HAWKQUEST®

Environmental Education using Live Birds of Prey

Thank you to Xcel Energy Foundation and their
Environmental Partnership Program

The Bernoulli Principle — How Birds Use Air Pressure to Fly 101

(Suitable for grades 4-12)

OBJECTIVE

To explain and demonstrate the Bernoulli Principle (greater air speed lowers air pressure) as it relates to a wing and how it helps birds fly.

TEACHER BACKGROUND

Humans live on the bottom of an ocean of air. Air is comprised of several invisible gases that have mass and exert a force, called air pressure. At sea level, air pressure is approximately 15 psi or pounds per square inch. Humans have adapted to this environment. They do not notice this force because pressure is pushing on them simultaneously from all directions.

For example, for every 15 psi pushing on the left side of your body there is an equal and opposite force, 15 psi pushing on the right side of your body equalizing the forces and making it seem like we do not live in a pressurized environment. However if we could reduce the air pressure to 10 psi on the left side of our body we would be pushed to the left by the greater pressure, 15 psi on our right side. To demonstrate air pressure's pushing power take an empty plastic milk container Suck out some of the air thereby reducing the air pressure inside the jug. What happens? The greater air pressure outside the milk container pushes in the walls.

Birds fly by using air pressure's pushing force to create wing lift. This is achieved by the physical law known as the Bernoulli Principle. Daniel Bernoulli, an 18th century mathematician, discovered that as air speed increases, air pressure lowers. Bird wings are specially designed air foils. The upper curvature of the wings makes air travel faster over its top surface. Following the Bernoulli Principle, this reduces air pressure on top of the wing allowing the greater air pressure from below to help push the bird up into flight.

For a simple class demonstration of the the Bernoulli Principle, place two empty pop cans on their sides, separated slightly. Tell the class that you are going to blow air between the cans. What happens? Most students will think the blowing air will push the cans apart. Instead, the air speed between the cans increases and the air pressure lowers. The higher air pressure on the outside surfaces of the cans pushes them together.

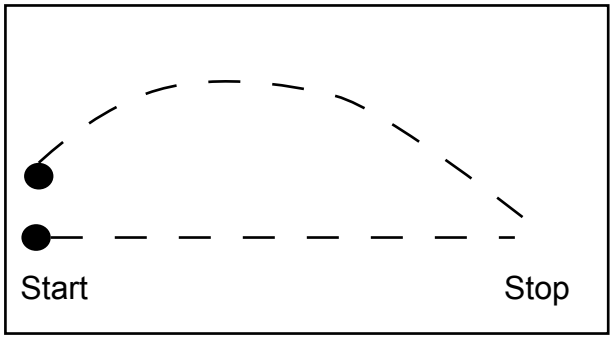
AIR MOLECULE GAME - HOW AIR MOLECULES MOVE AROUND A WING

GOAL

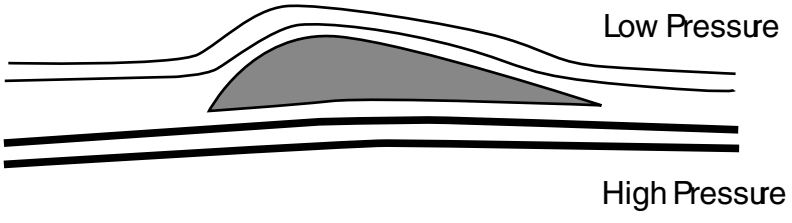
To understand how air molecules traveling above the wing need to travel faster than under the wing

PROCEDURE.

1. Pretend your classroom is a wing. Pick one wall of the classroom to represent the bottom of the wing. The three other walls will represent the top of the wing.
2. Have two students line up facing the leading edge of the pretend wing. The two students will be adjoined air molecules approaching a bird's wing.



3. At the start of the race, the students will separate along the edges of the wing, just like air molecules do when encountering a solid object. Have one student take the direct route (the bottom of the wing) along one wall. The other student needs to travel over the top of the wing, touching the center of the three remaining walls, curving round to meet their fellow air molecule.
4. The object of the race is not to beat each other to the finish line but to try to meet at exactly the same time on the opposite side of the wing. Who had to travel faster?



