Lesson 3: Heavier than Air—Planes

Not all aircraft are kept aloft by using lighter-than-air technology as did the hot air balloons in the last lesson. How else can we fly? This lesson teaches students how such heavy aircraft as planes become airborne and stay in flight. In the next several lessons students will gain understanding of the multiple forces that act on an object during flight.

Learning Objectives

Students will

- Be able to explain Bernoulli's principle
- Know what materials they can use to build a plane and why

Materials

These will vary depending on which experiments you elect to conduct. Think about how your students like to learn and choose the activities accordingly.

Time

2 hours

WELCOME AND CHECK-IN (10 MINUTES)

Welcome students to the classroom and ask a check-in question. Today's lesson focuses on flight, so a good introductory question will get students thinking about the subject matter. Some example questions are

- How do we get off the ground?
- How do you think engineers learned about flight before planes, helicopters, and other aircraft existed?

PART I: HISTORY OF FLIGHT (20 MINUTES)

> What types of things can get off the ground? Imagine man has no machine that can do so. Look around—what do you see flying?

Pose the question to students to facilitate a discussion.

> Many engineers started by watching birds and bugs and trying to mimic them.

Biomimicry: The design and production of materials, structures, and systems that are modeled after biological entities and processes

You want to get students to think about how flying apparatuses were designed. How did engineers get inspiration? Consider playing a video of early experimentation with individual flight techniques. There are many videos available online that depict humans attempting flight with winglike apparatuses. The objective here is to illustrate the evolution of flight design and the importance of trial and error in engineering.

> Eventually engineers realized that we needed to do more than attach wings to our arms and flap like birds!

Wright Brothers

The Wright brothers are an excellent example of perseverant engineers who never gave up on their goal and continued improving their design to eventually create a flying apparatus. Prepare a visual aid of the Wright brothers at work or photos of their designs for students to look at while you explain the following.

Providing historical context will illustrate the importance of perseverance, creative iteration, and teamwork, regardless of the era. There are many resources and books on the Wright brothers available online that depict their iterations.

The Wright brothers took a different approach. They decided their top priority was to control the plane, steer it, and have a safe landing. They too looked at the birds—not to figure out how to get off the ground but to inform them how to steer. They developed a technique to twist the wings (wing warping) to control their gliders. There was so much to learn, from how to shape the wings to how to shape the propellers to how to build an engine. They were methodical. They hypothesized, designed, built, tested, collected data, redesigned, and retested. Every time they tested their inventions they risked their lives!

To truly understand how complicated flight is, we have to start with the forces involved. How do we "beat the force" or overcome the forces that keep us earthbound?

As an additional activity, if you have computer access you can have students work in pairs to build their own airplanes online. There are many games and resources available to students that assist them in constructing an aircraft. Be sure to test out the game before you share it with students.

PART II: A BIT OF PHYSICS (45 MINUTES)

Have the following written or projected at the front of the classroom, and have a student read it aloud.

> Bernoulli's principle: The faster water moves over a surface, the lower the pressure it exerts on the surface.
>
> We need to understand the attributes, or qualities, of what we are flying through: air! Daniel Bernoulli was a Swiss mathematician and physicist who lived during the 1700s. He was trying to understand blood pressure when he discovered that the faster blood flowed, the lower the pressure it exerted. This principle was not only true for liquids but also for gasses.

This is another very simple explanation. What is important is that students gain a basic understanding of how pressure is affected by the speed of movement. Students will see this principle in action during the following experiments.

Play with Bernoulli

The following three activities all provide students with the opportunity to test Bernoulli's principle. Students should work in pairs and state their hypotheses prior to beginning each experiment.

You have the option of choosing which activities to conduct within your allotted class time. Regardless of which experiments you choose, you should write down the following steps on the board for students to follow along for each activity:

- Read through the activity directions.
- Predict what you think will happen.
- Write down your prediction (your hypothesis).
- Make a simple sketch of each activity and your findings.
  - Label where the air velocity was greatest.
  - Draw arrows to indicate the direction of movement.

> Each of these activities is designed to help you understand and test Benoulli's principle. You will work in pairs. Each person needs to be certain they understand every step. How can you check to make sure you aren't rushing your partner?

Alternate how you pair students to ensure that the same students are not always working together. Students should get a chance to work with as many new partners as possible.

Ask students if they are ready and if they have any questions.

