"Daniel and the Old Lion Hunter"

Theme

"When the speed of a moving fluid increases, pressure in the fluid decreases, and vice versa."

Daniel Bernoulli
Swiss mathematician and scientist
(1700 – 1782)

Goal

Students will understand and demonstrate Bernoulli's principle and its applications.

Who?

Daniel Bernoulli — Swiss scientist who discovered that the faster a fluid is traveling, the lower its pressure.

What?

fluid — a substance that can change shape under pressure; a gas or a liquid

conservation of energy law — the total energy in a fluid stays the same no matter what shape the fluid takes

Kinetic Theory of Gases — belief that gases are made up of tiny particles and that their random, constant motion hitting the walls of a container creates pressure

Where?

Basel, Switzerland — city where Bernoulli lived most of his life and taught at the university

St. Petersburg, Russia — city where Bernoulli taught from 1725 to 1733 and studied mathematics

"Daniel, that is enough demonstration for now!"

Groundwork

- Read chapter 21, "Daniel and the Old Lion Hunter."
- Gather the materials listed for lesson 5 in the unit introduction.
- Perform the activities to foresee any problems that might occur.
- Prepare the paper wing necessary for Demonstration 2 using an 8½" x 11" piece of paper. Draw a pencil line down the length of the paper, 1 inch from the right edge. Then fold, but DO NOT crease, the left edge of the paper to this line and tape it down the entire length of the page. The rolled edge is the "leading edge" of the wing and the sharp, single-thickness edge is the "trailing edge" of the wing.

Consider the Quotation

1) Ask students: Why do shower curtains come with magnets on their hems? Accept various student responses without comment. Explain that during this lesson, they will learn the answer to this question.

2) Students turn to the theme quotation and to *Who? What? Where?* on page 126 in the *Student's Quest Guide* to assist them in understanding this statement. Ask students to paraphrase this quotation. Write student versions on chart paper or the chalkboard.

3) Tell students that the theme quotation is Bernoulli's Principle, an important understanding about the nature of fluids (gases and liquids).

Directed Reading

Read to learn about Daniel Bernoulli's life and Bernoulli's principle

1) Ask students to recall what they learned from building Deep-Sea Divers and the other activities in the previous lesson.
   - Gases can be compressed, that is, the same matter can exist in a smaller volume.
   - The pressure of a gas increases as the volume decreases (at the same temperature) and vice versa.

2) Tell students that in this lesson they will learn about the eighteenth-century scientist Daniel Bernoulli, who also experimented with fluids (gases and liquids). His discovery eventually allowed men to design aircraft that can fly. Knowing about his discovery could help you save your roof if a hurricane heads your way, and it explains why shower curtains come with magnets on their hems.

3) On the map on page 222, students locate Basel, Switzerland, and St. Petersburg, Russia, where Daniel Bernoulli lived and worked. Students preview chapter 21 to formulate questions about Bernoulli and his work. Write students' questions on chart paper or on the chalkboard.

4) Students pair read chapter 21, "Daniel and the Old Lion," to find answers to their questions. When pairs have completed their reading, students discuss the answers to their questions with the class. The discussion should include the following points.

> *Daniel Bernoulli came from a highly talented family of mathematicians and scientists. Unfortunately, family members treated one another with jealousy and suspicion. Despite his father's objections, Daniel Bernoulli studied mathematics and discovered a principle that influences many aspects of our lives.*
>
> *Bernoulli's Law says that as the speed of a moving fluid increases, the pressure in the fluid decreases, and vice versa. In applying this principle to designing airplanes, engineers curve the top of the wing, causing the air to move faster across the top and creating a lower pressure area. The air below the wing moves slower, causing a higher pressure area. Higher pressure below and lower pressure above the wing creates "lift."*
>
> *During a hurricane, the rapidly moving air of the storm causes a low pressure area above the house. The still air in the house is at a higher pressure, which pushes the roof off. A less-than-perfect solution is to open the windows to allow the wind to blow through the house, keeping the pressure outside and inside equal.*

Cooperative Team Learning

Demonstrate Bernoulli's Principle

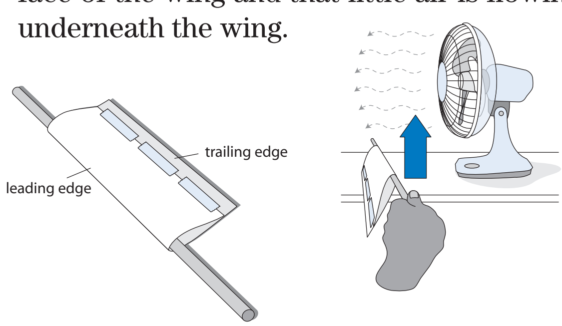
1) Students turn to *Fast Air, Low Pressure!* on page 127 in the *Student's Quest Guide*. Tell students they will witness demonstrations

and perform activities demonstrating Bernoulli's Principle in action.

