National Aeronautics and Space Administration

The Courage to Soar

Educational Product	
Educators	Grades 3–5

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Cover: Original art by Robert Sallee of Media Fusion.

Aircraft pictured:

a. *Bell X–1*
b. *X–43*
c. *B–2 Stealth*
d. *SR–71 Blackbird*
e. *Wright Flyer I*
f. *Spirit of Freedom* Balloon
g. Montgolfier Balloon
h. *B–52*
i. *Blackhawk*
j. *Voyager*
k. *Boeing 747*
l. *Curtiss JN 4–D Jenny*
m. *C–130*
n. *De Havilland Canada DHC–3 Otter* Float Plane

... with
o. Philip
p. Susan
q. Annie
r. Leapold
s. Straw Plane (construction on page 235)

The Courage to Soar

National Aeronautics and Space Administration

Marshall Space Flight Center

Exploration Systems Mission Directorate: Ares Projects

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How to Use This Guide

Activity Format

This educational guide is made up of ten activities, which are divided into one or more lessons about the topic. The objectives and national standards are given at the beginning of each activity. However, the location of the material lists and the pre-lesson instructions varies. For some activities, these are given at the beginning of the activity and include the necessary materials and instructions for all of the lessons in that activity. For other activities, the lists are simply too long, so they are included at the beginning of each individual lesson. The procedure for each lesson is always given with the lesson. When student text and vocabulary are a part of the lesson, they are located after the procedure. Special homework instructions, patterns, diagrams, charts, etc., are located with the lesson or at the end of the activity.

The activities in this guide have been divided into lessons that generally represent one class period of 1 to 1½ hours. Teachers should feel free to modify these lessons to meet the needs of their students, and to vary the length of time needed to complete each one. The preparation times to gather the materials and follow the pre-lesson instructions are listed at the beginning of each activity. The approximate teaching times for each lesson and the subjects that are emphasized for each lesson are listed there as well.

Unit Overview

Aviation is an interesting field of real-life adventure where problems are solved through experimentation and research. The area of aviation research, technology, and development is constantly growing, and many marvels in this field await our next generation. Through this unit, students will read several selections about aviation, research topics of interest, conduct scientific experiments, construct aircraft, and make connections with prior knowledge.

The Courage to Soar has been designed for students in third through fifth grades, and, with some minor modifications, it will interest and challenge grades six and seven as well. Even though the content is primarily science, the activities are rich in the language art skills of reading, writing, speaking, and listening. For many of the lessons, a student text with a vocabulary list is provided for guided reading instruction. In states where science subjects are mandated, teachers may use this guide to meet their language arts objectives while presenting enriching science activities to their students.

The first activity takes students back to the beginning of flight with a reading selection on kites and the construction of a sled kite. In the second activity, each student will research a person and an aircraft that were important to the development of flight. They will then use their research to create an illustrated flight timeline. This timeline provides a knowledge base for the remainder of the unit. It acts more as a chronology, where events are placed on a line in sequential order, rather than a strict timeline of equal increments.

In the next lessons, teachers will use literature and pictures of early aviation pioneers to highlight mans' endeavor to fly. Next, the students will move into an area of research known as authentic learning, or inquiry-based learning, where they will generate their own questions about flight and use a variety of research materials to find their answers. Their knowledge will be combined into an illustrated flight book. The students will continue their research as they conduct experiments to learn about the properties of air and the four forces of flight. Then, they will learn how to control an airplane as they construct and perform test flights of their own planes. The unit concludes with student presentations of their own designs of a Super Plane.

Opportunities for assessment are built into the lessons throughout the unit. Enrichment activities will give the students opportunities to make air cubes, hot air balloons, a rotor motor, and a paper model of the *X-43* airplane. Additional enrichment activities might include a trip to a local airport and/or a trip to a transportation or aircraft museum. Teachers are also encouraged to invite professionals associated with aeronautics to speak to their students. These may include a pilot, an aeronautical engineer, military personnel, or anyone who works for the airline industry. It is recommended that teachers contact the local chapter of the Academy of Model Aeronautics. To find the nearest chapter, log on to **http://www.modelaircraft.org** and click on "Chartered Club Search." Many clubs have speakers who will come to the classroom to acquaint students with their hobby. Some speakers may bring a model aircraft activity for the students.

Pre-unit Instructions

Teaching the vocabulary and student text

When student text is included in the lesson, the vocabulary words and their definitions are listed just before the student text. Teachers are free to teach the vocabulary as they would with any guided reading. One suggestion would be to duplicate all of the vocabulary lists (11 in all) for each child and have the students insert these in their logs so that they are readily available when the class begins to read the student text. You may want to duplicate the student text (11 lessons of student text) ahead of time as well.

Teachers who want to teach the unit again should ask their school to purchase 1-inch (2.5-centimeter) binders for the class, insert the 11 vocabulary lists and student texts in each binder, and use these as "readers" for the unit. The students will still need their own binders for notes, experiments, homework assignments, etc.

Materials

A list of materials is given at the beginning of each activity or, in some cases, each lesson. It is recommended that teachers begin to gather materials in advance of teaching the unit. **It may be helpful to duplicate the materials lists and pre-lesson instructions and give them to a team of parent volunteers.** As materials are collected, have a predetermined way to organize and store them. Labeled tubs or boxes make it easier to plan and prepare each lesson. **Use a color printer for printing pictures and laminate each one if possible.** Keeping and storing the materials will be helpful for teaching the unit again to future classes and will greatly reduce the prep time for each lesson.

In addition to gathering the materials ahead of time, teachers should try to fill their classrooms with a variety of picture books on airplanes and other aircraft, flight, the lives of famous aviators, the history of aviation, and planes of the future. Use the city or county library as well as the school library to find books on these subjects. These books will be needed for student research in Lessons 9–12. A list of suggested books is provided in the Resources section. The Resources section also lists related websites for students to explore.

Bulletin board

A week before beginning the unit, teachers should prepare a "Take Flight" bulletin board and ask the students to bring in pictures of man-made objects that fly in the atmosphere (not spacecraft). This should be an ongoing project as students continue to bring in pictures throughout the unit.

Student needs

Students will need a binder with three 1-inch (2.5-centimeter) diameter rings. This will be used as a student log as well as a place to store student text, experiments, and homework assignments.

It will be necessary to collect the materials needed for the sled kite in Lesson 2 several days beforehand.

Flight is an exciting unit of study for any age. As the bulletin board is completed, and as books and materials enter the classroom, students will begin to look forward to their study of aviation. Most importantly, teachers and students should have fun together as they take flight!

National Education Standards

Science

Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Abilities necessary to do scientific inquiry.	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈		✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈
Understandings about scientific inquiry.		✈	✈	✈	✈	✈	✈	✈					✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈
Position and motion of objects/Motion and forces.	✈	✈	✈	✈	✈	✈	✈	✈		✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈
Properties of Earth materials.													✈	✈		✈							
Objects in the sky.	✈	✈	✈	✈	✈	✈	✈	✈		✈	✈	✈	✈		✈	✈	✈	✈	✈	✈	✈	✈	✈
Abilities of technological design.					✈	✈	✈	✈		✈	✈	✈			✈		✈	✈	✈	✈	✈	✈	✈
Understanding about science and technology.		✈			✈	✈	✈			✈	✈	✈	✈		✈		✈	✈	✈	✈	✈	✈	✈
Risks and benefits.	✈	✈		✈	✈	✈	✈			✈	✈	✈					✈			✈	✈	✈	✈
Science and technology in local challenges/in society.	✈	✈		✈	✈	✈	✈			✈	✈	✈			✈		✈	✈	✈	✈	✈	✈	✈
Science as a human endeavor.	✈	✈		✈	✈	✈	✈	✈	✈	✈	✈	✈	✈		✈	✈	✈	✈	✈	✈	✈	✈	✈
History of science.	✈	✈		✈	✈	✈	✈		✈	✈	✈	✈				✈	✈	✈					

Mathematics

Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Compute fluently and make reasonable estimates.	✈													✈							✈	✈	
Understand patterns, relations, and functions.	✈																				✈	✈	
Use mathematical models to represent and understand quantitative relationships.																					✈	✈	
Analyze change in various contexts.					✈	✈	✈														✈	✈	
Investigate, describe, and reason about the results of subdividing, combining, and transforming shapes.					✈																		
Use visualization, spatial reasoning, and geometric modeling to solve problems.	✈	✈																		✈			✈
Understand measurable attributes of objects and the units, systems, and processes of measurement.		✈						✈						✈			✈		✈	✈	✈	✈	✈
Apply appropriate techniques, tools, and formulas to determine measurements.	✈	✈			✈									✈			✈		✈	✈	✈	✈	✈
Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.	✈				✈	✈		✈					✈	✈			✈		✈		✈	✈	✈
Select and use appropriate statistical methods to analyze data.						✈							✈	✈		✈	✈		✈		✈	✈	✈
Develop and evaluate inferences and predictions that are based on data.						✈							✈	✈							✈	✈	
Understand and apply basic concepts of probability.			✈		✈	✈		✈					✈	✈		✈	✈		✈		✈	✈	
Problem solving.	✈	✈	✈	✈	✈	✈	✈	✈					✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈
Reasoning and proof.													✈	✈		✈	✈		✈		✈	✈	
Communication.		✈	✈	✈	✈	✈	✈	✈					✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈

Geography

Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.	✈	✈		✈	✈	✈	✈									✈	✈					✈	✈
How to use mental maps to organize information about people, places, and environ-ments in a spatial context.					✈	✈	✈															✈	
The physical and human characteristics of places.	✈	✈	✈							✈	✈	✈				✈						✈	
How culture and experience influence people's perceptions of places and regions.					✈	✈	✈															✈	
The patterns and networks of economic interdependence on Earth's surface.										✈	✈	✈										✈	✈
The processes, patterns, and functions of human settlement.																						✈	
How human actions modify the physical environment.	✈	✈		✈	✈	✈	✈			✈	✈	✈										✈	✈
How physical systems affect human systems.	✈	✈			✈	✈	✈			✈	✈	✈										✈	✈
How to apply geography to interpret the past.	✈	✈		✈	✈	✈	✈			✈	✈	✈										✈	
How to apply geography to interpret the present and plan for the future.																						✈	✈

Language Arts

Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Students read a wide range of print and non-print texts, fiction and non-fiction, classic and contemporary works.	✈	✈			✈	✈	✈		✈	✈			✈		✈	✈	✈	✈		✈		✈	
Students read a wide range of literature from many periods in many genres.	✈	✈			✈	✈	✈		✈	✈													
Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts.	✈	✈			✈	✈	✈		✈	✈			✈		✈	✈	✈	✈	✈	✈		✈	
Students adjust their use of spoken, written, and visual language to communicate with a variety of audiences and for different purposes.	✈	✈	✈	✈	✈		✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈
Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.	✈	✈	✈	✈				✈	✈	✈	✈	✈	✈	✈		✈	✈		✈		✈	✈	✈
Students apply knowledge of language structure, language conventions, media techniques, figurative language, and genre to create, critique, and discuss print and non-print texts.	✈	✈	✈		✈		✈	✈	✈	✈	✈	✈	✈	✈		✈	✈		✈		✈	✈	✈
Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather and evaluate data from a variety of sources to communicate their discoveries.	✈	✈	✈	✈				✈	✈	✈	✈	✈	✈	✈		✈	✈	✈	✈		✈	✈	✈
Students use a variety of technological and information resources to gather and synthesize information and to create and communicate knowledge.	✈	✈	✈	✈			✈		✈	✈	✈	✈	✈			✈	✈		✈		✈	✈	✈
Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.	✈	✈	✈	✈	✈	✈	✈		✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈
Students use spoken, written, and visual language to accomplish their own purposes.	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈

Technology-ISTE

Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Students are proficient in the use of technology.	✈	✈	✈	✈					✈	✈	✈									✈	✈	✈	✈
Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works.									✈	✈	✈	✈								✈	✈	✈	✈
Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences.										✈	✈	✈											
Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences.										✈	✈	✈											
Students use technology to locate, evaluate, and collect information from a variety of sources.	✈	✈	✈	✈					✈	✈	✈									✈	✈	✈	✈
Students employ technology in the development of strategies for solving problems in the real world.																				✈	✈	✈	✈

Technology-ITEA

Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Relationships among technology and other fields.	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈
Cultural, social, economical, and political effects.	✈	✈		✈	✈	✈	✈			✈	✈	✈	✈		✈							✈	✈
Effects of technology on the environment.		✈		✈		✈	✈			✈	✈	✈										✈	
Role of society in the development and use of technology.	✈	✈		✈	✈	✈	✈			✈	✈	✈	✈	✈						✈		✈	✈
Influence of technology on history.	✈	✈	✈	✈						✈	✈	✈	✈	✈		✈	✈	✈		✈		✈	✈
Attributes of design.		✈	✈	✈	✈	✈	✈	✈		✈	✈	✈	✈	✈			✈	✈	✈	✈	✈	✈	✈
Engineering design.		✈	✈	✈				✈		✈	✈	✈	✈	✈	✈		✈	✈	✈	✈	✈	✈	✈
Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving.	✈	✈	✈	✈			✈			✈	✈	✈	✈		✈	✈	✈	✈			✈	✈	✈
Apply the design process.		✈	✈	✈	✈	✈	✈	✈		✈	✈	✈			✈	✈	✈	✈	✈	✈	✈	✈	✈
Use and maintain technological products and systems.	✈	✈	✈	✈	✈	✈	✈			✈	✈	✈		✈		✈	✈			✈	✈	✈	✈
Assess impact of products and systems.	✈	✈		✈		✈	✈					✈										✈	✈
Transportation technologies.	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈	✈		✈	✈		✈	✈	✈	✈	✈	✈	✈

Activity One—Kite Flight

Lessons 1–3

Pre-unit prep time: 1 hour

(See How to Use This Guide for instructions about gathering books, preparing a bulletin board, and duplicating vocabulary lists.)

Activity (Lessons 1–3) prep time: 40–50 minutes

(for gathering materials and following pre-lesson instructions)

Teaching time:

Lesson 1: 1–1½ hours
(Science, Language Arts, Technology)

Lesson 2: 1¼ hours
(Science, Language Arts, Technology)

Lesson 3: 1½–2 hours
(Science, Language Arts, Technology)

Objectives—Lessons 1–3

1. The students will identify man-made things that fly as they bring in pictures for the "Take Flight" bulletin board.
2. The students will distinguish between fiction and non-fiction as they listen to the story *Merle the High Flying Squirrel* or *Shibumi and the Kitemaker* and practice identifying other works as fiction or non-fiction.
3. The students will share their knowledge about flight and develop questions about flight as they construct a KWL (What We Know, What We Want to Know, What We Learned) chart.
4. The students will identify how kites were used in battle, for work, and for play.
5. The students will identify some of the famous people who flew kites and how they used the kites to accomplish their goals.
6. The students will construct and fly a sled kite.
7. The students will write, illustrate, and present stories about their personal kite-flying experiences.
8. The students will conduct research on people and aircraft significant to the development of flight.

National Standards—Lessons 1–3

Science

- Abilities necessary to do scientific inquiry—S2Ea, S2Ma.
- Understandings about scientific inquiry—S2Eb, S2Mb.
- Position and motion of objects/Motion and forces—S3Eb, S3Mb.
- Objects in the sky—S5Eb.
- Understanding about science and technology—S6Eb, 6Mb.
- Risks and benefits—S7Md.
- Science and technology in local challenges/in society—S7Ee, S7Me.
- Science as a human endeavor—S8Ea, S8Ma.
- History of science—S8Mc.

Mathematics

- Compute fluently and make reasonable estimates—M3.
- Understand patterns, relations, and functions—M4.
- Use visualization, spatial reasoning, and geometric modeling to solve problems—M11.
- Understand measurable attributes of objects and the units, systems, and processes of measurement—M12.
- Apply appropriate techniques, tools, and formulas to determine measurements—M13.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them—M14.
- Develop and evaluate inferences and predictions that are based on data—M16.
- Understand and apply basic concepts of probability—M17.
- Problem solving—M18.
- Communication—M20.

Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective—G1.
- The physical and human characteristics of places—G4.
- How human actions modify the physical environment—G14.
- How physical systems affect human systems—G15.
- How to apply geography to interpret the past—G17.

Language Arts

- Standards 1, 2, 3, 4, 5, 6, 7, 8, 11, and 12. (See Language Arts Matrix on page 8.)

Technology

- Students are proficient in the use of technology—I2.
- Students use technology to locate, evaluate, and collect information from a variety of sources—I10.
- Relationships among technology and other fields—T3.
- Cultural, social, economical, and political effects—T4.
- Effects of technology on the environment—T5.
- Role of society in the development and use of technology—T6.
- Influence of technology on history—T7.
- Attributes of design—T8.
- Engineering design—T9.
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving—T10.
- Apply the design process—T11.
- Use and maintain technological products and systems—T12.
- Assess impact of products and systems—T13.
- Transportation technologies—T18.

Materials—Lessons 1 and 2

- The book *Merle the High Flying Squirrel* by Bill Peet or *Shibumi and the Kitemaker* by Mercer Mayer or another appropriate fictional story about kites. (See Suggested Reading list.)
- A KWL chart on flight. (See Pre-lesson Instructions.)
- The "Take Flight" bulletin board for students to post pictures of man-made objects that fly.
- A copy of the student text for Lessons 1 and 2, "Kites in Flight," for each student.
- A copy of the Sled Kite Instructions (or Alternate Sled Kite Instructions and template) for each group of 3–4 students. (Even though students will construct their own kite, they will share these instructions.)
- World map.
- Student logs—A loose-leaf binder with three rings, each about 1 inch in diameter, is needed so that handouts can be inserted. The students should insert about 10 sheets of notebook paper.
- Materials for the sled kites.
  - 1 large plastic garbage bag at least 24 by 30 inches (61 by 75 centimeters) for each student.
  - 2 wooden dowels—24 inches (61 centimeters) long and ⅛ inch (3 millimeters) in diameter for each student.
  - Small ball of string for each student.
  - If the Alternate Sled Kite Instructions using a sled kite template are used, newspaper (or tissue paper) and 2 straws are needed instead of plastic garbage bags and dowels.
  - Scissors.
  - A yardstick or meter stick for each group.
  - Marking pen or pencil.
  - Roll of duct tape or packing tape.

Pre-lesson Instructions—Lessons 1 and 2

1. **Very important:** Two days before Lesson 1 is taught, write on the board a list of materials for the sled kite for each student to bring in: (1) one 24- by 30-inch (61- by 76-centimeter) garbage bag, (2) two 24-inch (61-centimeter) long dowels with ⅛-inch (3-millimeter) diameters, and (3) a small ball of string. Consider collecting money for the dowels and purchasing all of them for the students, or assign this task to a parent. Remember, students will need their materials for their sled kite before Lesson 2 begins. Decide on a way to organize and label these materials as they are brought to school. Paper lunch bags are one good way to organize individual materials.
2. Prepare a KWL chart. Use a large sheet of bulletin board paper about 4½ feet (1.4 meters) wide. Write the title "Flight" and then divide it into three equal columns, each 1½ feet (0.5 meters) wide. This should be displayed before class begins.

Flight

What We Know	What We Want to Know	What We Learned

3. Duplicate enough copies of the student text for Lessons 1 and 2, "Kites in Flight," for each student. Punch holes so that students can insert these copies in their logs.
4. Duplicate copies of the Sled Kite Instructions (or Alternate Sled Kite Instructions). Prepare one copy for each group of 3 or 4 students.
5. Duplicate enough copies of the homework assignment, "People and Aircraft that Contributed to the Development of Flight," for each student.
6. The "Take Flight" bulletin board should already be in place by this time. The homework for bringing in pictures of man-made objects that fly should have been given out by now as well. Students should be allowed to add pictures to this bulletin board throughout the unit.
7. Make an overhead transparency of "People and Aircraft that Contributed to the Development of Flight."
8. If possible, try to have some kites on display in the room as well as pictures of kites and hang gliders. (Ask staff members to bring in their kites.)
9. Divide the class into working groups of 3 or 4 students for constructing a sled kite. Each student will make his/her own kite. Copies of the instructions are shared so that students can help one another in their working groups.
10. Make plans for a large, open area outside (away from other classes) for kite flying in Lesson 3.

Important Note to Teachers: A teacher reference list to the Flight Timeline is provided at the end of Lesson 4. A brief description of each person and aircraft is given.

Lesson 1— A History of Kites

Procedure—Lesson 1

1. Read aloud either *Merle the High Flying Squirrel* by Bill Peet (for younger students) or *Shibumi and the Kitemaker* by Mercer Mayer (for all grades) to introduce the topics of kites and flight.
2. Ask the students which parts of the story were real and which parts were fantasy. Tell the class that this story about kites was fiction and that they will be reading a selection that is non-fiction. Briefly identify other works of fiction and non-fiction to make sure that students know the difference.
3. Direct the students' attention to the "Take Flight" bulletin board. Compliment students on all of the pictures that they have brought in and tell them that they will be referring to these pictures later in the unit. Ask the students if they have any questions or comments about any of the objects that are displayed.
4. Next, direct the students' attention to the KWL chart. Ask them what they know about flight. Record their answers in the "What We Know" column. Some students will know little or nothing about flight. If incorrect responses are given, try to guide the students to a correct response. You may have to make a note to look it up or record it in the "What We Want to Know" column. Use teacher discretion for displaying incorrect information in the classroom.
5. Ask the students what they would like to know about flight. Record their questions in the "What We Want to Know" column. Teachers may need to guide the class or even suggest some questions that may spark their curiosity. This may be a good time to encourage an interest in some famous aviators such as Charles Lindbergh, Amelia Earhart, or Chuck Yeager. Explain that the "What We Learned" column will be filled in after they have completed the unit on flight. The KWL chart should be on display throughout the unit.
6. Instruct the students to take out their logs (binders). Have them insert about 10 sheets of notebook paper in them. Explain that their logs will be used to answer questions, take notes, record data, and store reading selections, experiments, charts, and other information.
7. Distribute copies of the student text for Lessons 1 and 2, "Kites in Flight," and have the students insert this in their logs. (Even though the Readability Level is 4.9 on this selection, younger students can read and comprehend this with some help with the proper nouns.)
8. Introduce and teach the vocabulary as you would any guided reading. Locate Niagara Falls, Italy, Asia, and China on a world map. To make the heights of Niagara Falls more relevant, tell the students that the falls are higher than the Statue of Liberty (151 feet or 46 meters).
9. Read the section "A History of Kites." As the class discusses the text, question their understanding and encourage their questions. Find each country on the map as you read about it. Ask the students to identify ways that they could use kites for work, to solve a problem, or to conduct an experiment.
10. After reading the selection, use the Pythagorean Theorem ($a^2 + b^2 = c^2$) to show how General Han was able to calculate the distance to the inside of the wall. (This activity could be expanded with the use of student calculators.)
11. Distribute the homework assignment slips. Tell the students that they will be researching a person and an aircraft that contributed to the development of flight. Tell them that they will have three nights to complete the assignment and that it will be needed for the Flight Timeline project that will be done in class. Encourage the use of home and school computers, but other resources may be used as well.
12. Display the list of people and aircraft that contributed to the development of flight on an overhead projector. Read the list of people aloud and let the students choose a person that interests them. If a student does not have a preference, make assignments as necessary. When choices and assignments are made, have the students fill in their homework slips. Repeat the procedure for the aircraft. Give them the date, three lessons from today, that the research is due. Have them fill in the date, 2 days from today, when the class will fly kites.

Student Text—Lesson 1

The vocabulary and the complete student text for Lessons 1 and 2 begins on page 19.

People and Aircraft That Contributed to the Development of Flight

People

Wiley Post
The Red Baron
Jackie Cochran
Clyde Cessna
"Chuck" Yeager
Louis Blériot
The Mercury Seven
Samuel P. Langley
Leonardo da Vinci
Bessie Coleman
Jimmie Doolittle
Douglas Corrigan
National Aeronautics and Space Administration (NASA)
National Advisory Committee for Aeronautics (NACA)

Barnstormers
Eddie Rickenbacker
Ferdinand von Zeppelin
Sir George Cayley
Harriet Quimby
Charles Lindbergh
Amelia Earhart

Amelia Earhart

Anthony Fokker
Montgolfier Brothers
Tuskegee Airmen
Otto Lilienthal


Otto Lilienthal

Paul Cornu
Glenn Curtiss
Blanche Stuart Scott
Wright Brothers

Aircraft

X–15

Douglas DC–3

Fokker D.VII

B–52 Stratofortress

Bell X–1

SR–71 Blackbird

Lockheed SR-71 Blackbird

Aircraft of the Persian Gulf War

C–17 Globemaster III

B–2

X–29

F–35 Joint Strike Fighter

X–43

Gossamer Condor

Pan American Airways

Concorde

F–15 Eagle

Harrier Jet

Boeing 747

F–16 Falcon

Bell UH–1 Huey

Department of Defense

Bell UH-1 Huey

F–22 Raptor

EX Vin Fiz

Breitling Orbiter 3

Gondola

Voyager

Voyager

Wright Flyer III

Mitsubishi A6M5 Zero

Curtiss JN–4D Jenny

Douglas World Cruiser

F/A–18 Hornet

Bell XP–59A

Messerschmitt 262

Spirit of Freedom

Homework Assignment for People and Aircraft That Contributed to the Development of Flight

Research the person and aircraft you were assigned. Write one or two sentences in your log about the assigned person and aircraft and the dates that made them important. Bring in or sketch a picture of the person and the aircraft to help you illustrate your timeline cards.

My person is ____

My aircraft is ____

Due ____________________

We will be flying kites on ____________________
Bring in your own kite that day if you like.

Lesson 2—Famous People and Their Kites

Procedure—Lesson 2

1. Instruct the students to take out their logs. Review the vocabulary words.
2. Read the section "Famous People and Their Kites." As the class discusses the text, question their understanding and encourage their questions. Use the world map to locate the places mentioned in the selection.
3. After reading this section, ask the students to think about the tasks each person accomplished using kites. Ask them how they might have accomplished any of these tasks without using kites if they had lived back then. Next, have the students identify ways they could have accomplished these tasks using today's technology instead of kites.
4. Discuss the homework assignment "People and Aircraft That Contributed to the Development of Flight." Remind the students that it is due in 2 days. Try to assist those students who do not have research capabilities at home by providing the use of school computers.
5. Assign the students to their working groups and give each group a copy of the Sled Kite Instructions (or the Alternate Sled Kite Instructions).
6. Read and demonstrate each step as you assemble a kite for the class. Tell the students that they will build their kites today and fly them tomorrow.
7. Distribute the materials for the sled kites. Encourage group members to help one another. Walk around and assist as needed.
8. When all kites are assembled and labeled with names, put them in a secure place until the next class period.

Vocabulary—Lessons 1 and 2

Asia – a continent in the eastern hemisphere north of the equator that forms a single landmass with Europe

bamboo

bamboo – a tropical, tall, woody, plant with strong hollow stems

biplane – an airplane with two sets of wings usually placed one above the other

biplane

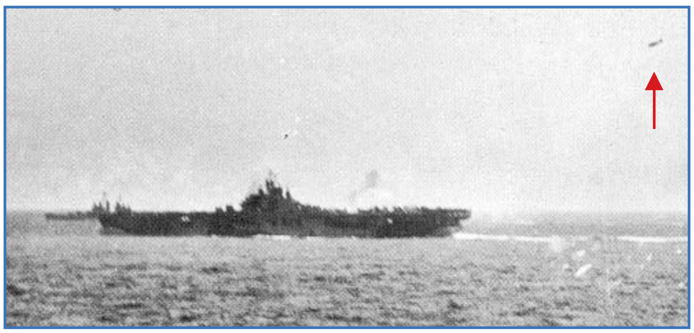
crane – a large, wading bird with long legs, a long neck, and a long bill

crane

dynasty – rulers from the same family that stay in power for many years

emperor – the ruler of an empire

gorge – a deep, narrow passage with steep, rocky sides



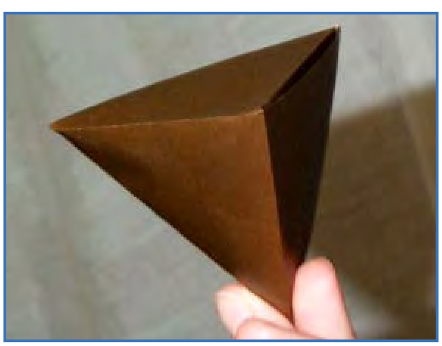
A kamikaze pilot (upper right corner) approaches the *USS Essex* in November 1944.

kamikaze – a Japanese pilot trained in World War II to make a suicidal crash attack, especially upon a ship

Marco Polo – an Italian merchant and traveler who journeyed from Europe to Asia from 1271–1295

Niagara Falls – waterfalls in the Niagara River between the cities of Niagara Falls, New York, and Niagara Falls, Ontario, Canada (Canadian Falls—158 feet or 48 meters high, American Falls—167 feet or 51 meters high)

The Niagara Falls flow into the Niagara Gorge.



tetrahedron

tetrahedron – a solid figure having four, same-size, equilateral triangles as faces

Student Text—Lessons 1 and 2

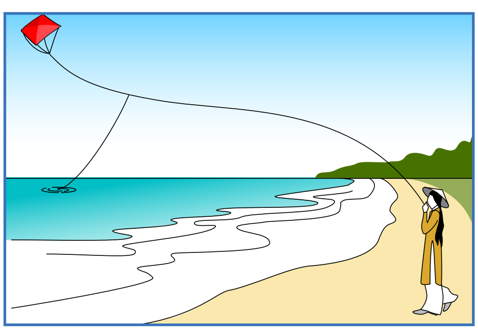
Kites in Flight

A History of Kites

When we think of kites, we can picture ourselves running across a grassy field. As we run, we let out some string. Slowly, the kite lifts high into the air to ride the wind.

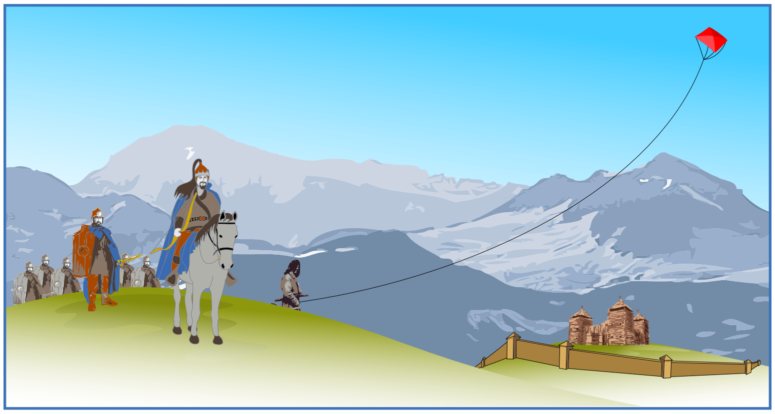

These children enjoy flying their kites on a grassy field.

People have been flying kites for over 2,000 years. The Chinese were the first to use kites. At first, they used silk and **bamboo**. Later, they replaced the silk with paper. The kites they made were very beautiful. Today, kites are used mostly for fun. But long ago they were used for work, not play.


Chinese fishermen used kites.

Chinese fishermen would tie a fishing line to the end of a kite. When a fish bit the bait, the kite jumped. Then the fish and the kite were pulled in. Chinese farmers used kites too. They put kites in their fields. The moving kite scared away the birds that tried to eat their crops.

Early Chinese kites were used in war. Some of these kites carried messages. A huge kite could carry a man. From high up, they could spy on the enemy. In 206 B.C.,



General Han used a kite to calculate the distance needed for the tunnel.

General Han used a kite to defeat an evil **emperor**. He flew a kite over a wall of the emperor's palace. Then, he measured the string. This length showed him how long to dig a tunnel. This tunnel would take his men inside the walls. General Han and his men dug the tunnel. Then, they crept through it to the other side of the wall. This surprised the enemy. Han was able to overthrow the evil emperor. The Han **dynasty** ruled China for the next 200 years.

From China, kite flying spread to Japan. At first, kites in Japan were flown for religious reasons. These kites took the shape of **cranes**, dragons, fish, and turtles. These shapes meant good luck or good fortune. Some kites were made to frighten away evil spirits. Today, the Japanese fly kites for fun or sport.

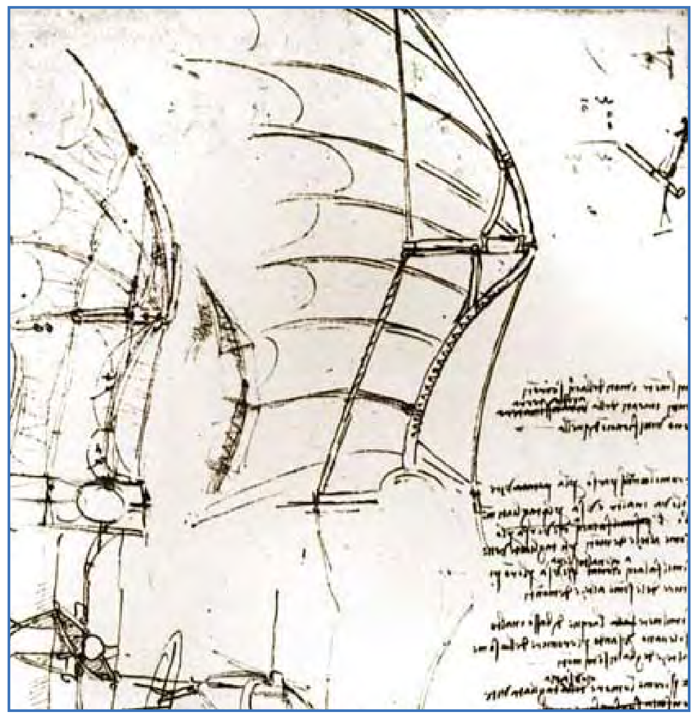
One of these sports is "kite fighting." It has been a popular sport in many parts of **Asia** for centuries. It is a contest in which a kite flyer tries to cut the string of another kite. Hundreds of kites fill the sky. At first, hundreds of battles go on at the same time. The winner of one fight goes right into a fight with another kite. A fighter kite is usually small and easily controlled. The string is coated with powdered glass to cut the other kite strings. Ground pottery or knife blades can also be used. It takes a lot of skill to be the last kite in flight.

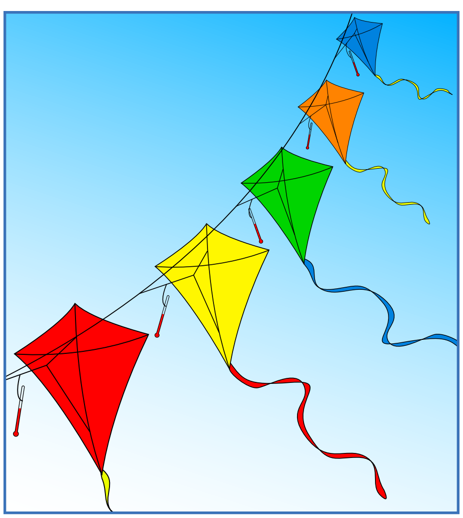
Chinese Dragon kite

Marco Polo was a famous trader. When he returned to Europe from China, he brought back tales of kites. But kites did not catch on in Europe at that time. Later, Dutch traders went back and forth between Europe and Asia. They brought kites back with them. Then, kites became more popular in Europe.

Famous People and Their Kites

Kites have been used by some very famous people. Leonardo da Vinci was one of these. He is best known for being an artist in Italy. But he was also a scientist. In the late 1400s, he began to study flight. At first, he studied birds. He also flew kites. From these studies, he drew some designs for flying machines. His interest in kites may have led him to study clouds and air flow.


Da Vinci's design for a flying machine c1488


Wilson used kites in his air-temperature experiments.

Alexander Wilson lived in Scotland. He used kites to do experiments. In the mid 1700s, he flew a whole line of kites. The kites were all placed on one line. Next, he put thermometers all along the line. Then he flew the kites. In this way, he measured the temperature at different heights.

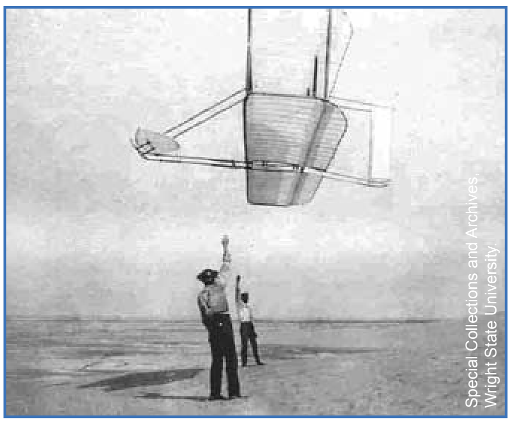
Painting of Ben Franklin flying a kite to discover electricity.

Most people know how Ben Franklin used a kite. He discovered electricity by flying one. In the mid 1700s, he flew a kite in a thunderstorm. He thought that lightning was a form of electricity. He was right! Lightning hit the kite and a key that was hanging from it. With the kite and key, Ben proved that lightning is electricity.

The **Niagara Falls** Bridge was built with the help of a boy and his kite. The bridge was built in the mid 1800s. To start, the builders had to get a line over the water. But steep cliffs, rapids, and swirling winds made this very hard. Someone thought that the problem might be solved by flying a kite over the **gorge**. So, a contest was held. A prize would be given to the first person to fly a kite across the Niagara Gorge. The winner was a young boy named Homan Walsh. Homan took a ferry to the Canadian side. From there, he flew his kite high over the river. Then he let it go slack. It fell on the American side. But the string had broken. Homan had to wait 8 days for the ice to clear from the river before he could go back to the American side and get his kite. He repaired the string and returned to the Canadian side. Once again, he flew his kite and it dropped to

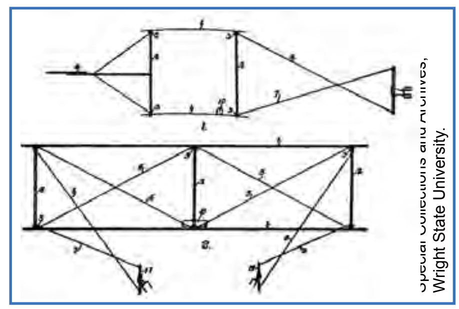
An early kite-flying contest was held to help builders get a line stretched across Niagara Falls, so they could build a bridge. Today it is all in fun, as flyers race their best kites to go higher and further.

the American side. This time it was caught and tied to a tree. The builders secured the kite string. Then, they began to add heavier and heavier line. Finally, a steel cable stretched across the gorge. Now, they could begin to build the bridge. For all of his trouble, Homan received the $5.00 prize.



The Wright Brothers fly the 1902 glider as a kite.

In 1899, Wilbur and Orville Wright built a **biplane** kite. This is the kite they used to invent wing warping. This was a way to twist the wings. It gave them greater control of the kite. The brothers also flew gliders. They often flew the gliders as kites to practice control. From these glider kites, they invented and flew the first airplane. In fact, their first airplane was like a box kite with a motor.



This diagram of the 1899 kite shows how the kite was controlled by wing warping.

B.F.S. Baden-Powell was a British soldier. He was also a kite flyer. He wanted to make a kite that could carry a person. He thought it could be used to spy on an enemy. In the 1890s, he built a kite. He named it the Levitor. This kite took him 108 feet into the air. The Levitor also helped an Italian named Marconi. He had invented the radio. He used the kite to lift an antenna high into the air. From there, it could pick up a signal from Canada. This was the first radio signal to be picked up from across an ocean.

Photograph of Marconi and associates raising the receiving antenna by kite at St. John's, Newfoundland in December, 1901.

Alexander Graham Bell was the inventor of the telephone. He also flew kites. Like the Wrights, he was trying to make a flying machine. In the early 1900s, he flew a special kite. It was made up of 3,393 **tetrahedrons**. The kite lifted a man 168 feet (51 meters) high. It stayed up for 7 minutes. But it did not lead to an airplane.

tetrahedron kite

During World War II, Paul Garber made a kite. He wanted to use it for target practice. His kite could loop, dive, and climb like a plane. The Navy anti-aircraft gunners practiced shooting the kites down. This would help them to shoot down real enemy planes. One day, the gunners were practicing. Suddenly, out of the fog came a surprise **kamikaze** attack. The gunners swung their guns from the kites. They aimed and shot the plane down. The ship was saved. The Navy bought over 300,000 kites to be used for target practice. Garber also used kites to pass messages from ships to aircraft.

the Garber target kite

Photo of Rogallo's flexible wing (Parawing), which was tested by NASA.

In the mid 1900s, Francis Rogallo invented a new kind of kite. It was called a delta wing kite. The wing was shaped like a parachute with three sides. People flew these by hanging below the wing. Today, these kites are called hang gliders.

In the 1970s, Peter Powell created a two-line stunt kite. The extra lines helped him to control his kite better. These sport kites became popular. They could travel at fast speeds and could be steered across the sky. Expert skill was not needed to fly them.

Rogallo's delta wing led to the sport of hang gliding.

stunt kite

Today, kites are more popular than ever. People fly kites, and people fly with kites. Kites are flown for fun, for sport, and even as an art form. Kites have come a long way. People have been flying kites for thousands of years. Remember that the next time you fly a kite.

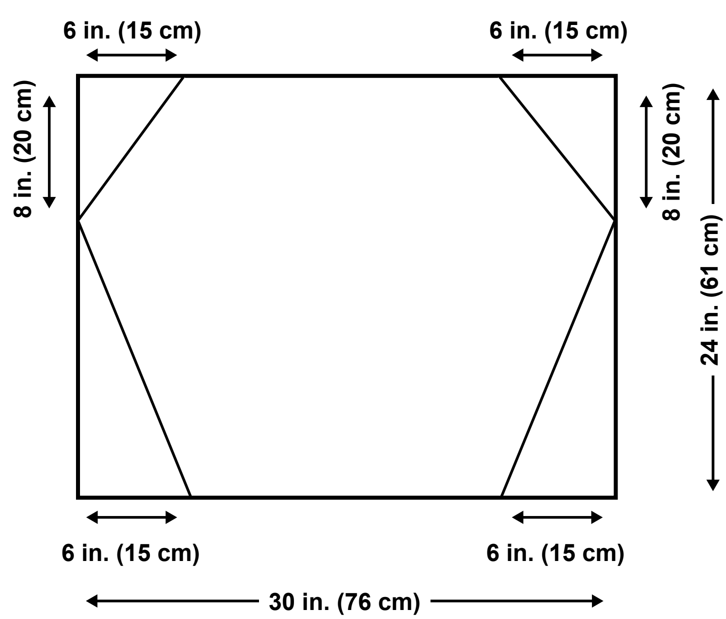
Making a Sled Kite

Materials

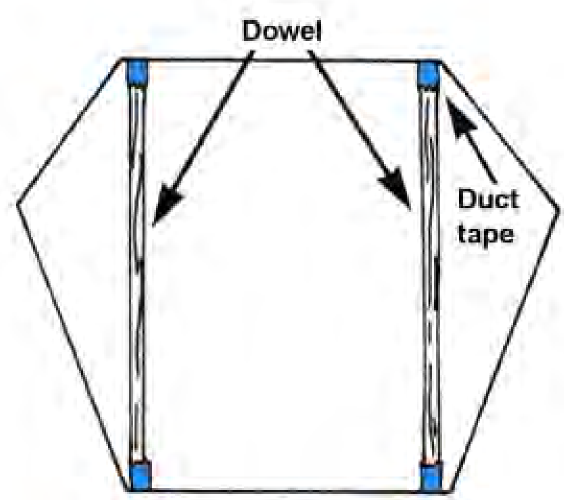
- Plastic garbage bag at least 24 by 30 inches (61 by 76 centimeters).
- 2 wooden dowels—24 inches (61 centimeters) long and ⅛ inch (3 millimeters) in diameter.
- Scissors.
- 1 yardstick or meter stick.
- Marking pen or pencil.
- Small ball of string.
- Roll of duct tape or packing tape.

