We Can Fly
Learning Lab

ESSENTIAL QUESTIONS — How does an airplane fly? What are the parts of an airport, and why are they important?

Lesson Overview

• Engage Section—students will be drawn into this lesson by discussing the parts of an airport and the four forces of flight.

• Explore Section—students will watch and/or participate in a number of activities that explore the physical forces affecting flight: weight, lift, drag, and thrust.

• Evaluate Section—students will revisit the Essential Questions to identify the four forces of flight.

Background Information

• A force is defined as a push or a pull. A force is a vector quantity, so it has both a magnitude and a direction.

• Weight—A force that is always directed toward the center of the earth. The magnitude of the weight depends on the mass of all the airplane parts, plus the amount of fuel, plus any payload on board (people, baggage, freight, etc.). The weight is distributed throughout the airplane. But, we can often think of it as collected and acting through a single point called the center of gravity. In flight, the airplane rotates about the center of gravity.

Flying encompasses two major problems; overcoming the weight of an object by some opposing force and controlling the object in flight. Both of these problems are related to the object's weight and the location of the center of gravity. During a flight, an airplane's weight constantly changes as the aircraft consumes fuel. The distribution of the weight and the center of gravity also changes. The pilot must constantly adjust the controls to keep the airplane balanced, or trimmed.

• Lift—To overcome the weight force, airplanes generate an opposing force called lift. Lift is generated by the motion of the airplane through the air and is an aerodynamic force. "Aero" stands for the air, and "dynamic" denotes motion. Lift is directed perpendicular to the flight direction. The magnitude of the lift depends on several factors including the shape, size, and velocity of the aircraft. As with weight, each part of the aircraft contributes to the aircraft lift force. Most of the lift is generated by the wings. Aircraft lift acts through a single point called the center of pressure. The center of pressure is defined just like the center of gravity, but using the pressure distribution around the body instead of the weight distribution.

The distribution of lift around the aircraft is important for solving the control problem. Aerodynamic surfaces are used to control the aircraft in roll, pitch, and yaw. To control the roll of the airplane, the ailerons are raised on one wing and lowered on the other. To control the pitch of the airplane, or the up and down motion, the pilot adjusts the elevators on the tail to make a plane descend or climb. To control the yaw of an airplane, the rudder is moved from side to side.

• Drag—As the airplane moves through the air, there is another aerodynamic force present. The air resists the motion of the aircraft and the resistance force is called drag. Drag is directed along and opposed to the flight direction. Like lift, there are many factors that affect the magnitude of the drag force.
including the shape of the aircraft, the "stickiness" of the air, and the velocity of the aircraft. Like lift, we collect all of the individual components' drags and combine them into a single aircraft drag magnitude. And like lift, drag acts through the aircraft center of pressure.

- **Thrust**—To overcome drag, airplanes use a propulsion system to generate a force called thrust. The direction of the thrust force depends on how the engines are attached to the aircraft. On some aircraft, such as the Harrier, the thrust direction can be varied to help the airplane take off in a very short distance. The magnitude of the thrust depends on many factors associated with the propulsion system including the type of engine, the number of engines, and the throttle setting.

For jet engines, it is often confusing to remember that aircraft thrust is a reaction to the hot gas rushing out of the nozzle. The hot gas goes out the back, but the thrust pushes towards the front. Action<—>reaction is explained by Newton's Third Law of Motion.

The motion of the airplane through the air depends on the relative strength and direction of the forces. If the forces are balanced, the aircraft cruises at constant velocity. If the forces are unbalanced, the aircraft accelerates in the direction of the largest force.

**Instructional Objectives:**

- Identify and understand the forces of flight—weight, lift, drag, and thrust;
- Identify various parts of an airport;
- Demonstrate Bernoulli’s Principle;
- Define an airfoil structure designed to obtain lift.

**Basic Materials:**

- Aerospace Academy: We Can Fly DVD available at the Fairfax Network Video Store or YouTube Channel.
- Bernoulli Strip—page 5, one per student
- Four Forces of Flight Activity Sheet—page 6, one per student
- Airport Traffic Pattern Diagram—page 7
- Toy parachute or sheet of paper
- Balloon

**INSTRUCTIONAL PROCEDURES**

[Note: Modify demonstrations for age appropriateness and time constraints.]

**Engage**

1. Introduce the lesson by asking questions to generate interest and assess prior knowledge:
   - Have you ever been on an airplane? Where would you go if you could fly anywhere in the world? How does a bird fly? How does an airplane fly?
   - Discuss students' answers and their fascination with flying.

2. Watch Aerospace Academy: We Can Fly stopping to check for understanding through questioning.

**Explore**

1. Discuss weight, lift, thrust, and drag. Use the activities listed below to demonstrate aerodynamic forces.

   - **Weight**—A measure of the heaviness of an object. Activity: Ask the students to stand up and jump. Then, ask why did they come back to the ground and introduce the concept of gravity and weight.

