The Flying Wing

Wind Tunnels

Lesson 2 of 3

Grade Level: 9-12

Subjects: Physical Science, Technology

Prep Time: > 30 minutes

Activity Duration: 50-minute period

Materials Category: General Classroom

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<th>National Education Standards</th>
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<td><strong>Science</strong></td>
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Objective: Students will construct a wind tunnel and test various items in the tunnel. Students will make mathematical comparisons between the force of the air and the distance the object moves.

Materials:

- 3-4 medium-sized cardboard boxes
- Duct tape
- Small- to medium-sized scale to measure weight
- Variable-speed fan
- Balsa wood wing
- Toy airplane
• Various small objects to test in tunnel
• Balance

Related Links:
NASA'S OBSERVATORIUM
Whirling Arms And The First Wind Tunnels
Glenn Learning Technologies Project
NASA’s Teaching From Space Program—Bernoulli Video Clip

Supporting NASAexplores Article(s):
Flying Wing
http://www.nasaexplores.com/show2_articlea.php?id=01-007

The Flying Wing

Wind Tunnels

Teacher Sheets

Objective

Students will construct a wind tunnel and test various items in the tunnel. Students will make mathematical comparisons between the force of the air and the distance the object moves.

Pre-activity

• Have students bring in boxes or contact a local store, which may be able to donate different size boxes.
• Purchase balsa wood before and drill one hole at each end. The wire can be inserted before class or have your first class insert the wire and leave for the other classes. The balsa wood will simulate an airplane wing.
Have students read "The Flying Wing". Discuss the advancements of aviation technology. Ask students, "why testing and review teams are so critical"?

Depending on the size of the tunnels, this activity may need to be done in a large room or gym.

**Activity**

Give students ample time to construct and decorate their wind tunnel. Encourage students to test a variety of different objects.

**Answers to Questions**

1. See student background information
2. Wind-swept ridges and blowing cave mouths could be used to test airfoils. Before building their own wind tunnel, the Wright brothers employed an unconventional testing machine: a bicycle with a third wheel mounted horizontally on the front of the frame. Two test shapes were mounted on the wheel, and the bicycle was pedaled rapidly (up to 15 mph) up and down the streets of Dayton, Ohio.
3. Aircraft, spacecraft, rockets, cars, trucks (reduced aerodynamic drag reduces fuel costs for long-distance truckers and increases top speeds of racecars), and buildings (to help quantify stresses from high winds) can be tested in wind tunnels.
4. Most wings are shaped so that air must flow faster over the top than the bottom. This results in a lower pressure on the top of the wing than on the bottom, and creates lift (Bernoulli lift). Dynamic lift is caused by the pressure of impact air against the lower surface of the airfoil. This is what you feel when you put your hand, angled upward, out the window of a moving car. (*We suggest that you not stick your hand out of a moving car.*)
5. See student background information.
6. Accept most student answers.
7. Wind tunnels include reliable and consistent airflow, low turbulence, and ability to make precise measurements, and reproducible conditions and results.
8. When the wing is horizontal, it will not rise at all.
9. A small angle will cause the wing to rise slowly, while a larger angle will cause the wing to rise more quickly. As air approaches the wing, it takes 2 paths. Some of the air travels over the wing while some of it travels under the wing. When the wing is angled, the air going over it travels more quickly than the air going underneath, the pressure above is less, and the wing raises.
10. With a small angle of attack, the string should be straight, pointed directly behind the plane. As the angle of attack gets bigger, the string will start to move around wildly. As the air hits the plane at a greater angle, it can no longer flow around the wings smoothly. Vortices, or swirls or air, occur behind the wings reducing the lift force. This is stall.

Extensions

- For a long-term project, student can build a better wind tunnel. Cost varies from $50 - $200.
- Have students research the history of wind tunnels.
- Review the Bernoulli video clip from NASA’s Teaching In Space Program. See the Related Links section for details.
Objective

Students will construct a wind tunnel and test various items in the tunnel. Students will make mathematical comparisons between the force of the air and the distance the object moves.