> Each of you is responsible for your own understanding, so make sure you write down anything and everything that helps you understand the results. How can you make sure everyone gets to participate?

Once students have received the instructions, group them and provide supplies. Try each experiment more than once and make sure that students take turns, giving everyone the opportunity to log the findings and execute the experiment. Keep students on task to make sure that you cover all of the material in this lesson.

1. **Paper Tent**

   Materials: one piece of paper (standard printer paper will suffice)

   Instructions
   - Tell students to fold the piece of paper lengthwise into a paper tent. Then they should predict what will happen when they blow through the underside of the tent. (Will the paper move? If so, in what direction?)
   - One student should blow through the paper, and the other should record the results.
   - Repeat with students switching roles.

2. **The Distance Between**

   Materials: two inflated balloons, each secured with string. Leave a tail of string on each balloon.

   Instructions
   - Instruct students to hold the two balloons together by the strings.
   - Ask students to predict what will happen to the balloons when they blow through the space between the balloons. They should write down their predictions.
   - Students should then blow between the balloons and notate their findings.
   - Students should then move the balloons so that they're suspended 4–6 inches apart and again predict what they think will happen when they blow between the balloons this time. Students

need to make sure that the balloons are not too close together. They shouldn't be blowing at the balloons but rather into the space between them.
- Groups should notate their results.
- Students should witness the balloons coming together, just as the paper did.

3. **From Here to There**

Materials: two plastic cups and one Ping-Pong ball per group

Instructions

- Place two plastic cups 6 inches apart and put the Ping-Pong ball in one cup.
- Ask students how they can get the ball from one cup to another without touching the ball or the cup.
- If students have ideas, encourage them to try out different things.
- Once students have exhausted their attempts, tell them to try blowing across the top of the cup with the ball in it. Students may have to try blowing with more or less force, but they should eventually get the ball to jump from one cup to the other.
- The ball jumps because the air pressure that moves across the top of the cup is less than the pressure inside the cup (Bernoulli's principle).
- After students have successfully jumped the ball from one cup to another, they can experiment with changing the distance between the cups.

This is good time to check students' understanding of Bernoulli's principle. Make sure that the entire class understands how and why they saw (or didn't see) the results of their experiments.

Now you have the basic understanding of a scientist, specifically a physicist. As an engineer you want to know what to do with this information. How could you use it to solve a problem such as getting off the ground? Well, if we speed up the air, it exerts less pressure. We want to go up, so if we can get the air on the top of a wing to move faster than the air on the bottom, then there will be less pressure exerted down from the top. So we could go up. Or if we could get the air on the bottom to go more slowly than the air on the top it would exert more force than the air on the top. So, again, we could go up.

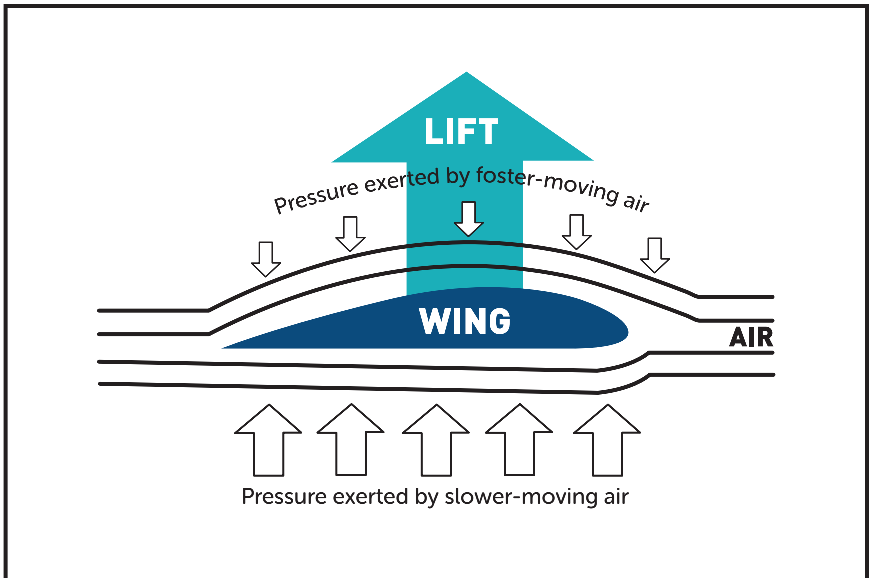
Here it would be helpful to illustrate how lift affects the wings of a plane. In the next several lessons you will begin to illustrate all of the concurrent forces exerted on a plane during flight: lift, drag, thrust, and weight.

