ACHIEVEMENT #5:

The Airplane

Teacher's Guide

Introduction

Flight was a challenge that caused people to try anything to get in the air – and stay there. Early pioneers studied birds – their wing shapes, how they took off and landed. There were many ingenious attempts to achieve the basic elements of flight -- thrust, lift, sustaining momentum, and landing – safely. Finally, traveling by air evolved from gliders to piston engines, and the airplane was no longer seen merely as a show-off attraction at county fares.

Two engineers revolutionized the aviation industry by inventing the jet engine - in England, Sir Frank Whittle, and, across the Channel in Germany, Hans von Ohain. These men discovered a radically different way to propel aircraft. Unprecedented speeds were possible. Increases in engine size and power helped to lower the operating cost per plane. Eventually making travel affordable for all.

At the beginning of the century hardly anyone went to Europe except the wealthy, and if they did it took 7 to 10 days by ship. Now, people travel all over the world in a matter of hours. And soon, we all could be spending summer vacations at space stations – simply because engineers searched for ways to make engines go faster!

Lesson Focus: Solving the Mysteries of Mechanical Flight

Lesson Synopsis: Students demonstrate the Bernoulli Principle, review the influences that affected the Wright Brothers, and make and modify paper airplanes.

Related National Science Education Standards:

Content Standard B (Physical Science):

As a result of their activities in grades 5-8, all students should develop an understanding of Motions and Forces. Fundamental concepts and principles that underlie this standard include:

- Unbalanced forces will cause changes in the speed or direction of an object's motion.

Related Benchmarks from Benchmarks for Science Literacy:

Section 3C (Issues in Technology):

By the end of 5th grade, students should know that:

- Once an invention exists, people are likely to think up ways of using it that were never imagined at first.
- Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems.

By the end of 8th grade, students should know that:

- Technology … is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live.

Related Standards for Technological Literacy:

Standard 3 (Relationships Among Technologies and Connections Between Technology and Other Fields):

In order to appreciate the relationships among technologies and other fields of study, students in grades 6-8 should learn that:

- A product, system, or environment developed for one setting may be applied to another setting.
- Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

Glossary:

aeronautics The science of flight. Scientists and engineers who study aeronautics learn about how and why airplanes fly.

aerodynamics A field of fluid dynamics that studies how gases, including air, flow and how forces act upon objects moving through air.

Bernoulli's Principle The principle that increasing the velocity of a fluid (including air) decreases its pressure. Explains how wing shape and position is important in generating lift.

drag The air resistance encountered by a moving object. Drag is one of the four forces acting on an airplane, the others being lift, thrust and weight.

lift The lifting force on a flying object (in particular, a wing or an aircraft), due to its motion relative to the surrounding air.

thrust The force acting on a rocket or an airplane, produced by the action of its motor and pulling it forward.

weight The force exerted on mass by gravity.

opposing forces Forces that are pushing or pulling in the opposite direction. For example, lift is perpendicular to the airflow around an aircraft. If the aircraft is flying straight and level, the lift force (which is pulling up) will be opposing the weight force (which is pulling the aircraft toward the earth).

Important Concepts:

- There are four forces that act upon airplanes to influence their flight.
- Innovation involves creativity and may involve applying knowledge from a wide variety of fields.

Materials for Each Inquiry Team for Engagement Activity:

Newspaper
Scissors
Ruler
Copy Paper

Materials for each Engineering Team for Engineering Challenge:

Copy paper
Tape
Scissors
Paper clips
Glue
Ruler
Other types/sizes of paper

Safety Precautions: Because a pointed paper airplane is a projectile, protective eyewear should be used during testing.

Procedure:

Engagement: Have students follow the directions in the Student Handout to demonstrate the Bernoulli Principle and to create a Ring Wing Glider.

Exploration, Explanation: Have students read the information on the Wright Brothers and explore the Timeline.

Extension: Have students do the Engineering Challenge.