ANALYSIS

A bird's wing is nature's original air foil. Air molecules split apart when they reach the leading edge of the wing. Because of the wing's curvature, the air molecule on the top needs to travel faster to meet the molecule, following a straighter, more direct route, on the bottom.

THE FLYING PAPER EXPERIMENT

GOAL
To demonstrate how faster moving air reduces air pressure over the wing and creates lift.

MATERIALS
Text Book
2 x 6 Inch Strip of Paper

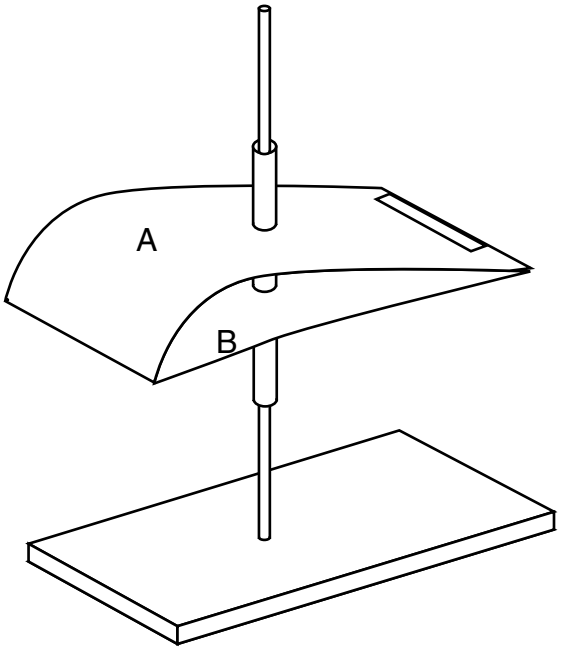
PROCEDURE
1. Place the shortest end of the paper partially into the pages of a closed text book and let it droop down. What does the paper do? Why?
2. Have the students blow over the top of the paper. What does the paper do now? Why?

ANALYSIS
At first, the paper droops down because its mass is pulled down by gravity. The air pressure above plus the mass of the paper pulled down by gravity does not equal the air pressure force pushing up. So it hangs down. By blowing over the paper the student is making the air move faster over the wing as demonstrated in the air molecule game. This reduces the air pressure above the paper The greater pressure below exerts a force and moves the object. In this case, it pushes the paper up.

WING LIFT EXPERIEMENT

GOAL
To build a paper wing and to observe how air pressure provides lift.

MATERIALS
Wing Template (See Attached)
Transparent Tape
Scissors
Sharp Pencil
Plastic Drinking Straw cut to 4 inches long
Long Piece of Wire
Clay or Styrofoam (strong enough to support the wire)
Hairdryer



PROCEDURE
1. To build a paper wing, copy the wing template and cut out the wing shape along the dark solid line. Fold along the dotted line between sides A and B. Tape the edges close, where sides A and B meet so the bottom (side B) is flat and the top (side A) is curved into an arch.
2. Using a sharp pencil, make a hole through the black dot on side A and poke straight through side B. Remove the pencil and push a straw through the two holes. Secure the straw on the top and bottom of the paper wing with small strips of tape.

3. Push a long piece of wire through the straw and position the wire vertically into a large piece of clay or styrofoam.
4. Using a hair dryer, blow air over the paper wing. When the angle of the blowing air is right, the paper wing will rise up the wire. Older students may continue to experiment with the direction of the blowing air to see if they can change the results.

NOTE
A piece of string can be substituted for the wire. Secure one end to a sturdy surface and pull the string vertically. Make sure the string is taut.

ANALYSIS
As demonstrated in the air molecule game, air needs to travel faster over the wing or air foil than the bottom. The faster moving air has lower air pressure. The greater pressure below pushes up on the wing. This upward pushing force is called **lift**. It helps birds rise into the air and fly.

