most famous balloonists—the Montgolfier brothers—and learn more about early balloon flights.

As an extension activity, students will spend the next three sessions building and flying their own hot air balloons.

As a summative assessment, students will reflect on the hot air balloons they constructed and flew. Students will explain the scientific concepts for why their hot air balloon was able to fly and also identify factors that may have influenced their balloon’s flight.

BACKGROUND

Density is an important concept in this lesson. It is a measurement of how much mass is contained in a given unit volume. The density of an object can be found by using the formula: density = mass / volume.

For example, a solid rock that measures one cubic meter (1m x 1m x 1m) weighs more (and therefore has more mass) than one cubic meter of styrofoam. The rock is denser, or has more molecules per cubic meter, than the styrofoam. If you dropped a one cubic meter rock in water, it would sink. If you dropped one cubic meter of styrofoam in water, it would float.

Hot air is less dense than cool air. Balloons rise when the air inside the balloon is heated and it becomes less dense than the air around it. Balloons can also fly when filled with a gas, like helium or hydrogen. Helium and hydrogen are lighter than air (nitrogen), so balloons rise when filled with these gases.

The hot air creates buoyancy. Buoyancy is another important concept in this lesson. Buoyancy is the ability or tendency to float in water or air or some other fluid. The principle behind buoyancy is called Archimedes’ principle, which is: The buoyant force on a submerged object is equal to the weight of the fluid that is displaced by the object.

A hot air balloon works in this manner:

1. A burner heats the air inside a balloon.
2. As air inside a balloon gets warmer, the density of the air in the balloon decreases.
3. The less dense air causes the hot air balloon to be lifted off the ground due to the buoyant force created by the surrounding air.

MISCONCEPTIONS

Some students may believe that since aircraft have become so advanced, balloons are no longer used for practical purposes other than leisure flights. See the **GOING FURTHER** section of the lesson plan for additional materials to help students further explore and clarify this idea.

DIFFERENTIATION

To support verbal reasoning in the class discussions occurring in the **EXPLORE** and **EXPLAIN** sections, organize the class into groups for Think-Pair-Share instead of a whole group discussion. This allows learners to think about the question, and discuss their thoughts with a partner before sharing with the larger group. Sharing encourages all students to participate and practice skills, including metacognition.

LEARNING PLAN

ENGAGE

Teacher Material: Hot Air and Gas Ballooning Presentation

Slides 1-3: Introduce the topic and learning objectives for this lesson.

Slide 4: Conduct the **Warm-Up.**

Take no more than 5 minutes of class time to complete the warm-up. If time allows, have students share their answers in class.

[DOK-L1; recall, list]

Warm-Up

Begin the warm-up by asking students if they have seen a hot air balloon in flight. Students will then write two to four sentences discussing what they saw. In addition, ask students to write two to four sentences about how hot air balloons are used today.

EXPLORE

Teacher Material: Hot Air and Gas Ballooning Presentation

Slides 5-6: Conduct **Formative Assessment**.

Many students have likely seen the animated movie *Up*. To hook the students, consider playing the clip at the beginning of the movie when the old man's house is being lifted by balloons. Slide 5 presents the questions for students to answer. Slide 6 guides students through checking their answer.

[DOK-L3; hypothesize, formulate]

Formula:

Student weight (lbs)	*x*	*453.59 g / 1 lb*	*x*	*1 L / 1 g*	*X*	*1 balloon / 14 L*	=	*Number of balloons required*

Formative Assessment

How many helium balloons would it take to lift yourself off the ground? Is this possible?

Students will discuss ways to calculate the number of balloons it would take to lift themselves off of the ground. In pairs, the students will then try to solve this problem. Use the information from the presentation to help set up this problem. When making their estimates, students should assume that one liter of air can lift one gram of weight and that one helium balloon holds 14 liters of air. Students should know (or use) that 1 lb. = 453.59 g. *(See formula above)*

Slide 7: Provide key terms and concepts for the lesson with definitions.

Slide 8: Introduce the concept of density through a hands-on activity.

Density is an important concept in this lesson. In this explore activity, perform a demonstration that will help students determine why some objects sink and others float. For the activity, follow the steps below.