Evaluation: Ask students to draw a sketch of their glider design and mark on the drawing the 4 forces that affect its flight, showing the directions of the forces.

Ideas for Further Exploration:

- Have students build kites and research their historical significance.
- Have students research the biographies of other important figures in the history of aeronautics and aviation.
- Have students research current issues related to the airplane, such as the need for upgrading of the Air Traffic Control System.

References:

- **Exploring Aeronautics**, a CD available for $5 from NASA. For details, see the website at: http://exploringaerospace.arc.nasa.gov/
- **What is Aeronautics?**, background information from NASA, online at: http://quest.arc.nasa.gov/aero/background/
- **757 Glider Kit**, downloadable file at http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Technology/Models/757.Glider.Kit/.index.html
- **Innovation Through Engineering**, downloadable poster and 3 activities, available at: http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Mathematics/Innovation.Through.Engineering/.index.html
- **The Process of Invention** (source of the reading material on the Wright Brothers), downloadable poster with an activity and background information, available at: http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/The.Process.of.Invention/.index.html
- **Aeronautics and Aerospace Teaching Resources**, online at: http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Physical.Science/Aeronautics.and.Aerospace/.index.html
- **NASA Paper Airplane Activity**, online at: http://www.grc.nasa.gov/WWW/K-12/aerosim/LessonHS97/paperairplaneac.html
- **Simple Paper Airplane Design**, the source of the basic design used in the Engineering Challenge, online at: http://edu.larc.nasa.gov/fdprint/a9.html

ACHIEVEMENT #5:

The Airplane

Student Handout

How do Airplanes Fly?

To begin to understand how airplanes are able to fly, try these simple experiments:

Materials for Each Inquiry Team:

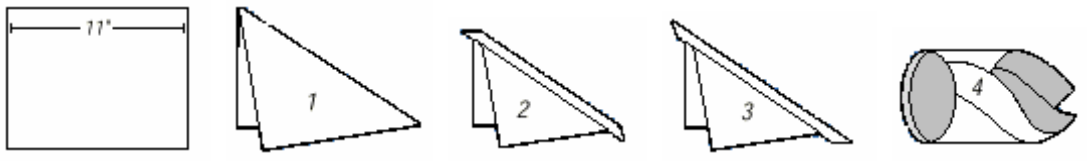
- Newspaper
- Scissors
- Ruler

1. Cut a piece of newspaper about 1 inch wide and 6 inches long. Hold one end against your lower lip and let the other end hang down. Now blow. What happens? Try blowing harder or more softly and note what happens.
2. Cut a sheet of newspaper into 2 pieces about the size of a sheet of notebook paper. Hold the 2 sheets about 2 inches apart. Now blow between them. What happens?

What's going on here? Flowing air has less pressure than still air. This is an extension of what Daniel Bernoulli discovered in studying water flow and is important in aeronautics. Because you blew across the top of your strip of newspaper, the air under the paper was pushing up harder than the air above was pushing down and so the paper moved up. When you blew between the 2 sheets of newspaper, the moving air did not press against the paper as hard as the still air on either side, so the sheets were pushed together by the still air. Aeronautical engineers apply their knowledge of the Bernoulli Principle in the design of aircraft, especially wings.

Make a Simple Ring Wing Glider

1. Fold a sheet of lightweight paper diagonally as shown below in step 1.
2. Make a ½ inch fold along the previously folded edge.
3. Make a second ½ inch fold along that edge.
4. Curl the ends of the paper to make a ring and tuck one end into the fold of the other.
5. Gently grasp the V between the 2 "crown points" and toss the glider lightly forward.



Solving the Mysteries of Flight the Wright Way

Why were the Wright Brothers successful in their engineering of the airplane? As you read some of the following information about the Wright Brothers, look for clues to their success and for experiences that influenced them. Make a list of these as you read.