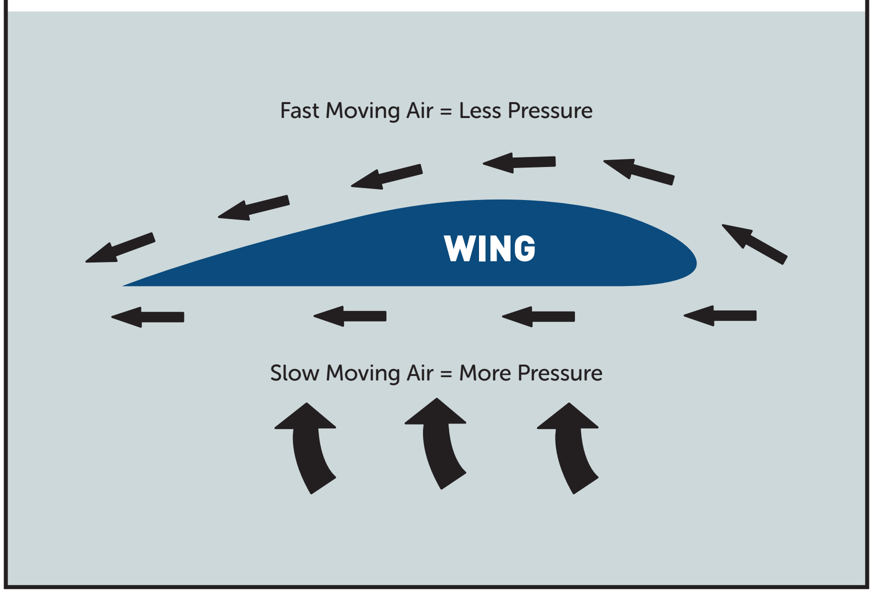
Now we have a way to create lift: We move air over a wing. Let's look at the opposing force, weight. Weight is the force exerted on all objects by gravity. The less an object weighs, the less gravity pulls it toward the Earth. Engineers must take this into account when designing a plane. If you want to lift a heavy load, then you need to have a large wing surface area or increased thrust. But increased wing size increases the weight of the plane, and more thrust means you need more fuel. One way to optimize lift is to use materials that are light but strong.

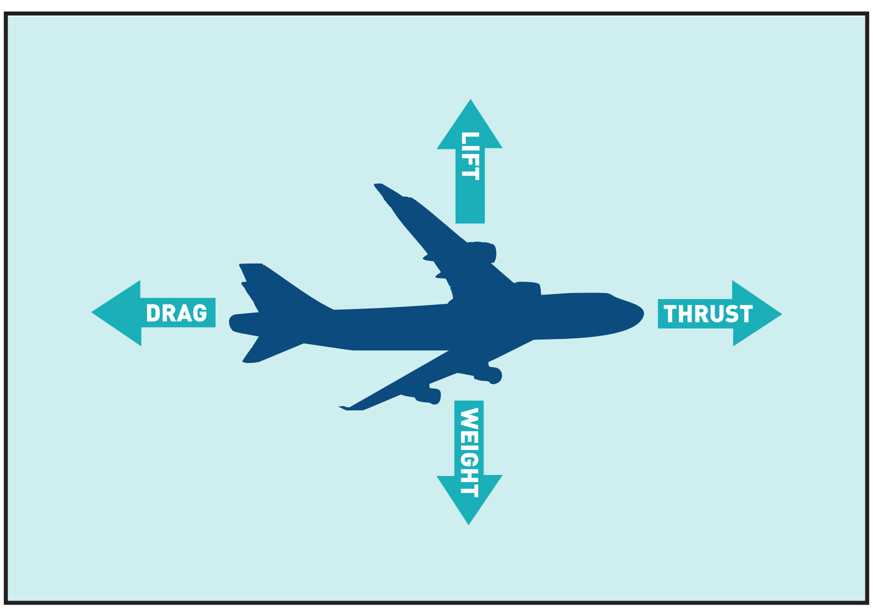
PART III: CONSTRUCTION MATERIALS (45 MINUTES)

To get students thinking about aerodynamics you will move into discussing the role that construction materials play in the design and flight of a plane.