Instructions for Assembling

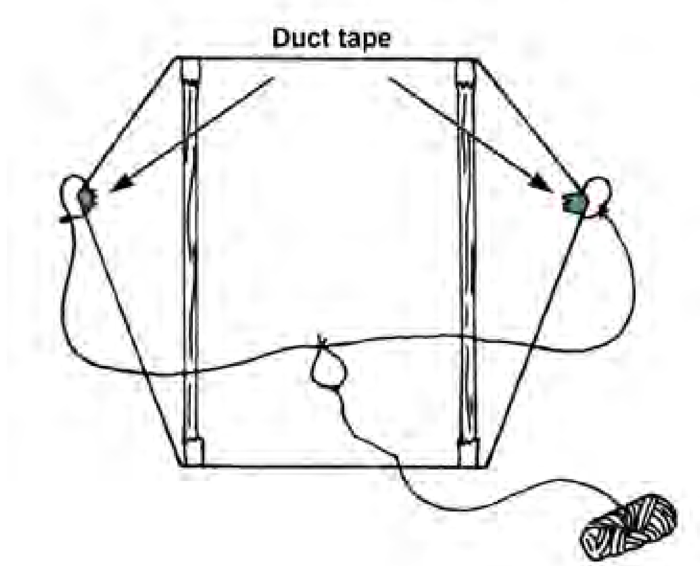
1. Flatten the plastic garbage bag on a large surface. Cut out a 24- by 30-inch (61- by 76-centimeter) rectangle.
2. On the two long sides of the rectangle, make a mark 6 inches (15 centimeters) from each of the four corners (4 marks).
3. On the two short sides, make a mark 8 inches (20 centimeters) from the two corners at the top (2 marks).



4. Use the yardstick to draw a line connecting the marks on each edge so that the line is opposite the corner.
5. Cut on these lines so that you are cutting off each corner.
6. Place the dowels on the kite so that each end of the dowel touches the 6-inch (15-centimeter) marks that are opposite each other. Tape the dowels firmly in place.



7. The kite will have a point on both sides. Wrap a piece of duct tape around these points to reinforce them.
8. Punch a small hole in the tape on both sides.
9. Cut a piece of string 2 yards (1.8 meters) long. Thread the string through the two holes, loop it over, and tie a knot on each side.
10. Fold the kite in half to find the center of the string. Tie a loop knot in the center of the string.



11. Tie the remaining ball of string to the loop knot, and you're ready to fly.

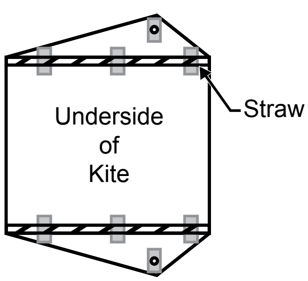
Alternate Sled Kite Instructions

Materials

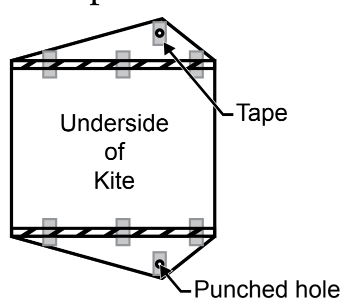
- Alternate sled kite template.
- 2 drinking straws.
- Clear tape.
- Scissors.
- String—two 18-inch (45.7-centimeter) lengths and a 1-yard (0.9-meter) length.
- Hole punch.
- 1 paper clip.
- Selection of paper (tissue, newspaper, crepe).
- Markers, crayons, pencils.

Instructions for Assembling

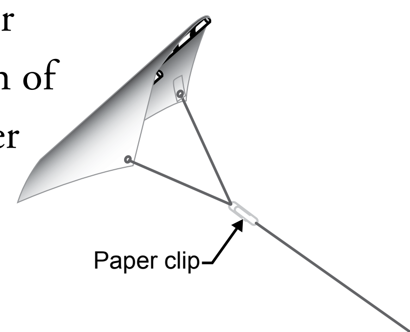
1. Make a copy of the alternate sled kite template. Cut out the sled kite.
2. Decorate one side of the kite using crayons, markers, etc.
3. Trim the length of the drinking straws so they will fit in the area marked for the straws.



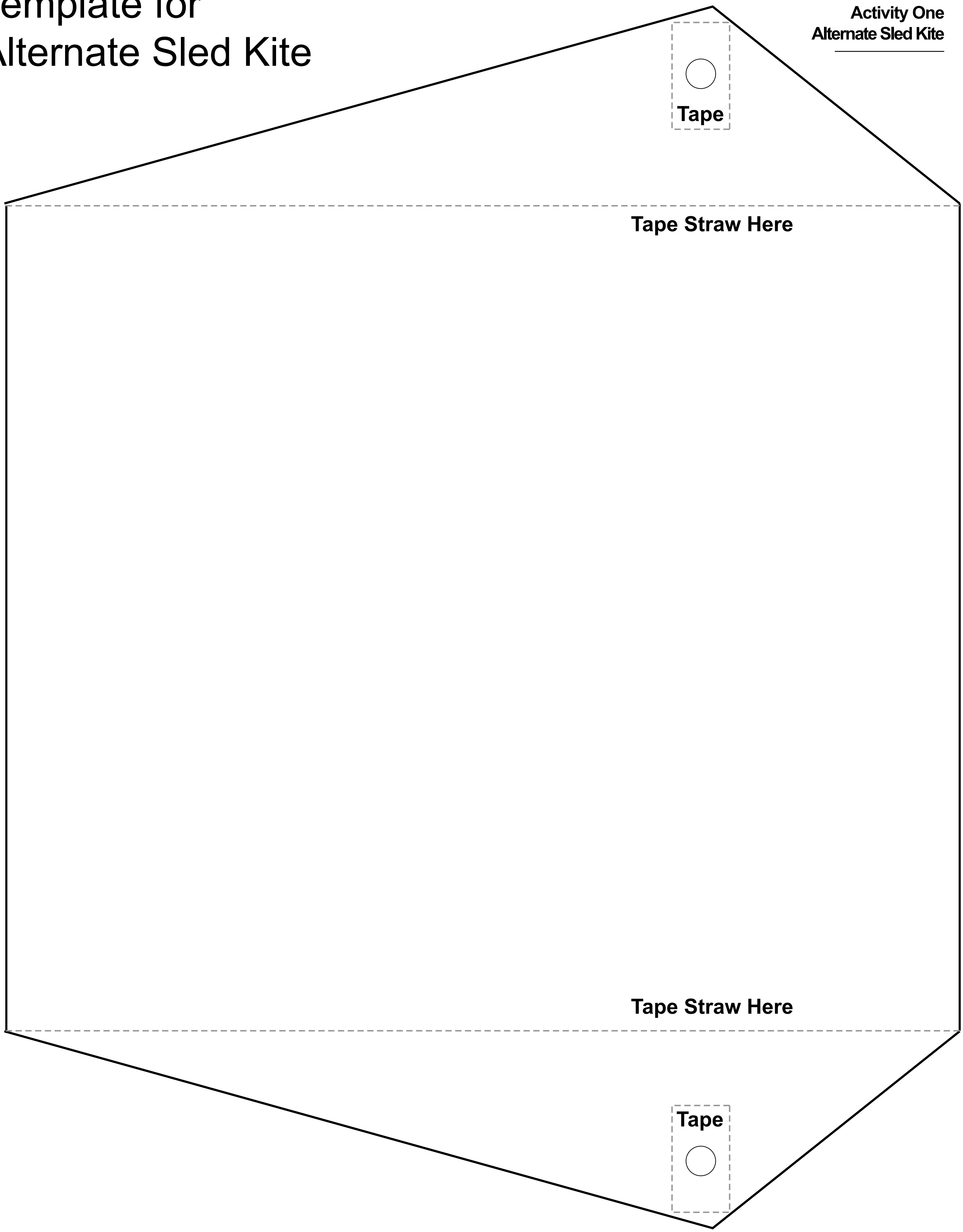
4. Place two or three pieces of tape in the marked areas covering the black circles.
5. Punch the two holes marked by the black circles.
6. Cut the two pieces of kite string 18 inches (45.7 centimeters) each. Tie a string through each hole. Tie them tight enough so you do not tear the paper.
7. Tie the opposite end of both strings to a paper clip.



8. Tie the 1-yard (or 0.9-meter) length of string to the other end of the paper clip, and you're ready to fly!



Template for Alternate Sled Kite



Lesson 3—Go Fly a Kite

Materials—Lesson 3

- 8- by 11-inch (20.3- by 28-centimeter) white drawing paper—1 for each student.
- Drawing and coloring materials such as magic markers, colored chalk, oil crayons, etc.
- Sled kites and personal kites brought from home.
- 12- by 18-inch (30.5- by 45.7-centimeter) multi-colored construction paper—1 for each student.
- Kite-flying field.

Pre-lesson Instructions—Lesson 3

1. Secure a large, open area outside—away from other classes—for kite flying.
2. Cut white drawing paper to make an 8- by 11-inch (20.3- by 28-centimeter) sheet for each student. This allows it to be matted on colored paper showing a border.

Procedure—Lesson 3

1. Distribute the sled kites. If some of the students brought their own kites, they should fly these at this time as well. Before going outside, have the students make some predictions about the successes or failures they are likely to encounter with their kites and record these on the board. Go outside and fly the kites.
2. Return to class to conduct a short discussion about the success and failure of the kites. Have the students try to identify why some kites flew better than others. This discussion should include the shape of the kites, kite tails, wind conditions, and even the terrain. Consider using a future P.E. period to test the redesign of the kites and/or different wind conditions.
3. Next, begin the writing assignment. Instruct the students to write a story about their kite-flying experiences (on loose leaf paper). Ask them to include their reasons for success or failure. Provide each student with a sheet of white drawing paper. Tell them to draw a picture of their experience flying their kites. Mat the individual stories and illustrations on 12- by 18-inch (30.5- by 45.7-centimeter) construction paper and put them on display.

Activity Two—The Flight Timeline

Lesson 4

Activity (Lesson 4) prep time: 50 minutes
(for gathering materials and following pre-lesson instructions)

Teaching time:

Lesson 4: 1½–2 hours
(Science, Language Arts, Technology)

Objectives—Lesson 4

1. The students will conduct research on people and aircraft significant to the development of flight.
2. The students will write a one- or two-sentence description of their topics and provide an illustration on their timeline cards.
3. The students will create a sequential timeline of aviation events.
4. The students will position their timeline cards on the timeline and present their information.
5. The students will analyze the information to interpret changes in aviation.

National Standards—Lesson 4

Science

- Abilities necessary to do scientific inquiry—S2Ea, S2Ma.
- Understandings about scientific inquiry—S2Eb, S2Mb.
- Position and motion of objects/Motion and forces—S3Eb, S3Mb.
- Objects in the sky—S5Eb.
- Understanding about science and technology—S6Eb, S6Mb.
- Risks and benefits—S7Md.
- Science and technology in local challenges/in society—S7Ee, S7Me.
- Science as a human endeavor—S8Ea, S8Ma.
- History of science—S8Mc.

Mathematics

- Problem solving—M18.
- Communication—M20.

Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective—G1.
- How human actions modify the physical environment—G1.
- How to apply geography to interpret the past—G17.

Language Arts

- Standards 1, 4, 5, 7, and 12.
  (See Language Arts Matrix on page 8.)

Technology

- Students are proficient in the use of technology—I2.
- Students use technology to locate, evaluate, and collect information from a variety of sources—I10.
- Relationships among technology and other fields—T3.
- Cultural, social, economical, and political effects—T4.
- Effects of technology on the environment—T5.
- Role of society in the development and use of technology—T6.
- Influence of technology on history—T7.
- Attributes of design—T8.
- Engineering design—T9.
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving—T10.
- Apply the design process—T11.
- Use and maintain technological products and systems—T12.
- Assess impact of products and systems—T13.
- Transportation technologies—T18.

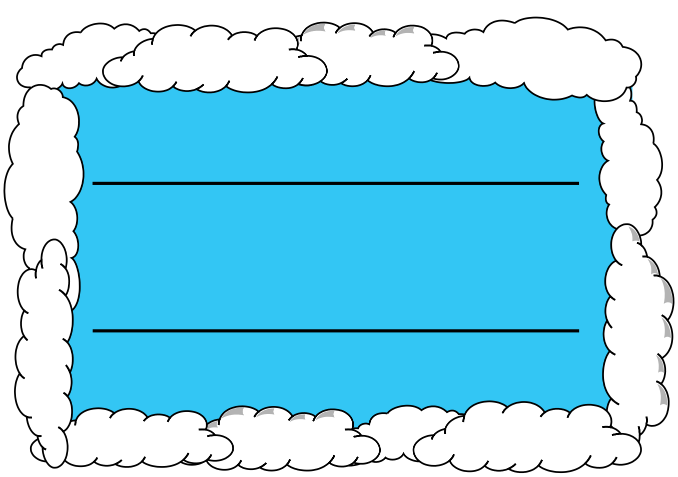
Lesson 4—Creating the Flight Timeline

Materials—Lesson 4

- Blue bulletin board paper—about 3 by 6 feet (0.9 by 1.8 meters) long. (The length depends on the number of entries. Six feet (1.8 meters) is sufficient for 25 students.)
- White construction paper or other white paper to be used as a cloud border around the timeline.
- Drawing paper (white) squares—about 4 by 4 inches (10 by 10 centimeters) (2 per student).
- Multi-colored construction paper—about 5 by 6 inches (13 by 15 centimeters) (2 per student).
- Drawing and coloring materials such as magic markers, colored chalk, oil crayons, etc.
- Black pens for bold writing.
- Access to a computer to complete or verify information.

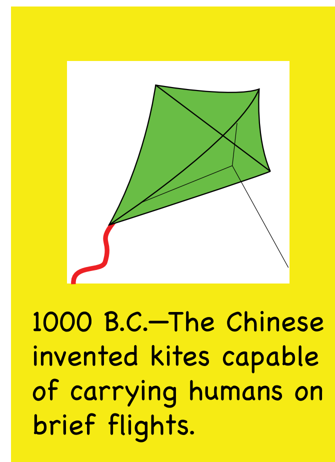
Pre-lesson Instructions—Lesson 4

1. Prepare the timeline background. Draw 2 black lines (each about 6-feet, 1.8 meters, long) horizontally across the bulletin board paper. One line should be parallel to and 9 inches (22.9 centimeters) from the top and the other should be parallel to and 9 inches (22.9 centimeters) from the bottom.
2. Use the white paper to cut out puffy clouds. Arrange them around the border. Students may want to help with this.



paper with cloud border

3. Cut out the white squares and the multi-colored rectangles.
4. Prepare a timeline card to be used as a demonstration. Glue a white square onto a piece of the colored paper. Position the white square towards the top of the colored paper so that the bottom part of the colored paper can be used for writing the information. If time allows, complete the timeline card by drawing a picture of a kite on the white square. (Draw the picture before gluing it on.) Underneath write: 1000 B.C.—The Chinese invented kites capable of carrying humans on brief flights.

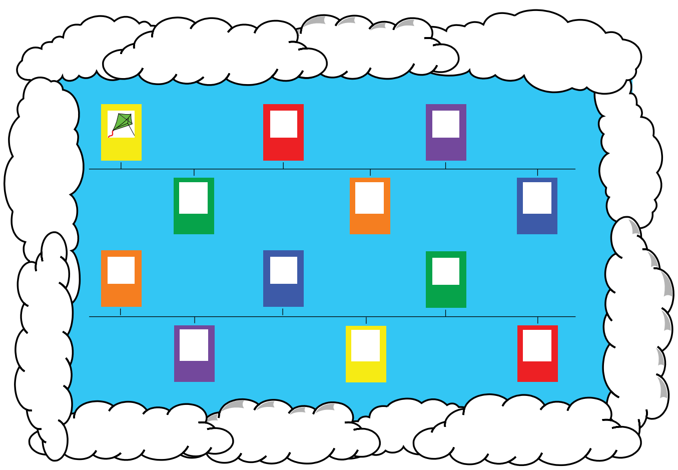


5. Have access to a computer for students who have not been able to complete their research.

Procedure—Lesson 4

1. Instruct the students to take out their logs and turn to their completed homework. Find out if there are any students who have not been able to locate information on their topics. After getting the rest of the class started, these students will need help with their research.
2. Show the class the timeline card that you made and explain how to position the white square onto the colored paper. **Remind them to draw the picture before gluing it on.**
3. If you completed the card, show the students how they will be placing their timeline cards on the timeline. At the beginning of the timeline, glue the timeline card of the kite about 1 inch (2.5 centimeters) above the line. Draw a ½-inch (1.3 centimeter) vertical line up from the line towards the center of the card.

4. Distribute two white squares to each student. Tell them to draw a picture of the person from their homework assignment. Their picture should show how this person was important to flight in their scene. On the other card, they should draw a picture of the aircraft from their homework assignment.
5. When their pictures are finished, have the students mount their pictures on a color card of their choice. Instruct them to write the date and the identifying sentence(s) below the picture.
6. When all of the students are finished, arrange the cards in chronological order and glue them on the timeline. Alternate the cards above and below the timeline. **Teachers, save time by using the Teacher Reference for the Flight Timeline to help with arranging the cards chronologically.**



flight timeline

7. When the timeline is completed, ask each student to read their card as it comes up in chronological order. Ask them to share any other information that they may have learned as they researched their person/aircraft. Use maps to find specific locations. Discuss the timeline. Help the students to understand the changes in aviation and how these advancements and improvements came to be.

Teacher Reference for the Flight Timeline

People

Leonardo da Vinci – (1485) He designed an ornithopter, a flying machine using arms and legs to activate flapping wings. He made over 100 drawings that illustrated his theories on flight.

Montgolfier Brothers – (1783) Joseph and Etienne designed the first hot air balloon, which carried a duck, a rooster, and a sheep 1,640 feet (500 meters) into the air. Two months later, two human volunteers flew 5½ miles (8.9 kilometers) over Paris in a Montgolfier balloon.

Sir George Cayley – (1853) He built the world's first glider capable of lifting a human. Known as "The Father of Aeronautics," he designed the airplane as we know it today with fixed wings, a fuselage (main body), and a tail.

Otto Lilienthal – (1890s) He was a German engineer who was a pioneer in his experiments with manned gliders. He wrote books on aviation and had an influence on the Wrights. After 2,000 glider flights, he was ready to begin powered glider experiments when he was killed in a glider mishap.

Samuel P. Langley – (1896) He launched the first reasonably large, steam-powered, model aircraft, which he called "aerodromes." In 1903, he tested a full-scale aerodrome with a pilot on board, but it failed.

Ferdinand Zeppelin – (1900) He invented the first rigid, motor-driven airship; and, in 1906, he built one that could fly 30 mph (48 kilometers per hour).

Wright Brothers – (1903) Orville and Wilbur invented and flew the world's first controlled, heavier-than-air, powered airplane, the *Wright Flyer I*, at Kitty Hawk, North Carolina, on December 17th.

Paul Cornu – (1907) He was a French bicycle maker who designed and flew the first powered helicopter to lift vertically into the air without assistance. It lasted only 20 seconds and hovered just 1 foot (30.5 centimeters) off the ground. It would be many years before a practical helicopter would be flown.

Glenn Curtiss – (1908) He made the first public flights in an airplane in the U.S. He became famous for winning many international flying competitions. He established the first U.S. flying school in 1909 and then organized his own airplane company, which became the largest aircraft manufacturer in the world during World War I. Known as "The Father of Naval Aviation," he was responsible for the first aircraft to take off and land on the deck of a ship at sea.

Louis Blériot – (1909) A Frenchman who built and flew the first airplane, *Blériot XI*, across the English Channel. His airplane company later built the Spad fighter, which was used by the Allies in WWI.

Blanche Stuart Scott – (1910) She was the first woman to fly solo. She flew with the Curtiss Exhibition Team until 1916.

Harriet Quimby – (1911) She became the first female licensed pilot in the U.S. In 1912, she became the first woman pilot to fly across the English Channel.

Anthony Fokker – (1910–1920) Known as "The Flying Dutchman," he established aircraft factories in Germany before WWI. He became famous as the builder of the Fokker biplanes and triplanes that were believed to be the fastest and most stable aircraft in the world. He is also known for developing an apparatus that allowed machine guns to fire through moving propellers.

NACA – (1915–1958) The National Advisory Committee for Aeronautics (NACA) was formed by Congress to study the problems of flight. At first, they worked on problems with military aviation, but, after WWI, the excellent research and testing performed by NACA engineers and scientists led to better and safer aircraft throughout the industry. NACA contributed to the development or improvement of every American airplane produced during this time. Their research transformed the airplane into a high-speed, high-altitude aerospace vehicle. NACA was transformed into NASA in 1958.

The Red Baron – (1917) This German pilot, whose real name was Manfred von Richthofen, used a red Fokker airplane to shoot down 80 Allied aircraft, more than any other fighter pilot during WWI. He became the most famous war ace in Germany but was shot down in April 1918.

Eddie Rickenbacker – (1918) He was America's top flying ace of WWI. Called the "Ace of Aces," he shot down 26 enemy planes. He later became a leading pioneer in commercial aviation.

Bessie Coleman – (1919) She was the first African American to earn a pilot's license. She trained in France but returned to the U.S. to become a popular pilot in air shows.

Barnstormers – (1920s–1930s) These were pilots who entertained and competed at air shows. They could spin, dive, and fly upside down. Daredevil men and women walked on wings and hung from the planes. Pilots competed for cash prizes and trophies for speed, altitude, and distance. These shows popularized airplanes in America and Europe. Coleman, Lindbergh, Earhart, Post, Doolittle, and Cochran performed in air shows.

Charles Lindbergh – (1927) He became famous when he made the first solo, non-stop flight across the Atlantic Ocean flying from New York to Paris. He made the 3,600-mile (5,800 kilometer) trip in 33½ hours in his plane, *The Spirit of St. Louis*.

Clyde Cessna – (1927) He formed the Cessna Aircraft Company, which made racing and sports aircraft. These planes enabled thousands of pilots to fly their own private planes.

Amelia Earhart – (1928) She was the first woman to cross the Atlantic Ocean by airplane and, in 1932, she became the first woman to solo across the Atlantic. In 1937, she attempted to fly around the world, but her plane was lost over the Pacific.

Wiley Post – (1933) He was the first pilot to fly solo around the world. It took 7 days, 19 hours in a Lockheed Vega nicknamed *Winnie Mae*. Post also made the first-ever flight around the world, in 1931, with Harold Gatty.

Douglas "Wrong Way" Corrigan – (1938) He became a legendary aviator when he mistakenly flew from New York to Ireland instead of to California, saying that he had misread his compass. He became a national folk hero because he provided great humor during a time of national distress. However, he had been denied permission to fly to Ireland in 1935 so his "mistake" seemed suspicious. He said he had gotten lost in the clouds.

Tuskegee Airmen – (1941) This was the first African American fighter squadron in the U.S. Armed Forces. Pilots, bombardiers, navigators, and maintenance and support crews were trained at the Tuskegee Institute in Alabama. They flew over 1,500 missions in WWII.

Jimmie Doolittle – (1942) After the attack on Pearl Harbor, he planned and led the Army Air Corps' bombing raid on Tokyo, Japan. Sixteen *B–25* bombers took off from an aircraft carrier in the Pacific. They successfully bombed Tokyo and three other Japanese cities. However, because they had been forced to launch early, they ran out of fuel before making it to the landing field in China. They lost 15 planes and 7 men. The news of Doolittle and his Raiders sparked morale. He was also the last chairman of the National Advisory Committee for Aeronautics (NACA), the predecessor of NASA.

Jackie Cochran – (1943) She was appointed to lead the Women's Air Force Service Pilots (WASP) in WWII. These women ferried military planes back and forth and performed other non-combat duties for the U.S. military. In 1953, Jackie became the first woman to fly above Mach 1, the speed of sound.

Chuck Yeager – (1947) He was the first pilot to break the sound barrier (fly above the speed of sound, Mach 1), going about 660 mph (1,062 kilometers per hour) in the *Bell X–1*. He was a fighter pilot during WWII, and became a test pilot in the early postwar years.

NASA – (1958) The National Aeronautics and Space Administration (NASA) is a U.S. Government agency. Known mostly for space exploration, NASA also conducts research and provides technology advances for safer, cleaner, quieter, and more affordable air travel.

The Mercury Seven – (1959) These men were military test pilots who became the first seven astronauts chosen by NASA for spaceflight. Scott Carpenter, Gordon Cooper, John Glenn, Virgil "Gus" Grissom, Walter "Wally" Schirra, Alan Shepard, and Donald "Deke" Slayton were selected after a variety of interviews and stringent written, physical, and psychological testing.

Octave Chanute, **William Piper**, and **Donald Douglas** can also be used.

Aircraft

Wright Flyer III – (1905) The Wrights' third plane was the world's first practical airplane. It could fly until the fuel tank was empty and set a record of 24½ miles (39.5 kilometers).

EX Vin Fiz – (1911) This plane, built by the Wright Company and piloted by Cal Rodgers, made the first crossing of the U.S. Since the plane was financed by Armour Company, it advertised a new grape-flavored drink called Vin Fiz, made by Armour.

Curtiss JN–4D Jenny – (1916) This was America's most famous WWI plane and was used by more than 90% of America's pilots for flight training. After WWI, hundreds were used by barnstormers, stunt plane pilots who also gave flights for a fee, in the 1920s and 30s. This was the first plane most Americans saw close up.

Fokker D.VII – (1918) The Germans had air superiority over the British and the French pilots in WWI with the *Fokker E*, but they lost this advantage until the *D.VII* was built. The *Fokker D.VII* was considered the best fighter plane of WWI.

Douglas World Cruiser – (1924) Two of these planes, in the U.S. Army Air Service, made the first trip around the world together.

Douglas DC–3 – (1935) This passenger plane popularized air travel in the U.S. With just one refueling stop, transcontinental flights across the U.S. became possible and quickly replaced trains as the favored means of travel.

Pan American Airways – (1939) This airline company flew the first trans-Atlantic passenger service.

Sikorsky VS–300 – (1939) This helicopter, built and flown by Igor Sikorsky, "The Father of the Helicopter," made the first successful helicopter flight in the U.S.

Mitsubishi A6M5 Zero – (1941) This was the primary Japanese Naval fighter plane in WWII. These planes were used to attack Pearl Harbor and later in kamikaze attacks near the end of the war.

Messerschmitt 262 – (1942) Built in Germany, this was the world's first operational turbojet aircraft and was piloted by Fritz Wendel. In 1944, it became the first jet plane used in combat.

Bell XP–59A – (1942) Built for testing purposes, this was America's first turbojet aircraft powered by the first American jet engine, the General Electric I–A.

Bell X–1 – (1947) This was the first aircraft to exceed the speed of sound. It was the first of the X planes, experimental aircraft designed for testing new technologies and usually kept highly secret. On October 14th, Chuck Yeager flew this rocket-powered plane about 660 mph (1,062 kilometers per hour) at 43,000 feet (13,106 meters) above California's Mojave Desert.

B–52 Stratofortress – (1954) The *B–52* bomber, used in the Vietnam War and Operation Desert Storm, is capable of dropping or launching the widest array of weapons in the U.S. inventory. It can fly 8,800 miles (14,162 kilometers) without refueling, and the H model (1962) is still used by the Air Force. *B–52*s are also used to air-launch experimental vehicles.

Bell UH–1 "Huey" – (1956) This was the first mass-produced helicopter powered by a jet engine. It was widely used for transport, military, fire support, medical evacuation, search and rescue, and reconnaissance roles, and later reconfigured as an attack helicopter for the Vietnam War.

X–15 – (1959–1969) This rocket-powered plane made 199 flights and set records for the highest altitude of 67 miles (108 kilometers) in 1963 and for the fastest speed of Mach 6.7 (4,520 mph or 7,274 kilometers per hour) in 1967. NASA used it for scientific and technological studies that bridged the gap between manned flight in the atmosphere and spaceflight.

SR–71 Blackbird – (1966) For 24 years, it remained the world's fastest and highest-flying jet aircraft. It was a long-range reconnaissance aircraft and, from 80,000 feet (24,384 meters), could survey 100,000 square miles (259,000 square kilometers) of the Earth's surface per hour.

Harrier Jet – (1969) This was the first airplane that could take off and fly like a regular airplane and also perform vertical take offs and landings and hover like a helicopter. Its nozzles point back for regular flight. For hovering or vertical take offs and landings, the nozzles are turned to point straight down.

Boeing 747 – (1970) This was the world's first and largest commercial jumbo jet capable of carrying up to 600 people. Flying at speeds over 550 mph (885 kilometers per hour), it can travel around one-third of the globe without refueling.

Concorde – (1976) The first supersonic (above Mach 1) transport, this was the only passenger plane to fly above the speed of sound. Built by the British and the French, it had a cruising speed of Mach 2.2 and a cruising altitude of 60,000 feet (18,288 meters). Service was discontinued in 2003.

Gossamer Condor – (1977) Flown by bicyclist Bryan Allen, it was the first aircraft to demonstrate sustained, maneuverable, human-powered flight, flying 1.3 miles (2 kilometers) in just under 8 minutes. In 1979, Allen powered (pedaled) the *Gossamer Albatross* across the English Channel.

F–15 Eagle – (1977) It is a small highly maneuverable jet plane designed to fly combat missions in all weather conditions. Its primary mission is to maintain air superiority. This jet was the U.S.'s answer to the Soviet Union's *MiG–25,* which at the time, was superior to the U.S. fighter jet, the *F–4 Phantom*, at the time. The *F–15* has a perfect combat record with over 100 victories and zero defeats.

F–16 Falcon – (1979) This was the first production military aircraft to incorporate a fly-by-wire flight control system.

F/A–18 Hornet – (1983) The U.S.'s first strike fighter used by the Navy and the Marines is a multi-mission fighter/attack aircraft that can operate from either aircraft carriers or land bases. It was one of the first military planes to use a digital fly-by-wire (DFBW) system, which is an electronic flight control system teamed with a digital computer. Most new aircraft, as well as all of NASA's space shuttles, are equipped with DFBW systems.

X–29 – (1984) This experimental plane was built to test the design of the forward swept wing and its very thin airfoil. It could fly at 50,000 feet (15,240 meters) at Mach 1.6, but it depended on an advanced computer system (fly-by-wire), which adjusted the control surfaces with up to 40 commands each second. It also tested advanced composite materials, which were very strong and lightweight. Only two were built and tested through 1992, but the design did not catch on for future aircraft.

Voyager – (1986) This was the first plane to fly non-stop around the world, 25,000 miles (40,000 kilometers), without refueling. Flown by Burt Rutan and Jeanna Yeager, the trip took 9 days.

Aircraft of the Persian Gulf War (Operation Desert Storm) – (1991) This was the first war fought and won almost completely by air power. The *C–130 Hercules*, *C–141 Starlifter*, and *C–5A Galaxy* aircraft transported combat and support troops and tons of equipment. *F–117* stealth fighters launched the attack to begin the war. *F–15C Eagles* and *F–14 Tomcats* maintained air superiority, while *F–16 Falcons*, *F–18 Hornets*, and British and French *Jaguars* attacked enemy air defense installations. *B–52G* bombers pounded enemy front-line troops and U.S. Coalition ground troops were supported by helicopter gunships and the *A–10 Thunderbolt II*.

B–2 – (1993) This was the first stealth bomber. It is a long-range bomber that can respond from a base in the U.S. to conflicts anywhere in the world within hours. Its design looks like one big wing and it uses a fly-by-wire system. It has the ability to fly undetected through enemy airspace by hiding from radar, flying quietly, and letting out very little exhaust. (The *F–117* was the first stealth fighter.)

C–17 Globemaster III – (1995) This military airlift aircraft (cargo plane) is capable of carrying up to 170,900 pounds. The cargo section is large enough to transport large-wheeled and tracked vehicles, tanks, helicopters, artillery, and weapons such as the Patriot Missile System. Able to airdrop paratroopers and cargo, it can also provide rapid positioning of forces.

Breitling Orbiter 3 Gondola – (1999) This balloon made the first non-stop flight around the world by balloon.

Spirit of Freedom – (2002) This balloon carried Steve Fossett on the first solo round the world non-stop balloon flight. The balloon was launched in Australia and landed there 15 days later. *Spirit of Freedom* was 140 feet tall and 60 feet wide (43 meters wide and 18 meters tall). Using a combination of hot air and helium, the balloon traveled 20,385 miles (32,806 kilometers) and flew as high as 34,000 feet (10,363 meters). At times, it flew at more than 100 mph (161 kilometers per hour) and once reached a speed of 200 mph (322 kilometers per hour).

X–43 – (2004) In March, the Hyper-X Program successfully air-launched this 12-foot, unmanned test vehicle to demonstrate the capability of its scramjet engine, which propelled the plane to fly just under Mach 7 (7 times the speed of sound, about 5,000 mph or 8,047 kilometers per hour). This was the first air-breathing (not a rocket-powered) vehicle to fly at hypersonic (above Mach 5) speeds. In November, the *X–43* flew at just under Mach 10 (10 times the speed of sound, about 7,000 mph or 11,265 kilometers per hour).

F–22 Raptor – (2005) This stealth, fighter/attack plane built for the U.S. Air Force flies faster than the speed of sound with high fuel efficiency. The combination of stealth, advanced avionics, and maneuverability gives pilots a first-look, first-shot, first-kill capability against the aircraft of any potential enemy. It replaced the *F–15* as America's front-line fighter.

F–35 Joint Strike Fighter – (Expected 2008) This plane, currently being built for the U.S. Air Force, Marines, and Navy, as well as the British Royal Navy, is a supersonic, stealth fighter. The U.S. Marine version and the Royal Navy version have Short Take-Off and Vertical Landing (STOVL) capabilities.

The ***C–130*** and ***F–117*** can also be used.

Activity Three—Aviation Pioneers

Lesson 5

Activity (Lesson 5) prep time: 30 minutes

(for gathering materials and following pre-lesson instructions)

Teaching time:

Lesson 5: 1½ hours
(Science, Language Arts, Technology)

Objectives—Lesson 5

1. The students will use prior knowledge to write a hypothesis to the following question: "What makes an airplane fly?"
2. The students will list the types of transportation available to people before the airplane was invented.
3. The students will realize that man has wanted to fly since he first saw birds in flight and that the first written record of flight was referenced in Greek mythology.
4. The students will identify some of the early aviation pioneers and the attempts that they made to achieve flight.
5. The students will identify some of the character traits of these aviation pioneers, especially those traits associated with never giving up.
6. The students will follow instructions to construct and fly a rotary wing model (Rotor Motor).
7. The students will conduct experiments with rotor motors to determine how they perform at different weights, different sizes, and different heights.

National Standards—Lessons 5

Science

- Abilities necessary to do scientific inquiry—S2Ea, S2Ma.
- Understandings about scientific inquiry—S2Eb, S2Mb.
- Position and motion of objects/Motion and forces—S3Eb, S3Mb.
- Objects in the sky—S5Eb.
- Abilities of technological design—S6Ea, S6Ma.
- Understanding about science and technology—S6Eb, S6Mb.
- Risks and benefits—S7Md.
- Science and technology in local challenges/in society—S7Ee, S7Me.
- Science as a human endeavor—S8Ea, S8Ma.
- History of science—S8Mc.

Mathematics

- Analyze change in various contexts—M7.
- Investigate, describe, and reason about the results of subdividing, combining, and transforming shapes—M8EUc.
- Measurement—M13.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them—M14.
- Develop and evaluate inferences and predictions that are based on data—M16.
- Understand and apply basic concepts of probability—M17.
- Problem solving—M18.
- Communication—M20.

Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective—G1.
- How to use mental maps to organize information about people, places, and environments in a spatial context—G2.
- How culture and experience influence people's perceptions of places and regions—G6.
- How human actions modify the physical environment—G14.
- How physical systems affect human systems—G15.
- How to apply geography to interpret the past—G17.

Language Arts

- Standards 1, 2, 3, 4, 6, 11, and 12.
  (See Language Arts Matrix on page 8.)

Technology

- Relationships among technology and other fields—T3.
- Cultural, social, economical, and political effects—T4.
- Role of society in the development and use of technology—T6.
- Influence of technology on history—T7.
- Attributes of design—T8.
- Engineering design—T9.
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving—T10.
- Apply the design process—T11.
- Use and maintain technological products and systems—T12.
- Transportation technologies—T18.

Lesson 5— They Never Gave Up

Materials—Lesson 5

- Student logs.
- Pictures of early aviation pioneers and their flying machines.
- A color picture of the Montgolfier balloon.
- A copy of the student text for Lesson 5, "They Never Gave Up," for each student.
- A copy of the Rotor Motor Instructions for each student.
- Several sheets each of different weights of paper such as heavy construction paper, cardstock, light cardboard, tissue paper, notebook paper, etc.
- Scissors—1 pair for each student.

Pre-lesson Instructions—Lesson 5

1. Duplicate enough copies of the student text for Lesson 5, "They Never Gave Up," for each student. Punch holes so that students can insert these copies in their logs.
2. Duplicate copies of the Rotor Motor Instructions on regular copy paper. If possible, duplicate the pattern of the rotor motor on several sheets of heavier paper. (See Materials List.) Try to have one alternate weight of paper for each student so that each student makes two rotor motors. If these cannot be printed, make several patterns for the students to trace using different weights of paper.
3. Find and print pictures of aviation pioneers, their aircraft, and their early attempts at flying. Print a colored picture of the Montgolfier Brothers' hot air balloon. To get started, try **http://www.centennialofflight.gov**. Click on "Images." Select "Lighter than Air" to find images of ballooning including the Montgolfier balloon. Select "Prehistory of Powered Flight" to find images for Cayley, Lilienthal, Chanute, and Langley.

Procedure—Lesson 5

1. Instruct the students to take out their logs. Remind the students that their logs will be used to answer questions, take notes, record data, and record the results of experiments.
2. Write the following question on the board: "What makes an airplane fly?" Have the students copy the question in their logs and give them 3–5 minutes to write their answers. Explain that since they've had no prior teaching on this subject, their answer will be only what they think makes an airplane fly. Do not discuss their answers at this time. This question will be asked again in a later lesson, and they will be given the opportunity to change their answers at that time. Remind students to leave enough space in case they want to change their answers later.
3. Before displaying the pictures of the early aviation pioneers, ask the students what kinds of transportation people used before the airplane was invented. Make a list of these on the board. As they become aware of all of the kinds of transportation over land and water, ask them why they think man still wanted to fly. After a short discussion, point out that man has wanted to fly since watching birds in flight, thousands of years ago. Tell them that they will be reading about many of these attempts in this lesson.
4. Direct the students' attention to the Flight Timeline. Point out Da Vinci, Montgolfier Brothers, Cayley, Lilienthal, Chanute, and Langley on the timeline, and read the captions. Tell the students that these men were among the early pioneers of flight and that they will be learning more about them in this lesson.
5. Display pictures of the early aviation pioneers and their aircraft. Make sure that the students understand the difference between powered flight and unpowered flight. Lilienthal and Chanute flew only gliders. Langley used a small steam engine to power his aircraft. Discuss the pictures and allow the students to make their own observations.
6. Distribute copies of the student text for Lesson 5, "They Never Gave Up," and have the students insert the text in their logs.
7. Introduce and teach the vocabulary as you would any guided reading.

8. Before reading the first paragraph, ask the students if they know any Greek myths or any characters from Greek mythology. Explain that Greek mythology is a group of stories about the gods, goddesses, heroes, and other characters of the ancient Greeks. They may know about the Trojan horse or the adventures of Odysseus or Hercules. You may want to use **http://www.mythweb.com/**. This site uses cartoons. (Be careful with other sites on this subject. The pictures can be very graphic.) Point out that Greek mythology is considered fiction, but that some of the stories may have parts that are based on actual events.
9. Read the first section, "Wanting to Fly." As the class reads, be sure to locate all of the geographic places mentioned in the selection on a world map.
10. Continue reading through the Montgolfier Brothers in the section, "Glides and Strides." Show the students a picture of their hot air balloon and let them observe the design. Make sure that they know that this was the first time a human actually "flew." Emphasize that balloons were lighter-than-air aircraft, whereas the gliders were heavier-than-air aircraft.
11. In the next paragraph, tell them that Cayley was known as the "father of aerial navigation" because he understood the principles of flight and he envisioned the airplane in its present-day form with fixed wings, a fuselage, and a tail. Show the pictures of Lilienthal, Chanute, and Langley as you finish reading the selection. Point out that people were trying to achieve flight in many different places, and that most were not working together.
12. Inform the students that these men all possessed the dream of flying. They also possessed other similar traits and aptitudes that allowed them to pursue their dream. Ask the students to identify some of these traits. **Possible answers: Creative, imaginative, scientific-minded, persistent, inventive.**
13. Encourage the students to read books about the people and planes that attempted to fly before the Wright Brothers achieved flight.
14. Distribute the "Rotor Motor Instructions" printed on regular copy paper and the scissors. Allow the students about 10 minutes to construct and fly their rotor motors.
15. Have each student make one more rotor motor. Distribute the rotor motors printed on different weights of paper or the patterns. Tell the students to make heavier, lighter, or larger models.
16. When all of the new models are complete, perform some "Drop Tests." Experiment with only two at a time. Be sure to allow the students to make predictions before each test. Compare the following:
    - Unfolded (cut but not folded) rotor motor to a regularly folded rotor motor (same weights).
    - A crumpled up rotor motor to a regular rotor motor (same weights).
    - Rotor motors of various weights and sizes.
    - Rotor motors dropped from different heights.
17. Explain to the students that, as the paper models fall, they will spin, imitating the rotation of the rotor blades of a helicopter. The spin will reduce the rate of fall by producing lift (defined in the vocabulary). There is no thrust (propulsion) to produce an upward movement, but the lift causes it to resist the force of gravity and descend more slowly.

Vocabulary—Lesson 5

aerodrome – the name given by Samuel Langley to his model airplanes; from the Greek words meaning “air runner”


aerodrome

engineer – a person who uses scientific knowledge to solve practical problems; someone who designs and builds mechanical or electrical devices

fixed – securely placed or fastened; firm; immovable


glider

glider – an aircraft that has no engine and is carried along by air currents

lift – a force that acts upward against gravity and makes it possible for airplanes to rise in the air

model – a small object, usually built to scale, that represents in detail another, often larger, object

monk – a man who retires from the ordinary concerns of the world and devotes himself to religion

myth – an ancient story dealing with supernatural beings, ancestors, or heroes

parachute – a device that fills with air and slows your fall

powered – supplied with power (such as an engine)

parachute

propeller

propeller – a device that causes an aircraft or boat to move forward, having a power-driven shaft with blades that are placed so as to thrust air or water in a desired direction when spinning

propulsion – a driving or propelling force

wingspan – the length of a wing from tip to tip

Student Text—Lesson 5

They Never Gave Up

Wanting to Fly

Man has always wanted to fly. Some of the earliest tales about flight are found in Greek **myths**. One myth tells the story of Daedalus and his son, Icarus. They used wings of feathers and wax to escape from the king in Crete. But Icarus flew too close to the sun. When the wax melted, he fell to his death. Another myth is about Pegasus. Pegasus was a horse with wings. He carried Bellerophon to fight a fire-breathing monster. When they attacked from the air, they were able to beat the monster.


Pegasus

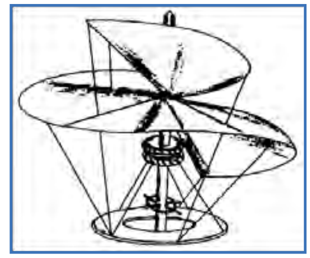
During the 11th century, an English **monk** named Eilmer wanted to fly. So, he tried to make wings for himself. He stretched linen over a wooden frame. Then, he glued feathers to the cloth. Eilmer jumped from a tower. He "flew" about ⅛ of a mile (201 meters) before he fell and broke both legs.


DaVinci's 1490 sketch of a flying machine

Leonardo da Vinci lived in Italy. He was an artist and a scientist. In the late 15th century, he wanted to know more about flight. At first, he studied the flight of birds. He also studied the clouds. His first sketches were for an aircraft with flapping wings. In a 1490 sketch, Leonardo intended

Da Vinci's drawing of a piloted flying machine, 1490

that the pilot lie down on the flying machine. Then, the pilot could work the wings with his arms and legs. Later, he drew the first detailed sketches of flying machines. One of his sketches shows a pilot using his legs to move the wings. The beating of the wings would keep the pilot airborne. Da Vinci even designed a machine for vertical flight. He called it a helixpteron, a Greek word meaning spiral wing. He also drew a sketch of a **parachute** made from a linen curtain. It was shaped like a pyramid with a 36-foot (11-meter) base and a 36-foot (11-meter) height. He wrote that anyone could use it to jump from any height without any risk.



Da Vinci's sketch of a helixpteron

Da Vinci's parachute sketch

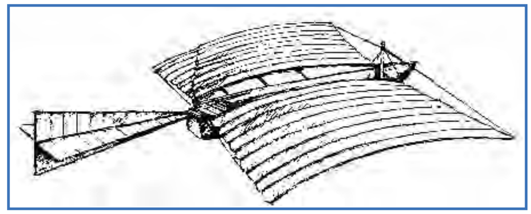
In the early 1600s, many men tried to fly like the birds. They were called "birdmen" or wing flappers. They would strap wings to their bodies. Then they would jump from a high tower or hill. Most of these men were ridiculed by those who saw them try to fly. Many met death in their attempts.