2) For Demonstration 1, hang the two balloons by their strings from the dowel about 2 inches apart. Ask the students to discuss within their teams and record a prediction as to what will happen when someone blows a stream of air between the two balloons. Then invite a volunteer to do so (be certain that the balloons are still before performing the experiment and that the student blows between the balloons and not on the balloons). Discuss as a class student observations and explanations and have students record them on their quest sheets.

3) Have students follow the instructions for Activity 1 and Activity 2, recording their observations and explanations. Circulate around the room to assist student teams that need help to achieve successful results. Stop between activities to discuss the explanations as a class.

4) For the final demonstration, insert the wooden dowel into the "leading edge" or rolled edge of the paper wing (see illustration below). Place the fan on a table or desk and turn it on to a medium speed. Hold the dowel in front but below the face of the fan (the wing should hang vertically with the sharp, "trailing edge" down at this point). Slowly raise the dowel just until the fan is blowing over the upper surface of the wing and the wing is lifting up or "flying" in the breeze. Have students come up to feel that the air is principally flowing over the top surface of the wing and that little air is flowing underneath the wing.



Students should record their observations and explanations. Discuss the explanations as a class.

Conclusion

1) Revisit the question about magnets on the hems of shower curtains as presented earlier in the lesson. Ask students to use the knowledge gained in this lesson to figure out the answer. Allow students an opportunity to brainstorm briefly with a partner or teammates. Class discussion should include the following points.

> *Shower curtains come with magnets because heat generated in the shower causes the air in the shower to move and swirl about. This air motion inside the shower creates a lower pressure area compared to the relatively still air at a higher pressure outside the shower. The magnets keep the shower curtain from being sucked into the low pressure area of the shower and tangled about your legs!*

2) Display the transparency *Scientists Speak: Daniel Bernoullli.* What was the scientist's most important idea? What law or principle did he state on which future scientists could base their work? Students review chapter 21 to find out. Write students' suggestions on the chalkboard so that the class can formulate the best statement. Write the statement in the speech balloon on the transparency. Ask a volunteer to copy it onto the photocopy and hang Bernoulli on the time line.

3) On the overhead projector, display *Professor Quest cartoon #24.* Ask students to relate the cartoon to the theme of the lesson.

Homework

In their journals, students list some careers that require knowledge of Bernoulli's Principle (airplane designer, shipbuilder, bridge builder, car mechanic, geologist, engineer) and explain how it enables people to do these jobs.

Curriculum Links

Science link — Students use library and Internet resources to research the shapes of bird wings and the impact of their study, historically and today, on the design of airplane wings.

Science link — Students investigate the four basic forces of flight: lift, drag, thrust, and weight using library and Internet sources. Prepare a poster presentation of how these forces are created and how they relate to one another to achieve flight.

Science/Art link — Students use the library and Internet resources to find patterns for the construction of paper airplanes. Most paper airplanes have simplified wings with no real airfoil shape. (An airfoil is the cross section of the wing.) Nevertheless, lift is generated when the wing is at an "angle of attack" as it slices through the air (see caption on bottom of page 228 in *Newton at the Center*). Construct several paper planes and investigate the effects of flying them at various angles of attack.

Art link — Students examine the 1768 painting *An Experiment on a Bird in the Air Pump* by Joseph Wright of Derby on page 219 (this painting is also available on the National Gallery, London web site). What does this painting reveal about the state of science in the mid-eighteenth century?

Art link — Students design a "What Is Air?" mural, illustrating ideas about air held by the Greeks up to Renaissance scientists' discoveries about air.

References

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"Bernoulli's Principle." *Theoretical Physics at the University of Winnipeg.* http://theory.uwinnipeg.ca/mod_tech/node68.html. Access date August 2002.

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O'Connor, John and Edmund F. Robinson. "Daniel Bernoulli." *School of Mathematics and Statistics, University of St. Andrew, Scotland.* http://www-gap.dcs.st-and.ac.uk/~history/Mathematicians/Bernoulli_Daniel.html. Access date August 2002.

"See How Planes Fly." *NASA's Observatorium Teacher's Guides.* http://observe.arc.nasa.gov/nasa/education/teach_guide/planes_fly.html. Access date July 2007.

Quest Sheet Answers

Fast Air, Low Pressure!
Student's Quest Guide pages 127-130

Demonstration 1

Predict: Most students will probably predict that the balloons will be pushed apart.

Observe: If the volunteer is careful to blow straight through the space between the balloons and not on the balloons themselves, the balloons will be pushed together.

Explain: "Fast" air blown between the balloons creates an area of low pressure (Bernoulli's Principle). Now the air pressure on the outside of each balloon in the still air is higher than the pressure between the balloons. The balloons are pushed together by this higher pressure.

Activity 1

Observe: With some practice, the card will defy gravity and remain in place against the spool.