THE BERNOULLI PRINCIPLE -- TEST YOUR KNOWLEDGE
See if your students understand the Bernoulli Principle. Imagine you are in your house with all the windows and doors shut when a tornado hits. The wind outside is moving the air very fast. The air pressure in your house remains the same. Your roof is lifted off but by what? The wind speed or something inside the house?

Tornados do not tear off roofs. It is the higher air pressure in the house that exerts a force on the roof. The faster the outside air moves, the lower its air pressure and the greater force on the roof from within. Remember 15 psi air pressure equals 180 pounds per square foot of pressure pushing up on the ceiling. As long as the inside and outside air pressures remain the same, it stays up. Lower the outside pressure significantly by high winds of a tornado and the ceiling just lifts up, like a bird's wing. There is no longer an equal pressure holding it down.

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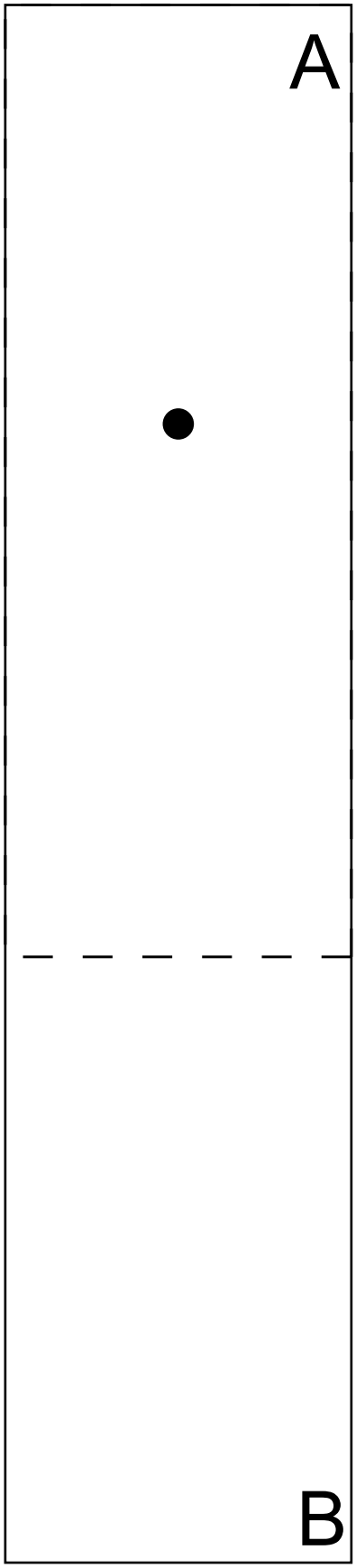
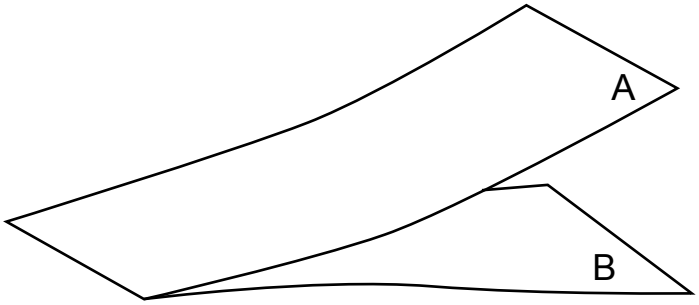
12338 N. Second St. Parker, Co 80134
(303) 690-6959 www.hawkquest.org


A
B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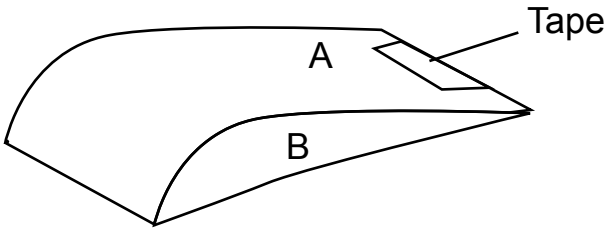
Tape
A
B