NATIONAL MUSEUM OF THE UNITED STATES AIR FORCE™

Forces & Motion: How an Airplane Achieves Lift

Students will learn about forces and motion as they study the scientific principles behind flight.

Learning Objectives:

The students will:

- Learn about basic scientific principles related to how an airplane achieves lift
- Discover the relationship between Newton's Third Law of Motion and flight
- Learn about the Bernoulli Principle
- Learn about the Coanda Effect

Purpose:

Students will increase their knowledge of motion and forces through the study of the principles behind how an aircraft achieves lift.

Background:

The explanation for how an airplane achieves lift has always been somewhat controversial. Powered, heavier-than-air flight began in 1903, but scientist are still working out the basics of the full explanation for how an aircraft – as small as a paper plane and as huge as the USAF's C-5 – are able to fly! A combination of three major principles contribute to the scientific theory of flight: the Bernoulli Principle, the Coanda Effect and Newton' Third Law of Motion. First we want to discuss the four forces that affect an aircraft in flight: thrust, drag, weight, and lift. Thrust is a force that moves an aircraft in the direction of the motion, drag is the force that acts opposite of thrust, weight is the perpendicular force caused by gravity, and lift is the perpendicular force that acts in the opposite direction from weight. These following demos help to explain the most difficult of the four forces to understand: lift. For further information on the four forces of flight and the other scientific theories, please see the **Resources** section.

Grade Level: 9 - 12

Ohio Learning Standards/Science (2018)
Expectation of Learning
Nature of Science

Physical Science
PS.FM.1: Motion
PS.FM.2: Forces
PS.FM.3: Dynamics

Physics
P.M.3: Projectile motion
P.F.1: Newton's laws
P.F.2: Gravitational force & fields
P.F.5: Air resistance & drag
P.F.6: Forces in two dimensions

Materials Required:

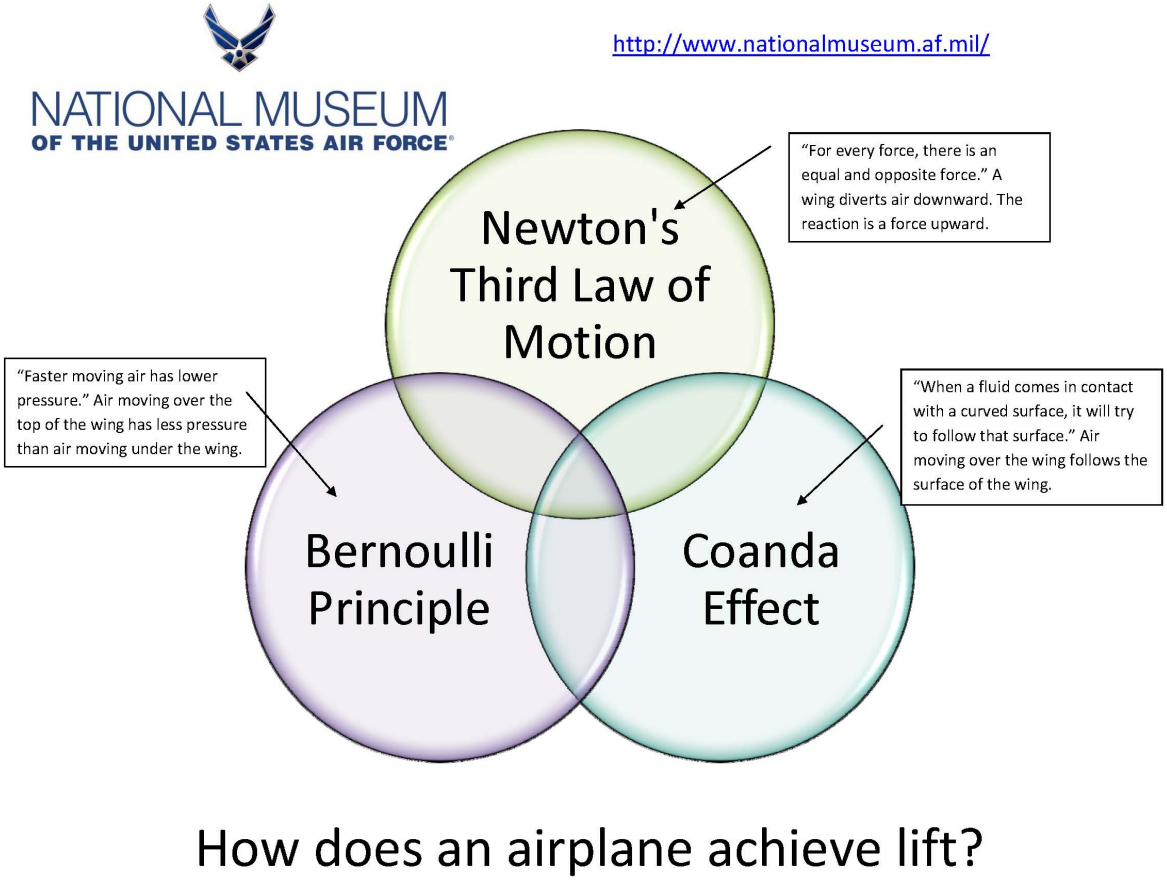
- Hairdryer
- Ping pong balls
- Plastic bottle
- Craft pom-pom
- Spoon
- Source of running water

Procedure:

A. Warm-up

1. Review the four aerodynamic forces of flight, the Bernoulli Principle, the Coanda Effect, and Newton's Third Law.

2. Use a Venn diagram to show the relationship between the Bernoulli Principle, the Coanda Effect and Newton's Third Law of Motion.