- Provide a large clear tank or tub of water and pairs of sinking and floating objects:
    - Two cans of soda–regular and diet
    - Orange with peel and orange peel only
    - Two bowling balls–one more than 12 lbs and one less than 10 lbs
- Allow students to first classify the objects as ones that with either sink or float.
- Drop items in the tank and have a discussion as to why the items sink or float. Test the pairs prior to class, some cola products work better than others.
    - Whether an object sinks or floats in water depends on its density. Water has a density of 1g/mL, if an object's density is calculated to be greater than that of water, it will sink, and if it is calculated to be less than water, it will float.
    - Coke and Diet Coke have different densities because regular Coke has 39 g of sugar (greater density). Diet Coke does not have sugar.

Slide 9: Connect the above demonstration to how hot air balloons float with the questions below:

Questions

Why do hot air balloons rise?
A hot air balloon rises when the air inside the balloon becomes heated. The heated air is less dense than the surrounding air and enables the balloon to float.

Why do helium balloons rise?
Helium is a gas that is less dense than air, even when it's not heated.

EXPLAIN

Teacher Materials: Hot Air and Gas Ballooning Presentation, Hot Air and Gas Ballooning Teacher Notes
Student Material: Hot Air and Gas Ballooning Student Notes

Slides 10-15: Provide information about how a hot air balloon works using the concepts of density and buoyancy. In addition, students will learn about the parts of a hot air balloon and how pilots operate them. Students are also provided information about how hot air balloons differ from gas balloons.

Questions

Ask students: Will a hot air balloon rise or fall if the pilot allows hot air to escape?
Correct responses include: The balloon may go down if hot air escapes, the balloon may stop its ascent or slow down if hot air escapes.

Slide 16: Provide students with **Hot Air and Gas Ballooning Student Notes** to complete while watching the following video:

- "Hot Air Balloon—Montgolfier Brothers" (Length 12:09)
  http://video.link/w/pJJd

(Stop the video at 12:09 as it goes further into the history of ballooning.)

Divide the class into small groups and ask students to review their responses with one another. Bring groups together to discuss the answers. Answers are provided in **Hot Air and Gas Ballooning Teacher Notes.**

Slide 17: Provide students with information on a number of "ballooning firsts."

Slide 18: Instruct students to return to their small groups. Pose the following questions to the groups. Bring the groups back together for a class-wide discussion.

Questions

1. Why do you suppose animals were sent in hot air balloons before humans? What risks would have been involved? Why do you think a sheep, duck, and rooster were chosen?
   Maybe they were unsure of health risks they would face, such as breathing. These animals were chosen because it was thought a sheep would react like a human, a duck would probably be fine after the flight, and a rooster served as the control group because it didn't fly at high altitudes.

2. It is roughly 30 miles between Philadelphia, Pennsylvania, and Gloucester County, New Jersey. If the flight took 45 minutes, at what speed was it traveling? Do you think using a balloon was faster or slower than the way people traveled back then?
   The balloon was traveling at 40 miles per hour (rate = distance/ time, so 30 miles/45 min = 23 miles/min or 23 miles/min x 60 min/1 hr = 40 mph). People used horses and carriages, so the balloon would have been faster, but its flight was dangerous and could have been adversely impacted by weather and other factors.

3. What do you suppose would have been some concerns for the first manned flight? What questions do you think the scientists were thinking about?
   How to steer, how to descend, how to control the speed, how to land safely, and how to prevent the balloon from catching fire.

EXTEND

Teacher Materials: Hot Air and Gas Ballooning Presentation, Hot Air and Gas Ballooning Teaching Aid

Slides 19: As an extension activity, students will spend the next three sessions building and flying their own hot air balloons. They will work in small groups to build the balloons. Teachers should refer to **Hot Air and Gas Ballooning Teaching Aid** for materials required, a step-by-step guide to building the balloons, steps for flying, and safety guidelines. It is recommended that teachers complete this activity in advance in order to determine the best way to fly the balloons based on the chosen heat source.

Teaching Tips

Optional Approach: If the class is running short on time, a pre-constructed balloon could be used for demonstration purposes or the entire class could work on different parts in order to construct one balloon.