The Flying Toy

Wilbur (1867-1912) and Orville Wright (1871-1948) were brothers. They lived in Dayton, Ohio, at 7 Hawthorn Street. Their older brothers were Reuchlin and Lorin. Katharine was their younger sister. Their father, Milton, was a bishop in the Church of the United Brethren in Christ. Their mother, Susan, the daughter of a wagon maker, made toys for her children and encouraged their curiosity. One day, Bishop Wright brought home a small toy "helicopter" made of wood with two twisted rubber bands to turn a small propeller. Wilbur and Orville played with it until it broke then made new copies of the toy themselves. They also sold toys to their friends, including handmade kites. The Wright brothers did things together from the time they were small boys.

The Bicycle Business

The Wright brothers went into the printing business together in 1889. Three years later, they opened their first bicycle shop. Initially, they sold and repaired bicycles. They would replace spokes, fix broken chains, and sell accessories. In 1896, they began to build their own brand of bicycles. The Wright brothers' experiences with bicycles aided them in their investigations of flight. They used the technology they learned from their bicycle business in their airplanes: chains, sprockets, spoke wires, ball bearings, and wheel hubs. Their thoughts on balancing and controlling their aircraft were also rooted in their experience as cyclists.

The Search for Control

Orville and Wilbur Wright were convinced of the need to control an aircraft in three axes of motion. An elevator, or horizontal control surface, in front of the wings on their aircraft, enabled the pilot to control climb and descent (pitch axis). The elevator was controlled by a lever in the pilot's left hand. A "wingwarping" system controlled the aircraft in a roll (roll axis). To initiate a roll, the pilot would shift his hips from side to side in a cradle on the lower wing, "twisting" the wings left or right or restoring them to level flight. Orville and Wilbur developed this idea from observing birds in flight. They observed the buzzards keeping their balance by twisting their wings and sometimes curving one wing more than the other. In 1902, the brothers added a vertical rudder to the rear of their machine to control the left and right motion of the nose of the aircraft (yaw axis).

The Kite/Glider Experiments

The Wright brothers began their aeronautical research in 1899. Their first aircraft was a small kite with a five-foot wingspan that was used to test their notions of aircraft control. In 1900, they built their first machine designed to carry a pilot and chose Kitty Hawk, NC, as a suitable testing ground. With its strong steady winds, open areas, and tall sandy dunes, the area was perfect for their experiments. When their 1900 aircraft produced less lift than expected, the Wright brothers flew it as a kite and gathered information that would enable them to design improved machines. They returned to Kitty Hawk in 1901 with a new glider that did not perform as they expected. While they had learned a great deal with their first two machines, they had also encountered new puzzles and dangers.

The Wind Tunnel

To simulate flight conditions, the Wrights tested small model wings in a wind tunnel they had built. The wind tunnel was a box with a fan at one end that blew a steady stream of air over model wings mounted on a special "balance" inside the tunnel. Using this device, the brothers were able to gather information that could be used to design the wings of the gliders and powered aircraft that would carry them into the air. The wind tunnel provided them with information on the most satisfactory wing shape. It also enabled them to calculate the size of wing that would be required to lift them into the air, the performance of their propellers, and the amount of power that their engine would have to produce. They based the design of their next glider on this information.

Controlling the Aircraft

During the 1901 glider tests, the Wright brothers had discovered that "wingwarping" created unequal drag on the two wings. Key to solving the control problem was the addition of a rudder to the glider design in 1902. They developed a direct linkage between the rudder and warping system. With the success of this system design, the Wrights were ready to move onto a powered aircraft.

