

Wingin' It

Students learn about the Bernoulli effect by building an airfoil (airplane wing) and making it fly.

Grade Levels	Science Topics	Key Science Skills
5–8	Aerodynamics of lift Bernoulli effect Force Velocity Pressure	Formulating models Observing Inferring Questioning Controlling variables Hypothesizing Making models

Time Required

Advance Preparation	10 minutes
Set Up	5 minutes
Activity	25–35 minutes with introduction and discussion
Clean-up	2 minutes

What you'll need

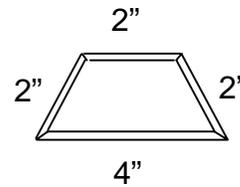
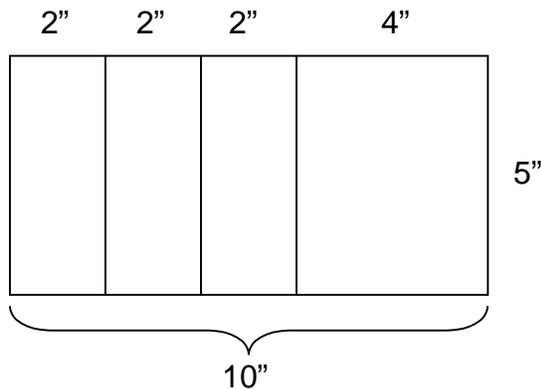
- Regular weight copy paper
- 5" x 10" corrugated cardboard
- Ruler
- Bamboo skewers (shish kebab sticks, available in grocery stores) or knitting needles
- Clear tape
- Scissors
- Pencil
- Small electric fan
- Cardboard, cardstock, manila file folder or heavy weight paper 4"x6" or larger
- Pencil-top erasers

Do this first!

Assemble the base

Build two bases for the class to use as wing testers.

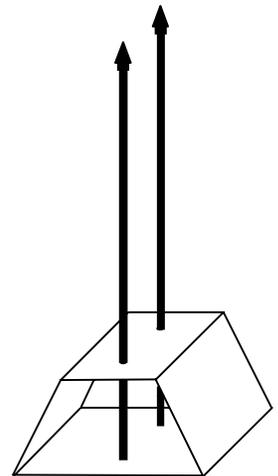
1. With a 5"x10" piece of corrugated cardboard, make a fold at 2", 4", and 6" from the end.
2. Fold the cardboard into a box-like structure with open ends shaped like a trapezoid with the widest edge on the bottom.
3. Tape the structure together into this shape.



4. Repeat steps 1 – 3 to make a second base.

Insert the rods

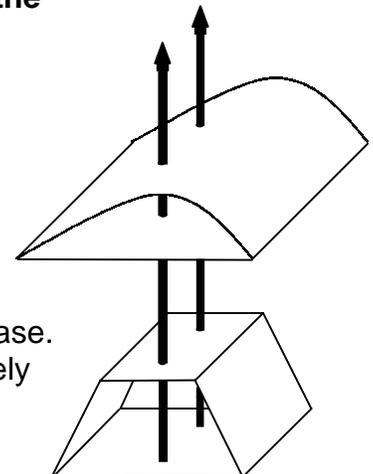
1. Make two dots 3 in. apart in the center of the top side of the cardboard base.
2. Poke the rods (skewers or needles) through the top of the base at the dots. Make sure that the rods are straight with the ends secured in the bottom of the base to keep them stationary.



CAUTION: Place pencil end erasers on the sharp ends of the skewers or knitting needles for safety.

Make a sample paper wing

1. Photocopy one "wing worksheet" for each student or student group, and extras for optional extensions.
2. Follow directions under "Student Procedure," steps 1–3 to make your sample wing.
3. Place the wing over the skewers onto your assembled base. The holes should be large enough that the wing falls freely to the base over the rods.



Getting Ready

1. Tape the trapezoidal base with the rods to the table.
2. Set up the fan. Test and adjust using the sample base and wing. Position the fan so that the wind blows over the top of the wing, and the wing rises up the rods. Start with the fan approximately 12 in. away from the base and adjust the distance as needed. Depending on the size and capacity of your fan, you may need to adjust its height, angle, or distance from the base.

CAUTION: Always replace eraser tops on skewer ends immediately after airfoil is placed on base to avoid eye injuries with active students.

Why do this?

Ask Students: How do planes fly?