Glides and Strides

The Montgolfier Brothers lived in France. In the late 1700s, they flew the first hot air balloon. It was made out of cloth and paper. A basket hung below. They filled the balloon with hot air. Then they put a duck, a sheep, and a rooster in the basket. They flew over 1,640 feet (500 meters) high into the skies of France.

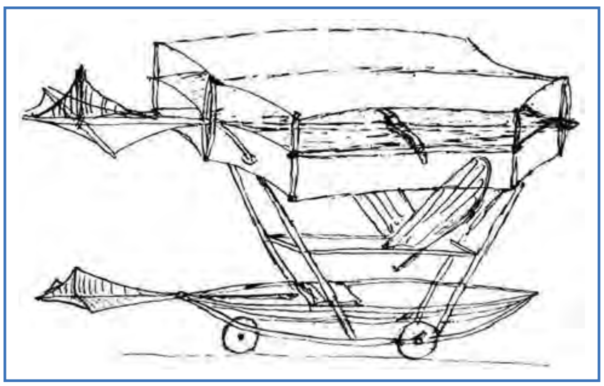
Montgolfier balloon

Two months later, two humans made a balloon flight. They flew a distance of 5½ miles (8.9 kilometers) over Paris. Ballooning soon became very popular in Europe.

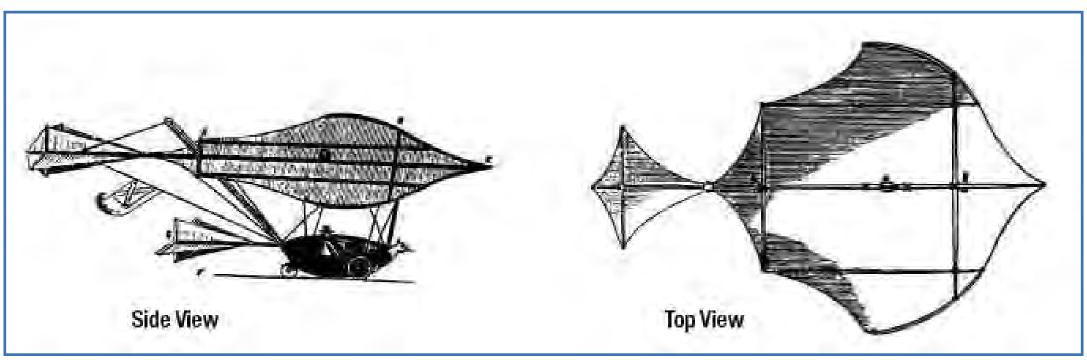


Cayley's 1799 design of an aircraft with fixed wings, a fuselage, and a movable tail

Sir George Cayley lived in England. In the early 1800s, he made and flew a **model glider** with **fixed** wings. He also made a glider with three wings. It could lift a person off the ground. Cayley was the first person to understand what made things fly. He was the one who designed the airplane as we know it today. He saw the airplane as a machine with three main parts. It would have fixed wings, a fuselage (main body), and a tail. He also knew that it needed three systems. One would be needed for **lift**, one for **propulsion**, and one for control. Cayley spent many years studying about flight. Then, he built a full-size glider with three wings. Although it lifted a 10-year-old boy a few yards off the ground, it was really not a flight. Later, his coachman was a pilot of one of the gliders. He made the world's first flight in a glider with fixed wings.

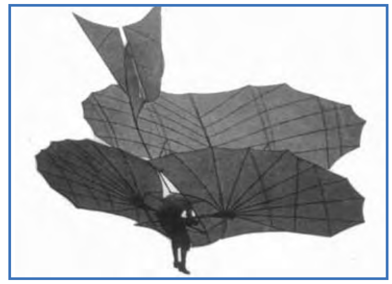


Cayley's sketch of the 1849 glider that lifted a 10-year old boy



sketches of Cayley's 1853 glider, which was piloted by his coachman

Otto Lilienthal was a German **engineer**. In the late 1800s, he began to build gliders. He built 16 kinds of gliders. He flew and tested the gliders using no power. He wanted to get a feel for controlling a craft in the air. Then he would be able to make and fly a **powered** aircraft. With power, he could stay in the air longer. His gliders were controlled by shifting his weight from side to side. After several years of gliding, he realized he needed more flying space. So, he constructed a hill and built a shed on top. He used the shed to store his gliders. He would run down the hill with his glider and leap into the wind. On one of these glides he flew 150 feet (46 meters). He could also launch himself from the top of the shed. He made almost 2,000 glider flights. Finally, he was ready for powered flights. But before he could begin, he fell to his death in a glider flight.



Lilienthal glider

Lilienthal's hill and shed

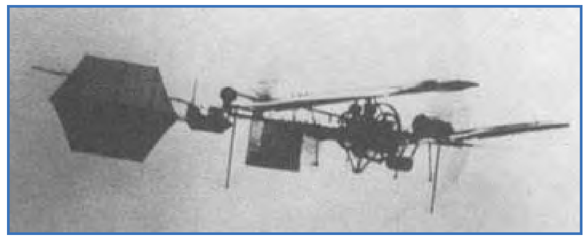
Chanute with his Lilienthal-type glider, 1894

Octave Chanute lived in the U.S. He was known for building the first bridge across the Missouri River. He also had an interest in flight. He went to Germany to visit Lilienthal. There he learned all he could from him about gliding. He then returned to the U.S. to build his own gliders. His gliders had wings that were mounted on rubber springs. This allowed them to move back and forth when struck by wind gusts. He took his gliders to the sand dunes near Lake Michigan. There he

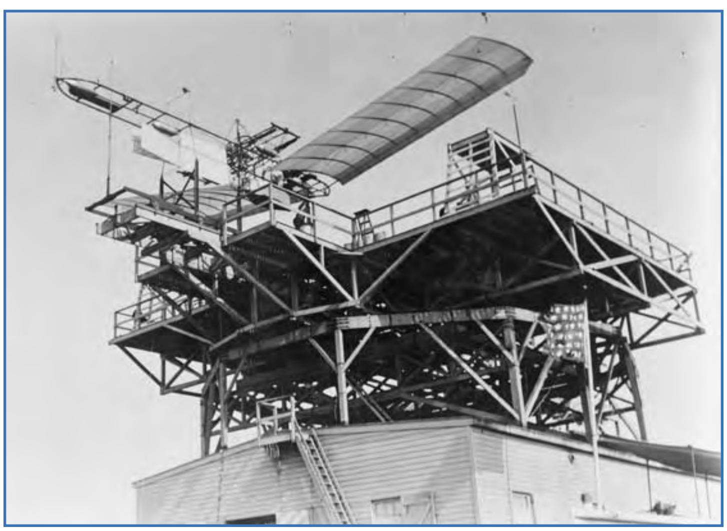
Chanute's multiple-wing glider

made hundreds of flight tests. His longest flight was 14 seconds. This was only 1 second shorter than the record. After many flights, Chanute wrote *Progress in Flying Machines*. The Wrights read this book when they first had an interest in flight. Later, the Wrights came to Chanute for advice. He became a good friend and supporter of their work.

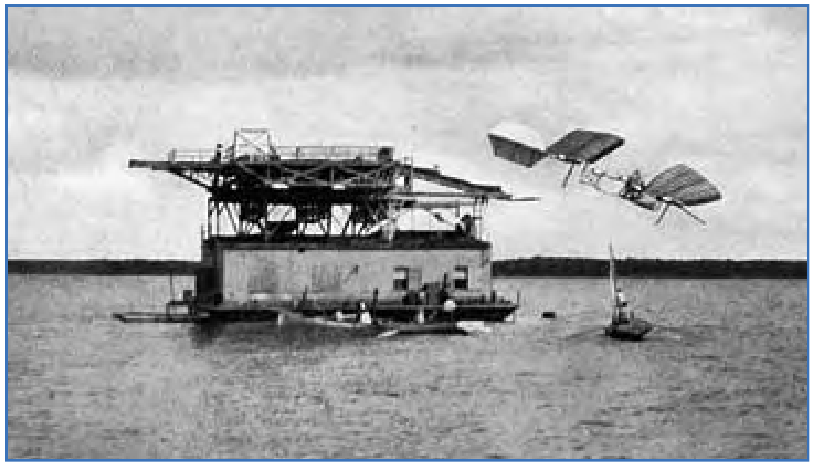
Powered Flight Attempted


Langley's quarter-size model aerodrome, it flew successfully in 1901.

Dr. Samuel Pierpont Langley was an American scientist. He was the head of the Smithsonian Institute in Washington, DC. He spent 10 years testing model planes. He designed a model with two pairs of curved wings. One pair of wings was behind the other. A small steam engine and two **propellers** were in between. He called these models **aerodromes**. At first, he tested them on an indoor track. Later, one took off from the top of a houseboat. It weighed 26 pounds (12 kilograms). It had a **wingspan** of 14 feet (4.3 meters). It stayed in flight for 90 seconds and covered ½ mile (0.8 kilometers). It was the first time a steam engine had driven an airplane. Six months later, he flew another model that went ¾ mile (1.2 kilometers).


Langley's Great Aerodrome was catapulted from a specially constructed houseboat on the Potomac River near Quantico, Virginia, in 1903.

Langley did not try again for several years. He then built a full-size airplane that used gasoline.

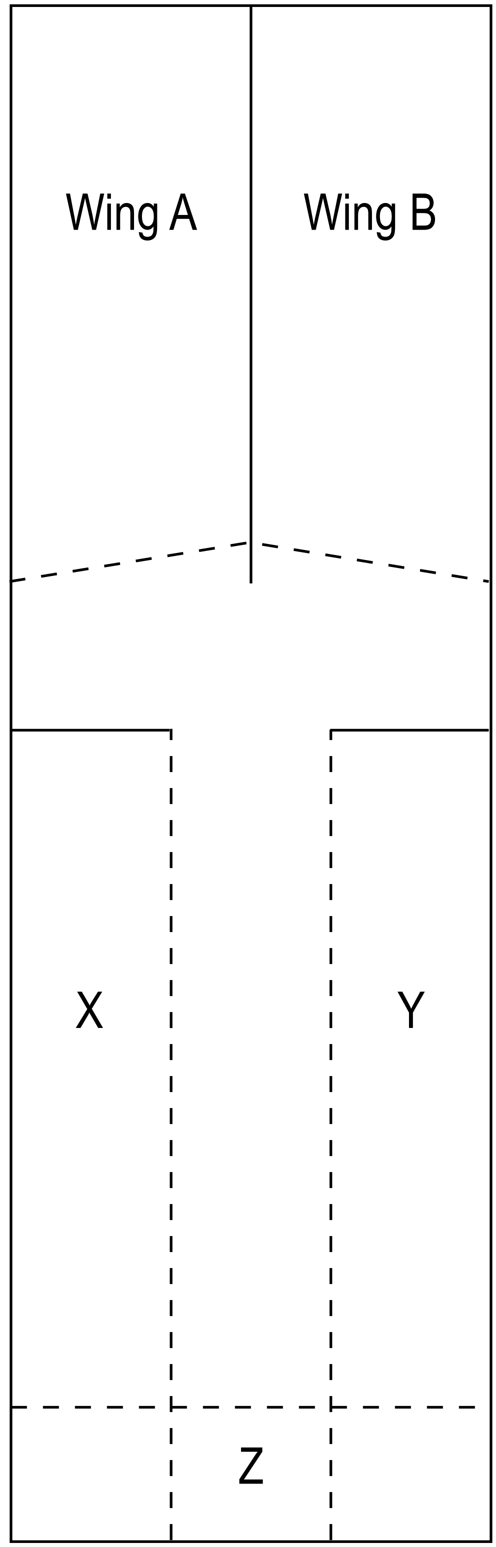

Both flight tests of the Great Aerodrome failed.

He called it the Great Aerodrome. The plane was 55 feet (17 meters) long. It had a wingspan of 48 feet (14.6 meters). Langley launched this plane from the roof of a houseboat as well. But this time it had a pilot. The pilot stood in front of the controls. He started the engine. Then, he gave the signal to launch. The Great Aerodrome lurched forward and fell right into the river.

Two months later, the next test also failed. In papers all over the U.S., Langley was ridiculed. *The New York Times* wrote an article. It said that a man-carrying airplane might one day be built. But it would take engineers 1 to 10 million years to do it. The article was wrong. Only 9 days later, Orville Wright made history. He flew the first powered airplane.

Rotor Motor Instructions

1. Cut along the solid lines of the template.
2. Fold along the dotted lines.
3. The propeller blades (Wing A and Wing B) should be folded in opposite directions.
4. X and Y fold toward the center.
5. Z is folded up to give the body rigidity.
6. Stand up and drop the rotor motor.



Activity Four—Having the Right Stuff— The Wrights and Blériot

Lessons 6–7

Activity (Lessons 6–7) prep time: 15–20 minutes
(for gathering materials and following pre-lesson instructions)

Teaching time:

Lesson 6: 1¼–1½ hours
(Science, Language Arts, Technology)

Lesson 7: 1–1¼ hours
(Science, Language Arts, Technology)

Objectives—Lessons 6–7

1. The students will list the character traits of the Wright Brothers and Louis Blériot as they read the biographies of those men.
2. The students will list in sequential order the tests and trials leading to the successful flights performed by the Wright Brothers and Louis Blériot.
3. The students will compare and contrast the lives of the Wright Brothers to the life of Louis Blériot.
4. The students will recognize their own character traits and identify other traits that they might want to acquire to accomplish their own life goals.

National Standards—Lessons 6–7

Science

- Abilities necessary to do scientific inquiry—S2Ea, S2Ma.
- Understandings about scientific inquiry—S2Eb, S2Mb.
- Position and motion of objects/Motion and forces—S3Eb, S3Mb.
- Objects in the sky—S5Eb.
- Abilities of technological design—S6Ea, S6Ma.
- Understanding about science and technology—S6Eb, S6Mb.
- Risks and benefits—S7Md.
- Science and technology in local challenges/in society—S7Ee, S7Me.
- Science as a human endeavor—S8Ea, S8Ma.
- History of science—S8Mc.

Mathematics

- Analyze change in various contexts—M7.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them—M14.
- Develop and evaluate inferences and predictions that are based on data—M16.
- Understand and apply basic concepts of probability—M17.
- Problem solving—M18.
- Communication—M20.

Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective—G1.
- How to use mental maps to organize information about people, places, and environments in a spatial context—G2.
- How culture and experience influence people's perceptions of places and regions—G6.
- How human actions modify the physical environment—G14.
- How physical systems affect human systems—G15.
- How to apply geography to interpret the past—G17.

Language Arts

- Standards 1, 2, 3, 4, 6, 8, 11, and 12. (See Language Arts Matrix on page 8.)

Technology

- Relationships among technology and other fields—T3.
- Cultural, social, economical, and political effects—T4.
- Effects of technology on the environment—T5.
- Role of society in the development and use of technology—T6.
- Influence of technology on history—T7.
- Attributes of design—T8.
- Engineering design—T9.
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving—T10.
- Apply the design process—T11.
- Use and maintain technological products and systems—T12.
- Assess impact of products and systems—T13.
- Transportation technologies—T18.

Materials—Lessons 6 and 7

- Pictures of early aviation pioneers and their flying machines. (See the Resources section at the end of this guide and Pre-lesson Instructions for Lessons 6 and 7.)
- Pictures of the Wright Brothers—as many as possible showing their planes and different events in their lives. (See Resources and Pre-lesson Instructions.)
- A copy of the student text for Lesson 6, "The Wright Brothers," for each student.
- A copy of the student text for Lesson 7, "Louis Blériot," for each student.
- Picture books and biographies on the Wright Brothers and Louis Blériot.* (See Resources.)
- Chart paper – four sheets.
- A U.S. map.
- Student logs.

*At the time of this writing, there is only one children's biography of Louis Blériot. Alice and Martin Provensen wrote *The Glorious Flight Across the Channel With Louis Blériot*, published in 1983 by Viking Penguin, Inc.

Note to Teacher for Lessons 6 and 7:
As children read the biographies of successful people, it is important for them to identify the character traits, the skills, and the lessons learned that led to their success. The Wright Brothers in the United States and Louis Blériot of France represent the efforts of man to successfully build a flying machine. Even though they were on opposite sides of the Atlantic Ocean, these men shared similar skills and character traits. Students should recognize that Blériot and the Wrights were highly creative and possessed outstanding mechanical aptitudes. In their aeronautical pursuits, they were visionaries who were not daunted by their failures or the ridicule of others. They were men of determination, drive, patience, and perseverance. The Wrights carefully and methodically conducted tests and gathered data to improve and redesign the next craft for the next test. Blériot failed many times before he found success. For years, they studied, tested, and bravely piloted their own inventions. As they aspired to accomplish their goals, they exhibited many characteristics that led to a successful flying machine. By identifying these traits in the lives of these three men, students will be guided to recognize those traits they already possess and those they might want to acquire to accomplish their own life goals.

Pre-lesson Instructions—Lessons 6 and 7

1. Duplicate enough copies of the student text for Lesson 6, "The Wright Brothers," for each student. Punch holes so that students can insert these copies in their logs.
2. Duplicate enough copies of the student text for Lesson 7, "Louis Blériot," for each student. Punch holes so that students can insert these copies in their logs.
3. Locate and print as many pictures of the Wright Brothers and Louis Blériot as possible. Include the pictures of each of the Wright flying machines from 1900–1903. Use **http://www.centennialofflight.gov**. For movies, click "Sight and Sounds" on this site.
4. Write the homework assignment on the board. (The trays or plates will be needed for Lesson 8; so, write in the due date accordingly.) If possible, have a Styrofoam® tray or plate to show them what is needed.

Homework Assignment

Bring in one Styrofoam® tray or plate.
Due ________________

Lesson 6— The Wright Brothers

Procedure—Lesson 6

1. Have the students copy the homework assignment. Show them the tray or plate and tell them this will be needed for a project in a few days. Answer any questions they might have.
2. Show the class the photographs of the Wright Brothers. Also, share some of the pictures in the picture books of their biographies. When you show the pictures of the planes, be sure to show them in chronological order. Compare the planes of today with the Wright Brothers' planes. If possible, show some movie clips at this time. (See Pre-lesson Instructions Step 3.) Encourage questions from the students about what they observe in the pictures and movies.
3. Engage the students in a short discussion on character traits. Tell the students that a character trait is a particular feature of one's personal nature, the qualities a person has, or what kind of person they are. Some examples of character traits are **helpful**, **lazy**, **patient**, **giving**, **hardworking**, **brave**, **considerate**, **honest**, and **compassionate**. Have the students recall some of the characters that they have previously read about and the character traits that applied to those characters. Record this list on the board.
4. Introduce and teach the vocabulary as you would any guided reading.
5. Before reading the text, locate Iowa, Indiana, and Dayton, Ohio, on a U.S. map. Tell the students that the brothers grew up in these states. Also, locate the Outer Banks of North Carolina, the long peninsula that forms part of the east coast of that state.
6. Distribute copies of the student text for Lesson 6, "The Wright Brothers," and have the students insert this in their logs. Read the student text as you would any guided reading. As the class reads and discusses the text, question their understanding and encourage their questions. Use the pictures and picture books to complement the text. As the students read, they should record in their logs the character traits and skills that they recognize in the brothers.
7. After reading, have the students report the character traits and skills they observed. List these on a piece of chart paper and discuss why each is important to the success of an inventor. **Possible answers: smart, hard-working, thorough, careful, paid attention to details, good planners, methodical, ethical, persistent, observant, persevering, driven, clever, self-starters, creative, brave, patient, mechanical-minded, determined, organized.**
8. Locate Dayton, Ohio, and Kitty Hawk, NC, on a U.S. map again. Discuss why the terrain and weather at Kitty Hawk was a good choice for testing aircraft. **Answer: windy, sand for soft landings, few trees or houses, remote, hills for gliding.**
9. On another sheet of chart paper, list the steps the brothers took that led to their success in achieving powered flight.

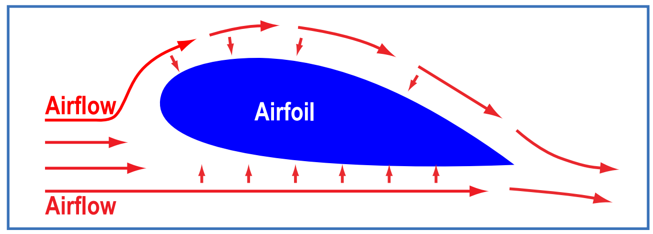
   Answer:

   - **Read everything they could find on flight.**
   - **Built and flew 1899 kite to test wing warping.**
   - **Found the windiest location in the U.S.**
   - **Built 1900 glider; flew it first as a kite to test controls; observed how it flew and how it responded to the controls; made adjustments to the controls; then flew and piloted it as a glider.**
   - **Built 1901 glider; increased the wingspan for better lift; observed how it flew; adjusted the wings; found it didn't work as predicted.**
   - **Realized Lilienthal's tables were wrong; built wind tunnel; tested 200 different wings; made their own tables.**
   - **Built 1902 glider with thinner, longer wings and a rudder; then observed the glider during tests and adjusted it as needed; satisfied with results.**
   - **Built 1903 *Flyer* with engine and propellers; tested it; crashed it; repaired damage; then obtained successful flight.**
10. Encourage the students to read biographies of the Wright Brothers, Blériot, and other early pilots. For a more detailed story of Charles Taylor, see **http://www.centennialofflight.gov/wbh/charlestaylor.htm#**.

Vocabulary—Lesson 6

adjustments – a change or correction so as to make something better

airfoil – a section of a wing, rudder, or rotor blade used for testing the reaction from air through which it moves



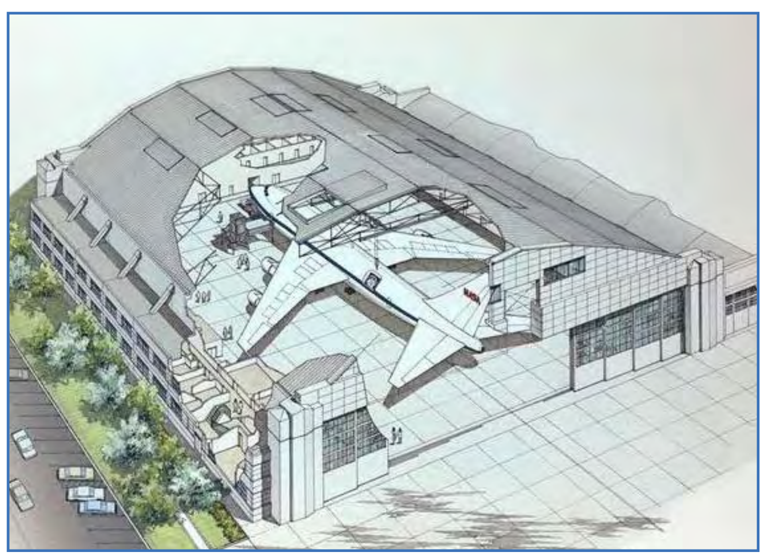
sketch of an airfoil

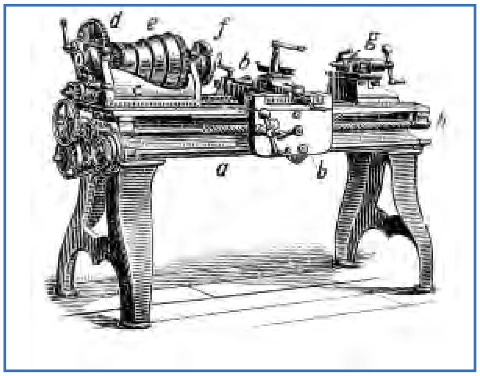
craze – a practice or interest followed for a time with exaggerated interest


double-decker bus

double-decker – something, such as a vehicle or structure, that has two decks, floors, or layers

hangar – a large building where aircraft can be stored and maintained


hangar



1911 lathe

lathe – a machine for shaping a piece of material, such as wood or metal, by rotating it rapidly while pressing against a fixed cutting or shaping tool

machinist – a craftsman skilled in operating machine tools

mechanical – of or relating to machines or tools

minister – one who is authorized to conduct religious functions in a Christian church, especially a Protestant church

pamphlet

pamphlet – a small book consisting of a few sheets of printed paper, stitched together, often with a paper cover

photography – the act of taking and printing photographs

pioneer – one who ventures into unknown or unclaimed territory to settle; or one who opens up new areas of thought, research, or development

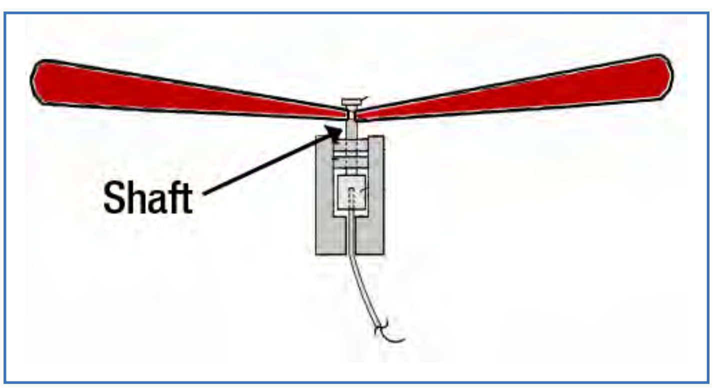
published – prepared and printed for distribution and sale

a building in a remote location

remote – located far away, hard to get to, and sparsely populated; sometimes hidden away or secluded

rudder – a flat movable piece (as of wood or metal) fastened in an upright position attached to an aircraft for guiding or steering

rudders on the tail sections of airplanes



propeller shaft

shaft – a rotating rod that transmits power or motion; a propeller shaft connects a propeller to an engine

tables – an orderly arrangement of data organized in rows and columns

typhoid fever – a highly infectious disease characterized by high fever, headache, coughing, intestinal bleeding, and rose-colored spots on the skin

vertical – being or situated at right angles to the horizon; upright

The National Transonic Facility is a modern-day wind tunnel at NASA's Langley Research Center.

wind tunnel – tubular structures or passages in which high-speed movements of air or other gases are produced; objects such as aircraft, parts of aircraft, or models of these are placed inside the wind tunnel so researchers can investigate the flow of air around them and the aerodynamic forces acting upon them

wing warping – a means to control aircraft roll by twisting (warping) the aircraft's wing tips

Student Text—Lesson 6

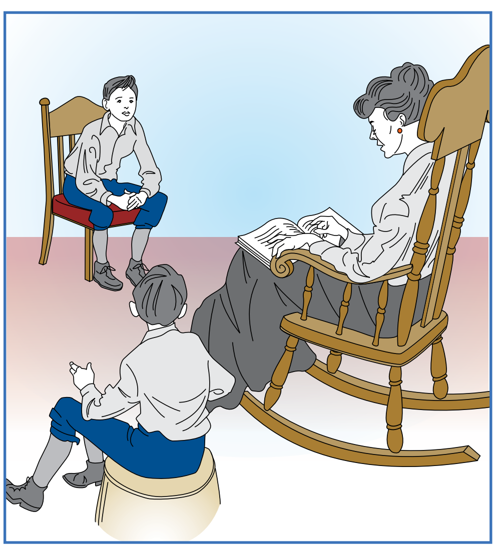
The Wright Brothers

Growing Up

From the time they were little, the Wright Brothers were best friends. Wilbur was born in 1867 in Indiana. Orville was born in 1871 in Ohio. They lived with their parents, two brothers, and a sister. Their father was a **minister** in the church. He taught them about hard work and never giving up. Their mother was good at math and science. She was also good at knowing how things work. The brothers would go to her for help with their projects.

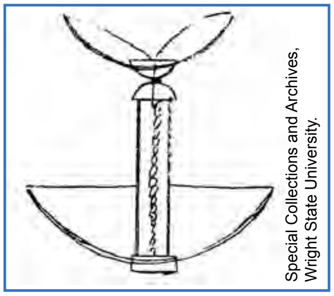

Wilbur Wright


Orville Wright


The family spent their nights reading to each other.

Like most boys, Will and Orv liked sports. But, unlike most families in those days, their home was filled with books. They spent their nights reading to each other. The boys also loved **mechanical** things. They wanted to know how things worked. Sometimes they repaired their broken toys. Sometimes they took the toys apart. They also built new toys.

When the boys were very young, their father brought them a toy as a gift. It was a small flying machine. It was made of cork, bamboo, and thin paper. When


Special Collections and Archives, Wright State University.

Orville's sketch of the toy helicopter

they threw it into the air, a twisted rubber band caused the propeller to spin. This caused the toy to fly up and away. They called it "the Bat" and played with it constantly. "The Bat" was the beginning of their interest in flight.


the Wright home in Dayton, Ohio

As Will and Orv grew older, they had many interests. Will loved to read. He helped his father with the church newspaper. He even invented a machine to fold the papers for mailing. Orv was always coming up with new ideas. He made and sold kites to his friends. He delivered newspapers. He collected junk and sold it. Once he put on a circus. He used real animals that had been stuffed. One time the brothers built a **lathe**. This was a machine used for doing woodwork. With it, they built a new front porch for their family's house. Their neighbors liked the porch. They asked the brothers to make wooden things for them, too.

Side by Side in Business


WEST SIDE NEWS

West Side News

At 17 years old, Orv decided not to finish high school. He had started a printing company. Soon Wilbur joined him. They built a larger printing press. They **published** the *West Side News*. They put out a new issue every week for a year.

At this time, a bicycle **craze** hit. So, Will and Orv each got a bike, too. Will enjoyed long rides. Orv got into racing. Soon Will and Orv were repairing bikes for their friends. The brothers' ability to fix things was well known. So, they

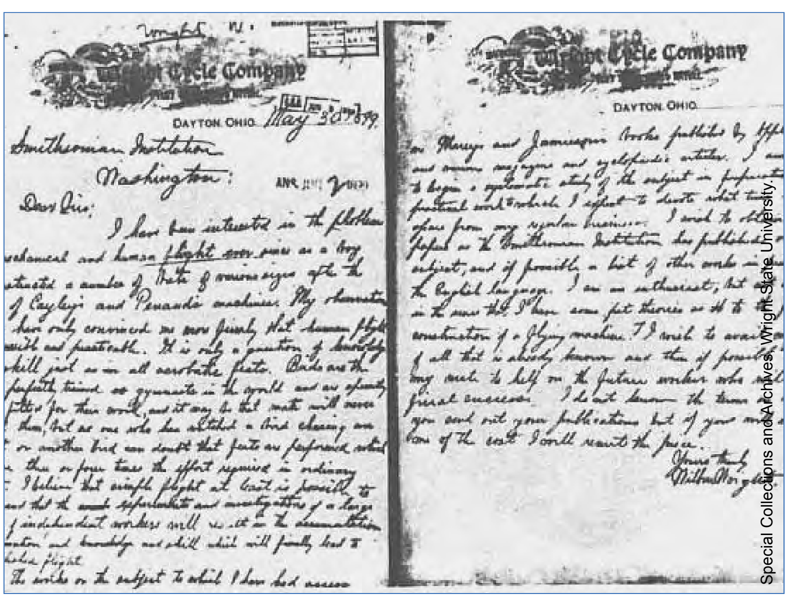
the Van Cleve bicycle

opened a bicycle shop. They sold, rented, and repaired bikes. Later, they designed and built three models of their own. One of these designs was the Van Cleve bicycle. The brothers built and sold it in their bicycle shop in Dayton. The bicycle season ended in the fall. This gave Will and Orv lots of spare time. They found a new interest in **photography**. This hobby would come in handy in the years to come.

the Wright Cycle Shop
in Dayton, Ohio

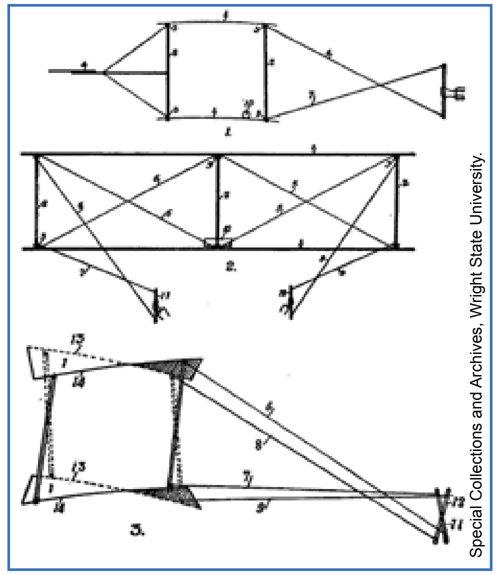
An Old Interest Renewed

In 1896, the brothers heard about the death of Otto Lilienthal. They knew about his work with gliders. His death caused the brothers to think about flying again. They began to look for some research on flight. At first, they could only find books on the flight of birds. They read a lot about how birds glide and soar.



Wilbur's letter to the Smithsonian Institution

In 1899, Wilbur wrote to the Smithsonian Institution. He wanted to find out what was known about flight. They sent back **pamphlets** and a list of books on the subject. The Wrights read all of these. They learned about the men who were trying to fly. They took notice of the work done with gliders. As they studied this work, they began to notice a common problem. These men had tried to balance the glider by shifting their weight. Some had fallen to their death. The brothers set out to solve the problem of control.

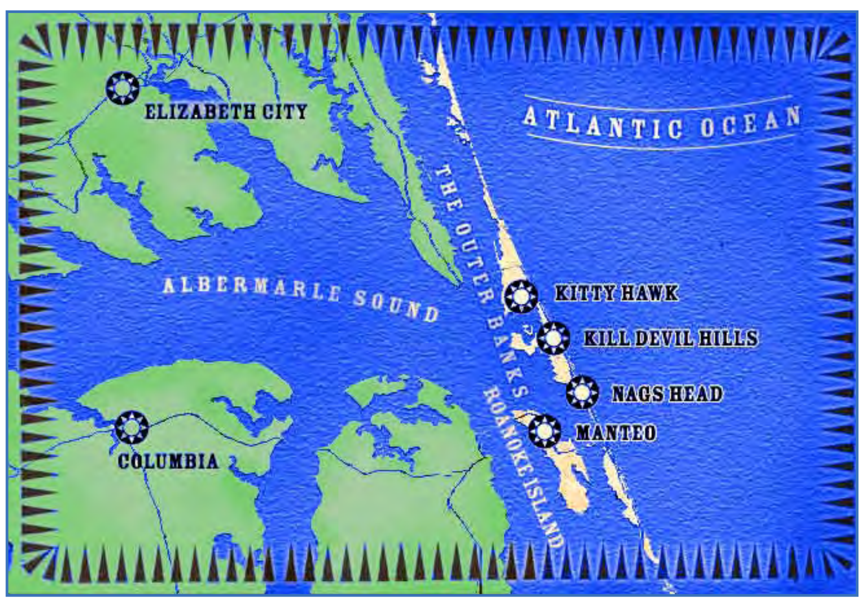


a sketch of the 1899 kite

In 1899, the brothers built a special kite. Its **double-decker** wings were 5 feet (1.5 meters) long. The kite tested their ideas for control. They called it "**wing warping**." When Wilbur twisted the wings, he could make it go where he wanted. It would climb, dive, or go left or right as he worked the controls.


Kitty Hawk, NC

The next step was to build and test a full-size glider. They would need an open, windy place to fly. Will wrote to the U.S. Weather Bureau. They sent him a list of the windiest places. Kitty Hawk in North Carolina seemed to be the best place. It was a narrow strip of land between two bodies of water. The Atlantic Ocean was on the east. The Albemarle Sound was on the west. The wind speed was about 10 to 20 miles an

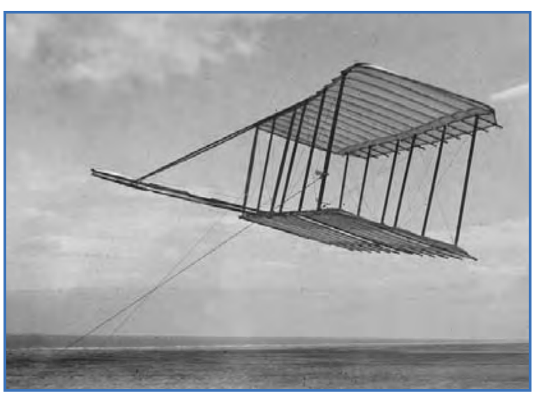


an old map of Kitty Hawk, NC, and the surrounding area hour (16 to 32 kilometers per hour). The sandy beach would give them soft landings. There were very few trees or houses. It was also **remote**. They would not need to worry about reporters. They would not have to bother with curious onlookers.

The Three Gliders

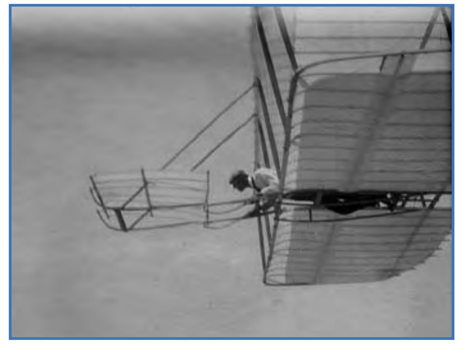
The busy time at the bike shop ended in the fall. So, in September 1900, Will and Orv set out for Kitty Hawk. For a few days, they stayed with Bill Tate, the postmaster. Then they moved into their tent. It took over 2 weeks to put the glider together. It was a biplane, which meant it had two pairs of wings. The wings were 17 feet (5.2 meters) long and covered with a sateen cloth.

Bill Tate and his family on the post office porch


1900 glider flown as a kite

For 3 weeks, they flew the glider as a kite. They wanted to test the controls before it was manned. They watched the glider fly. They made changes, **adjustments**, and repairs. They also took many photos. In fact, all of the photos that recorded the flights were taken by the brothers. This hobby had come in handy after all.

One windy day, they were ready. They carried the glider to Kill Devil Hills near Kitty Hawk. It was the tallest group of the sand dunes there. They took the glider about 100 feet (30.5 meters) up to the top of the highest hill. Wilbur was the pilot. He lay on the lower wing. Orv and Bill Tate held the tip of each wing. They ran into the wind. The glider began to fly on its own. That day, Will made about a dozen glides. Altogether, he spent about 2 minutes in flight. But this was enough to show that the control system worked. The brothers left the glider in the sand. But Bill Tate's wife cut the sateen cloth from the wings. She washed it and made dresses for her daughters.



Wilbur flying the 1900 glider

The Wrights abandoned the 1900 glider in the sand.

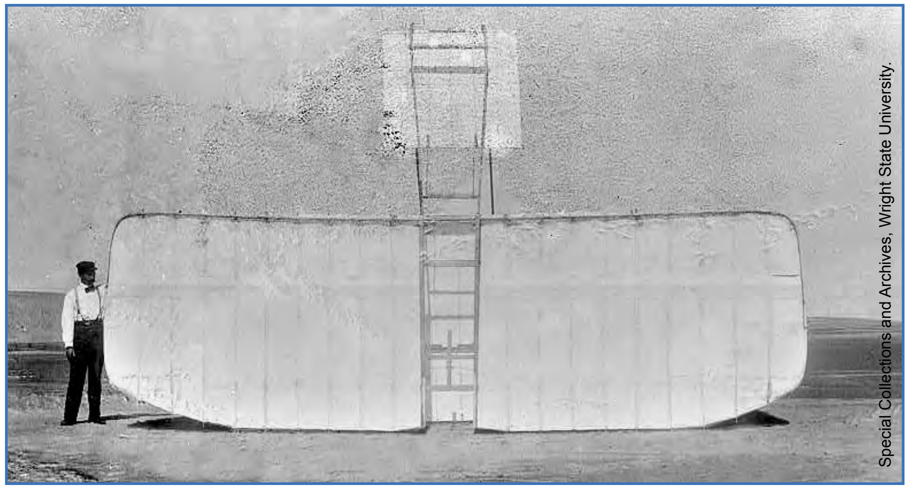
The brothers went back to Dayton. That winter, the Wrights built a new glider. The new glider had a 22-foot (6.7 meter) wingspan. They hoped this would give the glider more lift. It was the same as the 1900 glider in all other ways.

They went back to Kitty Hawk the next July. It was 1901. They moved their camp to the base of Kill Devil Hill. In spite of terrible rain, they built a large wooden shed. They slept in their tent and used the shed as a workshop and a **hangar**. After the rains, there came a terrible outbreak of mosquitoes.

Big Kill Devil Hill

the 1901 hangar

After this came more trouble. The new glider did not perform well. The new wings were designed using data from Lilienthal. He had made air-pressure **tables** based on all of his glider flights. But the Wright glider didn't lift as expected. Will and Orv made adjustments. Still the glider failed to lift as the tables said it would. One day Wilbur crashed. He suffered some cuts, bruises, and a black eye. After this, they only flew the glider as a kite. Again, it spun out of control. In late August, the Wrights went back to Dayton. They were very upset. They were ready to give up. They did not plan to return to Kitty Hawk.

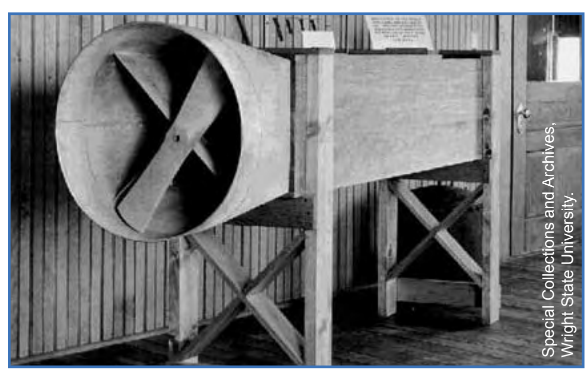


a bottom view of the 1901 glider

launching the 1901 glider

The next winter, Octave Chanute asked Wilbur to give a lecture. Chanute was also a gliding **pioneer**. He wanted Will to talk about his work on flight. He felt that the Wrights were on the right track. He did not want the brothers to give up their hope of flying. Having Will give a talk was a good idea. The people asked questions. They all wanted to know more about what the Wrights were doing. When Will got back home, the brothers got back to work.

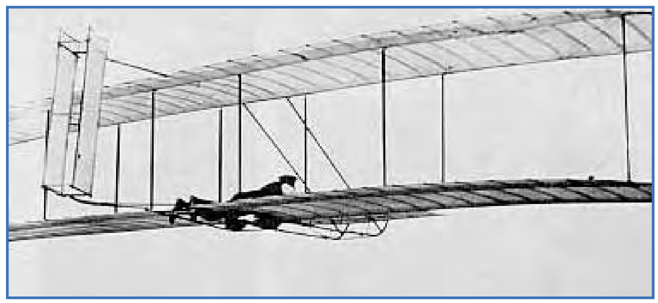
The brothers knew that Lilienthal's tables must be wrong. They also knew that they needed their own data. So, they built a **wind tunnel** to



To make more accurate tests, the brothers built a wind tunnel.

test lift and drag. Drag is the force that holds an airplane back. They tested over 200 model wings (**airfoils**) in the wind tunnel. The wings were all different shapes and sizes. For weeks, they tested and measured. They wrote down all of their data. Now, all the facts were their own. These tests helped them to understand how an airfoil works.

The Glider That Really Caught the Wind



the 1902 glider with
twin controllable rudders

In 1902, a new glider was built. This one had thinner wings that were 32 feet (9.8 meters) long. It had a tail built of two 6-foot (1.8 meter) **vertical rudders**. At the end of August, the brothers were back in Kitty Hawk. The glider was assembled in a few weeks. This time they took turns being the pilot. Orv finally had his first flight. They had to make more adjustments. They also tried to use just one vertical board for the rudder.

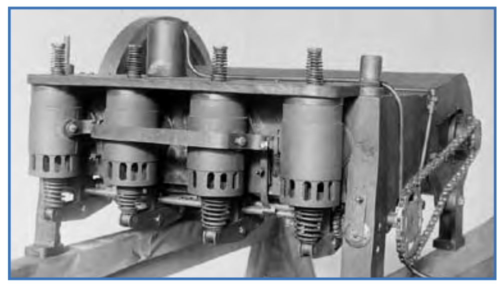
the 1902 glider banking right

That fall, Wilbur and Orville made over a thousand gliding flights. For the first time in history, an aircraft could be controlled in three ways. It could go up and down, turn from side to side, and roll. Will and Orv were now the most experienced glider pilots in the world. They planned to return to Kitty Hawk next year. This time their aircraft would have a power of its own!

