AEROSPACE Center For Excellence

# Aerodynamics: Heavier Than Air

**Session Time:** 5, 45-minute sessions

## LESSON SUMMARY

Students will model and understand two of the underlying physics concepts of aerodynamics: Bernoulli's principle, Newton's Third Law.

## LESSON STANDARDS

**NGSS**

- MS-ETS-1
- MS-ETS-2

**ITEEA**

- STEL-7L
- STEL – 8H

## LEARNING OBJECTIVES

**The learner will:**

- Define and explain terminology associated with aerodynamics.
- Identify and describe basic forces acting on an object in flight.
- Explain how Bernoulli's principle applies to an object in flight.
- Explain how Newton's Third Law applies to an object in flight.

## TEACHER BACKGROUND

The previous lesson focused on aerostatics, which is the study of gases that are not in motion, i.e., the science of lighter-than-air aircraft. This lesson will focus on the science of aerodynamics, which is the study of the way objects that are heavier than air move through air.

**Lift** is the force that opposes an aircraft's weight and allows it to fly. Bernoulli's Principle and Newton's Third Law of Motion have roles in creating lift.

**Bernoulli's Principle** states that as the speed of a fluid increases, its pressure decreases. A fluid includes both liquid and gaseous forms. Air/gasses are a fluid.

An airplane's wing (**airfoil**) has an upper surface that is curved much more than the bottom surface. As the plane moves through the air, the air flows faster over the curvier top of the wing than the less curvy underside of the wing; thus, the pressure on top of the wing is lower than the pressure on the underside resulting in a net upward force called lift.

**Newton's Third Law** states that for every action, there is an equal and opposite reaction. When the wing moves through the air, air is deflected downward off the rear of the wing. Per Newton's Third Law of Motion, the equal and opposite reaction is a lifting force that elevates the wing.

Commented [AB1]: Maybe add in that air/gasses are a fluid.

Commented [AB2]: Technically, this is a misconception as lift works at right angles to the direction of motion. It doesn't always have to be up.

Commented [KR3R2]: I took out upward.

Commented [AB4]: I'm editing online at home. Double check in the app that this footer is correct. It looks wrong.

Commented [KR5R4]: It is correct

## MISCONCEPTIONS

- **A fluid is a liquid only.**
  - The word *fluid* refers to a substance that has no fixed shape and gives easily to external pressure – a flowing substance. This can be a gas or a liquid. Air is a fluid and is subject to all the "laws" impacting fluids.
- **Sticking your hand out the window creates lift.**
  - Sticking your hand out the window actually illustrates drag.
- **The bottom of an airplane's wing is flat.**
  - The bottom of an airplane's wing has a slight curve.

## VOCABULARY

**Aerodynamics** – the study of the way objects move through air
**Bernoulli's Principle** – as the speed of a fluid increases, the pressure within that fluid decreases
**Fluid**- a substance that has no fixed shape and gives easily to external pressure; a flowing substance; a gas or a liquid
**Newton's First Law of Motion** – an object at rest remains at rest while an object in motion remains in motion unless acted upon by an outside force
**Newton's Third Law of Motion** -for every action, there is an equal and opposite reaction

## LESSON PREPARATION

### Materials: Teacher

- Aerodynamics Presentation
- Computer/laptop
- Projector

### Materials: Student

**Per Group/Pair**

- 2 bendable straws (1 for Bernoulli's activity, 1 for Newton's Third Law)
- 3 non-bendable straws (1 for Bernoulli's activity, 2 for Newton's Third Law)
- 1 cheese ball
- 1 10.7cm x 14 cm piece of copy paper
- 2 empty soda cans
- 1 piece of 9 cm x 16.5 cm cardboard
- 4 water bottle caps with holes drilled in the middle or model wheels. *Note: If you use the model wheels, then eliminate two of the non-bendable straws as the wheels come with axles.*
- 1 10" (25.4cm)wood skewer cut in half
- 1 9" balloon
- 1 small rubber band

Commented [AB6]: We have been listing out all our thinksheets and handouts up here so teachers know what to print out and how many copies to make.