Materials

- 3 - 4 medium-sized cardboard boxes
- duct tape
- small- to medium-sized scale to measure weight
- variable-speed fan
- balsa wood wing
- toy airplane
- various small objects to test in tunnel
- balance

Background Information

For people to fly, they needed to understand the flow of air over aircraft surfaces and how to use this information to improve aircraft design and construction. This meant building laboratories in which wings, fuselages, and control surfaces could be tested under controlled conditions. Today aircraft designs undergo significant wind tunnel testing before being built to full size and test-flown.

Frank H. Wenham is generally credited with designing and operating the first wind tunnel, in 1871. A fan, driven by a steam engine, propelled air down a 12-ft. (3.7 m) tube to the model.

A wind tunnel is an enclosed structure that lets researchers simulate the same conditions a real aircraft would encounter as it flies through the atmosphere. In a wind tunnel a highly-instrumented aircraft model or an aircraft part is held steady while air moves past it to simulate flight conditions. Wind tunnels let researchers safely take measurements often impossible to make while an aircraft is flying. Computers collect the instrument readings for later analysis by researchers. Wind tunnels test new flight concepts before any flights are made.
A wind tunnel is really a fairly simple device. Most designs feature each of the five components described below. The overall design creates high-speed, low-turbulence airflow through the test section and allows researchers to measure the resulting forces on the model being tested.

**Settling Chamber** - The purpose of the settling chamber is to straighten the airflow.

**Contraction Cone** - The contraction cone takes a large volume of low-velocity air and reduces it to a small volume of high-velocity air without creating turbulence.

**Test Section** - The test section is where the test article and sensors are placed.

**Diffuser** - The diffuser slows the speed of airflow in the wind tunnel.

**Drive Section** - The drive section provides the force that causes the air to move through the wind tunnel.

Wind tunnels can be **open- or closed-loop**. In an open-loop tunnel, the air flows in one end of the tunnel and out the other. In a closed-loop tunnel, the air is recirculated.

With the advent of the wind tunnel, aerodynamicists finally began to understand the factors that controlled lift and drag, but they were still nagged by the question of model scale. Can the experimental results obtained with a one-tenth scale model be applied to the real, full-sized aircraft? Almost all wind tunnel tests were and still are performed with scale models because wind tunnels capable of handling full-sized aircraft are simply too expensive.

**Procedure**

*Make Your Own Wind Tunnel*

1. Looking at the diagram above, design your own wind tunnel using tape and boxes. The wind tunnel should be large enough that both hands will fit into it easily.
2. Before taping the tunnel together, make one-inch divisions on the floor of the tunnel for measuring the distance that objects move when the wind current is applied.

3. Tape several boxes together with both ends open.

4. Put a small fan at the open end of the settling chamber.

5. Choose several objects (at least 5) to test in the tunnel, suggestions are pencil, paper clip, tissue, cotton, small- to medium-sized balls, barrette, bottle cap, toy airplane or car.

6. Determine the weight of each object tested.

7. Measure the distance the object moves (in inches) when the fan is turned on.

8. Turn on the fan at different speeds to make a mathematical comparison between the force of the air and the distance the object moves.

Data Table for steps #6 & #7

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10. Place the wing made out of balsa wood inside the tunnel and varying the angle of the wing. Answer question #8 - #9.

11. Attach a row of thin thread or string to a toy airplane.

12. Put the plane in the tunnel and vary its angle of attack. Answer question #10.

Questions

1. Name and describe all five parts of a wind tunnel.
2. Can you think of other sources of airflow that could be used to test airfoils?
3. What kinds of things can benefit from wind tunnel testing?
4. How does air flowing over a surface create lift?
5. Discuss the difference between open- and closed-loop wind tunnels.
6. List four reasons for testing in wind tunnels.
7. List at least three advantages of using a wind tunnel.
8. How does the wing behave when it is horizontal?
9. How does varying the angle affect the wing?
10. Write a conclusion summarizing your findings after step #12.

Link to Relevant Web Sites and Additional Resources

http://observe.ivv.nasa.gov/nasa/aero/tunnel/tunnel_links.html