Explain: Blowing through the center of the spool creates a jet of fast moving air through the hole that hits the card and spreads out over its surface. This fast moving air creates an area of low pressure on the spool side of the card (higher-speed air results in lower air pressure: Bernoulli's Principle). But the outside of the index card is experiencing atmospheric pressure (which acts on everything perpendicular to the surface at any point) pushing the card against the spool and toward the lower pressure.

Activity 2

Observe: With practice, the water is drawn up the standing straw and blown out in tiny droplets.

Explain: The stream of fast air blown over the top of the standing straw creates low pressure in the top of that straw (Bernoulli's Principle). But the pressure remains unchanged at the other end of the standing straw (in the water). This difference in pressure causes the water to rise up the straw to find a new level of equilibrium. If the water is drawn up high enough, it is blown away by the airstream.

Demonstration 2

Observe: When air rushes over the top of the wing, the wing "lifts" up and "flies" in the airstream.

Explain: Airplane lift is generated, in part, by a pressure difference between the upper and lower surfaces of a wing. As the air blew over the top surface of the wing (with little air flowing underneath the wing), a low pressure was created on the upper surface. (This is Bernoulli's Principle: as speed increases, pressure decreases.) The higher pressure area under the wing in the relatively still air then "lifts" the wing into the airstream.

UNIT IV — LESSON 5 — CHAPTER 21

QUEST SHEET

Fast Air, Low Pressure!

Materials:

For classroom demonstrations: wooden dowel, two balloons on strings (Demonstration 1); medium-size fan, wooden dowel, piece of paper, tape (Demonstration 2). **For each team:** 3" x 3" piece of an index card, a pushpin, a large thread spool, 2 in. piece of straw for each student (Activity 1); glass with water, scissors, two straws for each student (Activity 2)

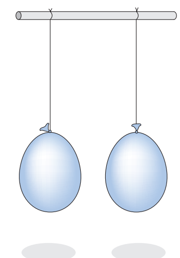
Demonstration 1

Predict:

What will happen when someone blows a stream of air between the two balloons suspended from the dowel?

Observe:

What happens?



Does this agree with your prediction?

Yes No

Explain:

Why did the balloons move this way?

UNIT IV — LESSON 5 — CHAPTER 21

Activity 1

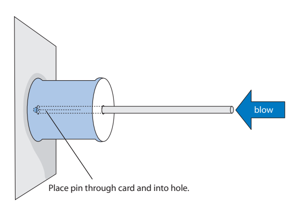
Take turns within your teams performing this experiment. Everyone should use his or her own straw.

First hold the index card up close to your mouth and blow. As you probably suspected, the card just blows away.

Now push the pushpin into the center of the index card. (The pushpin helps to keep the card roughly centered on the spool, but does not provide any support.) The experimenter then pushes one end of the straw into the hole in the spool of thread. With one hand, position and hold the index card against the other end of the spool, sticking the point of the pushpin into the hole. Blow very hard into the straw and slowly let go of the card.

Observe:

What happens?



Explain:

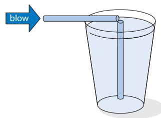
Why did this happen?

UNIT IV — LESSON 5 — CHAPTER 21

Activity 2

This activity demonstrates the operation of a paint sprayer (or perfume sprayer) as explained in *Newton at the Center*, page 226. Take turns doing the "spraying."

Fill the glass ¾ of the way full with water. Cut one straw to stand vertically in the center of the glass ½ in. above the surface of the water. Use one hand to hold this straw in place but do not allow it to touch the bottom of the glass. Then position the second straw horizontally at a 90-degree angle to the "standing" straw so that air exiting this straw will zip across the top end of the standing straw. (Straws must be well aligned for the full effect.) Now blow (hard!) through the horizontal straw.



(If nothing happens, adjust the position of horizontal straw and try again. If still nothing happens, shorten the horizontal straw a bit.)

Observe:

What happens?

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Explain:

Why did this happen?

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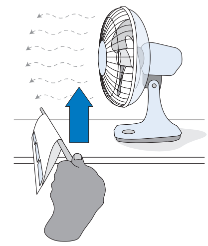
UNIT IV — LESSON 5 — CHAPTER 21

Demonstration 2

The shape of an airfoil (a cross section of an airplane wing) is designed with Bernoulli's Principle in mind. Observe this classroom demonstration.

Observe:

What happens when air flows over the top of the paper wing?



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Explain:

Using Bernoulli's Principle, explain why the wing behaved as it did.

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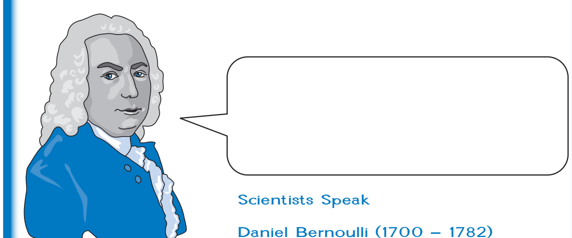

Scientists Speak

Daniel Bernoulli (1700 – 1782)