Students may suggest that the motor pulls it up, the air lifts it up, propellers push it up, or air pressure forces it up.

In reality, there are many factors, which contribute to the airplane lifting into the sky. The Bernoulli effect is one of those factors.

Is an airplane wing like a bird's wing? How is it similar or different?

Students may suggest that an airplane wing is different than a bird's wing because it is not made of feathers, or because it doesn't go up and down. They may suggest it's the same as a bird's wing because it sticks out sideways from the body.

Show the students a sample wing for the activity. This type of wing is called an "airfoil."

Hand out the Wing Worksheet and ask students *not* to fold it yet.

Make some observations about the placement of the dotted "fold" line on the Wing Worksheet.

Students will notice that it is not in the middle. It does not divide the wing into equal halves.

Make observations about the wing you have made.

Students will notice that it is curved on top and pointed on one side.

Demonstrate how to gently fold the wing along the fold line without making a heavy crease. Demonstrate how to tape the edges of the wing neatly together to form the wing. (See "Make a paper wing" Student Procedure, steps 1–2.)

Consider a red ant starting at the dashed line and walking along the top (the long arched surface) of the wing. Now suppose a black ant starts in the same place at the same time and travels along the bottom (short flat surface) of the wing. Which ant will travel farther? If the two ants meet at the same time at the end of the wing, which ant will have to go faster?

The red ant traveling along the top of the wing will have to go faster since it will have to travel farther in the same amount of time. The red ant travels a greater distance because the top surface of the wing is longer.

Normally ants do not walk across airplane wings, but air and wind does pass across the wing.

What is air/wind made of?

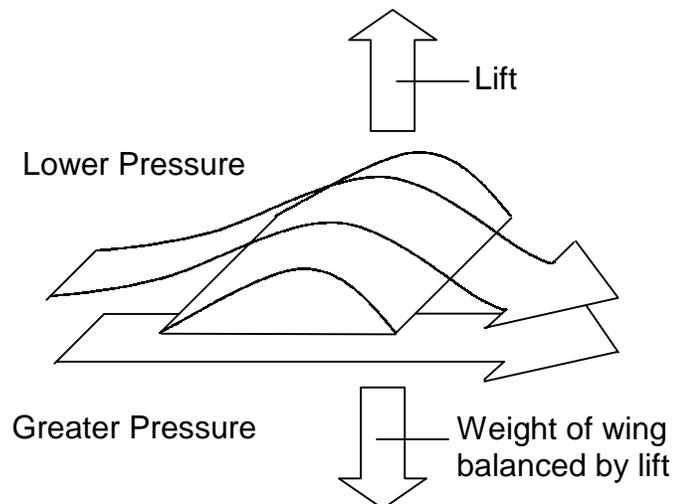
Students may suggest any of the following, all of which are correct: gas, oxygen, nitrogen, carbon dioxide, molecules, atoms.

Remind students that we can't always see molecules of a gas (like the air they're breathing right now!). Sometimes we can see gases, such as the steam (gaseous water molecules) from a teapot. If air is made of molecules, imagine wind (moving air) passing over our airplane wing.

Do the air molecules blowing over the top wing have to travel farther than the air molecules blowing along the bottom of the wing?

Answer: Yes. Air molecules travel farther over the long top of the wing, just as the ant has to walk farther. Since the air molecules on the top surface of the wing have to go farther in the same amount of time, they are moving faster than the air molecules on the lower wing surface. When the molecules move faster over a greater distance, they are more spread out (less dense).

When molecules move, they put pressure on whatever they strike. The more molecules that strike the object, the more pressure or force there is on the object. Because there are more air molecules per inch along the bottom of the wing, the pressure of the molecules hitting the bottom of the wing is greater than the pressure from the less dense layer of molecules on the top surface of the wing. This pressure difference causes the wing to be pushed or lifted upward.

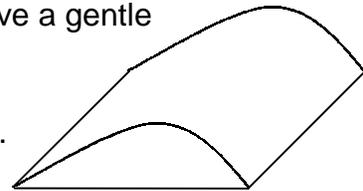


What to do

You will take turns testing your wings on the wing tester.