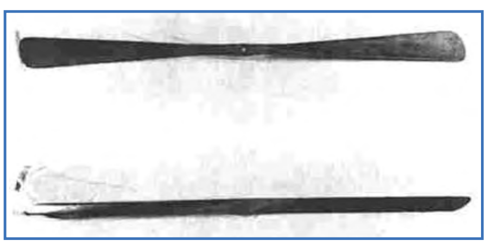
Building the *Flyer*

Charlie Taylor built the engine for the *Wright Flyer I.*

Back to Dayton they went. The brothers began to design a new airplane. This time it would not fly by the wind. It would fly using its own power. They looked for a company to build an engine. But no company was willing to build it. So, the Wrights were faced with building their own engine. They did it with the help of Charles Taylor. Charlie was a **machinist**. He was hired in 1901 to run the Wrights' bicycle business. While the brothers were away or busy with their flying business, Charlie was in charge. The three men planned and sketched each part of the engine. However, it was Charlie who put it all together.

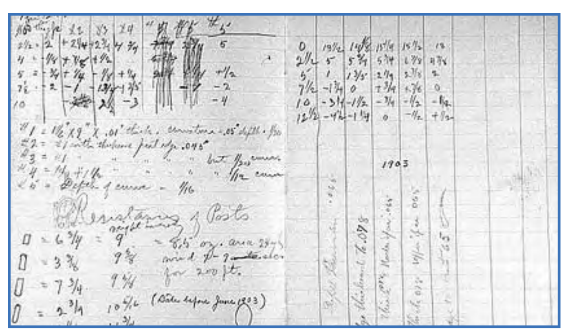


1903 engine *(Note bicycle chain.)*



The *Flyer's* propellers were carved by hand from laminated layers of spruce.

The brothers put two propellers on the new plane. These would give the plane thrust. Thrust is the force that pushes an airplane forward through the air. The plane was like the 1902 glider, except it was stronger to hold more weight. The wingspan was 40 feet (12.2 meters) long. They named it the *Flyer*. During this time, the brothers continued to study, test, and record data. They filled over five notebooks with the data. The brothers drew diagrams and tables. They wrote down the results of their tests.



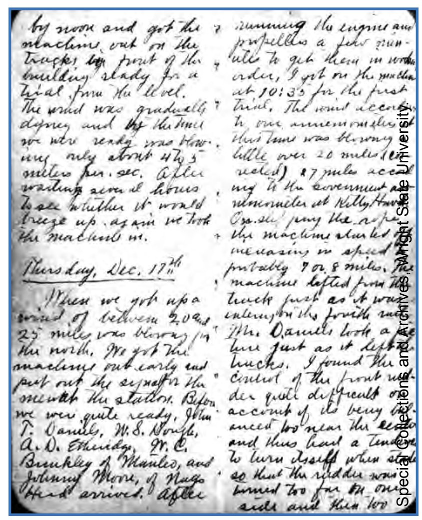
some of the many calculations that the brothers made to design efficient propellers

Will and Orv returned to Kitty Hawk in the early fall of 1903. That fall brought rain, snow, and freezing, windy days. They repaired their wooden shed and built a second one. On nice days, they flew the 1902 glider. Then, they were ready to test the engine. During the first test, the engine backfired and destroyed a propeller **shaft**. The shafts were shipped back to Dayton. Charlie fixed the shafts and sent them back to Kitty Hawk. But then, the brothers saw that one of the shafts had cracked. This time, Orville went back to Dayton with the shafts. On December 14th, the brothers were finally ready to fly. Wilbur won the coin toss that decided who would be the first to fly. With Wilbur laying on the wing, the *Flyer* rose up from the rail. But it immediately lost lift and crashed into the sand.

the *Flyer* and camp at Kill Devil Hill

Flight at Last!

It took two days to get the *Flyer* ready for flight again. On Thursday, December 17, 1903, Orv put the camera in place. It was his turn to fly. He lay down on the wing. He ran the motor for a few minutes. Then, he released the wire that held the plane to the rail. Up went the *Flyer*! It stayed up for 12 seconds and flew 120 feet (36.6 meters). The first flight of a powered, heavier-than-air, controlled, piloted aircraft had taken place!



by noon and got the machine out on the tracks in front of the building ready for a trial from the level. The wind was gradually dying and by the time we were ready was blowing only about 4 to 5 meters per sec. After waiting several hours to see whether it would breeze up again we took the machine in.

Thursday, Dec. 17th

When we got up a wind of between 20 and 25 miles was blowing from the north. We got the machine out early and put out the signal for the men at the station. Before we were quite ready, John T. Daniels, W. S. Dough, A. D. Etheridge, W. C. Brinkley of Manteo, and Johnny Moore of Nags Head arrived. After

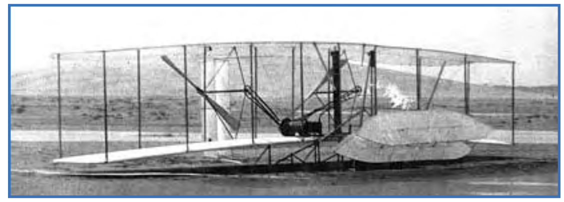
running the engine and propellers a few minutes to get them in working order, I got on the machine at 10:35 for the first trial. The wind according to our anemometers at this time was blowing a little over 20 miles (corrected) 27 miles according to the Government anemometer at Kitty Hawk. On slipping the rope the machine started off increasing in speed to probably 7 or 8 miles. The machine lifted from the truck just as it was entering on the fourth rail. Mr. Daniels took a picture just as it left the tracks. I found the control of the front rudder quite difficult on account of its being balanced too near the center and thus had a tendency to turn itself when started so that the rudder was turned too far on one side and then too

the December 17th entry from Orville's journal

the first flight

Taking turns, the brothers made three more flights that day. Wilbur made the longest flight. He stayed up for 59 seconds. The *Flyer* was able to cover 852 feet (260 meters).

The plane was carried back to camp. They hoped to fly the next day. Suddenly a gust of wind caught the plane. It was tossed over and over. The *Flyer* and the hopes of more flights were ruined.



The front elevator frame was broken on landing at the end of the fourth flight.

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The telegram the Wrights sent to their father informing him of their success.

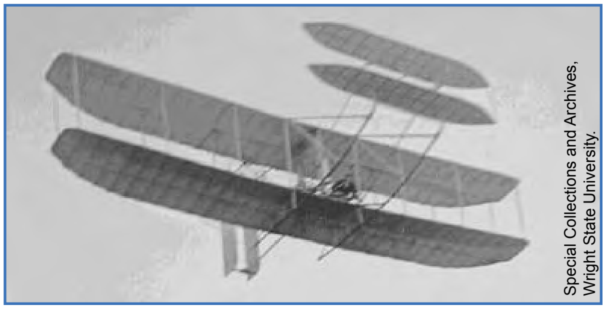
After lunch, the Wrights telegraphed their father with their news. "Success four flights thursday morning # all against twenty one mile wind started from Level with engine power alone # average speed through air thirty one miles longest 57 [sic] seconds inform Press home ####Christmas." The rest of the world barely noticed the first flight.

The next year the Wrights built the *Flyer II*. They tested it the following spring. But they did not go back to Kitty Hawk. They chose a field close to Dayton. It was a 100-acre cow pasture called Huffman Prairie. The Wrights made over 80 flights in the 1904 *Flyer II*. Many crash landings led to many repairs. That year, Will flew the first complete circle in the sky.

the 1904 *Flyer II* on the track

The 1904 *Flyer II* was catapulted into the air at Huffman Prarie.

The brothers made several changes the next year. The *Flyer III* was a much improved plane. It could fly until the fuel tank was empty. A new record was set. Will stayed up for 39 minutes.



the 1905 *Flyer III*

He flew 24.5 miles (39.4 kilometers)! The brothers finally had a real working airplane. Now the world began to take notice.

Wowing the Crowds

By 1908, the *Flyer III* had two seats.

For the next 2½ years, the brothers stayed on the ground. Then, in 1908, Wilbur sailed to France with the *Flyer III*. He assembled the plane and showed the French what the *Flyer III* could do. By that time, the *Flyer III* had a seat for the pilot and for one passenger. Will made over 100 flights in France. A letter to Orv tells how he was received there. He wrote, "…the newspapers and the French aviators went wild with excitement. [Louis] Blériot and Delagrange were so excited they could scarcely speak…"

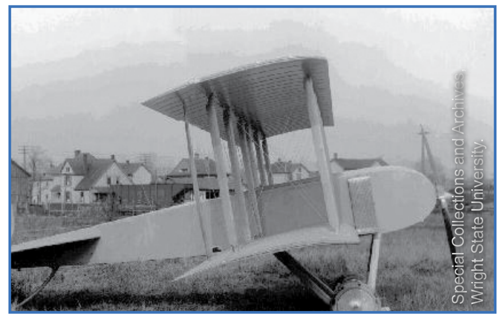
The 1908 crash was the first passenger death in an airplane accident.

While Will was wowing the crowds in France, Orv began to show the U.S. what their plane could do. His flights took place at Fort Myer, Virginia. People came from nearby Washington, DC, to watch Orville fly. These crowds were just as amazed as the crowd in France. Orv was in his third week of flights when he crashed. The man flying with him was killed.

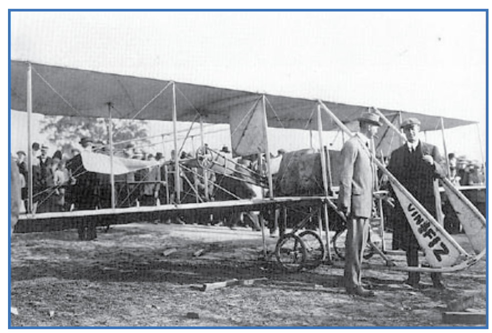
Orville was in the hospital for 7 weeks. Then he and Katharine, their younger sister, joined Will in France. Together they visited parts of France and Rome. On the journey home, they made a few stops. They were honored and praised by crowds in Paris, London, New York, and Dayton.

The Later Years

In 1909, Will and Orv started their own airplane company in Dayton. The Wright Company built and sold *Wright Flyers.* They continued to change and improve their planes. They added wheels, improved the controls, and increased the speed. Cal Rodgers piloted one of the Flyers to make the first coast-to-coast flight in the U.S. It was named the *Vin Fiz* after the soft drink that sponsored its flight.



The 1911 *Wright Model L* was designed for the U.S. Army.



The Wright Model *EX Vin Fiz* was the plane piloted by Cal Rodgers in his trip across the U.S. in 1911.

In 1912, Will caught **typhoid fever**. He died four weeks later at the age of 45. Orville lived until he was 76 years old. In 1948, he died of a heart attack. He lived to see jet engines replace propellers. He lived to see a plane fly faster than the speed of sound. Twenty-one years after Orville's death, Neil Armstrong stepped onto the Moon. He was carrying a piece of the original cotton wing and some wood from the *Wright Flyer I*, the plane that started it all.


Orville was one of the founding members of the National Advisory Committee for Aeronautics.

Lesson 7—Louis Blériot

Procedure—Lesson 7

1. Review the list of the Wright brother's character traits and the steps they took to achieve powered flight.
2. Introduce and teach the vocabulary as you would any guided reading. Use a world map to point out the English Channel, England, and France. Try to find Calais, France, and Dover, England, Blériot's approximate starting and ending points for the flight across the Channel. Also, locate Haiti in the West Indies.
3. Distribute copies of the student text for Lesson 7, "Louis Blériot," and have the students insert this in their logs. As the class reads and discusses the text, question their understanding and encourage their questions. The prize money offered by *The London Daily Mail* of 1,000 pounds translated to about $5,000 in U.S. currency at that time.
4. Have the students record in their logs the traits and skills Blériot exhibited as he tried to perfect his flying machine.
5. After reading, list Blériot's traits and skills on a sheet of chart paper. **Possible answers: brave, inventive, observant, creative, methodical, determined, mechanical-minded, patient, persevering, careful, competitive, endured pain, risked everything to pursue his dream.**
6. Next, list the steps Blériot took as he attempted to achieve flight.

   Answer:

   - **Saw a bat-wing-shaped plane at an exhibit.**
   - **Built a wing-flapping aircraft with a motor that failed.**
   - **Built a glider, took off from the water pulled by a motorboat, and crashed.**
   - **Built a plane with a motor and propeller, was his own pilot, failed.**
   - **Built a plane with two motors and two propellers, neither had lift.**
   - **Built a plane with wheels; but, the plane still had no lift.**
   - **Finally built *Blériot VII* and achieved successful flight.**
   - **Built *Blériot XI* and crossed the English Channel.**
7. Draw a Venn diagram on the board. Compare and contrast the lives of the Wrights to the life of Blériot as you fill in the diagram. A Venn diagram is provided so that teachers can use this as homework or as an insert into the student logs. Venn diagram suggestions are also included.
8. Conclude the discussion by allowing the students to share their dreams for future success. Have them identify which traits and skills of the Wrights and Blériot will help them achieve success. Students may want to record this information in their logs.

Vocabulary—Lesson 7

Allied Forces – the nations that fought together against the Central Powers of Europe during World War I, such as Russia, France, Great Britain, and later many others, including the United States

English Channel – an arm of the Atlantic Ocean between western France and southern England that opens into the North Sea

map of the English Channel

floatplane – an airplane equipped with one or more floats for landing on or taking off from a body of water

floatplane

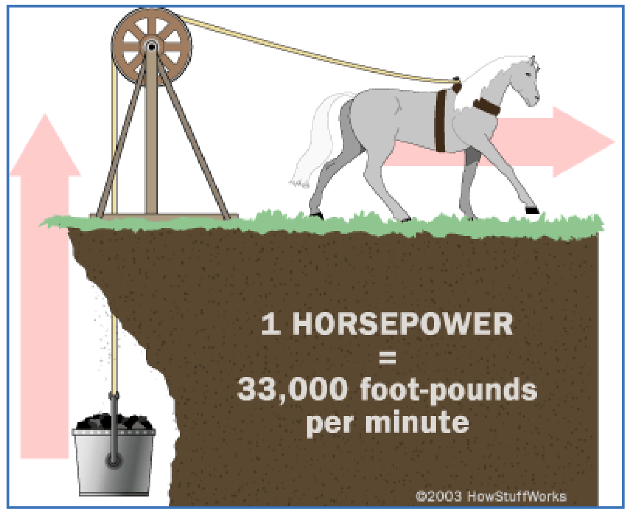
car headlamp

gust – a strong, abrupt rush of wind

Haitian – a native or inhabitant of Haiti, which is a country of the West Indies

headlamp – a light with a reflector and lens mounted on the front of an automobile

horsepower – a unit of power equal to 746 watts



Horsepower is the common unit used for measuring power. James Watt found that an average horse, hitched to a rig as shown in the figure above, could lift a 330-pound (150 kilogram) load straight up a distance of 100 feet (30.5 meters) in 1 minute. The above figure shows 1 horsepower. "Courtesy of HowStuffWorks.com"

isolated – set apart or cut off from others

monoplane – an airplane with only one pair of wings

Blériot monoplane

pounds – the basic unit of money in the United Kingdom (1 pound = 20 shillings or about 2 U.S. Dollars)

English pound—
coin or paper

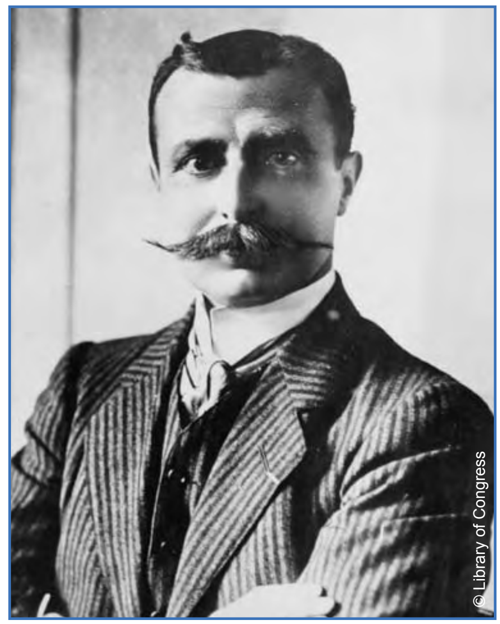
trial run – a test, as of performance or acceptance

Student Text—Lesson 7

Louis Blériot

Before the Dream

The first time Louis Blériot saw a flying machine, he knew he wanted to fly. He was one of the early pioneers of flight. He is best known as the first man to fly across the **English Channel**. Louis was already rich before he had the dream to fly. But he had gotten rich off of cars, not planes.



Louis Blériot

Louis was born in France in 1872. He went to an arts and trade school in Paris. Once he got his degree, he went on to become an inventor. Karl Benz had invented the car when Louis was 13. But it was Louis who invented **headlamps** for cars. He set up his own company to make the lamps. Before he was 30, he had earned a fortune. Before he became interested in flight, he got married and had five children.

Blériot crossing the English Channel, July 25, 1909

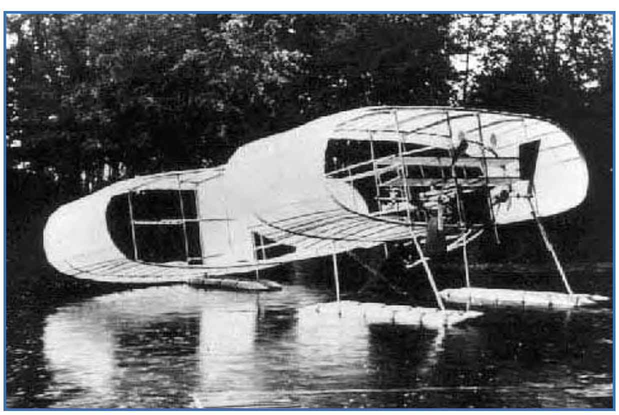
Trying to Find What Works

Louis probably saw a machine similar to this ornithopter.

One day, Louis went to an exhibit. There he saw a machine that would change his life. It was a plane with wings in the shape of bat wings. This inspired him to build his own planes. So, over the next 9 years, he built, tested, and crashed more than a few planes. Louis did not stick to one kind of design for his planes. He worked by trial and error. When one plane did not work, he would build a different one.

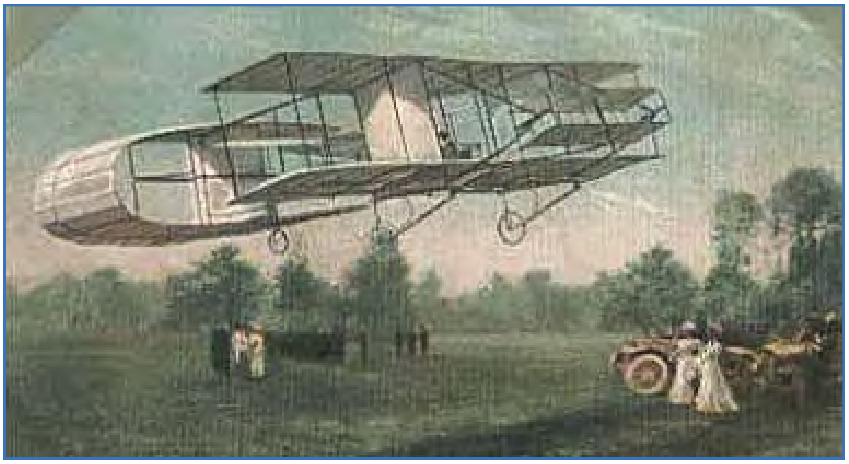
His first plane, the *Blériot I*, had wings like a chicken. A little motor made them flap. The machine was intended to fly by flapping its wings. The flapping wings did not work. Louis' first attempt to fly had failed, but he kept working.

Louis then teamed up with Gabriel Voisin. They built a glider. It was also a **floatplane**. *Blériot II* was built to take off from the water. A motorboat pulled the glider. The glider went up into the air. Then, it crashed into the river. The pilot was not hurt. But it made Louis want to learn to be a pilot.



Blériot III, September 1906

In 1906, Louis began to build and fly his own planes. So, when the next plane was built, Louis was the pilot. The plane (*Blériot III*) had a motor and a propeller. But it would not take off from the water. The next Blériot design had two motors and two propellers. It could float, but it could not fly.



Blériot IV, November 1906

Louis could have given up, but he did not. Instead, he made the next plane with wheels. Then it could take off and land on the ground. It was called *Blériot IV.* The plane made little hops over the ground. It tried to get up. But it could not fly.

His next plane (*Blériot V*) rose slightly off the ground and "flew" over a field. KABOOM! It hit a rock and crashed. Even though it crashed, Louis was encouraged. With each flight, he was learning. Like the Wrights, he made changes. Each plane was better than the last. Sooner or later, he knew he was going to fly.

Blériot V

Finally Getting It Right

Blériot VII, Louis' first successful plane, October 1907

Six years had passed. Many planes had failed. Louis had suffered cuts, bruises, and broken bones in his crashes. But finally, in 1907, Louis took *Blériot VII* up into the sky. How wonderful he felt. How proud his family was. Even after *Blériot VII* crashed, Louis pressed on. He went on to redesign, rebuild, and pilot his own planes.

Late in the summer of 1908, Wilbur Wright was in France. The French saw what the *Wright Flyer* could do. They were amazed. One day, a powerful man from England was in the crowd. He was Lord Northcliffe, owner of *The London Daily Mail*. This was a widely read newspaper in London. After seeing Wilbur fly, he had an idea. He thought that a contest would bring even more readers to his paper. He offered 1,000 **pounds** to the first man to fly non-stop across the English Channel.

By the summer of 1909, Louis was broke. He had spent his fortune on his many planes. He wanted to compete for the *Daily Mail* prize, but he had spent all of his money. Then an odd thing occurred. His wife had visited friends in Paris. A rich **Haitian** planter was also there with his young son. The boy climbed onto a balcony and was about to fall. But Louis' wife grabbed him just in time. The planter loaned Louis the money he needed to make the Channel crossing.

The Two Competitors

So, in July, Louis was near the town of Calais at the starting point of the race. Hubert Latham was also there. Latham was the favorite to win the prize. He was very popular in France and in England. His plane had a 50 **horsepower** engine. The wingspan was 42 feet (12.8 meters). It was a **monoplane** and it was large and strong. The *Blériot XI* was also a monoplane. It only had a 25 horsepower engine. Its wingspan was a little over 25 feet (7.6 meters). No one thought Louis had a chance to win.

Blériot at the starting point of the race in Calais, France


Latham's failed attempt to cross the Channel, July 19, 1909

On July 19, Latham took off across the Channel. He was 7 miles (11.3 kilometers) out when his engine failed. He and his plane had to be rescued from the water. Then, he went back to his camp to wait. The weather was awful and the wind was worse.

Louis was waiting, too. He was also aware that he did not know where to land, even if he did make it to England. So, he made plans with a newsman on the English side. The man would scout out the best place to land. The Dover cliffs rose as high as 300 feet (91 meters). But the man found a landing place only 100 feet (30.5 meters) above the water. He would wave a French flag as a signal. He sent Louis a picture postcard. It showed the landing site marked with an X.

Days went by. Both camps kept an eye on each other. But the weather was still too bad for flying. At this time, Louis could barely walk. In one of his plane's **trial runs**, he had badly burned his foot. He had to use crutches and the pain was great. How would he control the rudder with his foot in so much pain?

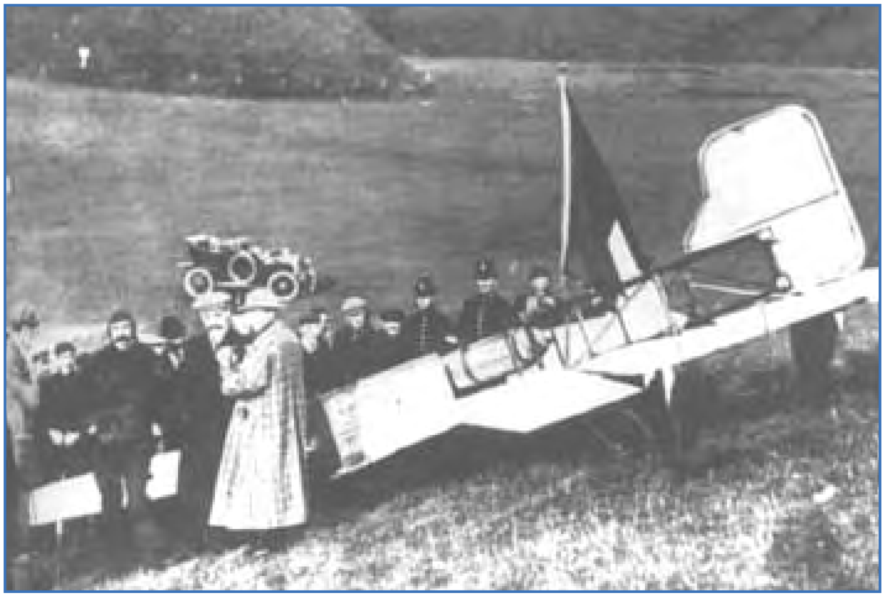
One night, the wind seemed to be dying down. Latham took note of this. He ordered his crew to wake him if the wind stayed calm. The wind did stay calm, but his crew stayed asleep. However, in the Blériot camp, the crew was wide awake. The contest rules did not allow for a night flight. So, near daybreak, they went to get Louis.

Winning the Prize Against the Odds

Early on the morning of July 25, Louis limped out to *Blériot XI*. His foot was infected and he could hardly walk. Yet, he was thinking of the dangers ahead. The channel was over 20 miles (32.2 kilometers) wide. Its waters were cold and choppy. Seeing through the fog would be impossible. And, if he crashed, a rescue ship probably couldn't find him. On top of everything else, airplane motors usually overheated after 15 minutes. Louis knew the trip would take over twice that long. The plane's engine was warmed up. Then a flag signaled sunrise, and Louis was up in the air. He was quickly lost in the clouds. The swirling fog was so thick he couldn't see. Louis had no compass. But he knew the cold, choppy waters were below him. There was wind and there was rain. But the cool rain helped to prevent his engine from overheating.

the path of the Blériot flight across the Channel

When Louis later gave an account of the trip, it showed his concern. He wrote, "I am alone. I can see nothing at all. For 10 minutes, I am lost." Louis flew as straight as he could. When he finally spotted the coast, he knew that he had been blown off course. He looked down and saw three ships. He knew they were headed for the port of Dover. So, he followed them. As he neared the Dover cliffs, the **gusts** were stronger. His plane had to fight the wind. But then he spotted his friend. He was wildly waving the French flag in the wind.



Blériot landed in Dover, England, after crossing the Channel.

Now Louis had to land in the violent wind. But each time he tried to land, a gust would lift him up. So, he just cut off the engine and the plane dropped! The plane was damaged; but, Louis was fine. "So what?" he said. "I had crossed the Channel!" The 37-minute flight made him famous.

Success Has Its Rewards

Orders for the *Blériot XI* began to pour in. Everybody wanted one. It became one of the most popular aircraft in the time before World War I. The flight changed England. It was not **isolated** from the rest of Europe any more. Barriers of land and sea no longer existed for the airplane.

Two months later, Louis was at the great air show in Rheims. Here he set a world speed record. Latham was there, too. He had made one more attempt to cross the Channel just 2 days after Louis. But once again his engine failed, and he had to be rescued from the sea. However, in Rheims, he won the prize for the highest altitude in a plane.

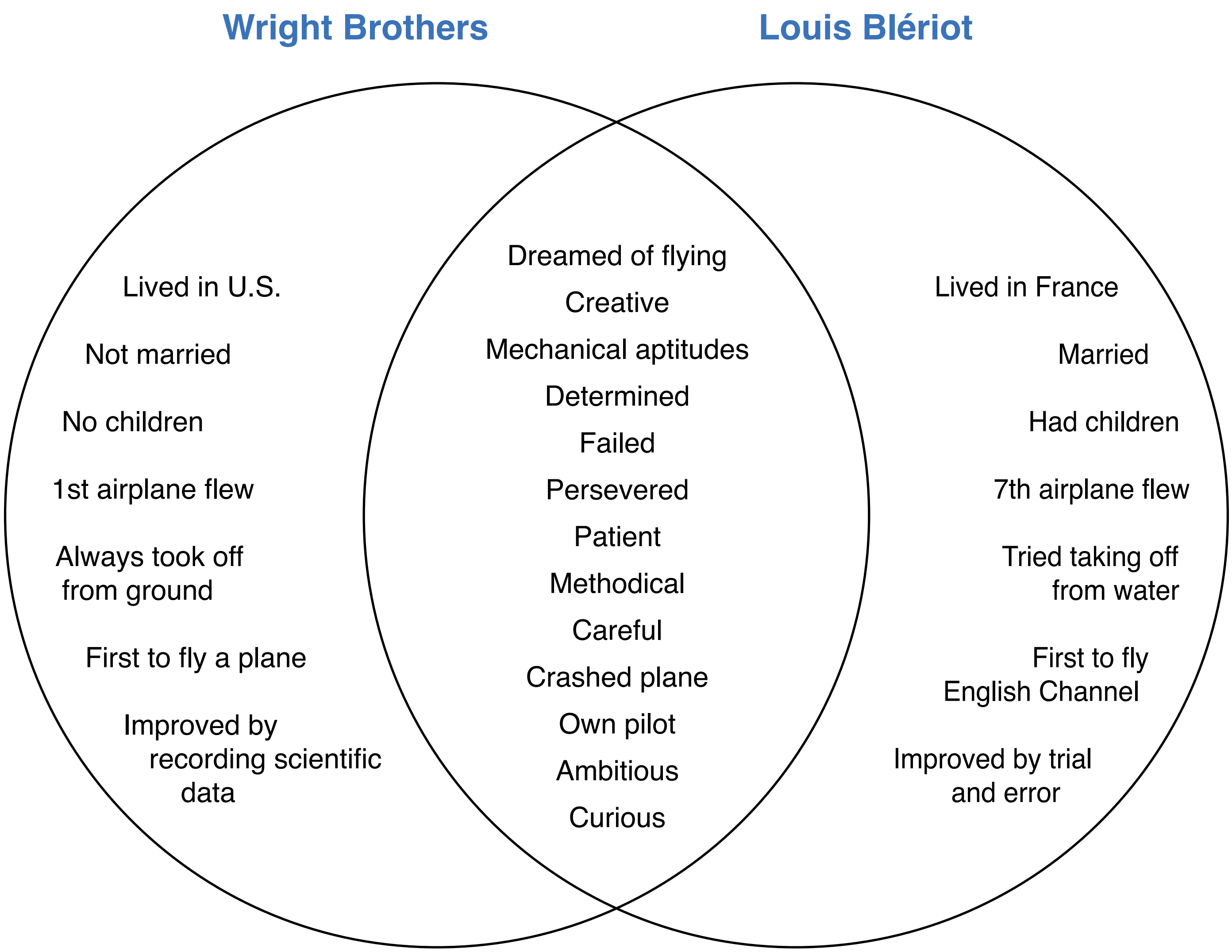
Blériot's accident at Rheims, 1909

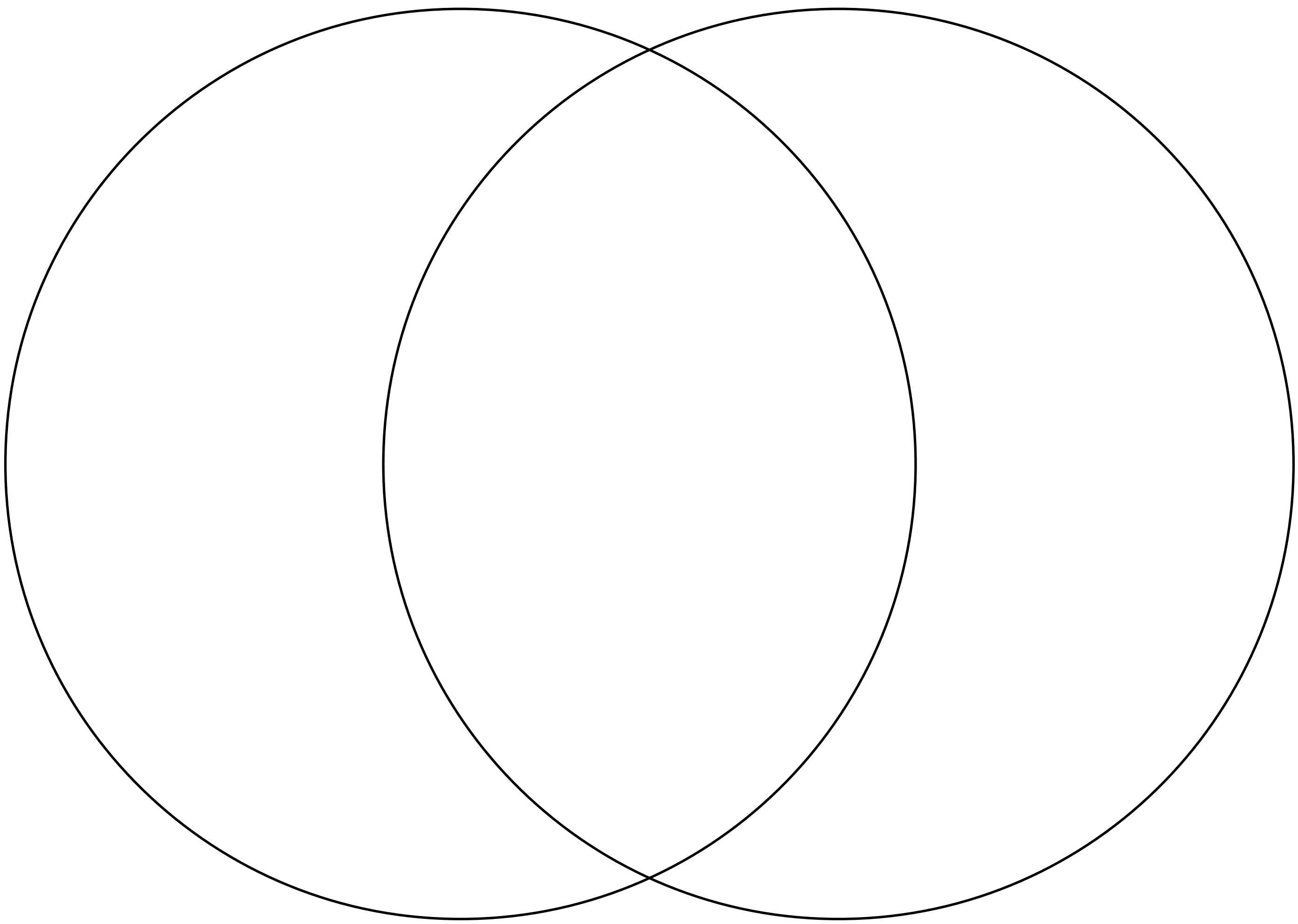
Louis was involved in over 50 crashes throughout his life. Still, he loved to fly. He continued to build and fly his own designs. His company produced many famous aircraft. During World War I, they built over 5,000 SPAD fighter planes. This plane was used by all of the **Allied Forces** during the war.

The *SPAD VII* fighter was one of the best Allied combat aircraft of World War I.

The *SPAD XIII* was used extensively in World War I by French and U.S. troops.

Louis died of a heart attack in 1936. He had made many contributions to the field of aviation. His dedication made him one of the great pioneers of flight.


Wright Brothers
Louis Blériot
Lived in U.S.
Not married
No children
1st airplane flew
Always took off from ground
First to fly a plane
Improved by recording scientific data
Dreamed of flying
Creative
Mechanical aptitudes
Determined
Failed
Persevered
Patient
Methodical
Careful
Crashed plane
Own pilot
Ambitious
Curious
Lived in France
Married
Had children
7th airplane flew
Tried taking off from water
First to fly English Channel
Improved by trial and error



Activity Five—Flying a Styrofoam® Plane

Lesson 8

Activity (Lesson 8) prep time: 10–15 minutes
(for gathering materials and following pre-lesson instructions)

Teaching time:

Lesson 8: 1–1¼ hours
(Science, Math)

Objectives—Lesson 8

1. The students will use prior knowledge to construct a Styrofoam® airplane.
2. The students will measure and compare distances.
3. The students will re-evaluate their answers to the following question: "What makes an airplane fly?"
4. The students will begin to gain insight and build inquiry into the subject of flight.

National Standards—Lesson 8

Science

- Abilities necessary to do scientific inquiry—S2Ea, S2Ma.
- Understandings about scientific inquiry—S2Eb, S2Mb.
- Position and motion of objects/Motion and forces—S3Eb, S3Mb.
- Objects in the sky—S5Eb.
- Abilities of technological design—S6Ea, S6Ma.
- Science as a human endeavor—S8E.

Mathematics

- Understand measurable attributes of objects and the units, systems, and processes of measurement—M12.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them—M14.
- Develop and evaluate inferences and predictions that are based on data—M16.
- Problem solving—M18.
- Communication—M20.

Language Arts

- Standards 4, 5, 6, 7, and 12.
  (See Language Arts Matrix on page 8.)

Technology

- Relationships among technology and other fields—T3.
- Attributes of design—T8.
- Engineering design—T9.
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving—T10.
- Apply the design process—T11.
- Transportation technologies—T18.

Lesson 8—Will it Fly?

Materials—Lesson 8

- The book *The First Air Voyage in the United States* by Alexandra Wallner.
- Student logs.
- A Styrofoam® tray or plate for each student.
- Scissors for each student.
- Clear tape dispensers (about 4).
- A 25-foot (7.6-meter) tape measure for each group—Ask the students to bring these in if needed.
- An inside flying field (gymnasium or cafeteria) or outside if no wind is blowing.

Pre-lesson Instructions—Lesson 8

1. Be sure that each student has a Styrofoam® tray or plate for their plane.
2. Secure a flying field for the students to fly their planes. Before class begins, mark a line for students to stand behind as they throw their planes. Try to provide a "flying lane" for each group.
3. Divide the class into groups of 4 or 5 students.

Procedure—Lesson 8

1. Read aloud *The First Air Voyage in the United States* by Alexandra Wallner as an introduction to this activity.
2. Distribute the Styrofoam® trays, or plates, and scissors to the students. Set out the dispensers of clear tape.
3. Instruct the students to cut out and build a Styrofoam® airplane that they will fly. Each student should build their own plane, but they may feel more comfortable working in pairs. Give no further assistance. Allow up to 15 minutes for students to complete their planes.
4. Assign the students to their groups, give each group a tape measure, and then go to the flying field. Remind students to bring their logs, a pencil, and their planes. Assign a lane to each group. As each student flies his/her plane, the distance should be measured by the group and recorded in their logs. Have the "winners" of each group fly their planes until only two or three planes remain.
5. When the students return to the classroom, examine the planes that flew the longest distance. Ask the class to hypothesize why some planes flew farther than others. Did some fly straight while others did not? Were they larger? Did they have larger wings? Were they more aerodynamic? (Define aerodynamic as streamlined or as something shaped to resist drag.) Did they use more force as they thrust it forward with their hands?
6. Have students open their logs to the following question: "What makes an airplane fly?" Tell them they have 5 minutes if they want to revise their answers, or they may use the time to write a hypothesis about why their plane did or did not fly. Remind them once again that they're not expected to know the correct answer, but hopefully they are beginning to wonder how these huge, heavy machines can stay up in the air. It is suggested that they be allowed to work in their "flying groups" to come up with an answer.
7. Discuss the students' answers and their hypotheses.
8. Write the homework assignment on the board. Use the flight timeline, as well as the KWL chart, for suggestions for questions. Tell the students to discuss their homework with their parents to come up with the two questions. Explain that two questions are required in case someone else chooses one of their questions. Do not tell them that they will be paired for research.

Homework assignment

In your log, write two questions about flight that you would like to research. This is due tomorrow (or the next class period).

Activity Six—Looking for Answers—
A Research Project

Lessons 9–12

Activity (Lessons 9–12) prep time: 10–20 minutes
(for gathering materials and following pre-lesson instructions)

Teaching time:

Lesson 9: 1¼–1½ hours
(Science, Language Arts)

Lesson 10: 1–1½ hours
(Science, Language Arts, Technology)

Lesson 11: 1–1½ hours
(Science, Language Arts, Technology)

Lesson 12: 1–1½ hours
(Science, Language Arts, Technology)

Objectives—Lessons 9–12

1. The students will use multiple sources to research their questions on flight.
2. The students will practice the research skills of using a Table of Contents, using an Index, and finding Web sites on the Internet.
3. The students will read non-fiction materials to acquire information.
4. The students will gather and evaluate information.
5. The students will apply their knowledge of language to write a one- to three-paragraph answer to their questions on flight.
6. The students will apply the knowledge gained from their research to illustrate their page of a class product (class book) on flight.
7. The students will communicate their research findings in a presentation to the class.

National Standards—Lessons 9–12

Science

- Abilities necessary to do scientific inquiry—S2Ea, S2Ma.
- Position and motion of objects/Motion and forces—S3Eb, S3Mb.
- Objects in the sky—S5Eb.
- Abilities of technological design—S6Ea, S6Ma.
- Understanding about science and technology—S6Eb, S6Mb.
- Risks and benefits—S7Md.
- Science and technology in local challenges/in society—S7Ee, S7Me.
- Science as a human endeavor—S8Ea, S8Ma.
- History of science—S8Mc.

Geography

- The physical and human characteristics of places—G4.
- The patterns and networks of economic interdependence on Earth's surface—G11.
- How human actions modify the physical environment—G14.
- How physical systems affect human systems—G15.
- How to apply geography to interpret the past—G17.

Language Arts

- Standards 1, 2, 3, 4, 5, 6, 7, 8, and 12. (See Language Arts Matrix on page 8.)

Technology

- Students are proficient in the use of technology—I2.
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works—I7.
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences—I8.
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences—I9.
- Students use technology to locate, evaluate, and collect information from a variety of sources—I10.
- Relationships among technology and other fields—T3.
- Cultural, social, economical, and political effects—T4.
- Effects of technology on the environment—T5.
- Role of society in the development and use of technology—T6.
- Influence of technology on history—T7.
- Attributes of design—T8.
- Engineering design—T9.
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving—T10.
- Apply the design process—T11.
- Use and maintain technological products and systems—T12.
- Assess impact of products and systems—T13.
- Transportation technologies—T18.

Materials—Lessons 9–12

- Picture books and other trade books on flight, airplanes, famous aviators, the history of flight, and aircraft of the future. (See Resources.)
- Access to computers.
- White 9- by 12-inch (22.9- by 30.5-centimeter) construction or drawing paper—several sheets for each team.
- Multi-colored 12- by 18-inch (30.5- by 45.7-centimeter) construction paper to be used as the pages for the book.
- Drawing and coloring materials such as magic markers, colored chalk, oil crayons, etc.
- Student logs.

Note to Teacher for Lessons 9–12:
Authentic learning is the learning that takes place when students generate their own questions and then research the answers. This strategy allows students to find answers to things they really want to know about. It is one form of inquiry-based learning. In this activity, students will conduct research to find answers to their questions about flight. These answers with supporting illustrations, will be mounted on a "page," (a 12- by 18-inch (30.5- by 45.7-centimeter) sheet of white construction or drawing paper). Students will give a presentation to the class about their research. All of the pages will then be put together to make a class book.

In Lesson 9, the teacher will model how to research a question. Modeling this procedure is especially important in third grade where some students may be doing research for the first time. If computers are used for the model question, allow knowledgeable students to demonstrate the research process. Teachers may want to ask for volunteers ahead of time so that students will be prepared. Older students may not need this instruction.

This activity has been divided into four class periods, but teachers should allow more or less time according to the needs of their students.

Pre-lesson Instructions—Lessons 9–12

1. By this time, 25–30+ books on flight need to be in the classroom. If the class is going to use Internet sources, computers should be available for this lesson.
2. Computers need to be available for Lesson 11 if the students will be using them to type their final copy of the question and answer.
3. In Lesson 10, teachers may want to ask an educational assistant or parent volunteer to assist those students who need help with research and taking notes.
4. Have the multi-colored 12- by 18-inch (30.5- by 45.7-centimeter) paper, the 9- by 12-inch (22.9- by 30.5-centimeter) drawing paper, and all of the drawing and coloring materials available before the start of Lesson 11.
5. **Very important:** At this time, it is suggested that teachers look at the Materials lists for Lessons 13–19 to make a check list of materials needed for the many experiments in those lessons. To gather these materials, use a team of parent volunteers or ask students to bring in some or all of the materials.
6. Remember to write the homework assignment on the board at the end of Lesson 12 to prepare the students for Lesson 13 on air.

Lesson 9—Modeling the Research Process and the Writing Process

Procedure—Lesson 9

1. Have the students take out their logs and turn to the two questions on flight, their homework from Lesson 8. As each student reads his/her question aloud, ask if there is another student with the same or similar question. These students should be paired to research their answer together. If there are students whose question is completely different from anyone else's, encourage those students to research their own question.
2. Continue with this procedure until all students have their question written at the top of a new page in their logs. It is recommended that teachers keep a personal record of the questions and the students who choose them. Do not have more than two students in a "team." This allows each student to be more involved in the research.
3. Model the research steps used to answer a question. (A short list of possible class questions for modeling is provided at the end of this step.) Have the students decide on a whole class question not chosen by any team. Write this question on the board. At this time, students working together should move to sit beside their partner so that they will begin to function as a team. Distribute the books to the class so that each team has several books.