- 1- balloon pump
- scissors
- tape
- glue
- ruler
- ramp – plank of wood or other material about two feet long.
- tennis ball
- sheet of 8” by 11” copy paper

**Per Student**

- strip of copy paper 11” x 1.5” (28 cm x 3.8 cm)
- Student Think Sheet|Bernoulli’s Principle
- Student Think Sheet|Newton’s Third Law
- Student Think Sheet|How Does A Wing Actually Work?
- Student Think Sheet| Winglets

## Advanced Preparation

- Print Student Think Sheets and Handouts
- Divide students into pairs or groups of 4.
- Cut copy paper into 10.7cm x 14 cm pieces by folding a sheet of copy paper in half long ways, and then in half again in the other direction to have four sections. Cut these apart.
- Choose cheese balls that are the roundest for the activity. If you do not have cheeseballs, then you can use ping pong balls. These are heavier and require a stronger stream of breath.
- Watch video for demonstration of Newton’s Third Law. Make a sample and test.
- Prep materials for balloon cars.
    - Cut cardboard bases 9 cm x 16.5 cm.
    - Poke holes in water bottle caps – use a heated nail or drill to make it easy.
    - If you have bendy straws for this part, cut off bendy section.
    - Cut sharp tip off skewer and then cut skewer in half (approx. 12.5 cm pieces).
    - Put materials for each car in a large Ziplock bag or small basket for easy distribution to groups.
- You may want extra straws for each activity that requires students to blow into them in case the first student does not have the ability to blow strong enough to achieve the desired results and another student wants to try.

# LESSON PLAN

## ENGAGE — DAY 1

**Slides 1 -3**

1. Introduce the lesson and learning objectives.

**Slide 4**

2. Tell students that in the last lesson they explored the flight of an object that is lighter than air. In this lesson, they will be learning the scientific principles behind the flight of an object that is heavier than air.
3. Remind the students of the four forces of flight that were reviewed in Unit 1 Lesson 3. Tell them that in this lesson they will be focusing on how one of these forces is created.
4. Hold up a strip of paper (1.5" x 11") by one end. Most of the paper should be hanging down. Ask "Is this paper heavier than air? How can we determine this?" *Drop it and see if it floats.*
5. Drop the paper. It will float down slowly. Ask: "What force caused the paper to drop?" *Gravity/weight*
6. Ask: "What force is needed to counteract gravity to get the paper to stay in the air?" *Lift*
7. Distribute a strip of paper to each student. Tell them that you are going to ask them to hold one short edge of the paper at the bottom of their lower lip and gently blow across the paper. Ask: "What do you think will happen to the paper? Why?" *Accept all reasonable answers; you are prompting them to think about what will happen.*
8. Have students gently blow across the paper and discuss what they think happened to make the paper go up. *The paper moved upwards. At this point, you are not looking for a correct answer but rather checking their misconceptions.*
9. Ask: "What force was just demonstrated?" *Lift*
10. Tell students that they are going to explore the physics of flight that allows an aircraft that is heavier than air to stay in the air.

## EXPLORE 1 — DAY 1

**Bernoulli's Principle**

**Slide 5**

1. Show students the definition of Bernoulli's Principle. Ask, "What is a fluid?" *A substance that flows or conforms to the outline of its container*
2. Ask, "Do you think air is a fluid? Why or why not?" *Accept all reasonable answers.*
3. Click on slide to show definition of a fluid and ask again, "Is air a fluid?" *Refer back to definition and probe to get students to understand that air meets the criteria of a fluid.*
4. Explain that since air is a fluid, it abides by Bernoulli's Principle which contributes to lift. Explain that in the activities, they are going to explore the principle that resulted in the strip of paper flowing up instead of down.

**Slide 6**

5. Distribute Student Think Sheet | Bernoulli's Principle.
6. Distribute materials for activities. These can be done in pairs or groups of 3.
7. Assign roles and rotate these for each activity. This allows each person in the group to be the experimenter performing the activity.
8. Students work through the activities on this sheet completing questions at the end of each one. Depending on the ability of your students, they may work independently or be led through each activity one by one. Pictures are provided on the Think Sheets and the presentation.
9. Notes for activities

Activity 1: Paper Tent

The tent sides should come together. If they do not, the students may have the straw too close to the tent or too far above the table.