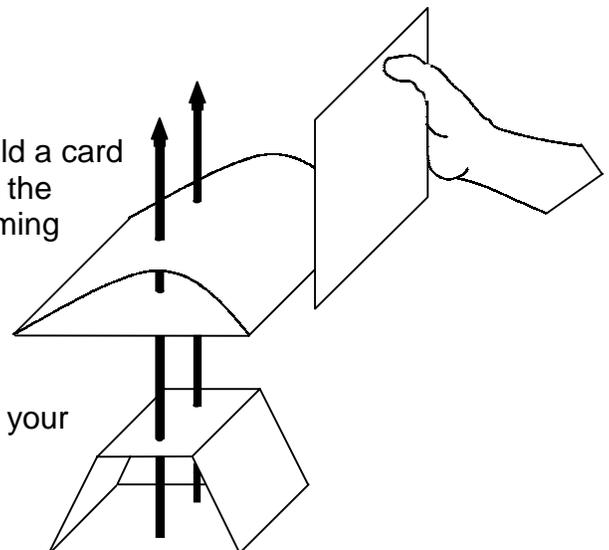
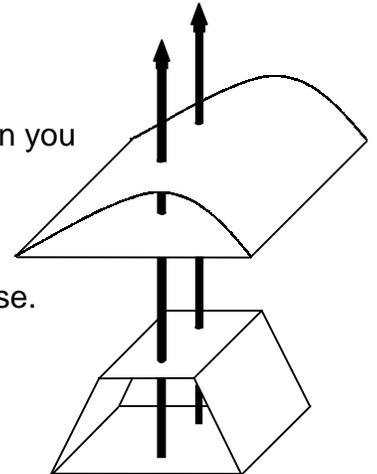
Part A: Make a paper wing

1. Make a light fold at the dashed line so that the printed surface faces out. Do not crease heavily. Note: the fold divides the paper into two *unequal* parts—a longer section and a shorter section.
2. Bring the corners of the paper together, causing the longer side to arch. Tape the edges of the paper together. The wing should have a gentle curve on the upper surface.
3. With the pencil, poke holes through the paper at the circles on both the upper and lower sides of the wing. Make a hole large enough for the yellow part of the pencil to pass through.



Part B: Test the paper wing

1. Draw your paper wing. What do you predict will happen when you test your wing in the wind of the fan?
2. Line up the holes in the wing with the rods in the cardboard base.
3. Slide the wing all the way down the rods to the cardboard base. The wing should be curved on the top and flat on the bottom. You may choose to experiment with different positions.
4. Trial 1:
 - Turn on the fan.
 - Observe the wing for 15–90 seconds. Record your observations.
 - Turn off the fan.
5. Optional Trial 2:
 - Turn on the fan.
 - When the wing is halfway up the rods, hold a card in front of the wing to block the wind from the upper surface of the wing. If the lift is coming from lower pressure on top of the wing, blocking the wind will cause the wing to slide down to the base.
 - Try to block the wind in different ways. Observe for 15–90 seconds. Write down your observations.



- Turn off the fan.

Stuff to talk about

What may have caused unexpected results (e.g., misaligned holes, someone moved the fan). These are called sources of error and can affect your experimental results. If we repeated the experiment, how would we fix these problems or “control the variables?”

In the 1700s a European scientist called Daniel Bernoulli developed an idea called the Bernoulli principle. The principle can explain why air moves through a prairie dog’s burrow, why smoke goes up a chimney, and how airplanes can fly. We call this the Bernoulli effect.

More stuff to do!

- A. Have students perform additional trials, placing the wing at different angles by making holes at other points in the wing. Encourage students to hypothesize, test, observe, make changes, retest, and draw conclusions. For example, students might put the rods through a different pair of holes on the upper surface of the wing, but in the same holes on the lower surface. This should adjust the angle of the wing. If the angle of the wing is too steep, the difference in air pressure above and below the wing will not be enough for lift.
- B. Have students repeat the experiment with different weights of paper. Try light construction paper, tracing paper, etc.
- C. Students may use the inquiry process to investigate different airfoil shapes, e.g., a box shape, a tube shape, a flat leading edge.