EVALUATE

Teacher Material: Hot Air and Gas Ballooning Presentation

Slide 20: Conduct **Summative Assessment**.

They should take no more than 10 minutes of class time to complete the assessment.

[DOK-L3; explain, draw conclusions]

Summative Assessment

Ask students to reflect on the hot air balloon they just constructed and flew. Students should explain the scientific concepts for why their hot air balloon was able to fly and also identify factors that may have influenced their balloon's flight.

Possible answers include:

A burner heats the air inside a balloon. As air inside a balloon gets warmer, the density of the air in the balloon decreases.

The less dense air causes the hot air balloon to be lifted off the ground due to the buoyant force created by the surrounding air.

Factors impacting flight could include weight of balloon, not gluing all seams well and leaving gaps, not cutting gores evenly, etc.

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Speech shows evidence of one or more of the following

- Knowledge of air density and pressure
- Understanding of how a hot air balloon rises
- Responds to questions of audience and instructor

- Shows understanding of concepts covered in the lesson.

Points	Performance Levels
9-10	Consistently demonstrates criteria
7-8	Usually demonstrates criteria
5-6	Sometimes demonstrates criteria
0-4	Rarely to never demonstrates criteria

GOING FURTHER

Show a video about one of the most well-known hot air balloon festivals in the world. Scroll to the bottom of the webpage to watch the video (Length 1:57). https://www.aopa.org/news-and-media/all-news/2016/october/13/hundreds-of-thousands-celebrate-balloon-fiesta

Have students watch "The Science Behind the Albuquerque Box" (Length 1:43) and build a model to describe this phenomenon. http://video.link/w/qJJd

Have students research how balloons were used in political, economic, and social satire in the 18th and 19th centuries.

One of the misconceptions that students might have is that since aircraft have become so advanced, balloons are no longer used for practical purposes other than leisure flights. To help clear up this misconception, introduce students to one of NASA's uses for high altitude balloons. Through the "Radiation Dosimetry Experiment" (RaD-X), NASA is trying to learn more about radiation exposure where commercial airlines fly. Have students watch NASA's RaD-X high altitude balloon launch (Length 4:52). http://video.link/w/uJJd

Have students respond to the following questions while they are watching the video:

1. When does the team start and stop data collection?
   They start collecting data on the ground and stop during the descent before touching down. The instruments must be turned off for landing.

1. How does the engineering team determine if the balloon flight has been a success?
   They check the data with their science models to see how well their models are predicting what will happen. They are testing to see if their assumptions (hypotheses) were correct, just as we do when using the engineering design process.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **HS-ETS1-1** - Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
    - Science and Engineering Practices
        - Asking Questions and Defining Problems
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.A: Defining and Delimiting Engineering Problems
    - Crosscutting Concepts
        - Systems and System Models
        - Influence of Science, Engineering, and Technology on Society and the Natural World
- **HS-ETS1-3** - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
    - Science and Engineering Practices
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.B: Developing Possible Solutions
    - Crosscutting Concepts
        - Influence of Science, Engineering, and Technology on Society and the Natural World
- **HS-PS2-2** - Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. (NOTE: This standard is not explicitly used as math is not required to complete the exercise).
    - Science and Engineering Practices
        - Using Mathematics and Computational Thinking
    - Disciplinary Core Ideas
        - PS2.A: Forces and Motion
        - PS2.B: Types of Interactions
    - Crosscutting Concepts
        - System and System Models

COMMON CORE STATE STANDARDS

- **RST.9-10.1** - Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- **RST.9-10.2** - Determine the central ideas or conclusions of a text; trace the text’s explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

- **RST.9-10.4** - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- **RST.9-10.5** - Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
- **SL.9-10.1.C** - Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.
- **WHST.9-10.1** - Write arguments focused on discipline-specific content.
- **WHST.9-10.2** - Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
- **WHST.9-10.4** - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
- **WHST.9-10.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
- **WHST.9-10.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **WHST.9-10.9** - Draw evidence from informational texts to support analysis, reflection, and research.
- **HSN-Q.A.2** - Define appropriate quantities for the purpose of descriptive modeling.
- **HSN-Q.A.3** - Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

REFERENCES

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