   Possible Questions
   (to be used as a class question for modeling)

   1. **How do birds fly?**
   2. **Who invented the hot-air balloon?**
   3. **How can someone become a pilot?**
   4. **Who invented the helicopter and how does it fly?**
   5. **How do you control (steer) an airplane?**
   6. **Who invented rockets?**
   7. **Who was Charles Lindbergh and why was he famous?**
   8. **What is the fastest airplane and how fast can it fly?**
   9. **What was the first non-stop flight around the world that required no refueling?**
   10. **Who was Amelia Earhart and why was she famous?**
   11. **What is lift?**
   12. **What do supersonic and hypersonic mean?**
   13. **What is the X–43?**
   14. **How is the Space Shuttle like an airplane?**

4. Instruct the students to use the Table of Contents and the Index of each book to locate information that would answer the class question. Allow about 10–15 minutes for the students to gather information.
5. Next, have the class share the information they have found and write these notes on the board. As the students share the information, have them hold up their books so the class will be familiar with the types of information found in them.
6. As recommended in the Note to the Teacher, students proficient in computer skills should model finding information on different Web sites. Remind students to use search engines such as **http://kids.yahoo.com/** and **http://www.askforkids.com**. Google and Yahoo may be used as well. Ideally, every team will have access to a computer, but there should be at least three computers available for research. Have the class gather around the computers as the students find information for the class question. If the computers are located in the classroom, the teacher will take notes on the board. If they are not in the classroom, the teacher needs to be prepared to take notes and add these to the notes already taken.
7. When all of the research is complete, review the notes on the board. Guide the class to find the main ideas. Remind them that each main idea constitutes a paragraph. Have the students compose the first topic sentence, which states the main idea. Next, find the supporting details and have the students state these as sentences to finish the paragraph.
8. Continue until each paragraph is written on the board and the answer to the class question is complete. Ask students to give suggestions for illustrations to the answer. This question and answer should be recorded. Students who finish their own research question early may volunteer to copy and illustrate the class question so it can be included in the final product.

Lesson 10—Conducting Research

Procedure—Lesson 10

1. Have the students take out their logs and turn to the question that they have chosen to research. Explain that during this class period they should find the information needed to answer their question and write the first draft of their answer. Tell the students that some of their individual answers will need only one paragraph. Teachers may want to remind students of the procedure used for research.
2. The teacher and volunteers may need to assist students in finding resources that contain information on their question. Teachers should make sure that each team has at least one resource to begin their research. Encourage volunteers to mingle among the teams and provide assistance as needed. Continue in this manner until each team has enough information to complete their answer.
3. Inform students that they should keep track of the books and Web sites where they acquired information. They may need to refer back to diagrams or illustrations that they want to include on their page. They will also need this to write a bibliography. Even young students should be taught to give credit to their resources. Younger students can use something as simple as the following: "This information was found in the following resources." Then they would list their resources.
4. As students begin to construct the first draft of their answers, remind them to paraphrase (put it in their own words) and not to copy. They may also need to be reminded to use the writing skills modeled in Lesson 9 when the class question-and-answer paragraph was written. After the first draft is written, they should proofread and edit their work. If the writing process is being followed, a second draft will be written for grading. If the writing process is not being followed, students may receive assistance with editing.

Lesson 11— The Finished Product

Procedure—Lesson 11

1. Tell the students that today they will be writing the final copy of their question-and-answer paragraphs and drawing the illustrations for their pages.
2. If the writing process was followed and the paragraphs were graded, return these graded copies to the students. Otherwise, instruct the students to take out their logs and turn to their edited paragraphs.
3. Remind them that their final copy will be "published" and should reflect their best work. The final copy of the question and answer can be handwritten on small-lined notebook paper or typed on the computer. It should cover an approximate 6- by 8 ½-inch (15.2- by 21.6-centimeter) area. Of course, longer answers will need to use a larger area.

4. When the students have finished the final copy of their questions and answers, they are ready to draw the illustrations using the white drawing paper. Tell the students to choose 2–4 illustrations to support their answers. Remind them to use the books or Web sites where they found their answers for help with the illustrations. Also remind them that this is non-fiction and all aspects of their illustrations should be realistic.

5. When the illustrations are complete, show the class how to crop them and arrange them, along with the question and answer, to fit on the page (the 12- by 18-inch (30.5- by 45.7-centimeter) multi-colored sheet of construction paper). Since the final product is a class book, be sure to leave a margin on the top or left side of the page where holes will be punched for binding the book together. When they have finished arranging them, they should glue them in place. If necessary, extra illustrations may be glued to the back of the page.

6. As the students work, move about the room to encourage and assist as needed.
7. Ask the students who finish early to produce the class question-and-answer page. It will need to be written and illustrated. Other students who finish early may want to design and illustrate the cover. Let the whole class decide on a title. As other students finish, they should peruse the books on flight or use the computer to learn more about flight.
8. Laminate each page.

Lesson 12—Presenting the Research

Procedure—Lesson 12

1. Distribute the laminated pages to each team.
2. Give the teams about 5 minutes to get ready to present their question and answer and explain the supporting illustrations.
3. Each team will make a class presentation. They will read the question and answer and explain the illustrations that support the research. They may also want to talk about how they found the answer and show any books they used to get their answer. The team should be prepared to answer any questions from the class and/or the teacher. Each presentation should last about 5 minutes.
4. After all presentations are made, collect each page. It is suggested that the pages be displayed on a bulletin board for a few weeks so that the students can see and admire their work. Then the pages can be taken down and bound into a class book. If a cover has not been made, select a few students to complete a front and back cover for the book and laminate these as well. Be sure to give the book a title chosen by the whole class.
5. Have the students copy the homework assignment below. (A master list of the ways air works for us is included for teachers at the end of Activity Seven.)

Homework Assignment

In your log, list the ways people use air to work for them. Find as many ways as you can. Bring in pictures of how air works for us for a bulletin board collage. Due ______________________________ (tomorrow or the next class period).

Activity Seven — The Matter of Air

Lessons 13–14

Activity (Lesson 8) prep time: 1–1½ hours
(for gathering materials and following pre-lesson instructions)

Teaching time:

Lesson 13: 1¼–1½ hours
(Science, Language Arts)

Lesson 14: 1 hour
(Science, Math)

Objectives—Lessons 13–14

1. The students will list the ways air is used to work for us.
2. The students will identify the characteristics of three states of matter.
3. The students will categorize objects in three states of matter.
4. The students will define and use the steps of the Scientific Process.
5. The students will conduct scientific experiments to predict and verify information.
6. The students will conduct experiments to discover the following properties of air: Air has no definite shape. It has volume and mass. Air exerts pressure: hot air expands and rises, cold air contracts.
7. The students will construct air cubes and assemble and launch hot air balloons as optional activities.
8. As an optional activity, students will write and illustrate stories about an adventure in a hot air balloon.

National Standards—Lessons 13 and 14

Science

- Abilities necessary to do scientific inquiry—S2Ea, S2Ma.
- Understandings about scientific inquiry—S2Eb, S2Mb.
- Position and motion of objects/Motion and forces—S3Eb, S3Mb.
- Properties of Earth materials—S5Ea.
- Objects in the sky—S5Eb.
- Understanding about science and technology—S6Eb, S6Mb.
- Science as a human endeavor—S8Ea, S8Ma.

Mathematics

- Understand measurable attributes of objects and the units, systems, and processes of measurement—M12.
- Apply appropriate techniques, tools, and formulas to determine measurements—M13.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them—M14.
- Select and use appropriate statistical methods to analyze data—M15.
- Develop and evaluate inferences and predictions that are based on data—M16.
- Understand and apply basic concepts of probability—M17.
- Problem solving—M18.
- Reasoning and proof—M19.
- Communication—M20.

Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12.
  (See Language Arts Matrix on page 8.)

Technology

- Relationships among technology and other fields—T3.
- Cultural, social, economical, and political effects—T4.
- Role of society in the development and use of technology—T6.
- Attributes of design—T8.
- Engineering design—T9.
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving—T10.
- Use and maintain technological products and systems—T12.
- Transportation technologies—T18.

Materials—Lessons 13 and 14

- Student logs.
- Pictures of how air works for us (homework assignment from Lesson 12).
- A copy of the student text for Lesson 13, "Air Works for Me," for each student.
- Copies of the Air Experiments 1–10 (teacher copies), which include a list of materials and answers for results and conclusions for the teacher.
- Copies of the Air Experiments 1–10 (student copies) for each student.
- A golf ball.
- A ping-pong ball.
- Clear plastic cup—8-ounce size or larger.
- 1 index card (5 by 8 inches or 12.7 by 20.3 centimeters).
- "The Scientific Process" chart (provided on page 123).
- A "Three States of Matter" chart (provided on page 124).
- A transparency of the Demonstration Experiment.
- Materials for the optional activities Hot Air Balloons and Air Cubes are listed with those activities.

Materials for each of the following experiments:

Demonstration Experiment—Air Power

- Pie pan or other shallow pan (or dish).
- Candle.
- Modeling clay.
- A tall, clear, glass jar (taller than candle and flame).
- 1½ cups of water.

Air Experiment 1—Perfume Spray

- 1 bottle of inexpensive, strong-smelling perfume.

Air Experiment 2—No Way In

- 1 paper towel.
- 1 plastic cup.
- 1 small bucket or pan filled with water.

Air Experiment 3—Blow Hard

- 1 clear plastic bottle (2-liter soda bottle).
- 1 balloon (helium quality).

Air Experiment 4—Balancing Act

- 2 balloons inflated to the same size.
- 3 pieces of string, each about 14 inches (35.6 centimeters) long.
- A 12-inch (30.5-centimeter) ruler.
- Balance scale for Follow-up Activity.

Air Experiment 5—The Real Paper Weight

- A 12-inch (30.5-centimeter) ruler.
- A 12- by 18-inch (30.5- by 45.7-centimeter) piece of newsprint.

Air Experiment 6—Brrrrrrr

- 1 balloon.
- A cloth or soft plastic measuring tape.
- Access to a refrigerator.

Air Experiment 7—Money Freeze

- 1 soda bottle (glass is best).
- 1 nickel.
- Water.
- Access to a freezer.

Air Experiment 8—Balloon Magic

- 1 balloon (helium quality).
- 1 plastic soda bottle.
- 1 pan of very hot water.

Air Experiment 9—Thermometer Reading

- 2 thermometers.

Air Experiment 10—Bottle It Up

- A 1-gallon plastic milk bottle with a cap.
- Very hot water.

Pre-lesson Instructions—Lessons 13 and 14

1. Duplicate the student text for Lesson 13, "Air Works for Me," so that each student has a copy.
2. Duplicate and collate the student copies of the Air Experiments 1–10 so that each student has a set.
3. Duplicate the "Three States of Matter" chart and "The Scientific Process" chart so that each student has a copy of each.
4. Punch holes in all of the above so students can insert these copies in their logs.
5. If necessary, duplicate a set of the teacher copies of the Air Experiments 1–10.

6. Make a transparency of the Demonstration Experiment.
7. Look over the materials list and make a check list of things that students or a team of parent volunteers can bring to school. As materials are gathered, check them off and place them in a big box or tub. Two days before teaching the lesson, make sure that the box has all the materials needed for each of the experiments.
8. Set up the Demonstration Experiment and Air Experiment 1 the evening before Lesson 13 is taught. Also, have the golf ball, the ping-pong ball, the clear plastic cup half full of water, and the index card ready to conduct the suggested comparison and experiment in the student text for Lesson 13.
9. Set up Experiments 2–10 the evening before Lesson 14 is taught.
10. Experiments 6, 7, and 9 have a time delay in which students will have to wait for the results. These are in Lesson 14. Teachers may want to set up those experiments with the students at the end of Lesson 13, or they could wait until the beginning of Lesson 14 before proceeding with the other experiments. Some experiments will need hot water so the teacher should handle this part of the procedure.
11. Prepare a bulletin board for students to create a collage with pictures of the ways that air works for us.
12. For conducting the experiments, divide the class into 10 groups with 2 or 3 students in each. Assign each group a number (1–10). This allows each group to conduct one experiment for the whole class. Also, students usually feel more comfortable working with a partner, especially when learning new material.
13. **It is recommended that teachers look carefully at the two optional activities for air: "Hot Air Balloons" and "Air Cubes."** Making an air cube helps the students to see the six properties of air at a glance. Making and launching hot air balloons is hard work and time-consuming. Yet, it will be a memorable and exciting experience for students. After all, the first successful endeavor for human flight began with the hot air balloon. Using parent volunteers will make the assembly and launch much easier. Also, consider using the writing activity about a hot air balloon adventure that follows the directions for making and launching the hot air balloons.

Lesson 13—Air Works for Me

Procedure—Lesson 13

1. As students come into class, have them attach their pictures of the ways air works for us on the bulletin board to form a collage. This activity can be ongoing for the next few days.
2. Instruct the students to open their logs to the lists of ways we use air, the homework from Lesson 12. As students contribute their ideas, write these on the board to form a master list. Some ideas may need to be explained. "Air Works for Us," found on page 122, is a master list for teachers.
3. After the discussion, instruct the students to pick 10 more items from the master list to add to their own lists in their logs. (Allow about 2 minutes.)
4. Distribute the "Three States of Matter" chart for students to place in their logs. If students have already studied this material, this should take only a few minutes of review. If not, more practice may be necessary. It might be helpful to name a few objects and ask the students to identify their state of matter. Examples of objects might include desk, milk, tree, oxygen, juice, helium, etc. Continue until it is clear that they understand the defining characteristics of each state.
5. Distribute "The Scientific Process" charts for students to place in their logs. Tell the class that they will be conducting experiments on air using the scientific process. Review the chart and explain each step.
6. Tell the students that they will be reading a selection on air, but first they need to see an experiment to demonstrate the Scientific Process and see the "power of air." Display the transparency of the Demonstration Experiment—Air Power, being sure to cover up the results and the conclusion. Then, direct the students' attention to the candle in the pie pan.
7. After reading the problem, write the students' hypotheses on the board. Conduct the experiment. Discuss the results and the conclusion. Emphasize that air has pressure.
8. Introduce and teach the vocabulary as you would any guided reading.

9. Distribute copies of the student text for Lesson 13, “Air Works for Me,” and have the students insert this in their logs. As the class reads and discusses the text, question their understanding and encourage their questions. Be sure to have the golf ball, the ping-pong ball, the clear plastic cup half full of water, and the index card ready to conduct the suggested comparison and experiment in the student text.
10. Before reading the section, “Molecules on the Loose,” divide the class into three groups. Each group will pretend to be the molecules of one of the three states of matter. Use vocal commands for the students to act out. Solid molecules stand together and vibrate, but do not change positions. Liquid molecules move closely around each other bumping shoulders. Gas molecules move all around the room. As the gas molecules are heated, the molecules (children) move faster and spread out. Some should actually leave the room. As the gases are cooled, the molecules move slower. Children outside the room should reenter. Then finish reading the selection.
11. Distribute the student copies of the Air Experiments 1–10 for students to insert in their logs. It is recommended that these experiments be done as a class and not in individual groups.
12. Assign the students to their groups and give each group their number. Tell them that the number of their group corresponds to the Air Experiment that they will conduct for the class. Instruct the students to move so that they are sitting with their group.
13. Read the problem in Experiment 1. Tell the students that they should help one another and agree on a hypothesis for the group. Allow 2 to 3 minutes for each group to discuss a hypothesis and write it on their individual experiment worksheets.
14. Ask if there is anyone who would like to volunteer his/her hypothesis. This may lead to a brief discussion that is usually fun and amusing. Remind students to show respect since their guesses will differ.
15. Ask Group 1 to perform the experiment. Have them read aloud the procedure and then conduct the experiment step by step. As the class observes what happened, write the result on the board for students to copy.
16. Next, discuss why this happened. Write this conclusion on a piece of chart paper for students to copy. All of the conclusions in this set of experiments will be the properties of air. When the experiments are concluded, six properties of air should be displayed on the chart. (See the student text for a complete list of these properties.) Tell the students that the rest of the experiments will be done in the next lesson.
17. Experiments 6, 7, and 9, in the next lesson, have a time delay. You may want to set these up with the students at this time so they will be ready for the next class period. (See the procedure for each experiment.)

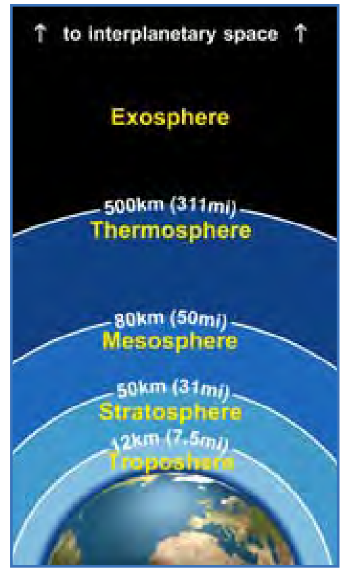
Vocabulary—Lesson 13

air pressure

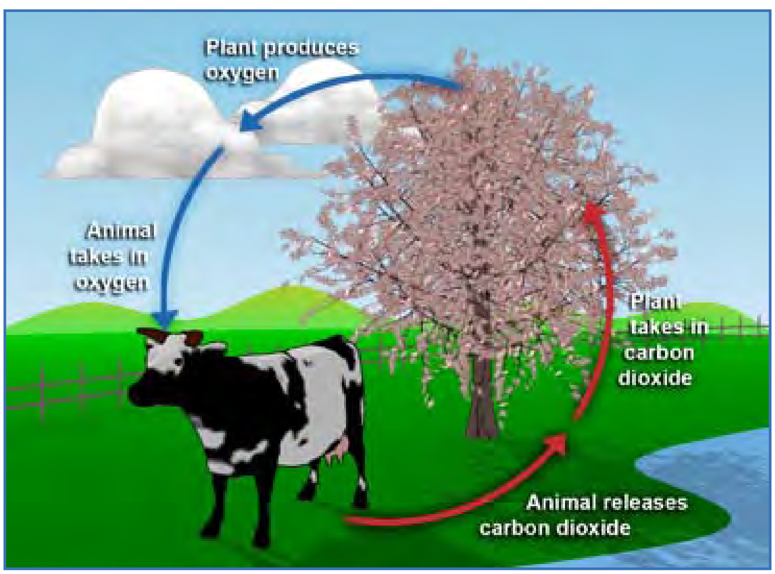
air pressure – the weight or force of air pressing on a surface

atmosphere – the whole mass of air surrounding the Earth

attracts – to pull to or toward oneself (or itself)

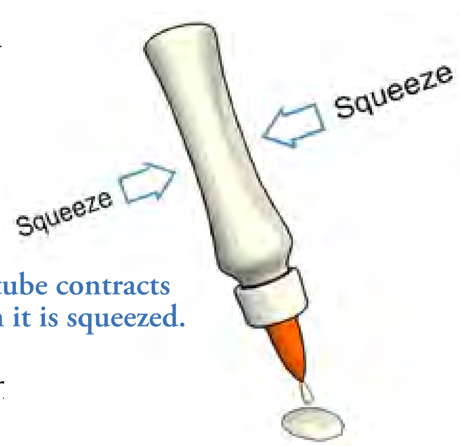


atmosphere



carbon dioxide (cycle)

carbon dioxide – a heavy colorless gas that is formed by animal respiration (the taking in of oxygen and the release of carbon dioxide) and is absorbed from the air by pl

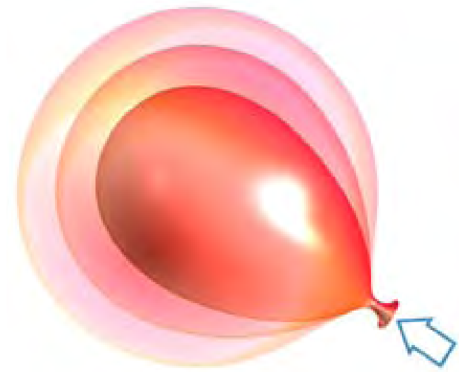


The tube contracts when it is squeezed.

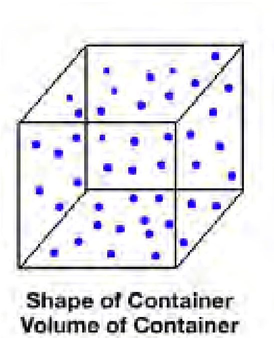
contract – to draw or squeeze together so as to become sr

exerts – to put into action

expand – to increase in size, number, or amount



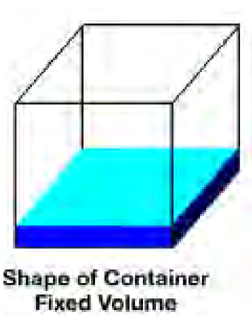
The balloon expands as air is pushed inside it.



gas

gas – a fluid, such as air, that has no fixed shape and tends to expand without limit

gravity – the force of attraction that makes objects fall toward the Earth



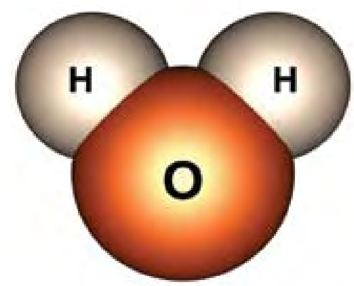
liquid

liquid – the state of matter neither solid nor gaseous in which a substance flows freely like water

mass – the amount of matter contained within an object

mass
The apple has more mass than the pencil because it contains more matter.

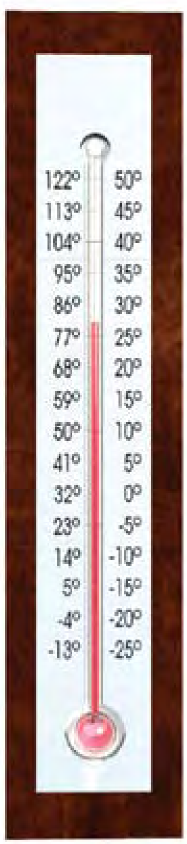
matter – the substance of which a physical object is composed; the material substance that occupies space, has mass, and makes up the observable universe



water molecule, H_2O

molecule – the smallest particle of a substance having all the characteristics of the substance

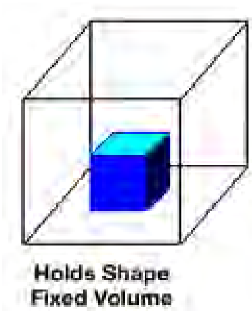
pressure – the application of force over a surface area



A thermometer is used to measure the temperature of an object to see how hot or cold it is.

Scientific Process (Scientific Method) – a systematic way of solving a problem or answering a question using observation and measurement. The five steps of the Scientific Process are: state the problem, create a hypothesis, perform the experiment, organize and analyze the results, and draw conclusions.

solid – a state of matter in which the molecules stay in a fixed position; a substance that keeps its size and shape



solid

temperature – the degree of hotness or coldness

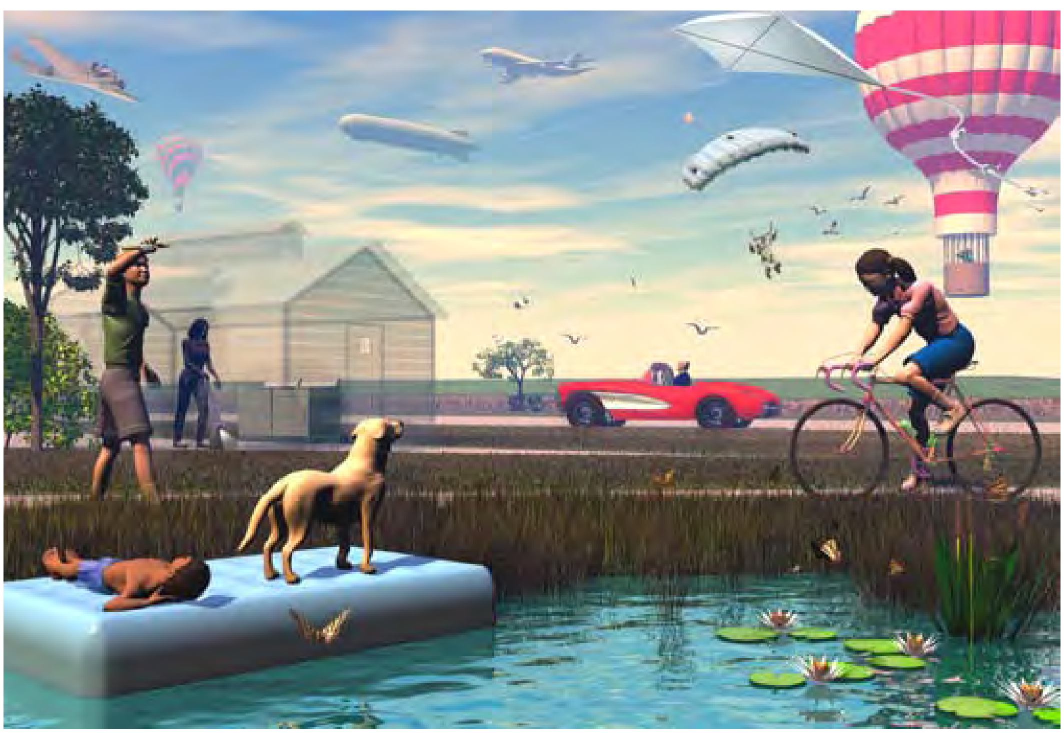
Student Text—Lessons 13

Air Works for Me

We Can't Live Without It

Did you know that we live at the bottom of an ocean? It is an ocean of air. We take the air around us for granted. We can't see it. We only feel it or notice it when the wind blows. So why pay any attention to it? We all know that air is necessary for life. Animals need the oxygen in air. Plants need the **carbon dioxide** in air.

The Earth's atmosphere is like an ocean of air.

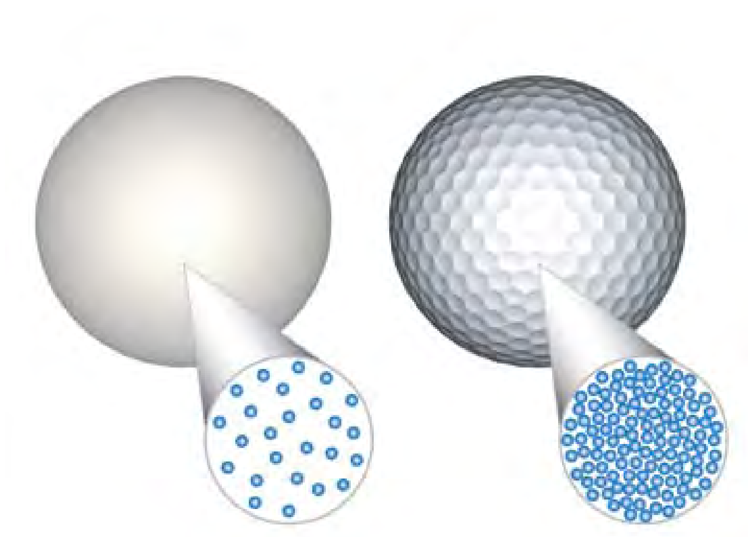

Find the ways air works for us in this picture.

Air is important to us in many other ways, too. It dries our clothes and vacuums our floors. It lifts kites and airplanes. We ride on it and can even sleep on it. As you explore all the ways air works for you, you may be surprised.

Air, Space, and Mass

Air is not just empty space. Ir fact, air takes up space. Blow a balloon. That stuff filling th balloon is air! It is taking up a space inside! We should be gl air takes up space. Soccer ball basketballs, volleyballs, and o sports items depend on air. H about our bicycle tires? We ri on the air that we pump in th

Air also has **mass**. Mass means how much **matter** is in something. Compare a ping-pong ball to a golf ball. They are about the same size. But the ping-pong ball is filled with a gas. The gas **molecules** are far apart. The golf ball is a solid. The molecules are close together. So, we would say that the golf ball has more mass because it has more molecules.



The ping-pong ball has less mass than the golf ball.

Air Is Pushy

Air is matter. It takes up space and it has mass. Because air has mass, Earth's gravity **attracts** it and gives it weight. And because it has weight, it presses on things—it **exerts pressure**. Think about it. You have mass. Your body is made up of millions of molecules. That means Earth's **gravity** gives you weight. Because you have weight, you exert pressure. Right now, you are probably sitting on a chair, a desk, or the floor. Therefore, you are exerting pressure on the chair, the desk, or the floor. Wherever you go, you exert pressure because you have weight.

Earth's gravity gives air weight.

The seated students are exerting pressure on their desks.

The pressure, or push, caused by air is called **air pressure**. Air pressure is a very strong force. It can make a hot air balloon rise into the sky. It can crush a can. It can hold water in a glass that is upside down. Try the following experiment.

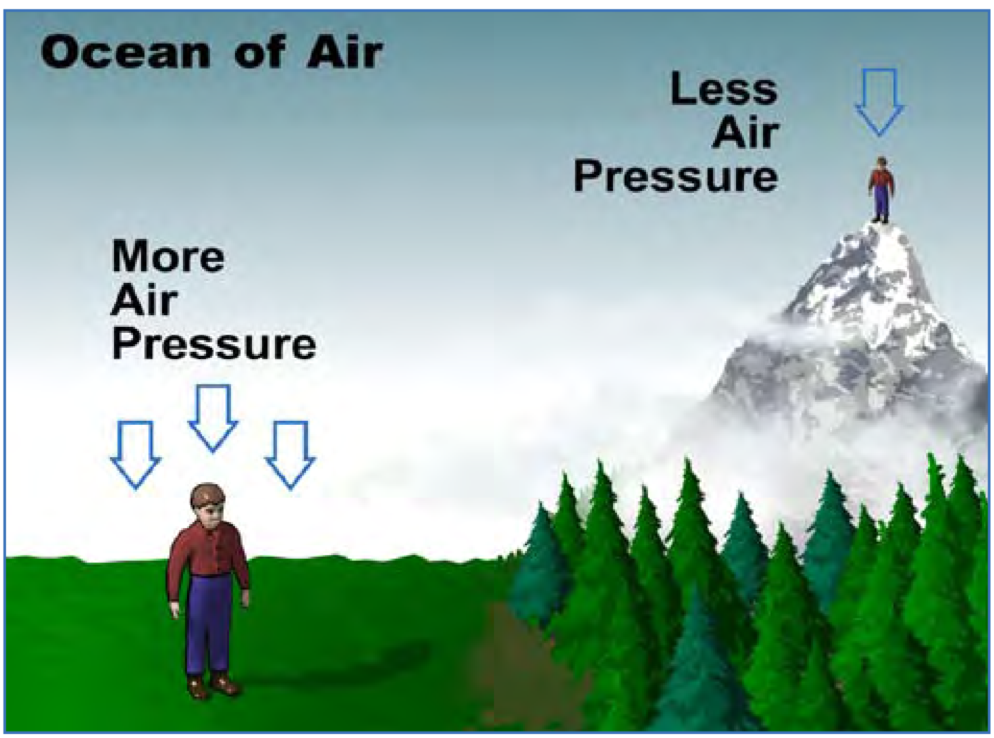
Air pressure is all around us and pushes in all directions.

Is This Magic?

Try this experiment.

Fill a plastic cup half-full of water. Take some of the water and rub it along the rim of the cup to make a good seal. Lay an index card on top. Lay your hand on the index card and turn the cup upside down. Take your hand away. The air pressure will hold the water in the cup!

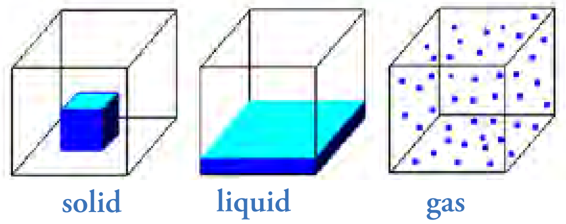
Since we are sitting at the bottom of an ocean of air, the air is always pressing on us. Air pressure changes as you go higher or lower in the **atmosphere**. As you travel higher in the sky, air pressure goes down. This is because the higher you go, the less air there is pressing down on you from above.



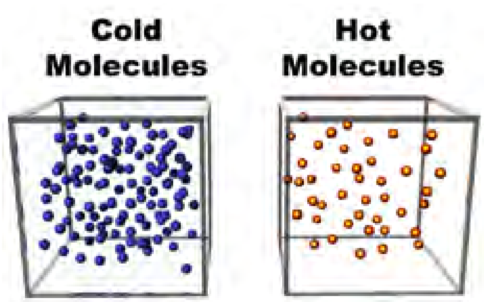
an ocean of air

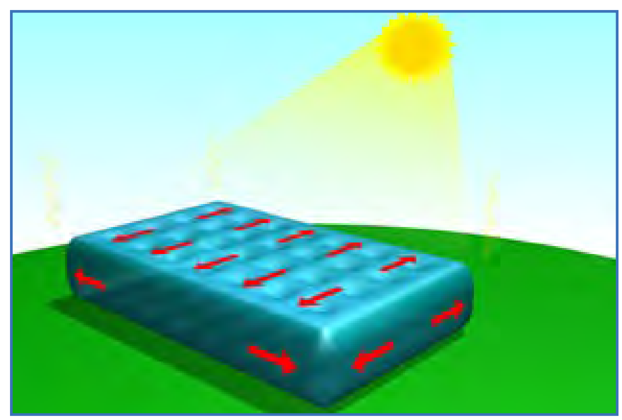
Picture yourself at the bottom of the ocean of air. All of the air above you is pushing on you. Now, picture yourself at the top of a very high mountain. There is less air above you. So there is less pressure on you.

Molecules on the Loose



Air, of course, is a **gas**. Gases are not like **solids** and **liquids**. Solids have a definite shape. The molecules are packed tightly together and stay in one place. Liquids have no definite shape of their own. The molecules are farther apart and they move and slide over each other. They take the shape of the container they are in. Water in a glass takes the shape of the glass. Pour the water out and it goes all over the place. It has no shape. A gas has no definite shape either. Air molecules move about freely. They will spread out to fill the container they are in. Have you ever tried to catch air in your hands? Forget it! It's impossible!

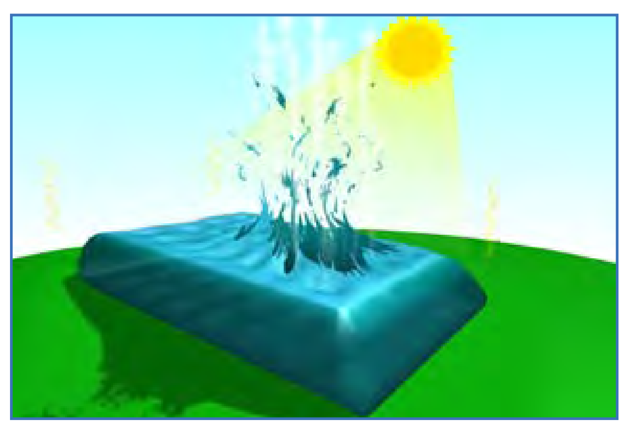




Hot molecules inside an air mattress spread and push until ...

Hot and Cold Changes

Air molecules are affected by **temperature**. In cold air, the molecules move more slowly. They are also closer together. When the air is hot, the molecules move quickly. Then they spread out, or **expand**, so that they are farther apart. If you leave an air mattress in the sun, it will burst. The air inside gets hot. The molecules spread out and push



... Boom!

on the mattress until… Boom! It's also why some windows in a closed-up car can break. The sun heats the cool air inside the car. The molecules spread out until they have no place to go. So, they push out and the window breaks. How could you keep this from happening to your car?

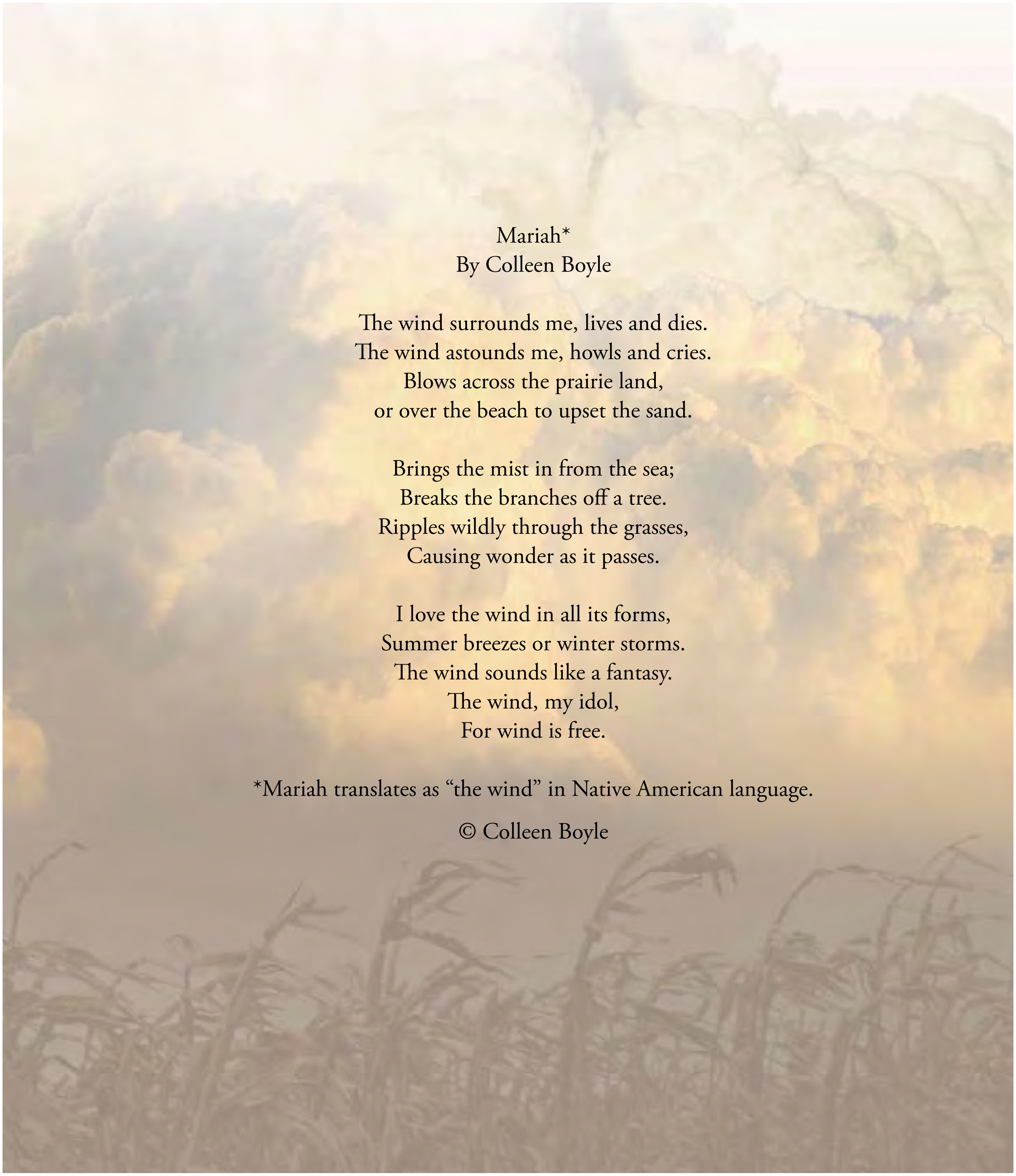

windows in a closed up car

Because it has fewer molecules, hot air has less mass than the same volume of cold air. So, a certain amount of hot air is lighter in weight than that same amount of cold air. Because it's lighter, hot air rises. So, why does smoke rise? Think about a hot air balloon. The air inside is hot and the air outside is cold. Do you see why it goes up? We will use the steps of the "**Scientific Process**" to conduct experiments. These experiments will help us discover six properties of air.

hot air balloon

Properties of Air

1. Air takes the shape of its container.
2. Air takes up space (has volume).
3. Air has mass. Gravity attracts this mass and gives it weight.
4. Air exerts pressure. We call this air pressure.
5. Hot air expands and cold air **contracts**.
6. Hot air rises.



Mariah*
By Colleen Boyle

The wind surrounds me, lives and dies.
The wind astounds me, howls and cries.
Blows across the prairie land,
or over the beach to upset the sand.

Brings the mist in from the sea;
Breaks the branches off a tree.
Ripples wildly through the grasses,
Causing wonder as it passes.

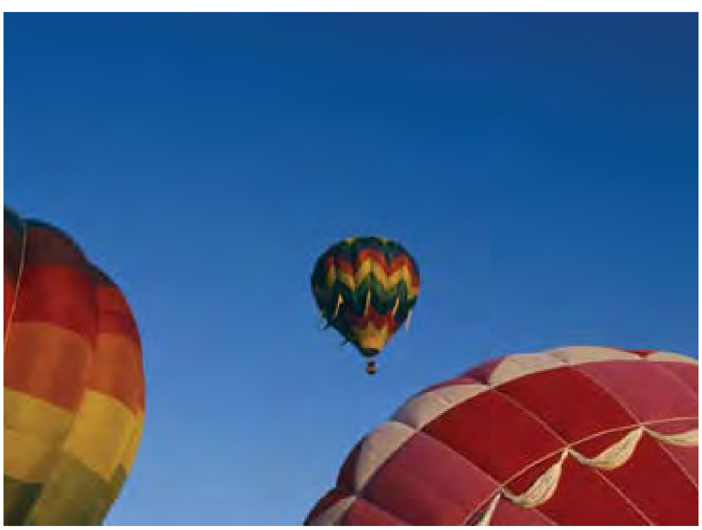
I love the wind in all its forms,
Summer breezes or winter storms.
The wind sounds like a fantasy.
The wind, my idol,
For wind is free.

*Mariah translates as “the wind” in Native American language.

Lesson 14—Discovering the Properties of Air

Procedure—Lesson 14

1. Instruct the students to take out their logs and turn to Air Experiment 2. Ask them to get their pencils then move to sit in their groups.
2. Follow the same procedure that was used for the first experiment on each of the remaining experiments. The teacher should read the problem aloud. Then allow 2 or 3 minutes for the groups to discuss and complete the hypothesis. After that, ask students to share their hypotheses and discuss why they think this will happen.
3. Next, call up the group that will be conducting the experiment. They will read the procedure aloud and then conduct the experiment step by step.
4. Let the students share what they observed. Write the results on the board for students to copy.
5. Discuss why this happened and write the conclusion on the chart (if it is different from previous conclusions) for students to copy. Remember, there should be six properties of air when the experiments are completed.
6. When all of the experiments are completed, review the chart on the properties of air and tell them that they will need to understand these as they continue their study of flight.
7. Hopefully, teachers will use the next two science lessons for the assembly and launch of hot-air balloons.



Optional Activity—Hot Air Balloon

Assembly

Prep time: 15 minutes

Teaching time: (1–1½ hours)

Pre-assembly Suggestion (30–45 minutes)

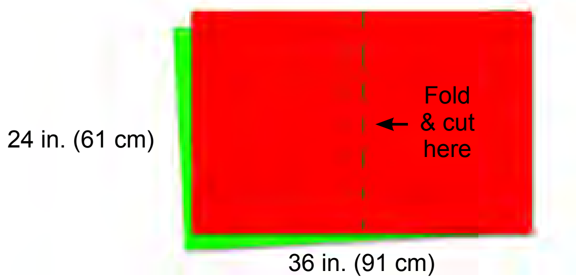
1. Ask for parent volunteers to help each group. It may be a good idea to invite these parents to come after school the day before assembling the balloons. Make a balloon together so they will understand the instructions and feel confident to help the students the next day. This will take approximately 30–45 minutes.
2. Divide the class into groups of three or four students. Each group will make a balloon. Hopefully, an adult will assist each group.
3. Duplicate enough copies of the "Instructions for Assembling Hot Air Balloons" so that each group has a set.

Materials for each group

- 7 sheets of 24- by 36–inch (61- by 91.4-centimeter) tissue paper. (Use 2 or 3 colors.)
- 1 glue stick.
- Scissors.
- 4 pennies.
- A copy of the "Instructions for Assembling Hot Air Balloons."