How does an airplane achieve lift?

B. Activities – to be done either as a teacher's demo or with class participation

Bernoulli Demonstrations

1. Review that the Bernoulli Principle states that faster moving fluids (including air) have lower pressure than relatively slower moving fluids.

2. Use diagrams, videos and/or animations that are readily available online to illustrate the concept that the air moving over the wing (due to the shape of the wing and/or the angle of attack) moves faster than the air moving under the wing.

2. Explain that the difference in air pressure above and below the wing and the resulting movement of air (and thus the wing) helps create lift.

3. Bernoulli strip demo
    - Give each student a strip of paper approximately 4 cm wide by 20 cm long.
    - Hold both corners of one end with the thumb and forefinger of each hand.
    - Position it so that it is curved down a bit, place it against the skin just below your lower lip and blow across the top of the paper
    - Ask the students to first predict what will happen and then to explain what happened (the paper lifts up) – they should use the Bernoulli Principle to explain

4. Bernoulli bottle demo
    - Hold an empty plastic bottle (with an opening around 3 cm in diameter) horizontally
    - Place a craft pom-pom or small ball of paper just into the opening of the bottle
    - Try to blow the pom-pom into the bottle. First ask the students to predict what will happen and then ask the students to explain what happened. The pom-pom will be forced back out of the bottle because, by blowing air in front of the bottle, a low pressure area (relative to the pressure inside of the bottle) was created in front of the opening of the bottle

5. Bernoulli tent demo
    - Take a letter-sized piece of paper and fold each end so that there are 6 to 7 cm inch 'legs' to form a "U" shape. If you want: fold the paper in half without any 'legs'
    - Place the paper on a table in a tent-like configuration
    - Blow underneath the tent and watch what happens (the tent falls flat). First ask the students to predict what will happen and then ask the students to explain what happened (faster moving air under the tent causes a low pressure system)

Coanda Demonstrations

1. Review that the Coanda Effect states that a fluid (including air) will follow a curved surface.

2. Use diagrams, videos and/or animations that are readily available online to illustrate the concept.

3. Hair dryer demonstration

    - Turn on a hair dryer full power on the cool setting
    - Direct the air flow straight up and place a ping pong ball in the air current
    - Ask the students to explain why the ball is staying above the hair dryer in the air flow, even if the hairdryer is tilted to either side, using the Coanda Effect to explain

4. Gutter protection devices – ask the students how the science behind the Coanda Effect can keep leaves out of the gutter along the edge of a home's roof (rain water runs down the roof while it follows the curvature of the metal cover before going into a small slit in the gutter, keeping larger items like leaves out of the gutter).

5. Spoon and water demonstration

    - Hold a spoon loosely under running water with the back of the spoon parallel against the edge of the flowing water
    - Ask the students to predict what will happen (the water will follow the curved surface of the back of spoon and be directed outward off the tip of the spoon in the opposite direction thus pulling the spoon into the flow of water)
        - This demo will actually also show Newton's Third Law
        - A good demonstration as to what happens to air as it leaves the trailing edge of the wing
    - If running water is not available for this demo, there is a good video of this activity online (see Resources section)

Newton's Third Law of Motion Explanation

1. Review Newton's Third Law of Motion.

2. Use diagrams, videos and/or animations that are readily available online to illustrate the concept.

C. Wrap up

1. After all the demonstrations are completed, review all of the principles and how they relate to flight.

Assessment/Evaluation:

The students should be evaluated on their class participation, listening skills and ability to follow verbal instructions, especially when they are involved with assisting in demonstrations, etc.

Extension:

Have students research other demonstrations regarding the Bernoulli Principle, the Coanda Effect and Newton's Laws of Motion. Ask them to share with the class in a few days.

Have students research the scientists for whom these principles are named.

Resources:

https://www.grc.nasa.gov/WWW/K-12/airplane/forces.html

https://www.grc.nasa.gov/www/k-12/airplane/index.html

https://www.grc.nasa.gov/WWW/K-12/airplane/bernnew.html

http://hyperphysics.phy-astr.gsu.edu/hbase/Fluids/airfoil.html

https://www.grc.nasa.gov/www/k-12/airplane/lift1.html

https://www.grc.nasa.gov/www/k-12/airplane/drag1.html

https://www.grc.nasa.gov/www/k-12/airplane/presar.html

https://www.grc.nasa.gov/www/k-12/airplane/right2.html

https://youtu.be/AvLwqRCbGKY (Coanda)