The Solution

At Kill Devil Hills, NC, at 10:35 am, the Wright 1903 Flyer took off under its own power with Orville as the pilot. It flew 12 seconds and went a distance of 37 meters. Orville and Wilbur took turns making three more flights that morning. Wilbur was at the controls for the fourth and longest flight, traveling 260 meters in 59 seconds. The Wright 1903 Flyer became the first powered, heaver-than-air machine to achieve controlled, sustained flight with a pilot aboard. Today, this amazing flying invention can be viewed as it is suspended overhead, at the National Air and Space Museum in Washington, DC. (www.nasm.edu/nasm/nasmexh.html)

The Wright 1904 Flyer

Having achieved success in North Carolina, the Wright brothers decided to continue their experiments closer to home. They built and flew their second powered airplane at Huffman Prairie, a pasture eight miles east of Dayton, Ohio. Progress was slow without the strong, steady winds of Kitty Hawk, but the brothers did achieve the first circular flight of an airplane on September 20, 1904. This first complete circle flight lasted only 1 minute 36 seconds and covered 1,244 meters. Stability problems still plagued the Wright brothers' invention. The modifications made during 1904 helped but did not solve the stability problem.

The Wright 1905 Flyer

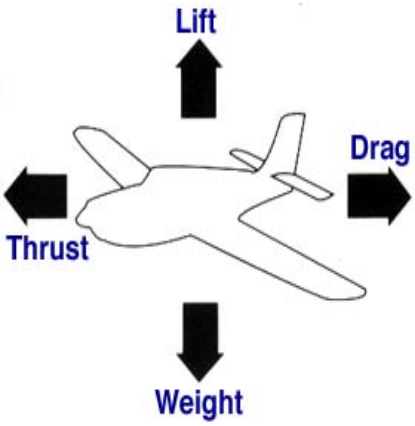
This Flyer was the world's first practical airplane. During more than 40 flights at Huffman Prairie, the machine was repeatedly banked, turned, circled, and flown in figure eights. On two occasions the flight exceeded half an hour. Wilbur and Orville Wright, brilliant self-trained engineers, had overcome complex technical problems that had barred the way to mechanical flight for centuries.

As you look at the Timeline, think about how the Wright Brothers' invention has changed our world!

Timeline of Events:

1738	Daniel Bernoulli publishes a book on "hydrodynamics", in which he presents the results of his study of fluids. These principles are later applied to "aerodynamics".
1889	Lilienthal publishes **The Flight of Birds as a Basis of Aviation**.
1891	Lilienthal builds and flies the first truly successful glider in history. Gradually modifying his design, he makes over 2000 flights in the next five years.
1892	Australian Lawrence Hargrave invents the box kite.
1894	**Progress in Flying Machines** published by Octave Chanute, an American civil engineer. He begins corresponding with the Wright Brothers.
1896	Samuel Pierpont Langley's 30-pound unmanned tandem-wing craft, employing a lightweight steam engine for propulsion, flies 4,200 feet at about 30 mph.
1899	Wilbur Wright notices that buzzards in flight adjust the shape and position of their wings. When he twists a long box used to ship a bicycle tube and observes how its shape changes, he decides to try using control lines to twist the wings on a biplane kite. He discovers that "wing warping" allows him to control the kite's direction.
1901	Langley builds a gasoline-powered version of his tandem-winged model, the first gasoline engine used to propel an aircraft, and launches large unmanned steam-powered models on many successful flights.
1901	Wilbur Wright is invited by Chanute to give a speech, entitled "Some Aeronautical Experiments", to the Western Society of Engineers.
1901	The Wright Brothers build a small wind tunnel and create delicate balances to measure the lift and drag for 200 different miniature wings of different shapes.
1903	Langley nearly drowns after he tries to fly a catapult-launched full-size version of his aircraft.
1903	Eight days after Langley's crash, the Wright Brothers **Flyer** makes the first successful manned and powered flight, after 4 years of testing and over 1000 successful glider flights. Their first flight lasted only 12 seconds, and they traveled only 120 feet.
1914-18	World War I encourages rapid development in aviation.
1920	Donald Douglas starts manufacturing airplanes.
1927	Charles Lindbergh becomes first person to cross the Atlantic solo and nonstop.
1937	Sir Frank Whittle in England and Hans von Ohain in Germany construct the first turbojet propulsion engines.
1947	Air Force established.
1947	First airplane to break the sound barrier (700mph), flown by USAF Capt Charles E Yeager
1970	The DC-10, the first "jumbo jet" from Douglas, makes its first flight.
1994	First computer-designed commercial aircraft, Boeing 777-200.