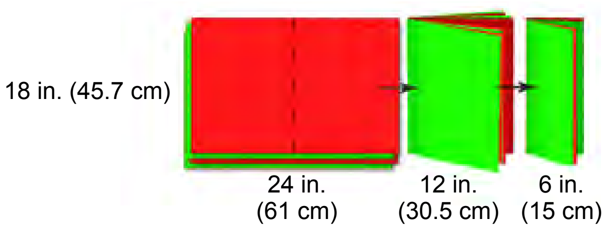
Instructions for Assembling Hot Air Balloons

1. Fold two sheets of different colors of tissue paper in half.



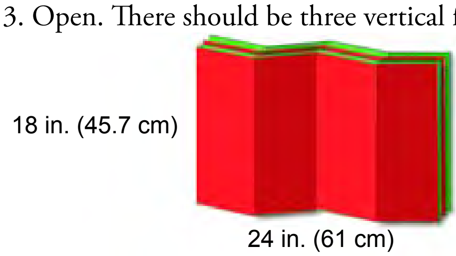
Cut both sheets on the fold.

2. Place these four sheets on top of one another and fold



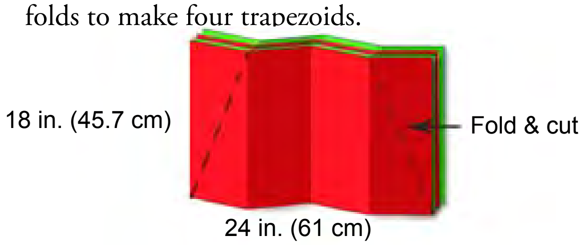
in half again. Then fold in half (lengthwise) again.

3. Open. There should be three vertical folds dividing

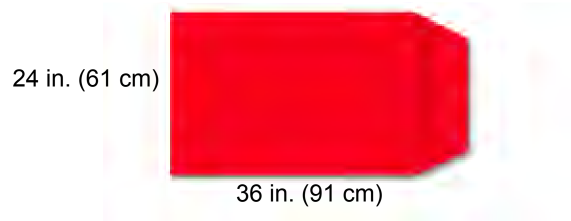


the paper into four equal panels.

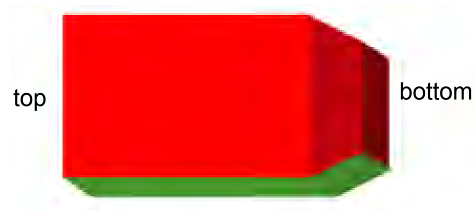
4. On the far right panel, make a diagonal fold from the bottom right corner to the top of the nearest fold. On the far left panel, make a diagonal fold from the bottom left corner to the top of the nearest fold. You should now see the shape of a trapezoid. Cut on the outer diagonal folds to make four trapezoids.



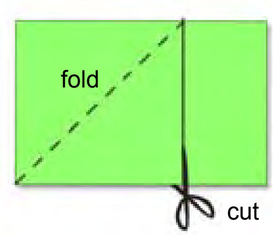
5. Lay a large (uncut) sheet of tissue paper out on the table. Glue the long side of the trapezoid to the bottom of the sheet. They should match up to be the exact length. Repeat this process until each of the four large sheets has a trapezoid glued to the bottom. Make sure the glue is thick and continuous so that no air can escape.



6. Glue the four panels together so that they become the sides of the balloon. Then glue the four trapezoids together so that they form a funnel-like opening at the bottom. Again, make sure that the glue is thick and continuous.



7. Using the last sheet, take the upper right corner and fold it over diagonally until it touches the bottom edge and the two bottom edges line up. Cut along the left edge of this folded triangle so that the rest of the panel becomes detached. Open the triangle to produce a square.



8. Thoroughly glue this square onto the four panels to form the top of the balloon.
9. Tape four pennies at the bottom where the edges of each trapezoid meet.
10. Let the glue dry over night.

Launch

Prep time: Ask parents to set this up before bringing the class outside.

Teaching time: 45 minutes–1 hour

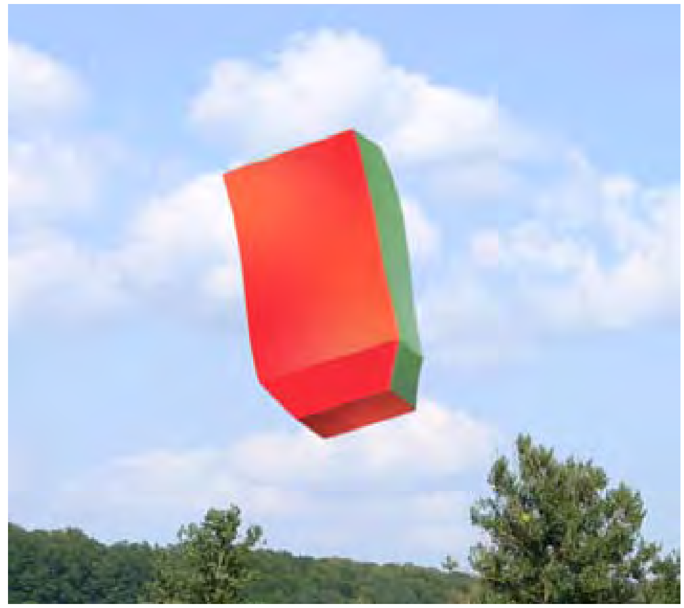
Materials

- One or two camp stoves (Coleman, etc.); usually parents can help with this.
- For each stove, purchase a 2-foot (0.6-meter) length of regular stovepipe.
- Pot holder mitts (4 per stove).

Instructions for Launching Hot Air Balloons

- Light the stove and bring to a moderately high temperature. Set the stovepipe directly onto the surface.
- Hopefully, the parent volunteer for each group will be present to help their group launch the balloon. Using pot holder mitts hold the balloon over the mouth of the stovepipe and have the students count to 80. This number varies with the outside temperature.
- When the balloon is full of air and the tissue paper is quite warm to the touch, let it go.

hot air balloon launch



student hot air balloon

Writing Activity: Have the students write a story about a hot air balloon adventure either in first or third person. In the pre-writing discussion, tell the students to first think of the setting, characters, and plot for their stories. Remind them that the plot is in three parts – the problem the character(s) encounters, what the character(s) does to solve the problem, and how the problem is solved. When they are ready to write the final draft, consider giving out drawing paper cut in the form of a hot air balloon with lines on the bottom half leaving the top for illustrations. Tell them to write and illustrate the story on this paper. Provide each student two pieces of heavier paper cut in the form of the same hot air balloon, but a little larger, to use as a cover. Provide some pictures of hot air balloons shown in many different colors and patterns and have the students decorate the cover with their own design.

hot air balloon cutout

Optional Activity—Air Cubes

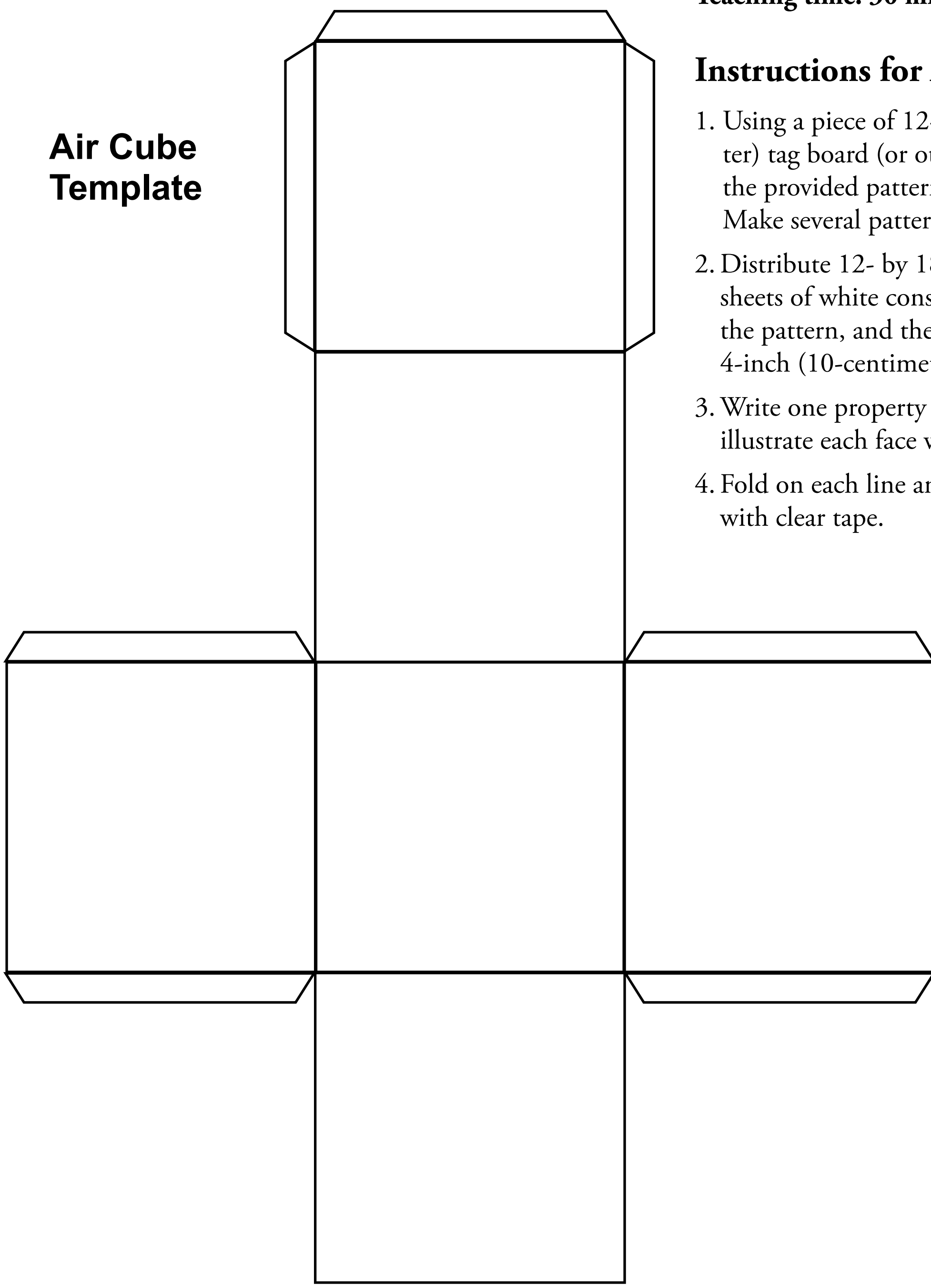
Prep time: 10 minutes

Teaching time: 30 minutes–1 hour

Instructions for Assembling

1. Using a piece of 12- by 18-inch (30.5- by 45.7-centimeter) tag board (or other stiff paper for patterns), enlarge the provided pattern to 4-inch (10-centimeter) squares. Make several patterns.
2. Distribute 12- by 18-inch (30.5- by 45.7-centimeter) sheets of white construction paper. Have students trace the pattern, and then draw lines to complete each 4-inch (10-centimeter) square.
3. Write one property of air on each face. If time allows, illustrate each face with an example.
4. Fold on each line and tuck in the tabs. Glue or tape with clear tape.

Air Cube Template



Air Works For Us

People/animals
Plants
Balls
Tires
Balloons
Hot air balloons
Submarines
Helicopters
Airplanes
Wind tunnels
Air conditioners
Waves/surfing
Sailboats
Pumps
Scuba divers
Bubbles

Musical instruments
Air mattresses
Running
Skydiving
Parachutes
Hang gliding
Bicycle/motorcycle
Horns
Weather/clouds
Birds
Gliders
Blimps
Weather balloons

Car airbags
Whistles
Fire
Rubber rafts
Fans
Kites
Clothes dryers
Hair dryers
Vacuum cleaners
Spreading seeds
Windmills
Hovercraft
Air guns
Air compressors
Straws

The Scientific Process

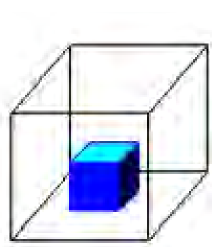
Problem	=	**Question.**
Hypothesis	=	**Guess the answer.**
Procedure	=	**Steps to follow when testing.**
Results	=	**What happened?**
Conclusion	=	**Why the results happened.**

The Scientific Process is a model for conducting experiments. It guides our thinking as we follow the steps. We begin by identifying the **Problem**. Then we use our prior knowledge to guess the answer. This "educated guess" is called the **Hypothesis**. Next, we conduct the experiment to test the hypothesis. This is called the **Procedure**.

After the experiment, we record the **Results**. The results are a summary of what happened in the experiment. Finally, we study the results to draw a **Conclusion**. The conclusion is important. It is the explanation of what happened in the experiment. The conclusion will prove or disprove our hypothesis. It ties everything together and answers our problem.

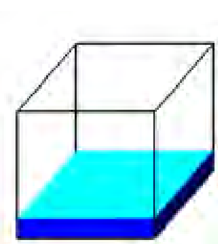
Three States of Matter

Solids	Liquids	Gases
A solid has a definite shape of its own.	A liquid has no definite shape of its own. It takes the shape of the container it is in.	A gas has no definite shape of its own. It takes the shape of the container it is in.
The molecules are packed tightly together.	The molecules are farther apart.	The molecules are far apart.
The molecules are arranged in regular patterns.	The molecules are not in any particular pattern or order.	The molecules are free to move about.
Even though the molecules vibrate, they stay in a fixed position.	The molecules are free to move and slide over each other.	Because the molecules are free, they spread out to fill the container they are in.



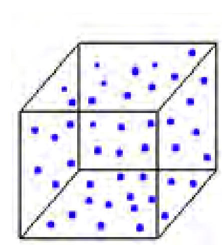
solid

Holds Shape
Fixed Volume



liquid

Shape of Container
Free Surface
Fixed Volume



gas

Shape of Container
Volume of Container

Demonstration Experiment—Air Power

Problem:

What will happen when a burning candle is placed in a pie pan filled with water and then covered with a tall glass jar?

Hypothesis:____

Materials:

- Pie pan or other shallow pan (or dish).
- Candle.
- Modeling clay.
- Tall, clear, glass jar (taller than candle and flame).
- 1½ cups water.

Procedure:

1. Stick the candle to the middle of the pan with a piece of modeling clay.
2. Pour the water into the pan.
3. Have an adult light the candle.
4. Place the jar over the candle and watch what happens.

Results:

The flame went out and the water was pushed up into the jar.

Conclusion:

The candle went out when all of the oxygen in the jar was used. Because the air in the jar was heated, it expanded and escaped into the water leaving fewer air molecules in the jar. As the air inside cooled, it contracted. The outside air pressure was greater than the inside air pressure and pushed down on the water in the pan forcing it up into the jar.

Air Experiments—Teacher Copies

Air Experiment 1—Perfume Spray

Problem:
What will happen when perfume is sprayed into a room?

Materials:
- 1 bottle of inexpensive, strong-smelling perfume.

Hypothesis:
The perfume will ______________________________

Procedure:
(Student procedure reflects directions to classmates.)
1. Instruct the students to gather at one end of the classroom.
2. Walk to the opposite end of the classroom, and spray the perfume two or three times.
3. Tell the students to raise their hands when they smell the perfume.
4. Invite them to move to other areas of the room to find out if the perfume can be smelled there as well.

Results:
The perfume could be smelled throughout the room.

Conclusion:
This happened because air takes the shape of the container it is in and spreads out to fill the container.

Air Experiment 2—No Way In

Problem:
What will happen to a paper towel in a cup when the cup is inverted and placed in a pan of water?

Materials:
- 1 paper towel.
- 1 plastic cup.
- 1 small pan or bucket filled with water.

Hypothesis:
The paper towel will ______________________________

Procedure:
1. Crumple a paper towel and stuff it in the bottom of the cup.
2. Turn the cup upside down (perfectly vertical) and submerge it in the pan.
3. Pull the cup out and check the paper towel.

Results:
The paper towel stayed dry.

Conclusion:
This happened because air takes up space. The air is trapped inside the cup and there is no room for the water to get in. The cup was full of air even though we cannot see it.

Air Experiment 3—Blow Hard

Problem:
What will happen to a balloon in a bottle when you blow into it?

Materials:
- 1 clear plastic bottle (2-liter soda bottle).
- 1 balloon (helium quality).

Hypothesis:
The balloon in the bottle will ______________________

Procedure:
1. Push the deflated balloon into the bottle and stretch the open end of the balloon back over the bottle's mouth.
2. Blow as hard as you can into the balloon.

Results:
The balloon in the bottle did nothing. It did not inflate.

Conclusion:
This happened because air takes up space and the bottle is full of air. When you try to blow up the balloon, the air trapped inside of the bottle prevents the balloon from inflating.

Note:
Trick your class! Before discussing the conclusion with the class, bring out another bottle with a balloon placed inside—just like the experiment. But before class, make a tiny hole in the bottom of this bottle. When you blow into the balloon, it will inflate. This will, of course, puzzle the students. See if they can figure out why your balloon inflates.

Air Experiment 4—Balancing Act

Problem:
What will happen when you have two balloons hanging from a ruler and you pop one of them?

Materials:
- 2 balloons inflated to the same size.
- 3 pieces of string, each about 14 inches (36 centimeters) long.
- A 12-inch (30.5-centimeter) ruler.
- Balance scale for Follow-up Activity.

Hypothesis:
The balloons will ______________________________

Procedure:
1. Inflate the balloons so that they are the same size.
2. Tie a string to each balloon.
3. Tie a string to the center of the ruler so that it is balanced.
4. Tape or tie each balloon to opposite ends of the ruler so the balloons balance.
5. Hold the string that is tied to the center and pop one of the balloons.

Results:
The balloons became unbalanced.

Conclusion:
This happened because air has mass. When the balloon was popped, all of the air inside was lost. The balloon lost mass. The inflated balloon still had air inside, so it was heavier, causing the ruler to tip down on the side of the heavy balloon.

Follow-up Activity:
1. Inflate two balloons so that they are the same size.
2. Place the balloons on either side of the balancing scale.
3. Pop one and observe.
4. Discuss what happened and why.

Air Experiment 5—Real Paper Weight

Problem:
What will happen to a piece of paper when a ruler is placed under it and then hit by your hand?

Materials:
- A 12-inch (30.5-centimeter) ruler.
- A 12- by 18-inch (30.5- by 45.7-centimeter) piece of paper.

Hypothesis:
The piece of paper will __________________________

Procedure:
1. Place a ruler on a table so that part of it sticks out over the side of the table.
2. Cover the part of the ruler on the table with a large sheet of paper.
3. Hit the part of the ruler hanging over the edge with your hand.

Results:
The piece of paper held the ruler down to the table.

Conclusion:
This happened because air exerts pressure. The ruler will be held to the table because the weight of the air pressing down on the paper resists being pushed up suddenly.

Follow-up Activity:
Older students may enjoy calculating the force exerted by the air pressure on the paper. Find the area of the paper in square inches. Multiply that number by 14.7 to determine the force (in pounds) of the air pressure on the entire surface of the paper.

Air Experiment 6—Brrrrrr

Problem:
What will happen to a balloon when it is placed in a refrigerator for a while?

Materials:
- 1 balloon (helium quality).
- A cloth or soft plastic measuring tape.
- Access to a refrigerator.

Hypothesis:
The balloon will ________________________________

Procedure:
1. Inflate a balloon and tie it shut.
2. Measure and record the distance around the balloon. (You can also tie a string around it so that the results will be more visible.)
3. Put the balloon in the refrigerator for at least 1 hour (or overnight).
4. Remove the balloon from the refrigerator and measure it again.
5. Compare the measurements.
   BEFORE_________AFTER__________

Results:
The balloon became smaller.

Conclusion:
This happened because cold air contracts. The density of air molecules and the speed at which they move is affected by temperature. Air contracts when it is cold and expands when it is hot. The balloon decreased in size because the air inside got cooler and contracted.

Air Experiment 7—Money Freeze

Problem:
What will happen to a wet nickel when it is placed on top of a soda bottle that has been in the freezer for at least 30 minutes?

Materials:
- 1 soda bottle (glass is best).
- 1 nickel.
- Water.
- Access to a freezer.

Hypothesis:
The nickel will __________________________________

Procedure:
1. Place an empty soda bottle in the freezer for at least 30 minutes.
2. Take it out and immediately cover the mouth with a wet nickel.
3. Wet your fingers and let the water drip around the edge of the nickel to form a seal. Now just wait and watch!

Results:
The nickel made a popping sound.

Conclusion:
This happened because cold air contracts and hot air expands. Inside the freezer, the cold air in the bottle contracts and takes up less space. This allows the bottle to hold more air. Once outside the freezer, the bottle warms, and the cold air inside warms and expands. The expanding air pressure causes the nickel to lift and fall back down as the air escapes.

Air Experiment 8—Balloon Magic

Problem:
What will happen to a balloon that has been stretched over the neck of a bottle when the bottle has been placed in hot water?

Materials:
- 1 balloon (helium quality).
- 1 plastic soda bottle.
- 1 pan of very hot water.

Hypothesis:
The balloon will ________________________________

Procedure:
1. Stretch a rubber balloon over the neck of an empty soda bottle.
2. Place the bottle into a pan of very hot water.
3. Watch.

Results:
The balloon filled with air.

Conclusion:
This happened because hot air expands. When the hot water heats the air trapped in the bottle, the air will expand. The air will fill the balloon as the air molecules move around faster and expand.

Air Experiment 9—Thermometer Reading

Problem:
What will happen when you place one thermometer near the ceiling and one near the floor?

Materials:
• 2 thermometers.

Hypothesis:
The thermometers will ____________________________

Procedure:
1. Place one thermometer near the ceiling and one near the floor.
2. Wait 15 minutes (or more) and check the temperature of each.
3. Compare the temperatures.

Results:
The temperatures were different. The temperature at the ceiling is higher than the temperature near the floor.

Conclusion:
This happened because hot air rises. Hot air expands and becomes less dense. Because it is less dense, it is lighter than cold air and it rises. The hot air in the room has risen toward the ceiling so the temperature there is higher.

Follow-up Activity:
1. Ask a student to hold a plastic bag upside down (open end pointed down). A long tube-shaped bag (bag for wet umbrellas) works best.
2. The teacher will point a hairdryer into the bag and turn it on warm or low for a few seconds.
   CAUTION: Do not touch the end of the dryer.
3. Turn the dryer off and tell the student to let go of the bag.
4. Repeat steps 1–3, but set the dryer on hot.
   USE CAUTION!

Air Experiment 10—Bottle It Up

Problem:
What will happen to a sealed plastic bottle when the air inside is heated and then allowed to cool?

Materials:
• A 1-gallon plastic milk bottle with a cap.
• Very hot water.

Hypothesis:
The bottle will ____________________________________

Procedure:
1. Fill the plastic bottle a little over half full of very hot water and allow it to sit for 1 minute.
2. Pour the water out and put the cap back on quickly.

Results:
The bottle collapsed.

Conclusion:
This happened because air exerts pressure. The hot water heats the air in the bottle causing it to expand. Some of it escapes out of the top. When the water is poured out and the bottle is sealed, the air that is left inside starts to cool and contract. Since there is less air in the bottle, it has less pressure than that on the outside. The outside pressure pushes the bottle inward causing it to collapse.

Air Experiment 1—Perfume Spray

Problem:

What will happen when perfume is sprayed into a room?

Hypothesis:

The perfume will ______________________

Procedure:

1. Instruct your classmates to gather at one end of the classroom.
2. Now you go to the opposite end of the classroom, and spray the perfume two or three times.
3. Tell your classmates to raise their hands when they smell the perfume.
4. Invite them to move to other areas of the room to find out if the perfume can be smelled there as well.

Results:

The perfume ____

Conclusion:

This happened because ____

____

____

Air Experiment 2—No Way In

Problem:

What will happen to a paper towel in a cup when the cup is inverted and placed in a pan of water?

Hypothesis:

The paper towel will ______________________

____

Procedure:

1. Crumple a paper towel and stuff it in the bottom of the cup.
2. Turn the cup upside down (perfectly vertical) and submerge it in the pan.
3. Pull the cup out and check the paper towel.

Results:

The paper towel ____

Conclusion:

This happened because ______________________________________

____

____

____

Air Experiment 3—Blow Hard

Problem:

What will happen to a balloon in a bottle when you blow into it?

Hypothesis:

The balloon in the bottle will ______

____

Procedure:

1. Push the deflated balloon into the bottle and stretch the open end of the balloon back over the bottle's mouth.
2. Blow as hard as you can into the balloon.

Results:

The balloon in the bottle ________________________________

Conclusion:

This happened because ________________________________

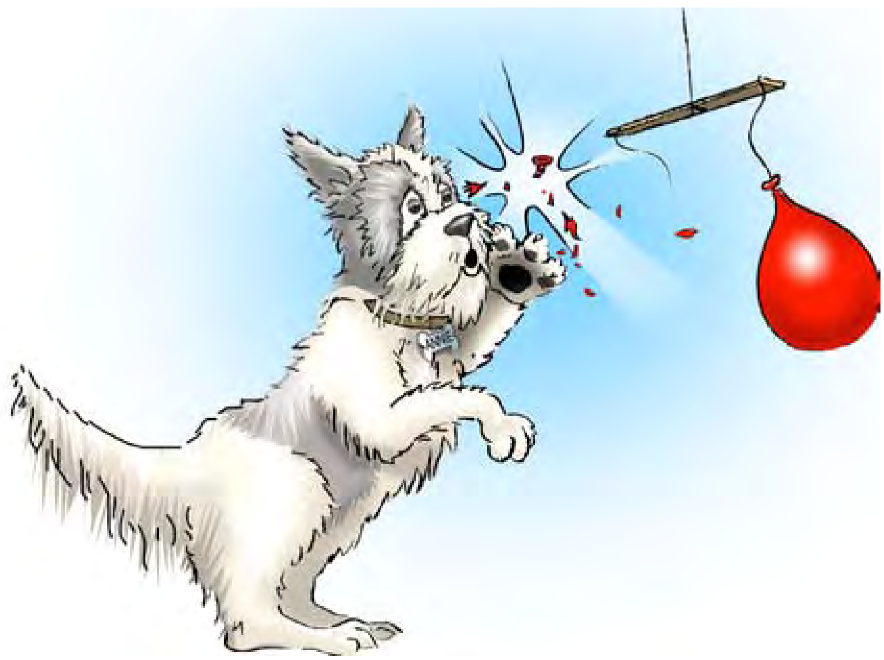
____

____

Air Experiment 4—Balancing Act

Problem:

What will happen when you hav
hanging from a ruler and you po



Hypothesis:

The balloons will ____________

____

____

Procedure:

1. Inflate the balloons so that they are the same size.
2. Tie a string to each balloon.
3. Tie a string to the center of the ruler so that it is balanced.
4. Tape or tie each balloon to opposite ends of the ruler so the balloons balance.
5. Hold the string that is tied to the center and pop one of the balloons.

Results:

The balloons ____

Conclusion:

This happened because ____

____

Follow-up Activity:

1. Inflate two balloons so that they are the same size.
2. Place the balloons on either side of the balancing scale.
3. Pop one and observe.
4. Discuss what happened and why.

Air Experiment 5—Real Paper Weight

Problem:

What will happen to a piece of paper when a ruler is placed under it and then hit by your hand?

Hypothesis:

The piece of paper will ______________
____

Procedure:

1. Place a ruler on a table so that part of it sticks out over the side of the table.
2. Cover the part of the ruler on the table with a standard size sheet of paper.
3. Hit the part of the ruler hanging over the edge with your hand.

Results:

The piece of paper ____

Conclusion:

This happened because ____
____
____

Air Experiment 6—Brrrrrr

Problem:

What will happen to a balloon when i is placed in a refrigerator for a while?

Hypothesis:

The balloon will_______________

____

Procedure:

1. Inflate a balloon and tie it shut.
2. Measure and record the distance around the balloon. (You can also tie a string around it so that the results will be more visible.)
3. Put the balloon in the refrigerator for at least 1 hour (or overnight).
4. Remove the balloon from the refrigerator and measure it again.
5. Record and compare the measurements. BEFORE_________ AFTER_________

Results:

The balloon ____

Conclusion:

This happened because ______________________________________

____

____

Air Experiment 7—Money Freeze

Problem:
What will happen to a wet nickel when it is placed on top of a soda bottle that has been in the freezer for at least 30 minutes?

Hypothesis:
The nickel will ______________
____

Procedure:
1. Place an empty soda bottle in the freezer for at least 30 minutes.
2. Take it out and immediately cover the mouth with a wet nickel.
3. Wet your fingers and let the water drip around the edge of the nickel to form a seal.
4. Wait and watch!

Results: The nickel____

Conclusion:
This happened because ____
____

Air Experiment 8—Balloon Magic

Problem:

What will happen to a balloon that has been stretched over the neck of a bottle when the bottle has been placed in hot water?

Hypothesis:

The balloon will ________________
____

Procedure:

1. Stretch a rubber balloon over the neck of an empty soda bottle.
2. Place the bottle into a pan of very hot water.
3. Watch.

Results:

The balloon ____

Conclusion:

This happened because ____
____

Air Experiment 9—Thermometer Reading

Problem:

What will happen when you place one thermometer near the ceiling and one near the floor?

Hypothesis:

The thermometers will ________

____

Procedure:

1. Place one thermometer near the ceiling and one near the floor.
2. Wait 15 minutes and check the temperature of each.
3. Compare the temperatures.

Results:

The temperatures ____

Conclusion:

This happened because ____

____

____

Follow-up Activity:

1. Hold a plastic bag upside down (open end pointed down).
   A long tube-shaped bag (bag for wet umbrellas) works best.
2. Ask the teacher (or another adult) to point a hairdryer into the bag and turn it on warm or low for a few seconds. CAUTION: Do not touch the end of the dryer.
3. Turn the dryer off and let go of the bag.
4. Repeat steps 1–3, but set the dryer on hot. USE CAUTION!

Air Experiment 10—Bottle It Up

Problem:

What will happen to a sealed plastic bottle when the air inside is heated and then allowed to cool?

Hypothesis:

The bottle will ___________

Procedure:

1. Fill the plastic bottle a little over half full of very hot water and allow it to sit for 1 minute.
2. Pour the water out and put the cap back on quickly.

Results:

The bottle____

Conclusion:

This happened because ____

____

____

____

____

Activity Eight—The Four Forces of Flight

Lessons 15–19

Activity (Lessons 15–19) prep time:
1½ hours + 10–15 minutes for each lesson
(for gathering materials and following pre-lesson instructions)

Teaching time:

Lesson 15: 1½ hours
(Science, Language Arts)

Lesson 16: 1½ hours
(Science, Language Arts)

Lesson 17: 1½–1¾ hours
(Science, Language Arts)

Lesson 18: 1 hour
(Science, Language Arts)

Lesson 19: 1–1¼ hours
(Science)

Objectives—Lessons 15–19

1. The students will read about and participate in activities that demonstrate the four forces of flight.
2. The students will conduct scientific experiments to predict and verify information.
3. The students will conduct experiments that demonstrate the force of gravity showing that gravity is the natural force that pulls objects toward Earth and gives them weight.
4. The students will conduct experiments that demonstrate the force of lift that acts on an airplane in the atmosphere, showing that faster moving air has less pressure than slower moving air (i.e., Bernoulli's Principle).
5. The students will conduct experiments that demonstrate the force of thrust that acts upon an airplane in the atmosphere, showing that, for every action, there is an equal and opposite reaction (i.e., Newton's Third Law of Motion).
6. The students will conduct experiments that demonstrate the force of drag that acts upon an airplane in the atmosphere, showing that friction pushes against a moving object to slow it down.

National Standards—Lessons 15–19

Science

- Abilities necessary to do scientific inquiry—S2Ea, S2Ma.
- Understandings about scientific inquiry—S2Eb, S2Mb.
- Position and motion of objects/Motion and forces—S3Eb, S3Mb.
- Properties of Earth materials—S5Ea.
- Objects in the sky—S5Eb.
- Abilities of technological design—S6Ea, S6Ma.
- Understanding about science and technology—S6Eb, S6Mb.
- Risks and benefits—S7Md.
- Science and technology in local challenges/in society—S7Ea, S7Ma.
- Science as a human endeavor—S8Ea, S8Ma.
- History of science—S8Mc.

Mathematics

- Understand measurable attributes of objects and the units, systems, and processes of measurement—M12.
- Apply appropriate techniques, tools, and formulas to determine measurements—M13.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them—M14.
- Develop and evaluate inferences and predictions that are based on data—M16.
- Understand and apply basic concepts of probability—M17.
- Problem solving—M18.
- Reasoning and proof—M19.
- Communication—M20.

Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective—G1.
- The physical and human characteristics of places—G4.

Language Arts

- Standards 1, 3, 4, 5, 6, 7, 11, and 12.
  (See Language Arts Matrix on page 8.)

Technology

- Relationships among technology and other fields—T3.
- Cultural, social, economical, and political effects—T4.
- Influence of technology on history—T7.
- Attributes of design—T8.
- Engineering design—T9.
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving—T10.
- Apply the design process—T11.
- Use and maintain technological products and systems—T12.
- Transportation technologies—T18.

Pre-activity Instructions— Lessons 15–19

1. A list of materials is provided at the beginning of each lesson in this section rather than one list for the entire activity. Look over the materials lists and make a check list of things that students or a team of parent volunteers can bring to school. Since there are several experiments to demonstrate each of the four forces of flight, set up four big boxes or tubs and label each box with the following: GRAVITY, LIFT, THRUST, and DRAG. Check off the materials as they are brought in. Two days before each force is studied, make sure that each box has all of the necessary materials for the experiments.
2. The students should conduct all of the experiments in these lessons rather than viewing teacher demonstrations. Divide the class into six groups. Choose a leader and a recorder for each group. The leader makes sure that all directions are followed, and the recorder records all group information. The students will remain in these groups with the same leader and recorder for Lessons 16, 17, and 19. The two other jobs, reader and scientist, will be rotated among all members of the group after each experiment. In this way, all students will read and conduct several experiments.
3. There are a total of 18 experiments in Activity 8: six for gravity in Lesson 16, six for lift in Lesson 17, and three each for thrust and drag in Lesson 19. The experiments are set up at different stations and the groups rotate to each station until all experiments are complete for that lesson. If possible, have each station in a different room or area so that one group does not see the outcome of another group's experiment. Parent volunteers at each station would be necessary if this suggestion is followed. A few parents would be helpful to assist groups even if they are all performed in one room. Perhaps one parent could be responsible for scheduling volunteers. Each adult volunteer will need a teacher copy of the experiments.
4. Duplicate enough copies of the student text for Lesson 15, "The Four Forces of Flight at Work," Lesson 16, "The Pull of Gravity," Lesson 17, "It Lifts Me Up— The Force of Lift," and Lesson 18, "The Opposing Forces of Thrust and Drag," for each student. Remember to punch holes in these copies so students can insert them in their logs.
5. Duplicate and collate six student copies of the Gravity Experiments 1–6. Duplicate and collate six student copies of the Lift Experiments 1–6. Duplicate and collate six student copies of the Thrust Experiments 1–3, and Drag Experiments 1–3 so that each group has one set of each.
6. Duplicate and collate enough teacher copies of the Gravity Experiments 1–6 so that each adult (teacher and volunteers) has one set of each. Duplicate and collate enough teacher copies of the Lift Experiments 1–6 so that each adult (teacher and volunteers) has one set of each. Duplicate and collate enough teacher copies of the Thrust Experiments 1–3 and Drag Experiments 1–3 so that each adult (teacher and volunteers) has one set of each.

Lesson 15—The Four Forces of Flight at Work

Materials—Lesson 15

- Student logs.
- The book, *The Airplane Alphabet Book,* by Jerry Pallotta.
- A copy of the student text for Lesson 15, "The Four Forces of Flight at Work," for each student.
- Diagram of a plane shown in the center of the four forces of flight (provided on page 152).
- Frisbees® – 1 for each pair of students if possible. (Ask the P.E. teacher for these or ask students to bring them in.)
- 2 natural fiber, long, heavy ropes for tug of war (Ask the P.E. teacher for these. Do not use ropes made out of synthetic fiber.) Tie a piece of cloth at the center of each rope.
- 4 nametags, labeled WEIGHT, LIFT, THRUST, and DRAG, on strings made to be put around a student's neck.
- Toy airplane – about 12 inches (30.5 centimeters) long.
- An empty egg carton (or other lightweight, bulky item).

Pre-lesson Instructions—Lesson 15

1. Make sure that there are enough copies of the student text for Lesson 15, "The Four Forces of Flight at Work," for each student and that the holes have been punched.

2. Make the nametags for GRAVITY, LIFT, THRUST, and DRAG. Punch two holes in the top and insert a string long enough to fit over a student's head like a necklace.
3. Enlarge the provided diagram of the plane shown in the center of the four forces of flight or draw it on the board.

Procedure—Lesson 15

1. Read *The Airplane Alphabet Book,* by Jerry Pallotta, to the students as an introduction to this activity.
2. Divide the class into groups of 2, 3, or 4, depending on how many Frisbees® were brought in. Give each group a Frisbee® and tell them that they will be going outside for about 10 minutes to practice flight.
3. Provide the following instructions to the students before going outside. You may want to demonstrate these instructions.
   1) The term "round" means "each classmate in your group having one toss and one retrieval."
   2) For the first two rounds, you will use a spinning throw to throw the Frisbee® to your partner (or to a person in your group), but that person is not allowed to catch it. It must be retrieved from the ground. Watch carefully as the Frisbee® flies through the air. (Later, students will understand that it falls to the ground because of the forces of drag and gravity.)
   3) For the next two rounds, practice the difference between a toss and a spinning throw. Observe its speed as it leaves your hands as well as the speed during flight. Let the Frisbee® fall to the ground and not be caught. Take note of the distance of your flights. (Later, students will understand that it remains in the air longer because of thrust and lift. Their arms are providing the thrust and its shape and spinning action help to provide lift.)
   4) While you are throwing the Frisbee®, I (the teacher) will be visiting each group. I will give you an egg carton (or other bulky item) to toss to one another. Throw the egg carton as far as you can; but once again, it is not to be caught. Just let it go until it hits the ground. Observe its flight speed and the distance it travels. (Later, students will understand how the shape of the Frisbee®, aerodynamic and not bulky like the egg carton, helps it to go through the air faster and farther.)
4. When you return to the classroom, conduct an inquiry-based discussion relating the actions of the Frisbee® to the four forces of flight. Ask the following questions. "What caused the Frisbee® to fall?" (Gravity) "What caused it to soar through the air?" (Thrust) "Why did the Frisbee® slow down?" (Drag) You may want to write on the board, "Gravity caused it to fall. Thrust pushed it forward through the air. Drag slowed it down."
5. Next, compare the speed and distance of the egg carton to the speed and distance of the Frisbee®. Demonstrate this in the classroom by throwing each one a short distance using a spinning motion. Ask, "Which traveled the longer distance?" "Which one went faster?" Acquaint the students with the term "aerodynamic" in this discussion. Ask, "Why do swimmers and bicycle riders wear very tight clothing?" (It makes them more aerodynamic and reduces drag.) Draw a boxy-shaped car and a streamlined

car on the board. Ask which one is an example of being aerodynamic.

6. Then, compare spinning the Frisbee® to tossing it. Demonstrate this in the classroom. "Which action caused the Frisbee® to travel a greater distance?" Explain that the Frisbee® traveled farther while spinning because of the force of lift, which caused it to stay in the air longer. On the board, write, "Lift caused it to stay in the air."
7. Display, or draw on the board, the diagram of the airplane shown in the center of the four forces of flight.
8. Gently throw the Frisbee® again using a spinning action. Review the four forces of flight using the words "gravity," "drag," "thrust," and "lift." Have the students match the action of the Frisbee® with these words. The teacher gives the force and the student describes the matching action of the Frisbee®. Then the teacher describes the action of the Frisbee® and the students name the force (e.g., Gravity—The Frisbee® falls to the ground). Children have probably never heard these words used in relation to flight before; so that is why it is necessary to repeat these terms over and over.
9. Now, compare the forces on the Frisbee® to an airplane in flight using the diagram of the plane and the four sentences that are written on the board. The same forces act on both the plane and the Frisbee® in the same way.
10. Distribute copies of the student text for Lesson 15, "The Four Forces of Flight at Work," and have the students insert this in their logs.
11. Introduce and teach the vocabulary as you would any guided reading.
12. Direct the students' attention to the "Take Flight" bulletin board. Spend just a few moments identifying these flying machines. Tell the students that all of these objects have the four forces of flight acting on them just like the Frisbee® and the plane pictured in the diagram.
13. As the class reads and discusses the text, question their understanding and encourage their questions. Use the diagram of the plane as you discuss the four forces.
14. When the class has finished reading and discussing the student text, prepare the students for the four forces activity using the tug of war ropes and the toy airplane. Divide the students into four groups and try to have them somewhat balanced in strength. Name each group one of the four forces of flight.
15. Ask the LIFT and GRAVITY groups to take their places at either end of the rope, with both teams an equal distance from the tied cloth. Give the nametag necklaces LIFT and GRAVITY to the students at the front of each line. Remind the students that, because this activity is being done inside, they should not pull too hard.

16. Holding the toy airplane in your hand, stand in the middle area of the rope. Instruct the LIFT group to pull the hardest, and, as they do so, raise the plane as if it were taking off. Next, instruct the groups to maintain an equal tug on the rope. Explain that when the two forces are the same, the plane will fly at a certain altitude neither ascending nor descending. Then instruct the GRAVITY group to pull the hardest as you cause the plane to begin to land.
17. Ask this group to be seated and instruct the THRUST and DRAG groups to take their places at either end of the rope, an equal distance from the tied cloth. Give the nametag necklaces THRUST and DRAG to the first students in each line. As before, stand in the middle area and have the THRUST group pull the hardest as you cause the plane to ascend and then speed up. When the DRAG group pulls the hardest, the plane will slow down and descend.
18. Instruct this group to remain in place and ask the LIFT and GRAVITY groups to take their places on a second rope that is perpendicular to the THRUST and DRAG rope. These two ropes should be crossed with the pieces of tied cloth at the same point. Explain that all four forces work on the plane at the same time. When no one is pulling, the plane remains on the runway. When LIFT and THRUST pull the hardest, the plane ascends. When everyone pulls the same, the plane stays in flight at the same altitude. When GRAVITY and DRAG pull the hardest, the plane slows down and descends.
19. Practice this a few times until the students comprehend the relationship between the forces and the position of the plane. Let several students take turns holding the plane and let other students give the commands.

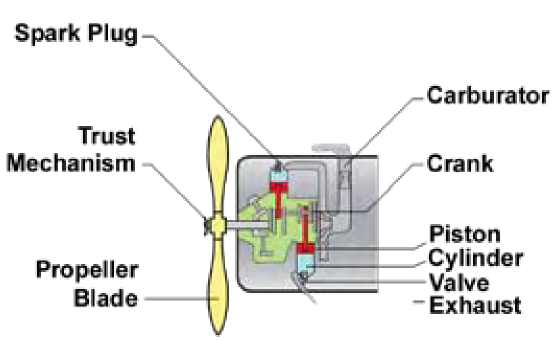
Vocabulary—Lesson 15

drag – the force of resistance to the motion of a vehicle body as it moves through a fluid such as water or air; drag acts in the opposite direction to thrust.

drag


This plane uses an engine connected to a propeller for thrust.

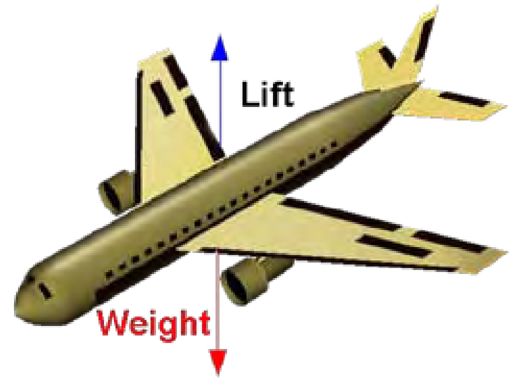
engine – the part of the aircraft that provides the power for takeoff and landing and sustains flight



Most propeller planes use piston engines.