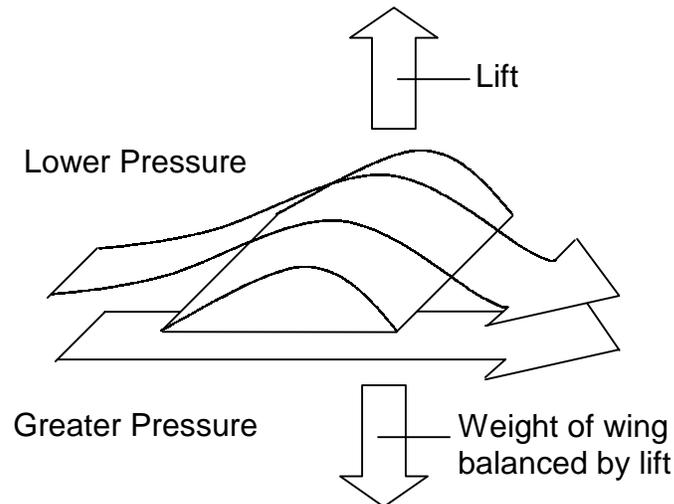
What’s happening?

There are many aerodynamic factors that make airplanes fly. In particular, the shape of the wings helps create the force necessary to lift the airplane into the air. Airplane wings are specially designed to provide the upward force called lift.

A cross-section of an airplane wing has a shape that is called an airfoil. The upper surface of an airplane wing is curved downward, and the lower surface is usually flat. As the wing moves through the air, the special shape of the wing changes the path of the air flowing around it, which affects the air pressure surrounding the wing. The air passing over the upper curvature of the wing moves faster than the air passing along the lower flat surface. The downward pressure of the faster-moving air above the wing is less than the upward

pressure of the air below the wing, so the wing is pushed up. This upward force resulting from a difference in air pressure is called lift.

Daniel Bernoulli developed the physical principle that describes these phenomena in 1783. He discovered that increasing the velocity of a gas (or liquid) would lower its pressure. Thus, most airplane wings are designed to take advantage of air pressure differences.



How it all fits in

MATH

Mark off the rods in half-inches. Record the height to which each wing rises. Calculate the mean, mode, and median of the results of the class. Graph results.

Mean: The sum of a list of numbers, divided by the total number of numbers in the list.

Median: "Middle value" of a list.

Mode: Most common (frequent) value.

Other Options: Have each student group collect data on multiple trials of each experiment. Each group will then calculate mean, median, and mode for their trials. How do these numbers differ from group to group or from the whole-class values? Discuss possible reasons for a wide range of numbers, such as the use of different bases or differing fan positions (different "variables" and "sources of error").

ZOOLOGY

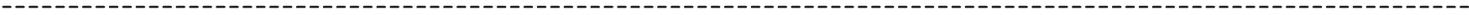
Research and report on the structure of the wings of birds. How does the size and shape of the wing affect the bird's flying habits? For example, compare an eagle, albatross, chicken, robin, duck, penguin, and emu. What is the wing shape? What is the overall body size and shape? What is the wingspan? Do they flap or soar? How long can they soar?

PHYSICS	Research and report on the discoveries of Daniel Bernoulli.
HISTORY	Research and report on the Wright brothers' first flight.
LANGUAGE ARTS	Study the Greek myth of Daedalus and Icarus.
ART	Look at the scientific and artistic designs of Leonardo da Vinci, then create da Vinci-like designs. Design and color an airfoil.
CULTURAL/ SOCIAL STUDIES	Investigate aircraft from other nations. How do the designs differ? Can you tell which aircraft originate from the same design? Can you tell which aircraft were manufactured by the same company? Investigate the impact that rapid air travel has had on our society.

Wing Worksheet



Upper Curved Surface



Lower Flat Surface



Supplies Worksheet

Instructions: Copy this worksheet and calculate the supplies you already have and what you still need. Then copy your completed worksheet to give to a teacher aid or a parent helper to gather the supplies designated in the right-hand “Supplies Needed” column.

No. of students: _____ **No. of groups:** _____

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
Regular weight copy paper for wing	1-3/student		
Corrugated cardboard for trapezoid base 5” x 10”	2/class		
Ruler	1/class		
Bamboo skewers or knitting needles	4/class		
Clear tape	small amount		
Scissors, paper cutter, or x-acto knife	1/class		
Sharpened pencil	1/student		
Small electric fan	1-2/class		
Cardboard, cardstock, or heavy weight paper 4”x6” or larger	2/class		
Eraser ends	4/class		

Note: This activity is a preliminary draft of one of several classroom activities, which are being developed to complement OMSI’s *Engineer-It!* exhibit. Comments and suggestions about this activity are welcome. Please send them to <stephanie.anderson@omsi.edu>.