   - **Lift**—The upward force created by a difference in air pressure. Moving air creates this difference as it moves around an airfoil (e.g., a wing). High pressure moves to replace the low pressure. Air: A physical substance which has weight. It has molecules which are constantly
moving. Air pressure: Created by the molecules moving around. Activity: Print out the Bernoulli strips on page 5 and distribute one to each student. Ask the students to hold the strip below their lips and blow on paper. Ask them why the paper is lifted. Explain the upward force created by difference in air pressure.

- **Drag**—The resistance caused by the shape of an object and its movement through the air. Activity: Drop a toy parachute or sheet of paper from varied heights to demonstrate drag.

- **Thrust**—The force developed by a propeller or jet engine that drives an airplane through the air. Activity: Blow up a balloon and release to demonstrate thrust.

2. Teaching the Airport Traffic Pattern

- **Background Information**

The Airport traffic pattern is what pilots use to increase safety and avoid accidents in the air near airports. Each pilot is expected to follow the same pattern in the air approaching the airport and preparing to land. Each section is called a “leg”. Each plane enters on the “45 to downwind” turns onto the “downwind”. The pilot continues on until, when looking over their left shoulder, he or she is 45 degrees to the runway and then turn “base”. He or she turns “final” when approaching the extended centerline of the runway (see Airport Traffic Pattern diagram). If the pilot does not land or is practicing, the pilot will continue on the centerline of the runway and then turn “crosswind” until he or she can turn back onto “downwind.” An “upwind” leg is not to common, but might be flown if there was another aircraft on the runway and the pilot had to “go around” (not land but continue around the pattern again), the pilot would sidestep to the right and fly the upwind so he or she can keep an eye on the runway and make sure no one is taking off, etc. Sometimes if the pilot is entering the pattern from the “wrong side”, the pilot might fly an upwind. In the United States, this is the standard pattern and it is a “left hand” pattern with all turns to the left. Some airports have right hand patterns to avoid noise sensitive areas, schools, terrain, etc.

- **Introduction**

Explain to students the importance of everyone knowing what to do and where to go when expected. Imagine if we went to lunch and everyone went different places or tried to line up for lunch at both ends of the lines. We know the “pattern” of lining up for lunch (use your school’s lunch routine or some other routine your students know well, such as dismissal procedures).

Show students the basic Airport Traffic Pattern and explain this is the procedure airplanes use to land at airports. Not all airports have air traffic controllers telling them what to do, and use the Internet to search for a local airport without a control tower near your town. Search the Internet for “list of airports in {fill in your state here}”. Have students discuss the pattern and how it works.

- **Extensions**

Discuss non-standard patterns like the “right hand” pattern and ask why a different pattern might exist. The airport in Manassas, Virginia has two runways next to each other. One runway flies a left hand pattern and the other runway flies a right hand pattern. Ask students why? Ask students to draw the pattern. They should see that depending on the wind if both runways flew left hand patterns, the runways would conflict with each other.

Practice the pattern with your students (This is a great indoor or outdoor recess activity). In the hall, gym, or your classroom, you can “build” a runway
using tape and a bit of imagination. If you have a compass you can figure out the correct runway numbers (a runway facing due north or 360 is runway 36; south (180) is 18; a heading of 150 would be runway 15. A runway heading north and south would have 36 painted at one end and 18 at the other, rounded to the nearest 10.

Tape runway markings to the floor (if you want to get really fancy you can put all the markings on a roll of paper so you can use it again) leaving enough room for the “planes” – students “flying” the pattern and “landing” on the runway. Make sure the students “fly” the pattern appropriately and leave enough space for the other airplanes. Pilots are required by law to “see and avoid” other aircraft. Students have to control their speed so they don’t catch up to other planes. Only one plane should be on the runway at a time. Students may quickly see how a traffic pattern can get very busy and they must move very carefully and do what’s expected or there could be an accident.

Suggested Online Resources

Aviation & Space Education — Learn about ACE Academies and aviation-type contests geared towards students, aviation curriculum to be taught in the classroom, and teacher workshops.

Aerospace Resources — Learning resources for teachers, students, and enthusiasts.
Bernoulli’s Principle
As the speed of the air increases, the pressure decreases. To learn more, visit http://www.nasm.si.edu.

Smithsonian
National Air and Space Museum
Steven F. Udvar-Hazy Center
The Four Forces of Flight

KEY WORDS:
Thrust
Lift
Drag
Weight
The legs start with the upwind leg, which runs parallel to the runway in the same direction you will land, followed by the crosswind leg that runs perpendicular to the runway, followed by the downwind leg that again runs parallel to the runway but in the opposite way you will land, followed by the base leg, which again runs perpendicular but on the end of the runway you will touch down, and finally the final leg that takes you on a straight line to the runway and your landing. Unless otherwise directed, all turns in a standard traffic pattern are made to the left.

From www.aopa.org/path/teacher.pdf