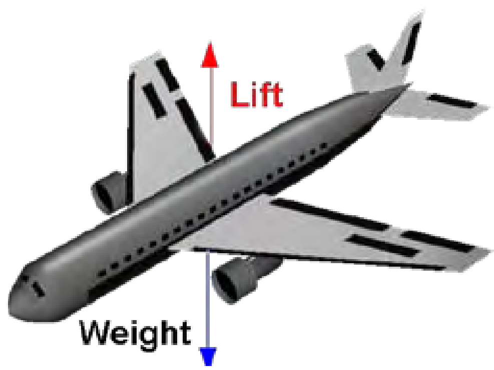

This plane uses jet engines for thrust.

force – a push or pull used to lift something, start it moving, or hold it in place against another force



Gravity is the force that pulls down on objects and gives them weight.

gravity – a force of attraction that makes objects fall toward Earth



lift

lift – a force that acts upward against gravity and makes it possible for aircraft to rise in the air

thrust – a forward force that pushes an aircraft through the air

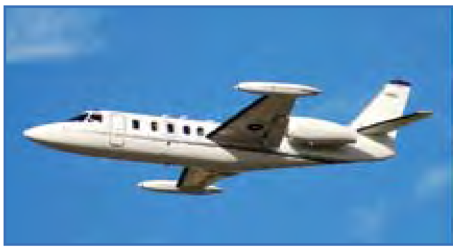
thrust


Gravity is what gives weight to objects on Earth. Scales measure the pull of gravity as weight.

weight – a response of mass to the pull of gravity

Student Text—Lesson 15

The Four Forces of Flight at Work



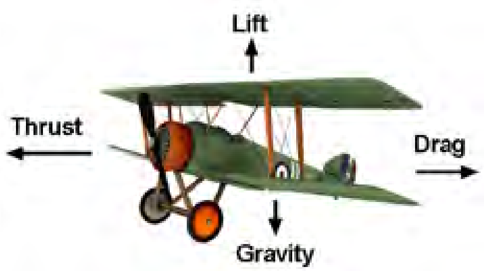
jet plane

propeller plane

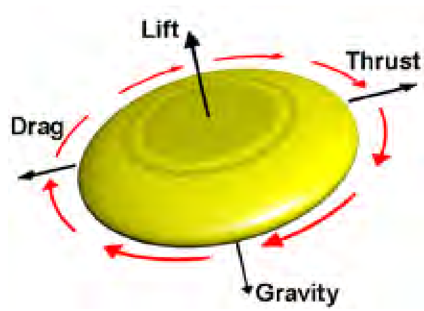
helicopter

We see aircraft flying in the sky all the time. All kinds of propeller planes, jet planes, and helicopters soar, zoom, and even roar through the air. Most of us think nothing about flying in the skies. Yet, knowing the science behind it helps us to understand the marvels of air travel.

The way an airplane flies may seem magical. We know a plane weighs way too much to float. So, how can something so big and so heavy fly? Four **forces** act on an airplane in order to achieve flight. A force is a push or a pull on something. A plane in the air is in the middle of a tug of war. The four forces of flight are pushing and pulling on it. **Lift** opposes **gravity**. **Thrust** opposes **drag**.



the four forces of flight

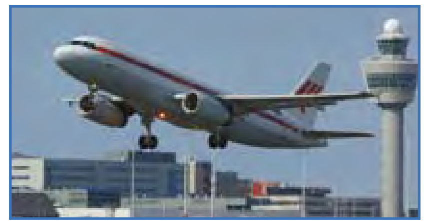


A Frisbee® uses the four forces of flight.

If you've ever flown a Frisbee®, you've observed the four forces of flight. As a Frisbee® flies through the air, lift holds it up. The thrust you give it with your arm moves it forward. Drag soon overcomes the forward motion of the Frisbee® to slow it down. And gravity brings it back to Earth again. Wings keep an airplane up in the air, but it takes all four forces to make a plane fly. They push a plane up, down, and forward, or cause it to slow down. Let's take a look at each of the four forces to further understand their meaning.

Gravity pulls down on the plane so it can land.

- Earth's gravity is the force that pulls down on objects, which gives them **weight**. All matter has weight. Weight means how heavy or how light an object is. Without gravity, an airplane could not land.

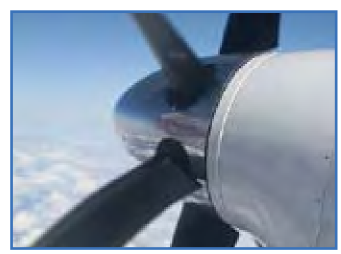


Lift holds the airplane in the air.

- Lift is the force that holds an airplane in the air. The wings create most of the lift used by airplanes.

Drag slows the airplane down.

- Thrust is the force that moves an aircraft forward. **Engines** usually provide thrust for airplanes, and the engine could be a propeller engine or a jet engine. Your hand provides thrust when launching a paper airplane.

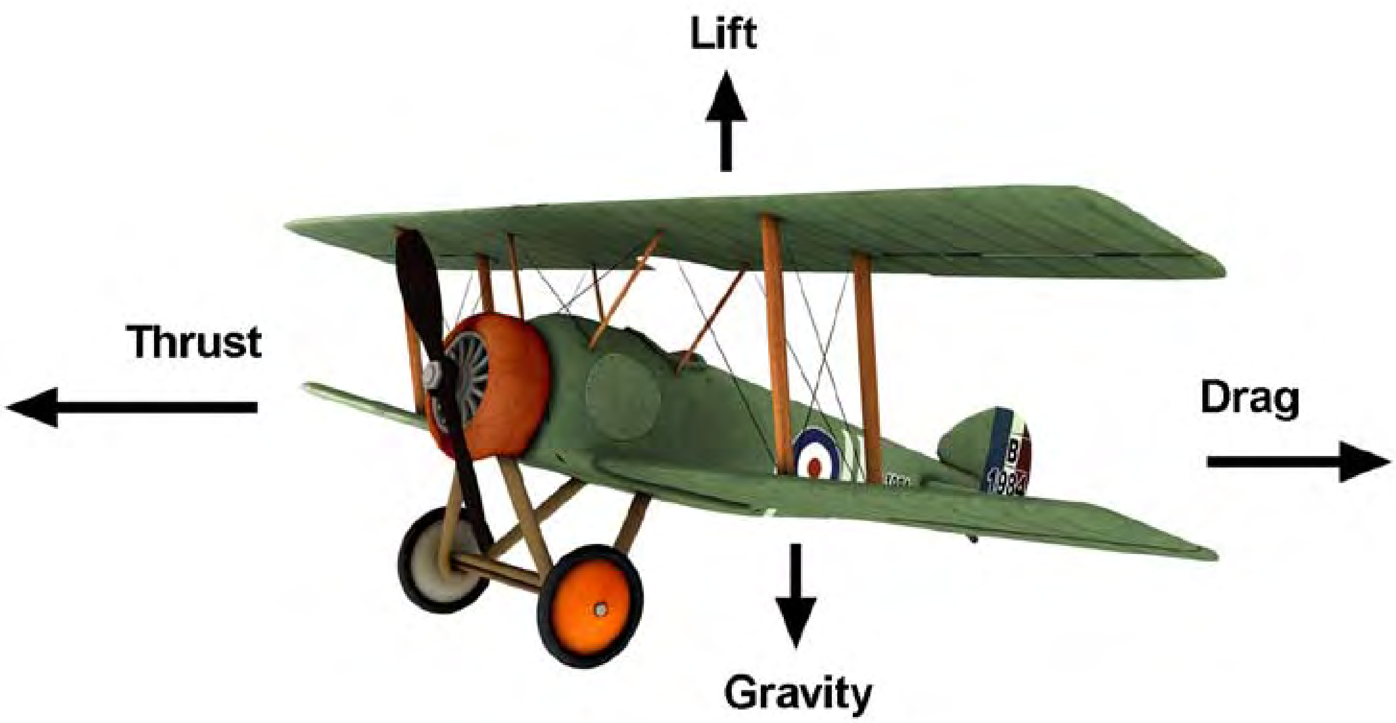


Thrust moves the airplane forward.

- Drag is caused by friction and differences in air pressure. You can experience drag by putting your hand out of a car window and feeling it pull back. Drag slows an airplane down so it can land.

The way each of the four forces act on the airplane makes the plane do different things. As stated earlier, each force has an opposite force that works against it. Lift works opposite of gravity. Thrust works opposite of drag. When the forces are balanced, a plane flies in a level direction. The plane goes up if the forces of lift and thrust are more than weight and drag. If weight and drag are greater than lift and thrust, the plane goes down. A plane flies because of the four forces of flight at work.

The Four Forces of Flight



Lesson 16—The Pull of Gravity

Materials—Lesson 16

- Student logs.
- A copy of the student text for Lesson 16, "The Pull of Gravity," for each student.
- Copies of the Gravity Experiments 1–6 (Teacher copies which include a list of materials and answers for results and conclusions) for the teacher and each adult volunteer.
- Copies of the Gravity Experiments 1–6 (Student copies) for each group (should be 6 groups).

Materials for each of the following experiments:

Gravity Experiment 1—Is There A Heavyweight Champion?

- 1 tennis ball.
- 1 baseball.
- 1 football.
- 1 golf ball.
- 1 basketball.
- 1 soccer ball.
- Access to a slide or other high, safe structure.

Gravity Experiment 2—Which One Wins?

Note: Choose objects that will not be susceptible to air resistance.

- Objects of different weights and shapes (e.g., pencil, book, shoe, shoe box, paper clip, tack, rubber band, etc.).

Gravity Experiment 3—Colliding Marbles

- 2 different-color, same-size marbles.
- A 12- or 18-inch (30.5- or 45.7-centimeter) ruler with a groove down the center.
- 3 books.
- Several marbles of different sizes.

Gravity Experiment 4—Flip the Coins

- 1 yard or meter stick.
- 4 different coins.
- Balance scale or small scale.
- Small objects such as a magnet, eraser, crayon, paint-brush, counter, cork, marble, or things volunteered by the students.

Gravity Experiment 5—Cup Stacking

- 4 paper cups. (Have a few extra in case some are damaged.)
- 4 playing cards.

Gravity Experiment 6—Paper Shape

- 12 sheets of notebook paper (2 for each group).
- 1 golf ball.

Pre-lesson Instructions—Lesson 16

1. Make sure that there are enough copies of the student text for Lesson 16, "The Pull of Gravity," for each student and that holes have been punched.
2. Make sure that there are six sets of the Gravity Experiments 1–6 (student copies) so that each group has one set.
3. Make sure that there are enough sets of the Gravity Experiments 1–6 (teacher copies) for the teacher and each adult volunteer.
4. Have the class divided into six groups with a permanent leader and a recorder as described in the pre-activity instructions. Directions for the reader and scientist jobs will be given in the procedure.
5. Check to see that all materials for the gravity experiments have been gathered. Set up each eriment in its station. Be sure umber and name each station ce each group will perform nem in a different order (e.g., Station 1 and Experiment 1).

station

Procedure—Lesson 16

1. Distribute copies of the student text for Lesson 16, "The Pull of Gravity," and have the students insert this in their logs.
2. Introduce and teach the vocabulary as you would for any guided reading. Find Pisa, Italy, on the world map.
3. Read the student text, "The Pull of Gravity," as you would any guided reading. As the class reads and discusses the text, question their understanding and encourage their questions. Notice that the Law of Falling Bodies is not revealed in the text. The students will discover this law in their experiments. FYI: The Law of Falling Bodies states, "In the absence of air resistance, any two bodies that are dropped from rest at the same moment will reach the ground at the same time regardless of their mass."
4. Tell the students that they will be conducting experiments on gravity. Assign them to their groups and designate a leader and a recorder for each group. Explain that all members of the group will take turns doing the two other jobs of reader and scientist.
5. Explain the job descriptions.
   - The leader makes sure that all directions are followed correctly.
   - The recorder records all group information. This will include filling out the experiment worksheets.
   - The reader reads the text of the experiment.
   - The scientist conducts the experiment.
6. Remind the students that the leader and the recorder stay the same throughout all of the experiments. (Teachers are free to change this when a classroom has many good leaders and many students who can write quickly and legibly.) However, all members of the group will take turns being the reader and the scientist. The first reader will be the first in alphabetical order by their first names, and the first scientist will be the first in alphabetical order by their last names. Then proceed in alphabetical order as they do each experiment.
7. Draw the following table on the board for the recorders to copy. Then, let the groups meet for a few minutes to schedule the readers and the scientists. Tell the recorders to record the names of the reader and the scientist for each station and to keep this schedule because it will also be used for Lessons 17 and 19.

Station Number	Reader	Scientist
1		
2		
3		
4		
5		
6		

8. Explain that each group will start at an assigned station and then rotate around all six stations. If stations are out of the room, the adult monitor at each station will direct them to the next station when the signal is given.
9. Give the set of Gravity Experiments 1–6 to the recorder of each group. Then give the following instructions. (Adult volunteers should be present to hear these.)
   1) Only 5 minutes will be allowed at each station; so get right to work.
   2) After the reader reads the problem, discuss the hypothesis and decide as a group what this will be. Remember that the hypothesis is a good guess. The recorder will write the hypothesis on the experiment worksheet. Then the reader reads the procedure as the scientist performs each step. Rotate the reader and the scientist at each station.
   3) After all steps are completed, the group should discuss the results and the conclusion. The group should help the recorder fill in the results and the conclusion.
   4) When your group has finished, wait for a signal (teacher preference) before proceeding to the next station.
10. Assign a beginning station to each group.
11. Keep track of time and monitor each station, assisting as needed. If stations are out of the room, volunteers should have a watch. If it is evident that more time is needed at each station, allow longer periods of time.
12. **Very important:** When students are unsure of a result or a conclusion, or if they arrive at an incorrect result or conclusion, adults should help to guide students to the correct conclusion, using the teacher copies of the experiments.
13. When all groups are finished, assemble together to discuss the results and conclusions of each experiment, making sure that they understand the properties of gravity.

14. The students should grasp the following concepts:
    1) **All matter has gravity.**
    2) **The bigger an object, the stronger the gravitational pull.**
    3) **Gravity gives everything weight. An object's weight is the force of Earth's gravity on it.**
    4) **Gravity is the natural force that causes objects to move toward the center of the Earth. It is the force that causes all things to fall.**
    5) **Without air resistance, all objects fall with the same acceleration (increase in motion), regardless of mass.**
    6) **Air resistance, a type of friction, works against gravity to decrease the acceleration of a falling object. Without air resistance, raindrops would hit us at the speed of a bullet and would be almost as dangerous!**
    7) **If an object has a large leading surface area, air resistance is able to oppose the force of gravity and slow the object down.**
15. Teachers may want to conclude the lesson with a video clip of Apollo 15 Commander David R. Scott demonstrating his experiment of the hammer and the feather. Log onto **http://www.hq.nasa.gov/alsj/frame.html** to view the video. Click on Apollo 15 Video and Movie Clips, "The Hammer and the Feather Journal Text 167:22:06 Quick Time Video Clip by Ken Glover or Journal Text," 167:22:06 MPEG Video Clip by Kipp Teague. Also, teachers may provide the students with the photo of Commander Scott (provided after the student text), which includes the Web site for the video in the caption.

Vocabulary—Lesson 16

astronaut – a person trained to travel and work in space

astronaut

attracts – to pull to or draw toward oneself or itself

Galileo

Galileo – (1564–1642) Galileo Galilei – an Italian astronomer, mathematician and physicist who developed the Law of Falling Bodies and discovered that the Moon shines with reflected light

Law of Falling Bodies – (to be determined through the experiments)

Leaning Tower of Pisa

Leaning Tower of Pisa – Architects began building this most famous bell tower to the Cathedral in Pisa in 1173, but work stopped 5 years later when they first noticed it leaning to the north. (It is caused, we now know, by a weak foundation of silty soil from a former stream.) Only three stories had gone up and it was good that they stopped. For if they had built all eight stories right away, without letting the tower settle, it probably would have collapsed. For the next 172 years, architects tried to adjust the lean but could never correct it. The tower was finally completed in 1350.

magnet – a body having the property of attracting iron

A horseshoe magnet attracts the iron in the pins.

Magnetic cranes are used to lift heavy loads of material containing iron.

Sir Isaac Newton

natural – existing as part of or determined by nature

Newton, Sir Isaac – the scientist who developed three laws to describe and explain motion; he also made many discoveries that help us to understand how our world works, including discoveries about gravity.

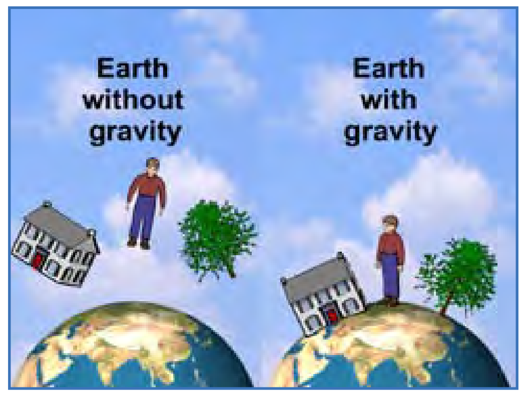
Universal Law of Gravity – a law which states that every object in the universe attracts every other object

Student Text—Lesson 16

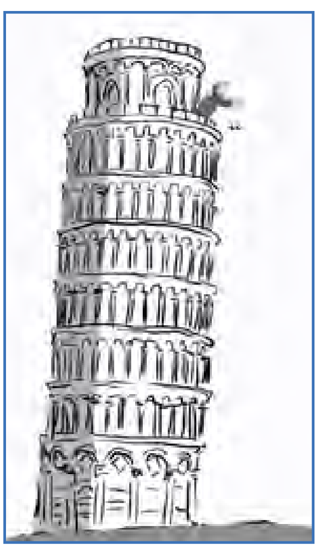
The Pull of Gravity

The Force of Attraction

Gravity is a force. A force is a push or a pull. Gravity is the **natural** force that pulls objects toward Earth. If the Earth did not have gravity, we would go flying into space. Some people like to compare Earth's gravity to a huge **magnet**. Unlike a magnet that attracts only iron, Earth's gravity **attracts** all objects to the ground. So, we do not have to worry about floating into space. Gravity is also the force that gives objects weight. If the Earth had no gravity, we would have no weight.



Earth's gravity attracts all objects to the ground.



Galileo tested his idea about gravity.

The Man Who Had To Prove It

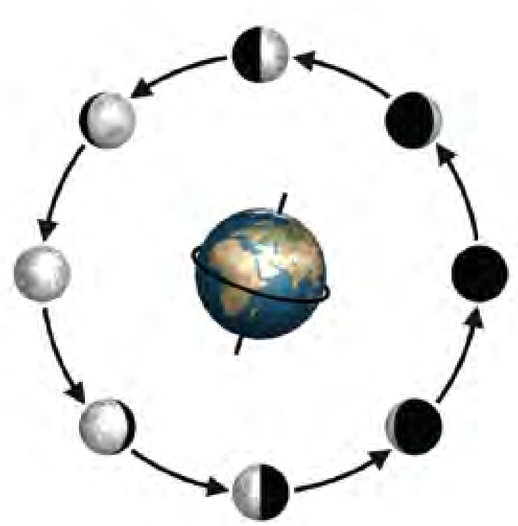
People have known about the pull of gravity for a long time. They knew that gravity caused things to fall. For thousands of years, people thought that a heavy object fell faster than a light object. But no one had tested this belief. That changed in the late 1500s. A man named **Galileo** studied gravity. He was known for proving his ideas through testing. Galileo set out to see if the belief was true or false. He went to the top of the **Leaning Tower of Pisa** in Italy. From there, he dropped some objects. They were the same size but not the same weight. He watched them fall. He also dropped balls. They had different sizes and weights. In one of the tests, one ball weighed 10 times more than the other. And they were the same size. What do you think happened? In each test, he studied how gravity affected the objects. He wrote the **Law of Falling Bodies**.

From Apples to the Moon

Newton wondered what force pulled the apple down to the ground.

Newton guessed that the force that pulled the apple down also held the Moon in orbit.

Sir Isaac Newton was an English scientist. One day, he was sitting beside an apple tree and he saw an apple fall. Some people say it hit him on the head. But that part was most likely made up in fun. The main thing is that he knew that gravity made it fall. He realized that no matter where you were on Earth, things would fall “down” to the ground. And he knew that “down” was toward the center of the Earth. If an apple would fall down from the highest tree, just how far up did this force go? Then he had a strange idea. He thought that Earth’s gravity might hold the Moon in its orbit. And that, without gravity, the Moon would fly off into space. Newton also thought that every object had its own gravity. He said that all the planets, moons, and stars attract each other. This was called the **Universal Law of Gravity**.



Earth’s gravity holds the Moon in orbit. This diagram shows the phases of the Moon as seen from Earth.

The Bigger, the Stronger

All matter has gravity. Even you and I have gravity. But we do not have enough mass to produce any real pull. Huge masses like the Earth have a strong pull. In fact, the bigger an object is, the stronger the pull. Earth's pull of gravity is very strong. It can hold the Moon in orbit. The Sun's pull of gravity is extremely strong. It holds all the planets in orbit. So, Newton was right!

The Sun's gravity holds the planets in orbit.

your weight on Earth, Mars, and the Moon

Gravity gives everything weight. An object's weight is the force of Earth's gravity on it. The greater the force of gravity on an object, the more it weighs. Sometimes this is hard to understand. No matter where we are in the universe, we still have the same mass. But we won't have the same weight. Remember, the bigger an object is, the stronger the pull. Earth has 6 times the mass of the Moon. So, its gravity is 6 times greater than the Moon. If you weighed 100 pounds (45.3 kilograms) on the Earth, you would weigh about 16 ½ pounds (7.5 kilograms) on the Moon. Each planet has a different pull of gravity. Since Mars has less mass than Earth, the gravity on Mars is less than the gravity on Earth. Mars' gravity is only about 38% that of Earth's gravity. If you weighed 100 pounds (45.3 kilograms) on Earth, you would weigh 38 pounds (17 kilograms) on Mars.

Commander David R. Scott

When one of NASA's **astronauts** stood on the Moon, he did an experiment. He dropped a hammer and a feather at the same time from the same height. We know which one would hit the ground first on Earth. But what do you think happened on the Moon?

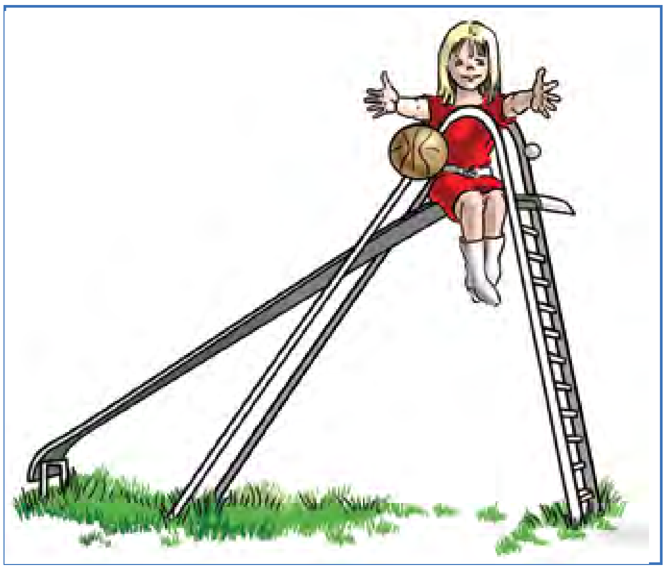
In the absence of air resistance, all objects fall with the same velocity.
So, on the moon, a hammer and a feather fall at the same rate.

Apollo 15 commander David R. Scott confirmed Galileo's hypothesis that, in the absence of air resistance, all objects fall with the same velocity. A geologic hammer in Scott's right hand and a falcon feather in his left hand reached the surface of the Moon at the same time. The demonstration was performed before the television camera on the lunar roving vehicle.

Log on to **http://www.hq.nasa.gov/alsj/frame.html** to view the video. Click on Apollo 15 Video and Movie Clips, "The Hammer and the Feather," Journal Text 167:22:06, "Quick Time Video Clip by Ken Glover," or Journal Text 167:22:06, MPEG Video Clip by Kipp Teague.

Gravity Experiments—Teacher Copies

Gravity Experiment 1—Is There A Heavyweight Champion?



Problem:
What will happen when you drop balls of different weights and sizes from the same height at the same time?

Materials:
- 1 tennis ball.
- 1 baseball.
- 1 football.
- 1 golf ball.
- 1 basketball.
- 1 soccer ball.
- Access to a slide or other high, safe structure.

Hypothesis:
The balls will ________________________________

Procedure:
1. Climb up the ladder of the slide and be safely seated. Have the teacher or another adult hand you the two balls.
2. Hold a different ball in each hand.
3. From the same distance, drop the balls at the same time.
4. Repeat several times using different balls.

Results:
Without air resistance, the balls hit the ground at the same time.

Conclusion:
This happened because gravity is the force that causes all objects to fall. Even though the balls have different masses and sizes, the force of gravity is the same regardless of mass or size, so that without air resistance all objects are pulled toward the ground (Earth) at the same rate.

Gravity Experiment 2—Which One Wins?

Problem:
What will happen when you drop objects of different weights and shapes from the same height at the same time?

Materials:
- Objects of different weights and shapes (e.g., pencil, book, shoe, shoe box, paper clip, tack, rubber band, etc.).

Note: Choose objects that will not be susceptible to air resistance.

Hypothesis:
The objects will ________________________________

Procedure:
1. Hold a different object in each hand.
2. From the same height, drop the objects at the same time.
3. Repeat several times using different objects.

Results:
The objects hit the floor at the same time.

Conclusion:
This happened because gravity is the force that causes all objects to fall. Without air resistance, gravity pulls each object down towards the ground (Earth) at the same rate even though the objects have different masses or shapes.

Gravity Experiment 3—Colliding Marbles

Problem:
What will happen when two marbles are knocked to the floor at the same time in a way that one of the marbles travels farther horizontally than the other?

Materials:
- 2 same-size, different-color marbles.
- A 12- or 18-inch (30.5- or 45.7-centimeter) ruler with a groove down the center.
- 3 books.
- Several marbles of different sizes.

Hypothesis:
The marbles will ______________________________

Procedure:
1. Place one marble at the edge of a table. This will be Marble B.
2. Position one end of a ruler on the table so that its groove flows into Marble B. Now place two books under the other end of the ruler to form a ramp.
3. Hold the second marble, Marble A, in the groove at the upper end of the ruler so that when it is released, it will collide with Marble B. Now release Marble A.
4. Observe the path of both marbles as they fly out and hit the floor.

Result:
Marble A rolls down the ruler and strikes Marble B. Both marbles move outward from the edge of the table, but Marble B travels farther horizontally than Marble A. They appear to hit the floor at the same time.

Conclusion:
This happened because gravity causes all objects to fall with the same acceleration (increase of motion) regardless of mass. If an object is traveling at some speed parallel to the ground, it will fall at the same rate as a stationary object. In this experiment, gravity pulls Marble A down the inclined ruler. Its speed and energy increase as it rolls. When Marble A collides with Marble B, most of this energy is transferred to Marble B, sending Marble B outward from the edge of the table. Marble A continues to move forward after the two marbles collide, but at a slower speed than Marble B. As soon as the marbles leave the table, gravity starts pulling them downward. They appear to strike the floor at the same time. But Marble B left the table a fraction of a second before Marble A, so it hit the floor an equal fraction of a second before Marble A. Even though the marbles had different horizontal speeds, gravity pulled them downward at the same rate. Objects thrown horizontally at the same time are the same height from the ground at any given moment during the fall. A bullet shot horizontally from a gun will hit the ground at the same time as one that was dropped from the same height.

Follow-up Activities:
Repeat the above procedure, but use three books under the edge of the ruler. Repeat the procedure using two marbles of different sizes.

Gravity Experiment 4—Falling Water

Note to the teacher: Free fall is the way scientists create microgravity on Earth for their research. By using drop towers, airplanes, sounding rockets, and orbiting spacecraft, they can achieve the actual acceleration of a free-falling object. In this experiment, a water-filled cup is inverted and dropped. Before release, the forces on the cup and water (their weight, caused by Earth's gravity) are counteracted by the cookie sheet. On release, if no horizontal forces are exerted on the cup when the sheet is removed, the only forces acting (neglecting air) are those of gravity. Since Galileo demonstrated that all objects accelerate similarly in Earth's gravity, the cup and water move together. Consequently, the water remains in the cup throughout the entire fall.

Problem:
What will happen to the water in a cup when you place a cookie sheet over a cup of water, invert it, and pull the cookie sheet quickly away from the cup?

Hypothesis:
The water will ________________________________

Materials:
- Plastic drinking cup.
- Cookie sheet (with at least one edge without a rim).
- Catch basin (large pail, waste basket).
- Water.
- Chair or step ladder.
- Towels.

Follow-up Activity Materials:
- Empty soda pop can.
- Sharp nail.

Procedure:
1. Place the catch basin in the center of an open area in the classroom. (Or perform this experiment outside.)
2. Fill the cup with water.
3. Place the cookie sheet over the opening of the cup. Hold the cup tight to the cookie sheet while inverting the sheet and cup.
4. Hold the cookie sheet and cup high above the catch basin. You may wish to stand on a sturdy table or climb on a stepladder to raise the cup higher.
5. While holding the cookie sheet level, slowly slide the cup to the edge of the cookie sheet. Observe what happens.
6. Refill the cup with water, take your position above the catch basin, and invert the cup on the cookie sheet.
7. Quickly pull the cookie sheet straight out from under the cup. Observe the fall of the cup and water.

Results:
When the cup is slid to the edge, the water runs out. When the cookie sheet is quickly removed, the water remains in the cup throughout the entire fall.

Conclusion:
This happened because all objects accelerate similarly in Earth's gravity. Therefore, the cup and the water move together.

Follow-up Activity:
1. Use a nail to punch a small hole near the bottom of an empty soda pop can.
2. Fill the can with water and seal the hole with your thumb.
3. Position the can over a catch basin and remove your thumb for just a second. Observe the water stream.
4. Reseal the hole with your thumb.
5. Predict what will happen if you toss the can through the air.
6. Now toss the can through the air to a second catch basin but do not allow the can to spin or tumble in flight. Observe.
7. Refill the can with water, but instead of tossing the can drop it while standing on a chair, desk or ladder. Compare your results.

Gravity Experiment 5—Cup Stacking

Problem:
What will happen to cups stacked on top of each other with playing cards in between when you pull the cards out?

Materials:
- 4 plastic cups.
  (Have a few extra in case some are damaged.)
- 4 playing cards.

Hypothesis:
The cups will ___________________________________

Procedure:
1. Stack two plastic cups on top of each other, open end down, with a card in between each cup.
2. Quickly pull out the card between the cups.
3. Try stacks of three and four cups with cards in between each cup. Always remove the top card first.

Results:
The cups fell onto each other.

Conclusion:
This happened because the force of gravity causes all objects to fall straight down towards Earth.

Gravity Experiment 6—Paper Shape

Problem:
What will happen when you drop a sheet of paper and a golf ball from the same height at the same time? What will happen if you crumple the sheet of paper and repeat the drop?

Materials:
- 12 sheets of notebook paper (2 for each group).
- 1 golf ball.

Hypothesis:
The sheet of paper will ___________________________
The crumpled paper will ___________________________

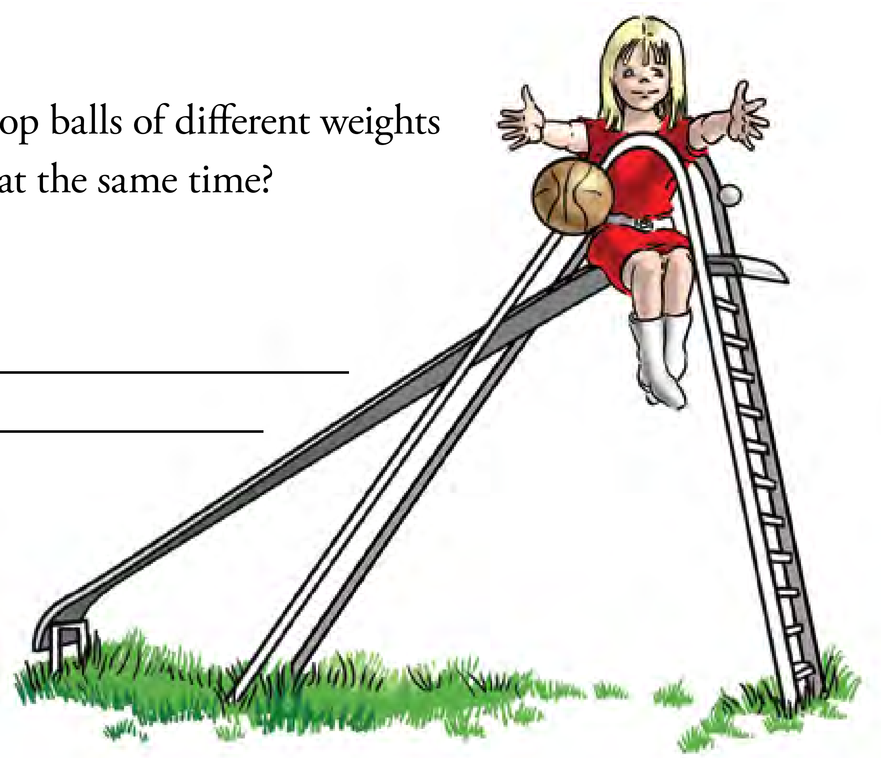
Procedure:
1. Drop the sheet of paper horizontally (face down) and the golf ball from the same height at the same time.
2. Now crumple the sheet of paper into a tight ball.
3. Drop the golf ball and the crumpled ball of paper from the same height at the same time.

Results:
The sheet of paper hit the floor after the golf ball. The crumpled paper hit the floor at the same time as the golf ball.

Conclusion:
This happened because even though both objects are still being pulled by gravity at the same rate, the horizontal sheet of paper has a small mass and a large surface area allowing air resistance to oppose the force of gravity and slow the paper down. The crumpled paper has a much smaller surface area that is less susceptible to air resistance.

Follow-up Activity:
Fold a sheet of paper vertically. With the folded edge down, drop the paper and the golf ball from the same distance at the same time. See what happens.

Gravity Experiment 1—
Is There A Heavyweight Champion?



Problem:

What will happen when you drop balls of different weights and sizes from the same height at the same time?

Hypothesis:

The balls will ______________________________

____

Procedure:

1. Climb up the slide and be safely seated. Have the teacher or another adult hand you the two balls.
2. Hold a different ball in each hand.
3. From the same distance, drop the balls at the same time.
4. Repeat several times using different balls.

Results:

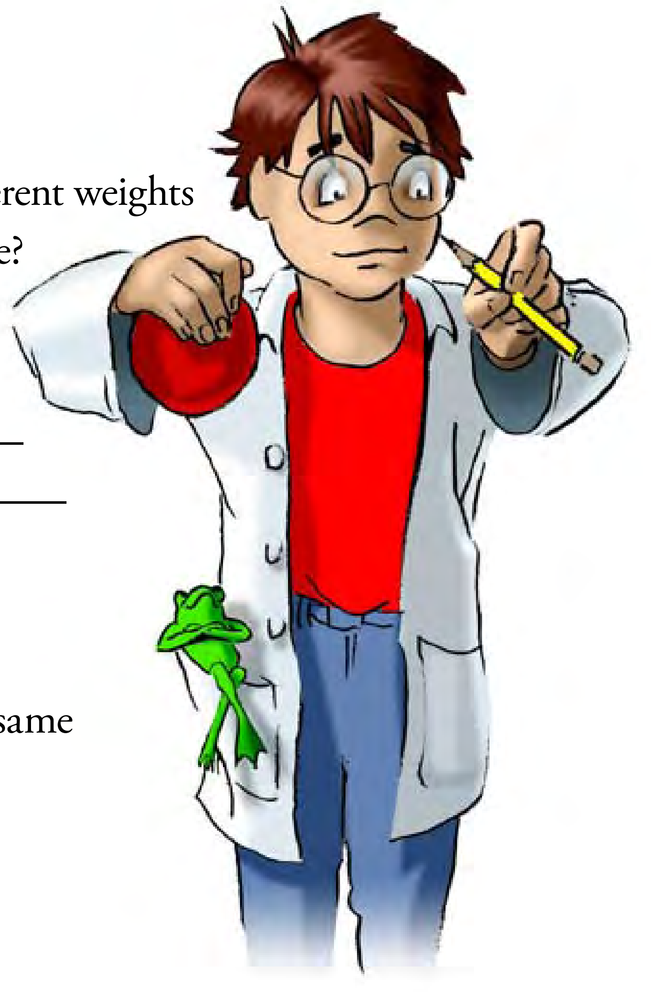
The balls ____

Conclusion:

This happened because ____

____

Gravity Experiment 2—Which One



Problem:

What will happen when you drop objects of different weights and shapes from the same height at the same time?

Hypothesis:

The objects will ______________________________

____

Procedure:

1. Hold a different object in each hand.
2. From the same height, drop the objects at the same time.
3. Repeat several times using different objects.

Results:

The objects ______________________________________

Conclusion:

This happened because ______________________________________

____

____

____

Gravity Experiment 3—Colliding Marbles

Problem:

What will happen when two marbles are knocked to the floor at the same time in a way that one of the marbles travels farther horizontally than the other?

Hypothesis:

The marbles will ____________________

Procedure:

1. Place one marble at the edge of a table. This will be Marble B.
2. Position one end of a ruler on the table so that its groove flows into Marble B. Now place two books under the other end of the ruler to form a ramp.
3. Hold the second marble, Marble A, in the groove at the upper end of the ruler so that, when it is released, it will collide with Marble B. Now release Marble A.
4. Observe the path of both marbles as they fly out and hit the floor.

Result:

The marbles ____

Conclusion:

This happened because____

____

Follow-up Activity:

Repeat the above procedure, but use three books under the edge of the ruler. Repeat the procedure using two marbles of different sizes.

Gravity Experiment 4— Falling Water

Problem:

What will happen to the water in a cup when you place a cookie sheet over a cup of water, invert it, and pull the cookie sheet quickly away from the cup?

Hypothesis:

The water will ____________________

____

Procedure:

1. Place the catch basin in the center of an open area in the classroom. (Or perform this experiment outside.)
2. Fill the cup with water.
3. Place the cookie sheet over the opening of the cup. Hold the cup tight to the cookie sheet while inverting the sheet and cup.
4. Hold the cookie sheet and cup high above the catch basin. You may wish to stand on a sturdy table or climb on a stepladder to raise the cup higher.
5. While holding the cookie sheet level, slowly slide the cup to the edge of the cookie sheet. Observe what happens.

6. Refill the cup with water and invert it on the cookie sheet.
7. Quickly pull the cookie sheet straight out from under the cup. Observe the fall of the cup and water.

Results:

The water____

Conclusion:

This happened because ____
____
____
____

Follow-up Activity:

1 Use a nail to punch a small hole near the bottom of an empty soda pop can.
2. Fill the can with water and seal the hole with your thumb.
3. Position the can over a catch basin and remove your thumb for just a second. Observe the water stream.
4. Reseal the hole with your thumb.
5. Predict what will happen if you toss the can through the air.
6. Now toss the can through the air to a second catch basin but do not allow the can to spin or tumble in flight. Observe.
7. Refill the can with water, but, instead of tossing the can, drop it while standing on a chair, desk, or ladder. Compare your results.

Gravity Experiment 5—
Cup Stacking

Problem:

What will happen to cups stacked on top of each other, with playing cards in between, when you pull the cards out?

Hypothesis:

The cups will ______________
____

Procedure:

1. Stack two plastic cups on top of each other, open end down, with a card in between each cup.
2. Quickly pull out the card between the cups.
3. Try stacks of three and four cups with cards in between each cup. Always remove the top card first.

Results:

The cups ____

Conclusion:

This happened because___________________________________
____

Gravity Experiment 6—Paper Shape

Problem:

What will happen when you drop a sheet of paper and a golf ball from the same height at the same time? What will happen if you crumple the sheet of paper and repeat the drop?

Hypothesis:

The sheet of paper will ______

____

____

The crumpled paper will ______

____

____

Procedure:

1. Drop the sheet of paper horizontally (face down) and the golf ball from the same height at the same time.
2. Now crumple the sheet of paper into a tight ball.
3. Drop the golf ball and the crumpled ball of paper from the same height at the same time.

Results:

The sheet of paper ____

The crumpled paper ______________________________________

Conclusion:

This happened because ____________________________________

____

____

____

____

____

____

Follow-up Activity:

Fold a sheet of paper vertically. With the folded edge down, drop the paper and the golf ball from the same distance at the same time. See what happens.

Lesson 17—It Lifts Me Up—The Force of Lift

Materials—Lesson 17

- Student logs.
- A copy of the student text for Lesson 17, "It Lifts Me Up—The Force of Lift," for each student.
- Copies of the Lift Experiments 1–6 (teacher copies which include a list of materials and answers for results and conclusions) for the teacher and each adult volunteer.
- Copies of the Lift Experiments 1–6 (student copies) for each group (should be 6 groups).
- A copy of the optional activity "Airfoil on a String" for each student, if used (provided on page 193).
- Scissors for each student.
- 1 sheet of notebook paper for each student.
- A thick textbook such as math or science for each student, the same for every student.
- Diagram of an airfoil (provided on page 192).
- Tug of war rope.
- Toy airplane.
- LIFT and GRAVITY nametag necklaces.

Materials for each of the following experiments:

Lift Experiment 1—Chin Ups

- 1 piece of 6- by 2-inch (15.2- by 5-centimeter) paper.

Lift Experiment 2—Paper Pull

- 2 strips of 2- by 12-inch (5- by 30.5-centimeter) paper

Lift Experiment 3—Can It

- 2 empty soda cans.
- 2 pieces of 14-inch (35.6 centimeter) string.
- A 12-inch (30.5-centimeter) ruler.
- Tape.

Lift Experiment 4—Ping-pong Funnel

- 1 small plastic funnel (4- or 5-inch (10- or 12.7-centimeter) diameter).
- 1 ping-pong ball.

Lift Experiment 5—Air Dance

- 1 hair dryer.
- 1 ping-pong ball.

Lift Experiment 6—Wing It

- A 5- by 8-inch (12.7- by 20.3-centimeter) index card.
- A 6-sided pencil.
- A 12-inch (30.5-centimeter) ruler.
- Tape.
- Hair dryer.

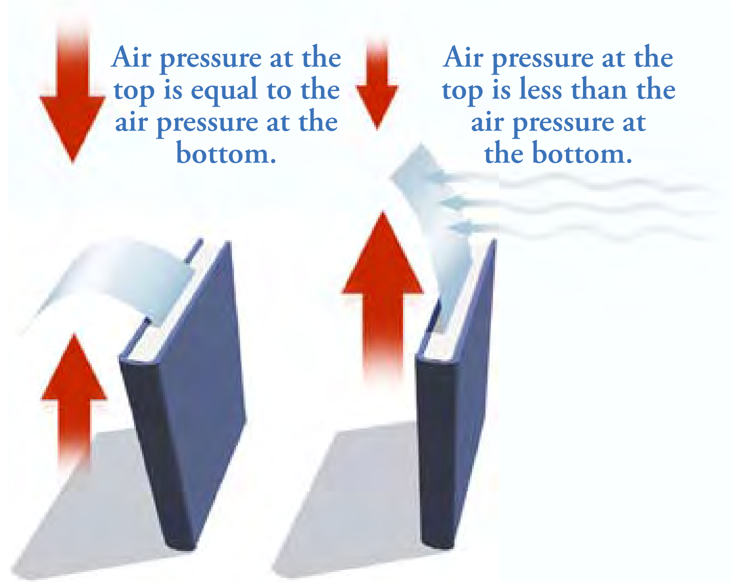
Pre-lesson Instructions—Lesson 17

1. Make sure that there are enough copies of the student text for Lesson 17, "It Lifts Me Up—The Force of Lift," for each student and that holes have been punched.
2. Make sure that there are six sets of the Lift Experiments 1–6 (student copies) so that each group has one set.
3. Make sure that there are enough sets of the Lift Experiments 1–6 (teacher copies) for the teacher and each adult volunteer.
4. Make adjustments to the six groups if necessary.
5. Enlarge the diagram of the airfoil.
6. Check to see that all materials for the lift experiments have been gathered. Set up each experiment in its station.

Procedure—Lesson 17

1. Instruct the students to cut a sheet of notebook paper in half vertically. Now have them take out a book. (The book needs to be the same for every student, such as a science book.) Insert the paper about 2 inches (5 centimeters) into the book and let the rest of the paper hang over. Ask the students the following question: "What will happen if you blow across the top of the paper?"

After the students have given their answers (their hypotheses), tell them to hold the book up to their mouths and blow hard across the top of the paper. The result will be that the paper will lift up. Tell them that the paper lifted because of the force of lift. Explain that the faster moving air has less pressure (i.e., it pushes less) than the stable (i.e., static) air underneath. Since the stable air underneath pushes harder, it caused the paper to lift up.



2. Display and discuss the diagram of the airfoil. Ask three students to come to the front of the room and stand facing a wall with their arms bent up and positioned between their bodies (at chest level) and the wall. Stand behind each one and push hard on each of their backs, not hard enough to hurt, but so they can feel the pressure. As they continue facing the wall, walk quickly by the three students pushing on their backs as you walk by. Now, run as fast as possible by the students, pushing on their backs as you run. Ask them to identify which time the pressure (pushing) was the greatest. Explain that by going by them fast, you were not able to push as hard and that it is the same with air. The faster the air moves, the less it pushes.