Let's look at some materials and explore their properties. Just because something is light, does


LIFT
Pressure exerted by foster-moving air
WING
AIR
Pressure exerted by slower-moving air


Fast Moving Air = Less Pressure
WING
Slow Moving Air = More Pressure


LIFT
DRAG
THRUST
WEIGHT

that mean that it is weak? Does heavier always mean stronger?

If a material is light, do you think it is weak or strong? Why?

Ask the students what materials we could use to build planes. Some potential answers may be

- Aluminum
- Brass
- Copper
- Plastic
- Steel
- Wood

Make a prediction as to which of these materials is the strongest and write it down.

Bend That Bar

This experiment will teach students about the strength, weight, and flexibility of certain materials. You will need the following:

- A scale that measures grams
- 1 calculator per group
- 1 spring scale
- 1 yardstick
- 1 Sharpie per group (different colored markers will allow students to see how their results compare with other groups. As added fun you can allow groups to name their team if you think it would help to create a cohesive team dynamic.)
- 1 bar 15–18 inches in length and 1/8–1/4 inch in diameter of each of the following
  - Aluminum
  - Brass
  - Copper
  - Plastic
  - Steel
  - Wood
- A printed table for each student group (students should work in groups of 4). You should also have this written on large poster board or banner paper at the front of the classroom. Have them measure distance in centimeters and mass in grams.

You should model how to use the scales for students to make sure that they get accurate readings during the experiment. Tell students that they will be measuring and notating the bend of various materials.

Ask students to predict which material they think will be best to build an airplane before weighing the bars. Why?

1. Students should weigh each bar and record the findings in their tables.
2. Next they should measure the length of each bar, marking from the same end 10 inches and 1 inch from the end of the bar.
3. Then one student should hold the bar against a flat surface, ideally a chair or the top of a desk so that 10 inches protrudes from the chair or desk. Students will need to hold the bar firmly so it does not loosen from their grasp but not so firmly that it does not move.
4. Another student will hold the yardstick vertically next to the end of the bar with the bottom of the stick resting flat on the ground.

Type of material	Mass of material	Initial height	Height after bending	Distance bent (initial minus after)	Strength-to-weight ratio (distance bent divided by mass)
Aluminum					
Brass					
Copper					
Plastic					
Steel					
Wood					

5. A third student will be in charge of measuring the distance the bar bends. The yardstick should be at the very end of the bar to measure the maximum bend.
6. Before bending any bar, students will need to measure the initial height of the bar. They should record the highest height of the bar for all measurements.
7. The fourth student should hang the spring scale at the 1 inch mark on the bar.
8. If you are using 1/8-inch bars, expect the weight of the scale to be significant on the bar. Also, if the wooden bar does not move, students can apply 1–5 pounds of pressure on the scale and measure the bar. Instruct students not to put more than 5 pounds of pressure on the bar, because it could break.
9. Students should record the new height of each bar when weighed down by the scale.
10. As a final step each group should write their findings on the group chart posted at the front of the classroom.

After all of the teams have written their findings at the front of the class, give students a few minutes to see how their findings compared with the rest of the class. Then facilitate a group discussion using some of the following questions:

- Which materials are similar in strength?
- Which materials are similar in weight?
- Which are the lightest? Which are the heaviest?
- Which materials bent the most?
- Which materials bent the least?
- Which material has the greatest strength-to-weight ratio?
- Which material has the least strength-to-weight ratio?
- What are the advantages of steel versus plastic?
- What are the advantages of plastic versus steel?

One concept to emphasize is that you didn't ask which material is the strongest. Help the students see there are numerous attributes to consider when choosing materials for any project. The point is to have students understand that there are many compounding factors to consider when designing a flying apparatus.

> Which material would you use to build an airplane? Why? Did your answer change from when you answered this question before the activity?

There are a number of factors to consider when choosing materials for an airplane. These are the types of questions that engineers must consider when designing and building almost anything. What if you weren't allowed to use the material of choice?

Have students clean up their work stations, return materials to where they found them, and return to their seats for the end-of-class discussion. As a leadership opportunity you can delegate a material captain to confirm that all materials have been returned and are accounted for. If you choose to create this role, ensure that you use it throughout all of your experiments and that you choose a different student for each lesson.

Guiding Discussion Questions

- Based on what you have learned so far, what materials would you use to construct an airplane and why?
- What does Bernoulli's principle state?