Activity 2: Floating Cheese Ball

If the cheese ball does not float, it may be too irregularly shaped; replace it with a rounder one. In addition, the students may be blowing irregularly, and they need to provide a steady stream of air.

Activity 3:

The cans should move towards each other. If they do not, have the students reposition the straw.

Commented [AB7]: Did you use this? https://www.nasa.gov/wp-content/uploads/2020/04/changing_pressure.pdf

The pictures make these much clearer. I had a hard time following this section and the worksheet.

Commented [AB8R7]: I think the cheese ball might be easier to do than the ping pong ball. Have you tried this one out yet?

Commented [KR9R7]: I fixed the think sheet and still need to add pictures.

Commented [KR10R7]: Added pics

## EXPLORE 2 DAY 2

**Newton's Third Law**

**Slide 7**

1. Tell students that in addition to Bernoulli's principle, Newton's Third Law of Motion is needed to understand how an aircraft can fly. Briefly explain that Sir Isaac Newton described three laws of motion in the late 1600's and that these Laws hold true today. Newton is still considered one of the most influential scientists in history. His First Law states that an object in motion will remain in motion and an object at rest will remain at rest until acted upon by an outside force.
2. Ask, "What general force is used to make an airplane move forward?" *Thrust – generated by a motor or other outside force in the case of a glider.*
3. State, "Newton's First Law Explains that a force is required to get the plane moving. However, it is his Third Law that helps to explain lift."
4. Click on slide to show Newton's Third Law: For every action, there is an equal and opposite reaction. Tell students that is what we will explore in this next activity.

**Slide 8**

5. Distribute Student Think Sheet | Newton's Third Law
6. Read the objective.
7. Distribute materials for the activity.

Commented [AB11]: I've been correcting it, but you are switching up the spelling of axel and axle. The second is correct, but the former is also a word so spell check isn't catching it.

**Slides 9- 12**

8. Use the slides to discuss directions. This can be done step by step for differentiation if needed. Set an amount of time for students to complete the car including adding sides and front to the car in addition to decorating.
   *Note: If your students work well independently, then you can skip these slides and they can use the Student Think Sheet to complete the activity.*
9. Once students have completed the activity, allow time to answer questions.

**Slide 13**

10. If time permits, discuss answers to questions with the whole group.

## EXPLAIN — DAY 3

**Slide 14**

1. Tell students that now that they have explored the two main principles involved in flight, they will watch a video to understand how Bernoulli's Principle and Newton's Third Law work together to keep an airplane in the air.
2. Distribute the Student Think Sheet | How Does a Wing Actually Work?
3. Play video stopping at each time stamp listed, allowing time for students to answer the questions on the Think Sheet.
4. Discuss the answers.

## ELABORATE — DAY 3

**Slide 15**

1. State, "We have just looked at two of the scientific principles that contribute to lift in an airplane. Now let's look at one of the causes of drag and how engineers used physics principles to reduce drag."
2. Distribute Student Think Sheet| Winglets
3. Click on slide to show the video: "What are Those Things on Airplanes' Wings."
4. Stop video at time stamps and have students answer questions.

   *Notes:*
   - *Several of the questions are very close together (3 – 5). You may want to play those sections all at once and then rewind, stopping at each point to have the students answer each question.*
   - *Some of the questions are directly from the video and some require them to think about the four forces of flight and the physical science concepts studied in this lesson.*

## EVALUATE — DAY 4

**Slide 16**

1. Show pictures of different types of fictional vehicles that have been shown to fly in atmospheric conditions (i.e. air).
2. Have students choose one and explain why it would or why it would not have been able to fly in a planet's atmosphere. Explanations must include the terms *lift*, *Bernoulli's Principle*, *Newton's Third Law* and *drag*. *Student answers should include reasonable evidence that the aircraft is or is not obeying the physical science concepts to produce lift.*

## REFERENCES

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