What Forces Act on an Airplane?



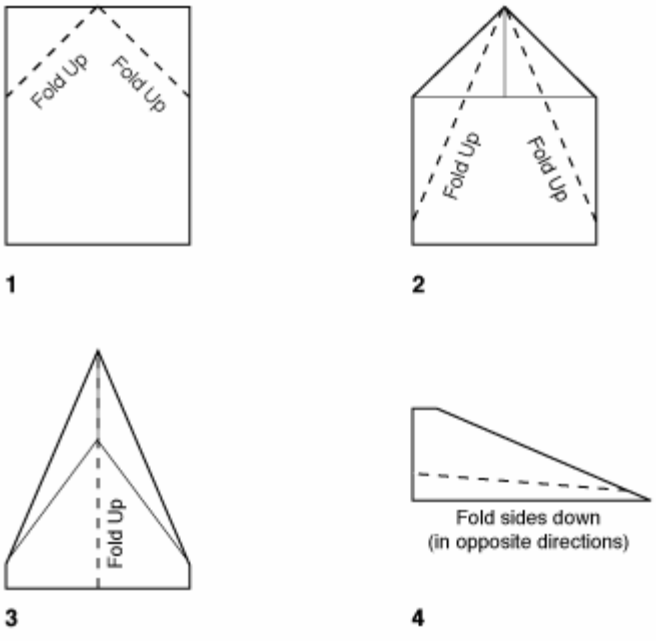
There are 4 forces that act on an airplane, **lift** (an upward push), **weight** (a downward push), **thrust** (a forward push), and **drag** (a backward push). It is the combination of all these forces that determines how the plane moves.

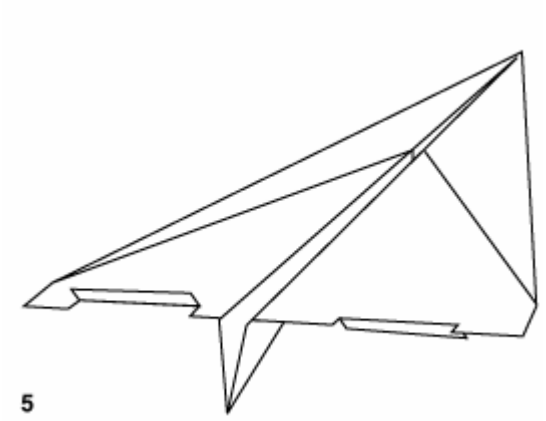
Engineering Challenge: Making and Improving an Experimental Glider

Materials for each Engineering Team:

Copy paper
Tape
Scissors
Paper clips
Glue
Ruler
Other types/sizes of paper

Folding Instructions for the Basic Glider, using 1 sheet of copy paper:





Testing Your Glider

Using protective eyewear, test the basic design in terms of how far it flies (distance), how long it flies (time aloft), and how straight it flies.

Modifying Your Glider: Things to Try

1. Change the size of the wings, either by folding differently or by cutting.

2. Add a flap to the back of each wing by making 2 small cuts and then bending the flap up or down. (Be sure the flap on one side matches the one on the other, or see if that matters.) By varying the distance between the cuts and the length of the cuts, you can try different size flaps.

3. Add a flap (rudder) to the tail. Try different rudder sizes and positions.

4. Try using paper clips to add weight to different areas of the body of the plane.

5. Try a larger or smaller **scale** version. (To do this, you will need to cut a piece of paper so that the ratio of its width to its length is 8 1/2 to 11, just as for the copy paper. An easy way to test smaller sizes would be to draw a black line around the edge of the paper and then to photocopy it at a reduced size and cut along the lines.)

6. Try using a different paper type.

7. Make a crease near the end of the wings and bend the tips up or down.

8. Cut off a "point" (on the nose, wings, or tail).

9. Try using a different paper size or shape – square, wider than long, long and narrow, so that the new model is not to scale.