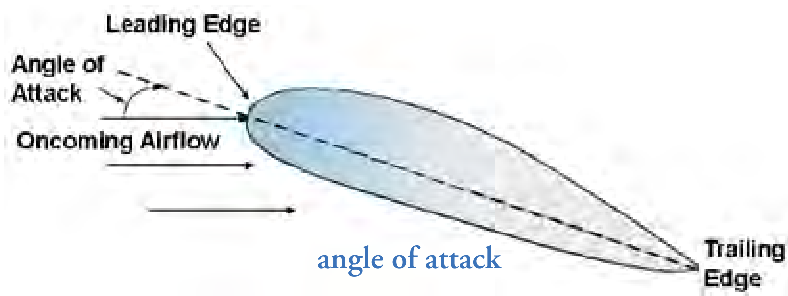
3. Look at the diagram again. Explain that as a plane flies into the air, the air rushes by the wing, but that the air moves faster over the top of the wing than it does the bottom. So, the slower moving air on the bottom is able to push harder. This is the force of lift.
4. Distribute copies of the student text for Lesson 17, "It Lifts Me Up—The Force of Lift," and have the students insert this in their logs.
5. Introduce and teach the vocabulary as you would for any guided reading.
6. As the class discusses the text, question their understanding and encourage their questions. Read and discuss the section, "Overcoming Gravity." Ask the students what they think it means to overcome gravity (**an opposite force needs to pull away from the Earth**). Use the tug of war rope and the toy plane as a review. Ask the LIFT and GRAVITY groups to take their places on the rope. Repeat the procedure with LIFT pulling harder than GRAVITY to make the plane go higher. Then GRAVITY pulls harder to make the plane descend.
7. Read and discuss the section, "Going Fast and Pushing Less." Tell the students that the lift experiments will demonstrate Bernoulli's Principle, i.e., faster moving air exerts less pressure than slower moving air. Look at the diagram of the airfoil and explain it once again.
8. Before reading the last section, "Lifting Higher," ask the students the question: "What circumstances might make a pilot want to fly at a higher altitude?" (**High mountains, storms**) After a short discussion, finish reading the section.
9. Tell the students that they will be conducting experiments on lift. Make any necessary changes to the groups at this time. Ask the recorder to get out the schedule for the reader and the scientist.
10. Distribute the Lift Experiments 1–6 to the recorder of each group.
11. Remind the class of the instructions for conducting the experiments. (Adult volunteers should be present to hear these.)
    1) Only 5 minutes will be allowed at each station; so get right to work.
    2) After the reader reads the problem, discuss the hypothesis and decide as a group what this will be. Remember that the hypothesis is a good guess. The recorder will write the hypothesis on the experiment worksheet. Then the reader reads the procedure as the scientist performs each step. Rotate the reader and the scientist at each station.
    3) After all steps are completed, the group should discuss the results and the conclusion. The group should help the recorder fill in the results and the conclusion.
    4) When your group has finished, wait for a signal (teacher preference) before proceeding to the next station.
12. Be sure that all adults have the teacher copies of the Lift Experiments 1–6 and that they know to provide guidance for the result and the conclusion if the students are struggling or if they reach an incorrect result or conclusion.
13. Keep track of time and walk around the room giving assistance as needed. Allow longer periods of time, if necessary, at each station.
14. When all groups are finished with the experiments, assemble the class together to discuss the results and the conclusions of each experiment, making sure that they understand the properties of lift.
15. The following concepts should be grasped by the students:
    1) Gravity is the force that pulls down on an airplane, so a force greater than gravity is needed to lift the airplane into the air.
    2) Daniel Bernoulli is credited with Bernoulli's Principle, which states that faster moving air has less pressure than slower moving (or static) air.
    3) An airplane wing is rounded on the top surface causing the air to flow faster over the top than it does on the bottom. The shape of the wing moving through the air produces lift.
    4) Pilots produce additional lift by flying the plane so that the wing meets the air at a slight angle.

Optional Activity:

See "Airfoil on a String" on page 193.

Vocabulary—Lesson 17

angle of attack – the angle of a wing to the oncoming airflow (Airflow is the motion of air molecules as they flow around an object, such as a wing.)



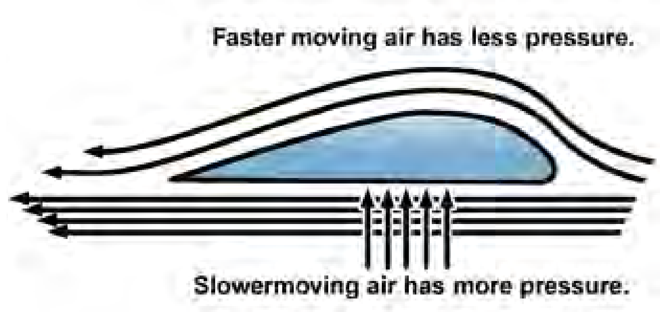
angle of attack

airflow

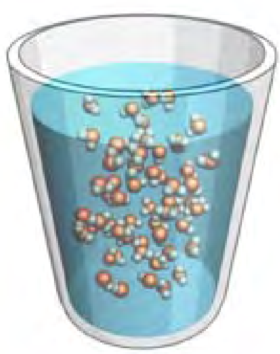
Bernoulli, Daniel – (1700–1782) Daniel Bernoulli was a Swiss mathematician. He was born on February 8, 1700, in the Netherlands to Swiss parents. As a university student, he studied philosophy and logic. His favorite subjects were mathematics and mechanics. From 1725 to 1733, he worked as a mathematician with his brother, Nicholas, at the St. Petersburg Academy of Sciences in Russia. He then worked as a professor at the University of Basel, in Switzerland, until his death on March 17, 1782. He is famous for his work in the field of fluids. In 1738, he wrote a book called *Hydrodynamica*. In this book, he explained his theories about how gases and liquids move, and how the speed at which they move affects the pressure they exert on objects they flow around. This is the basis for the explanation of lift. His work helped to lay the foundation for aeronautics, which would be developed many years later.

Daniel Bernoulli

Bernoulli's Principle – Daniel Bernoulli explained that, when a fluid moves faster, the molecules inside the fluid exert less pressure on the objects around them. Or, as the speed of a moving fluid increases, the pressure within the fluid decreases. This applies to all fluids, including water, air, and gases.

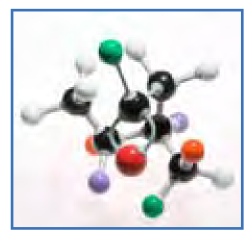


Bernoulli's Principle


fluid

fluid – a substance whose molecules move freely past one another and take the shape of its container; a liquid or gas

molecule – the absolute tiniest part of something that can still be called by that name (For example, two hydrogen atoms and one oxygen atom make up one molecule of water.)


molecules

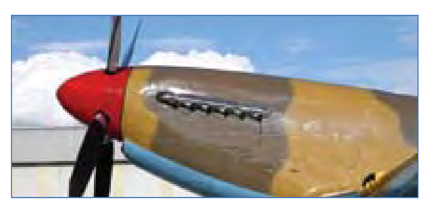
motorcycle – a two-wheeled motor vehicle resembling a heavy bicycle

example of Newton's Third Law of Motion

Newton's Third Law of Motion – the law, which states that, for every action, there is an equal and opposite reaction


motorcycle

nose – the front tip of an airplane

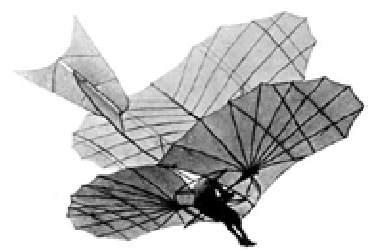

nose

Student Text—Lesson 17

It Lifts Me Up—The Force of Lift

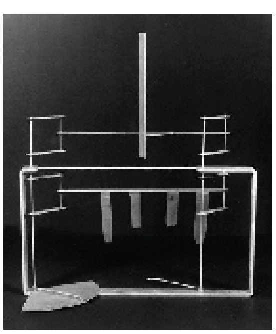
Overcoming Gravity

Gravity is the force that pulls down on an airplane. It gives the airplane weight. For an airplane to fly, it needs a force greater than gravity to push it up. That is why a plane needs the force of lift. Lift is an upward force. When a plane has lift, it can overcome the force of gravity.

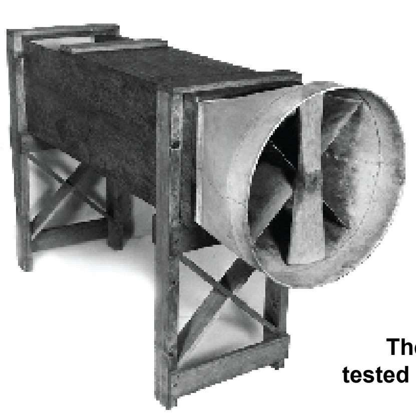


glider

But how does an airplane get lift? It all has to do with air. Wings are needed too, of course. Air and wings can be used to create lift. The aviation pioneers knew this. Even the birdmen knew this, but it took a few hundred years for them to find out that man could not fly by flapping. So, the aviation pioneers built gliders. The wings did not move on a glider. But the wings could be formed in such a way as to make the air push up on them. This is why the Wrights built a wind tunnel. They wanted to find the best way to design a wing so that the air would push up on it. They tested over 200 miniature airfoils of different shapes and sizes. Finally, they found the best shape for a wing so the air would lift up on it.



The lift balance tested the airfoil for lift.



Wind Tunnel

The drag balance tested the airfoil for drag.

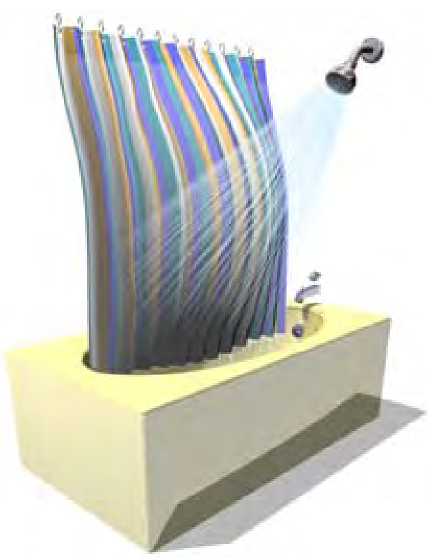
Special Collections and Archives, Wright State University.

Reproductions of the Wright Brothers wind tunnel and balances.

Going Fast and Pushing Less

fast moving air

We now know that an airplane gets lift in two ways. The first way is by making the air move rapidly over the wings. This is where Bernoulli comes in. **Daniel Bernoulli** was a Swiss scientist. He was working with **fluids**. A fluid is a substance whose **molecules** are free to move. Liquids and gases are fluids. So, water and air are fluids. He found that, when the flow of a fluid speeds up, it will not push as hard. In other words, the faster a fluid flows, the less pressure it will have. A shower curtain shows how this works. The water spray causes the air inside the shower to move faster. The fast moving air inside the shower pushes less. The air outside the shower is not moving very fast. So, it pushes more. And the curtain will push in. Have you ever noticed the jacket of a rider on a **motorcycle**? It puffs out when the rider is going fast. The fast moving air going by has less pressure than the still air inside the jacket. So, the air inside pushes harder and it puffs up the jacket.



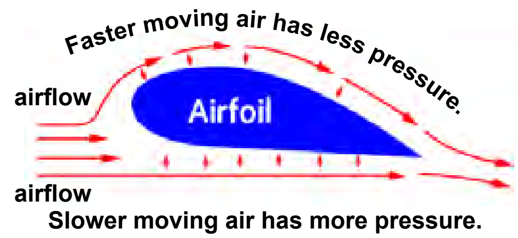
shower curtain

motorcycle rider with puffed shirt

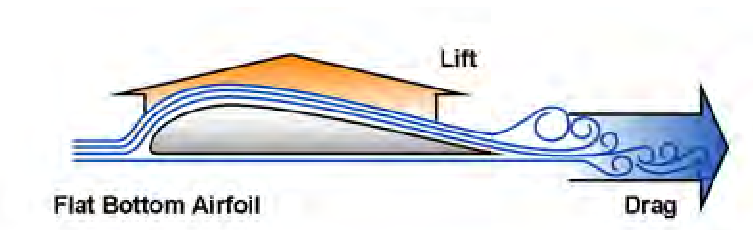
To understand lift, you must see how **Bernoulli's Principle** works on the wings. Airplane wings are rounded on top and flat on the bottom. This arched, or curved, shape on top causes the air flowing over it to move faster. So, the wing moving through the air has fast moving air on the top.

airplane wing cutaway

It has slower moving air on the bottom. We know that fast moving air has less pressure. It pushes less. The slower moving air has more pressure. It pushes more. So, the air on the bottom pushes more. This creates the upward force called lift on the wings of the plane.



airfoil wing

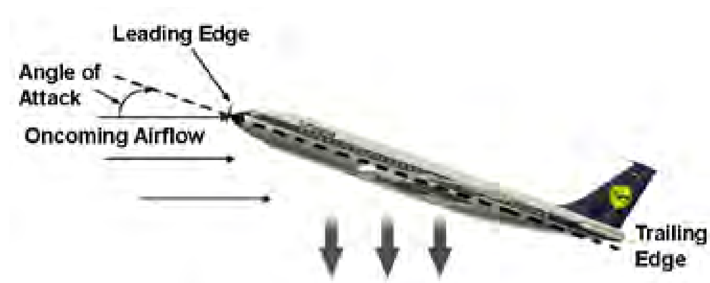


airfoil lift and drag

There is a second way that an airplane gets lift. It is by the **angle of attack** on the air. You may be thinking, "How in the world can a plane attack the air?" This means that a pilot can fly the plane so the wings meet the air at a slight angle. They zoom through the air with the wing slightly tilted up. The tilt causes the air to hit the bottom of the wing. This is called the angle of attack. The wing is shaped so that when the air hits the bottom of the wing, the air is pushed downward. That results in a reaction force, which pushes the wing upward. In other words, the wing exerts a force on the air. This causes the air to exert an equal and opposite force on the wing, causing lift. This is **Newton's Third Law of Motion**. It will be further explained when thrust is discussed.

Lifting Higher

Pilots must know the two ways to create lift. They know they must make the air move rapidly over the wings. They also know that more lift is created by the angle of the wings as they fly into the wind.



angle of attack

Pilots must also know how to make the plane go higher. There may be a bad storm. They may need to fly above it. Or there may be a high mountain in their path. So, they have to increase the lift. Lift can be increased in two ways. A pilot can increase the speed of the plane. This causes a faster flow of air over the top of the wing. So, the air below pushes up even harder. Or a pilot can increase the angle of attack. This means that the pilot lifts the **nose** of the plane so that more wind strikes the bottom of the wing. Watch a plane take off. Observe the steep angle of the plane as it flies into the wind. It's lifted higher and higher. As more air pushes on the bottom of the wing, it gives more lift. You can experience lift caused by the angle of attack. Put your hand out of the window of a moving car. Keep your palm down. Now, slowly rotate your hand causing the thumb to move up. See what happens.

plane taking off

pilot lifting the nose of the plane

pilot flying plane faster

We live at the bottom of an ocean of air. This air presses on every object on the Earth. We call this air pressure. Think about pressure being the same as a push. Pilots know how to make the air push the plane up instead of down. What if we had not discovered lift? What if there were no planes today? What do you think the world would be like without flying machines?

Lift Experiments—Teacher Copies

Lift Experiment 1—Chin Ups

Problem:
What will happen when you blow across the top of a piece of paper held against your chin?

Materials:
- 1 piece of 6- by 2-inch paper (15.2- by 5-centimeter) (or ¼ sheet of notebook paper)

Hypothesis:
The paper will ______________________________

Procedure:
1. Hold the piece of paper against your chin
2. Blow across the top surface of the paper.

Results:
The paper lifted up.

Conclusion:
This happened because the moving air you are blowing over the top surface of the paper has less pressure than the static (standing still) air below. This causes the paper to be pushed upward by the greater pressure of the static air.

Lift Experiment 2—Paper Pull

Problem:
What will happen to two long strips of paper when you blow air between them?

Materials:
- 2 strips of 2- by 12-inch (5- by 30.5-centimeter) paper.

Hypothesis:
The strips of paper will

____

Procedure:
1. Hold a strip of paper in each hand about 2 inches (5 centimeters) apart.
2. Blow between them.

Results:
The strips of paper came together.

Conclusion:
This happened because the air moving rapidly between the two pieces of paper has less pressure than the static (standing still) air pressing on the outer sides of the paper. This causes the paper to be pushed inward by the greater pressure of the static air.

Lift Experiment 3—Can It

Problem:
What will happen when you blow between two soda cans that are hanging from a ruler?

Materials:
- 2 empty soda cans with tabs.
- 2 pieces of 14-inch (35.6-centimeter) string.
- A 12-inch (30.5-centimeter) ruler.
- Tape.

Hypothesis:
The soda cans will ________________________________

Procedure:
1. Tie one piece of string to each tab of an empty soda can.
2. Tape or tie the strings to the ruler about 6 inches (15.2 centimeters apart.
3. Hold them up and wait for the cans to stop moving.
4. Blow between the cans.
5. Try blowing softly and then harder.

Results:
The cans came together.

Conclusion:
This happened because the air you blow between the cans is moving faster than the air around them. The pressure of moving air is less than that of static (standing still) air. The higher pressure around the objects pushes them together. The harder you blow, the faster the air is moving and the less pressure between the objects. So, they move together more quickly or with more force.

Lift Experiment 4—Ping-pong Funnel

Problem:
What will happen when you place a ping-pong ball in a funnel and blow down into the funnel?

Materials:
- 1 plastic funnel, 4- or 5-inch (10- or 12.7-centimeter).
- 1 ping-pong ball.

Hypothesis:
The ping-pong ball will

____

Procedure:
1. Place the ping-pong ball inside the funnel. (Invert the funnel.)
2. Hold the ball up in the funnel so that the ball covers the hole.
3. Lean over with the funnel in your mouth.
4. Blow hard and let go of the ball.

Results:
The ping-pong ball stayed up inside of the funnel, defying gravity.

Conclusion:
This happened because the fast moving air tends to follow along the curved sides of the funnel. The air pressure around the ball is thus lowered, and the greater pressure in the rest of the funnel pushes the ball up.

Follow-up Activity:
Thoroughly wash a funnel. Hold the funnel with the large end down over a 5- by 8-inch (12.7- by 20.3-centimeter) index card. Place your mouth over the small end of the funnel. Now, suck in the air as you would a straw and let go of the card. Observe. Now, blow air through the funnel and let go of the card. Observe.

Lift Experiment 5—Air Dance

Problem:
What will happen to a ping-pong ball when it is placed above a hair dryer that is turned on?

Materials:
- 1 hair dryer.
- 1 ping-pong ball.

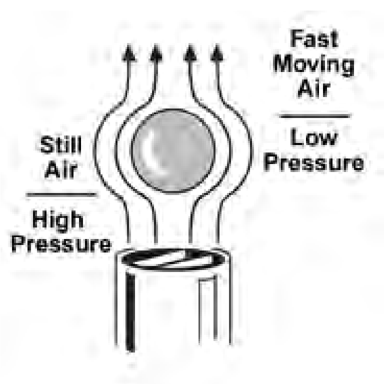
Hypothesis:
The ping-pong ball will ____________________
____
____

Procedure:
1. Point the hair dryer straight up and turn it on.
2. Put the ping-pong ball in the stream of air, close to the nozzle, and let go.

Results:
The ping-pong ball stayed in the middle of the air stream.

Conclusion:
This happened because the fast moving stream of air flowing around the ball has lower pressure than the static air in the room. Because the static air has a greater pressure, it pushes on the fast moving air to keep the ball in its place.

Follow-up Activity:
Try this experiment using the hair dryer at different speeds. Also, try tilting the hair dryer to see if the stream of air must be vertical. Does increasing the speed have an effect? (Teachers, have the students tilt the hair dryer only slightly at first. Then gradually tilt it until the ball drops.)



Lift Experiment 6—Wing It

Problem:
What will happen to a ruler with a curved card attached to it when you blow air across the card?

Materials:
- A 5- by 8-inch (12.7- by 20.3-centimeter) index card.
- A 6-sided pencil (not round).
- A 12-inch (30.5-centimeter) ruler.
- Tape.
- Hair dryer.

Hypothesis:
The ruler will ____________________________________

Procedure:
1. Fold over the index card vertically but do not crease it. Tape the two edges together.
2. Tape the edged-side of the card to the end of the ruler at the 2-inch (5-centimeter) mark. Tape the bottom of the card to the ruler as well.
3. Place the ruler on a six-sided pencil (fulcrum) with the card end down.
4. Weight the pencil down and very loosely tape the ruler to the pencil at the fulcrum to keep it from blowing away.
5. Hold the hair dryer facing the curved edge, and turn it on.

Results:
The ruler lifted up.

Conclusion:
This happened because the faster moving air flowing over the top of the paper has less pressure than the air under the ruler. The more stable air under the ruler has more pressure, lifting the ruler up.

Lift Experiment 1—Chin Ups

Problem:

What will happen when you blow across the top of a piece of paper held against your chin?

Hypothesis:

The paper will ____________________

____

Procedure:

1. Hold the piece of paper against your chin.
2. Blow across the top surface of the paper.

Results:

The paper ____

Conclusion:

This happened because ____________________________________

____

____

____

____

Lift Experiment 2—Paper Pull

Problem:

What will happen to two long strips of paper when you blow air between them?

Hypothesis:

The strips of paper will ______________________

____

Procedure:

1. Hold a strip of paper in each hand about 2 inches (5 centimeters) apart.
2. Blow between them.

Results:

The strips of paper ___________________________

____

Conclusion:

This happened because ______________________________________

____

____

____

____

____

____

Lift Experiment 3—Can It

Problem:

What will happen when you blow between two soda cans that are hanging from a ruler?

Hypothesis:

The soda cans will ______________
____
____

Procedure:

1. Tie one piece of string to each tab on an empty soda can.
2. Tape or tie the strings to the ruler about 6 inches (15.2 centimeters) apart.
3. Hold them up and wait for the cans to stop moving.
4. Blow between the cans.
5. Try blowing softly and then harder.

Results:

The cans ____

Conclusion:

This happened because ____
____

Lift Experiment 4—Ping-pong Funnel

Problem:

What will happen when you place a ping-pong ball in a funnel and blow down into the funnel? (A paper drinking cone will also work.)

Hypothesis:

The ping-pong ball will ______________________________

Procedure:

1. Place the ping-pong ball inside the funnel. (Invert the funnel.)
2. Hold the ball up in the funnel so that the ball covers the hole.
3. Lean over with the funnel in your mouth.
4. Blow hard and let go of the ball.

Results:

The ping-pong ball ____

Conclusion:

This happened because ____

____

Follow-up Activity:

Thoroughly wash a funnel. Hold the funnel with the large end down over a 5- by 8-inch (12.7- by 20.3-centimeter) index card. Place your mouth over the small end of the funnel. Now suck in the air as you would a straw and let go of the card. Observe. Now, blow air through the funnel and let go of the card. Observe.

Lift Experiment 5—Air Dance

Problem:

What will happen to a ping-pong ball when it is placed above a hair dryer that is turned on?

Hypothesis:

The ping-pong ball will ______________________

____

Procedure:

1. Point the hair dryer straight up and turn it on.
2. Put the ping-pong ball in the stream of air, close to the nozzle, and let go.

Results:

The ping-pong ball ____

Conclusion:

This happened because ____

____

Follow up Activity:

Try this experiment using the hair dryer at different speeds. Also, try tilting the hair dryer to see if the stream of air must be vertical. Does increasing the speed have an effect?

Lift Experiment 6—Wing It

Problem:

What will happen to a ruler with a curved card attached to it when you blow on it?

Hypothesis:

The ruler will ________________________

____

Procedure:

1. Fold over the index card vertically but do not crease it. Tape the two edges together.
2. Tape the edged-side of the card to the end of the ruler at the 2-inch (5-centimeter) mark. Tape the bottom of the card to the ruler as well.
3. Place the ruler on a six-sided pencil (fulcrum) with the card end down.
4. Weight the pencil down and very loosely tape the ruler to the pencil at the fulcrum to keep it from blowing away.
5. Hold the hair dryer facing the curved edge, and turn it on.

Results:

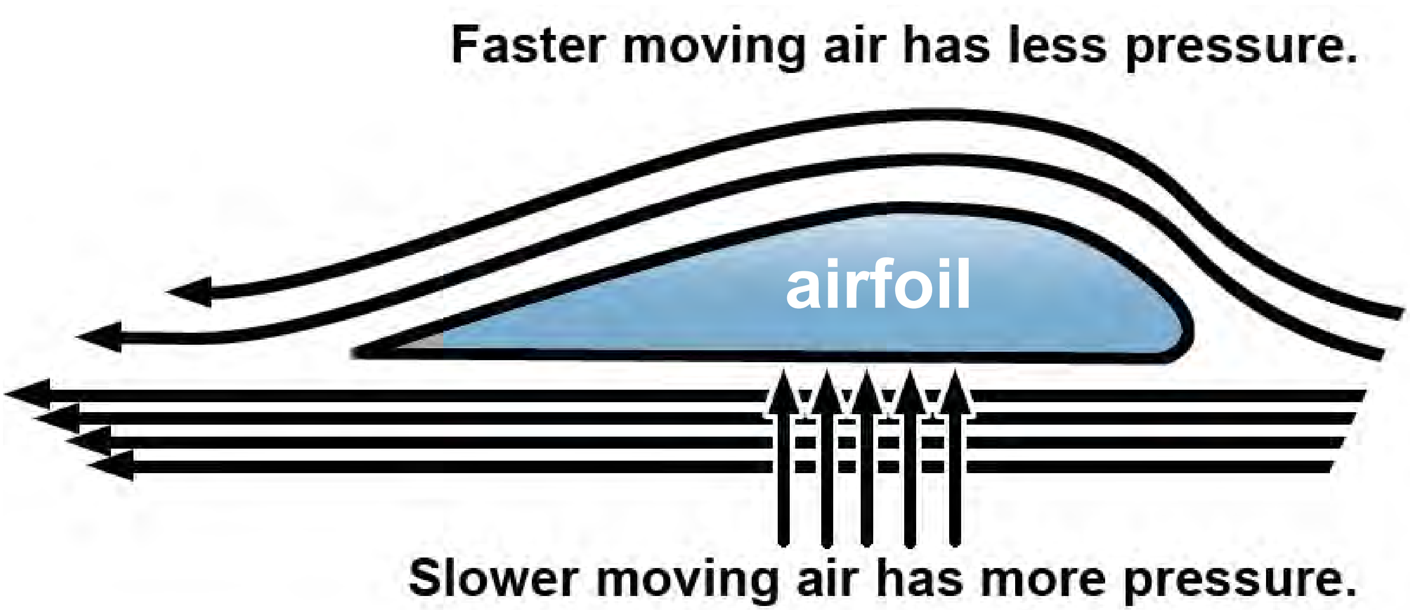
The ruler ____

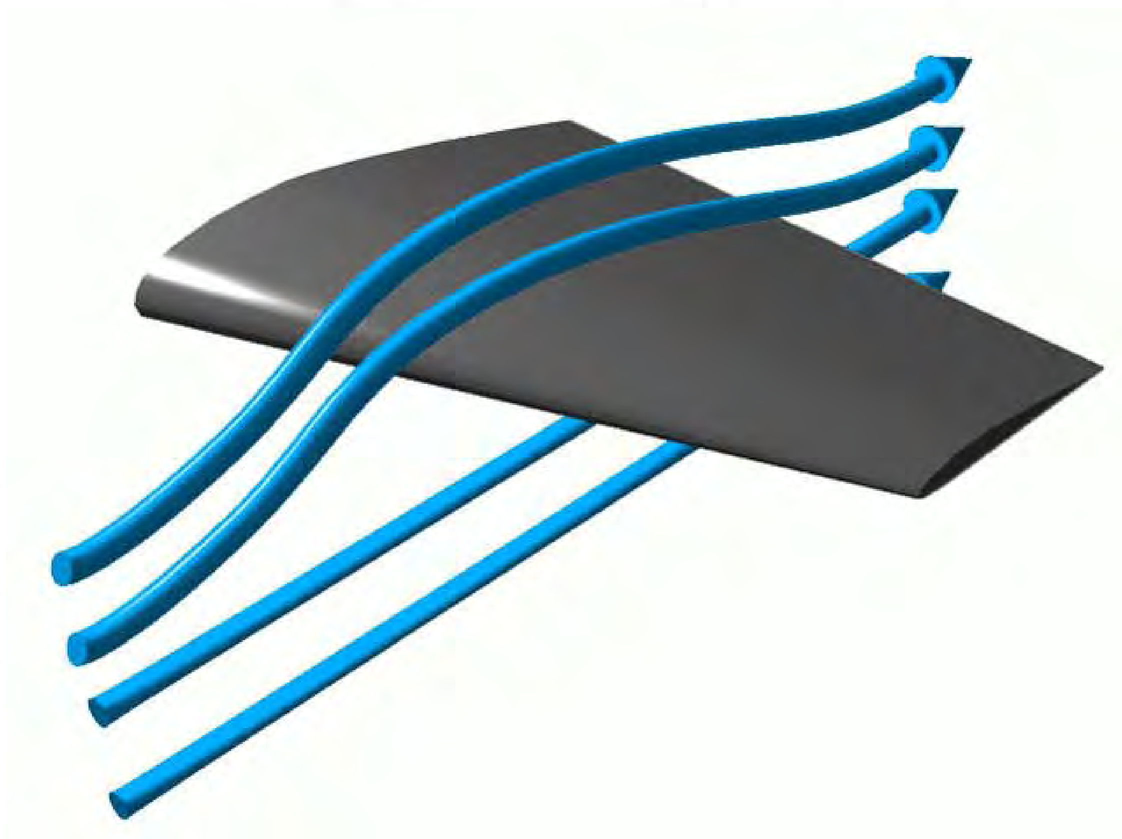
Conclusion:

This happened because ____

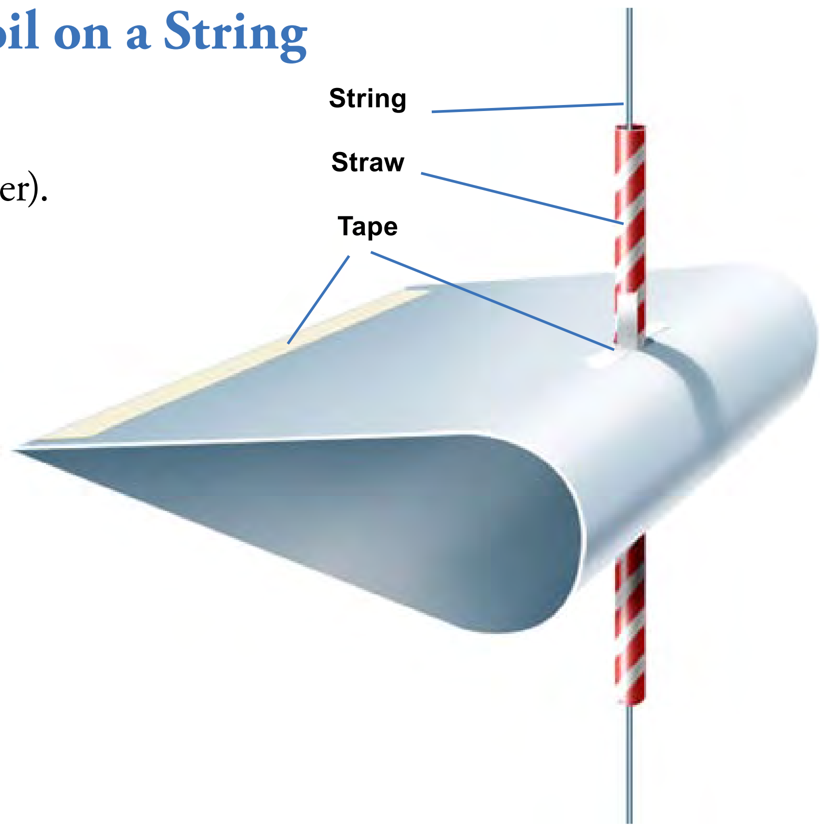
____

Airfoil


Faster moving air has less pressure.
airfoil
Slower moving air has more pressure.



Optional Activity—Airfoil on a String

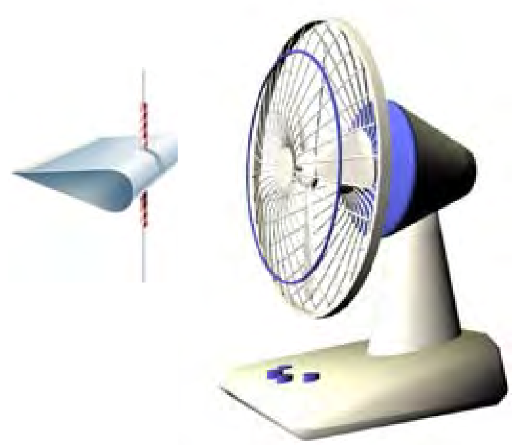


Materials

- Lightweight paper (notebook paper).
- Scissors.
- Straw – 1 straw for every 2 students.
- String – 18 inches (45.7 centimeters) for each student.
- Fan.

Instructions for Assembly

1. Cut a strip of paper about 1½ by 10 inches (3.8 by 25.4 centimeters) long.
2. Cut a length of straw about 3 inches (7.6 centimeters) long.
3. Fold the paper lengthwise to make a wing shape, but do not make a crease. Tape the two ends together.
4. Use a pencil to push a small hole through the wing. It should go through both the top and bottom of the wing.
5. Push the straw through the holes and tape it in place.
6. Thread the piece of string through the straw.
7. When it is your turn, hold the wing on the string lengthwise in front of a fan. Observe.



Lesson 18— The Opposing Forces of Thrust and Drag

Materials—Lesson 18

- Student logs.
- A copy of the student text for Lesson 18, "The Opposing Forces of Thrust and Drag," for each student.
- An electric fan (small room-size).
- A 12- by 18-inch (30.5- by 45.7-centimeter) piece of poster board, tag board, or thin cardboard.
- Roller skates or roller blades for an adult. (If you're brave!)
- A large ball such as a soccer ball, basketball, or volley ball.
- 2 sheets of notebook paper for each student.

Pre-lesson Instructions—Lesson 18

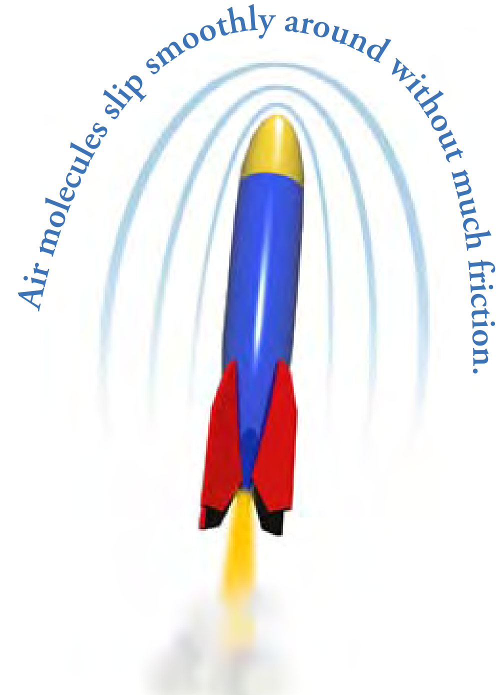
1. Make sure that there are enough copies of the student text for Lesson 18, "The Opposing Forces of Thrust and Drag," for each student and that holes have been punched.
2. Set up the fan and poster board, and have the roller skates and ball ready to demonstrate these activities as the text is read. If the teacher plans on demonstrating the roller skates activity, it may be wise to practice it first. (See the last paragraph in the student text section, "Pushing Forward With Thrust.")

Procedure—Lesson 18

1. Distribute copies of the student text Lesson 18, "The Opposing Forces of Thrust and Drag," so students can insert these in their logs.
2. Introduce and teach the vocabulary as you would any guided reading. Several words are repeated for review and others have a slightly different meaning to comply with their use in the text.
3. As the class discusses the text, question their understanding and encourage their questions. Read and discuss the first paragraph of the section, "Pushing Forward With Thrust." Remind the students about the Frisbees®. The thrust they gave them with their arm moved the Frisbee® forward.
4. Read and discuss the second paragraph of the section, "Pushing Forward with Thrust." Ask a student to hold a large sheet of stiff paper, such as tagboard, about 5 inches (12.7 centimeters) from the back of the fan. Ask the students what they think will happen when the fan is turned on. Then, turn the fan on. The fan will pull the paper next to the grill. Explain that the fan is pulling in air from the back and then pushing it out the front.
5. Finish the section, "Pushing Forward With Thrust." If you, the teacher, or another adult could put on a pair of roller skates or roller blades to demonstrate thrust, this is the ideal time to do it. Just do not lose your balance! Your students will not remember anything at all about thrust if you do! Ask the students what they think will happen when the ball is thrown. Then, use two hands to thrust the ball forward from your chest to a student. You will roll backwards, so be careful.
6. Begin to read and discuss the section "Slowing Down With Drag." When you read about riding a bicycle against the wind, allow the students to share their stories about that experience.
7. After reading paragraph 3 of "Slowing Down with Drag," draw a bulky vehicle on the board. Use vertical lines for the front grill section and the front windshield to form broad leading edges. Show how air molecules collide with the front of the vehicle. Then draw a streamlined vehicle with a small, rounded, leading edge and curved lines flowing backward. Show how easily the air flows over the surface. Ask the students to recall the term given to a vehicle that is designed, or shaped, to have less drag (**aerodynamic**). Ask the students to identify experiences where people need to be aerodynamic.
8. Finish reading the text. Then instruct the students to get out two identical sheets of notebook paper and perform the demonstration in "Paper Shape" on their own. Let them discuss their findings.

Vocabulary—Lesson 18

aerodynamic – designed in such a way as to reduce wind drag on a vehicle



The aerodynamic shape of the rocket reduces drag.

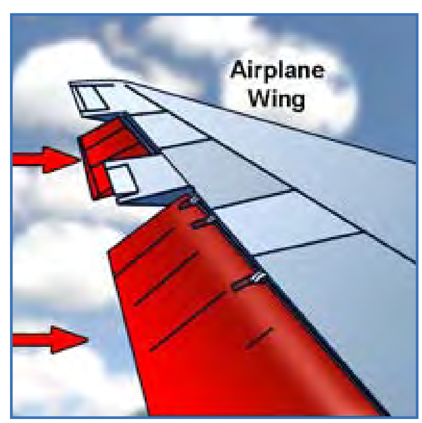
air resistance – a type of drag that occurs as an object moves through the air

Air resistance causes objects to slow down as they move through the air.

collide – crash together with violent impact

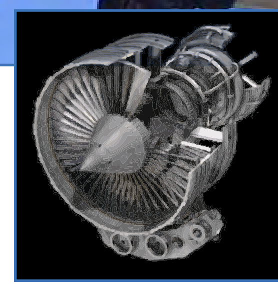
drag – the force of resistance to the motion of a vehicle body as it moves through a fluid such as water or air

flaps – part of the trailing edge of the wing that is lowered to increase lift and also to slow the aircraft down for landing by increasing drag



flaps

jet engine – a type of air-breathing engine, often used on aircraft. The engine draws air in at the front and compresses it. The air is combined with fuel and ignited, and the engine burns the resulting mixture. The combustion (burning) greatly increases the volume of the gases, which are then exhausted (pushed) out of the rear of the engine. The force of the gases being pushed out of the back thrusts the plane forward (Newton's Third Law of Motion).



jet engine

landing gear

landing gear – wheels, floats, or skis of an aircraft that first come in contact with the landing surface

Newton's Third Law of Motion – the law which states that for every action, there is an equal and opposite reaction

parachutist – one who uses a parachute (a device that fills with air and slows your fall)

parachutist

propeller

propeller – a device that consists of blades (shaped like airfoils) that spin around a central hub, like a fan; an engine causes the blades to turn. When the blades turn, they create thrust by biting into the air and forcing it to move back. The amount of thrust can be controlled by changing the speed or the twist of the propellers.

resistance – a force that tends to oppose or slow down motion

streamlined – describes an object designed so that it creates less drag and moves smoothly and easily through the air

a streamlined vehicle

thrust – a force, created by the engines, that pushes an aircraft through the air

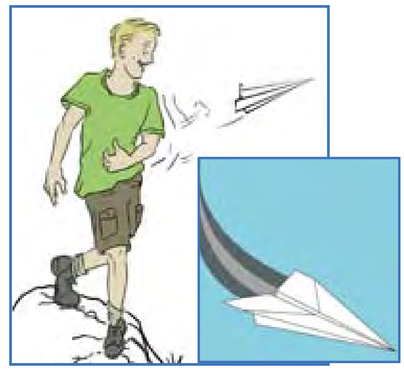
Student Text—Lesson 18

The Opposing Forces of Thrust and Drag

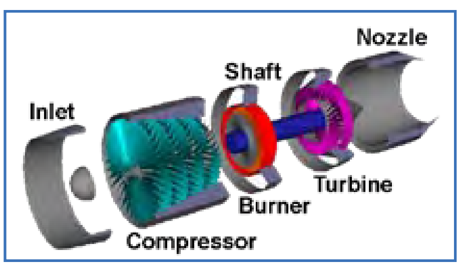
Pushing Forward With Thrust

Wings give an airplane lift. But wings cannot make a plane go forward. That takes the force of **thrust**. Thrust is the force that moves an airplane forward. Thrust affects how fast and how far you go. When you throw a paper airplane forward, you're providing the thrust. Birds flap their wings to create thrust.

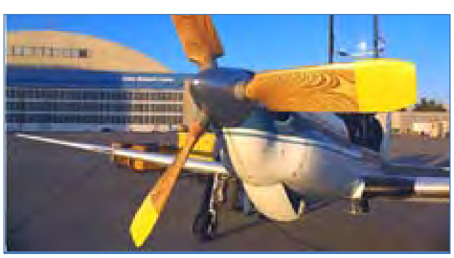
Birds flap their wings to produce thrust.



Throwing a paper airplane creates thrust.



cutaway on a jet engine



Thrust is provided by propellers on this plane.

In real airplanes, thrust is usually provided with propellers or a jet engine. When planes use propellers, an engine (usually a piston engine) turns the propellers at a very high speed. A propeller plane has a set of two or more small rotating wings. But the lift they create is pushed forward. This pulls the plane through the air. Like a fan, the propellers pull air in and push it out in the opposite direction. Jet airplanes use jet engines. These jet engines pull air in and mix it with fuel. Then the burning gas goes out the back, pushing the plane forward.

We know that Sir Isaac Newton studied gravity. He also studied motion. He is known for his three laws of motion. **Newton's Third Law of Motion** states, "For every action there is an equal and opposite reaction." In both kinds of engines, air is pulled in and then pushed out in the opposite direction. When the air pushes backward, it thrusts the plane forward. This is how thrust works.

throwing a ball while on skates

The next time you're on roller skates or roller blades, try this. Stand still and throw a ball forward. When you thrust the ball forward, this action will create an equal and opposite reaction. What happened?

Slowing Down With Drag

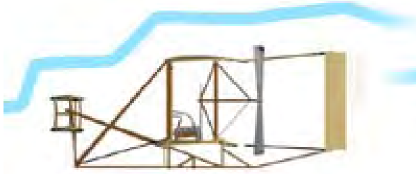
Look at the opposing forces at work on a plane again. Gravity works against lift on a plane. **Drag** works against thrust on a plane. Drag is the **resistance** of the airplane to forward motion. It wants to hold a plane back. You can feel a force pushing on you when you ride your bicycle against the wind. As you pedal forward through the air, the air pushes back. This is drag.

student riding against the wind

Drag is caused by air pushing against the airplane. This is called

air resistance. As an airplane moves through the air, it **collides** with air molecules. These air molecules must go around the plane. The air "rubs" against the metal of the plane. This is one way drag slows the airplane down.

The plane collides with air molecules.



Air molecules collide with bulky objects.

aerodynamic

The shape of the plane can make more or less drag. A **streamlined** plane has less drag. It moves through the air more easily. This is because its shape allows the air to flow easily over it. A bulky shaped plane has more drag. Air cannot flow easily over it. We call a plane **aerodynamic** if it has little drag.

The surface of the plane can also affect drag. A smooth surface has less drag than a rough one.

We can feel drag when we put our arm out the window of a moving car. But if we lift our hand up, palm forward, this creates more drag.

If a pilot wants to increase his speed, he gives the plane more thrust. When thrust is greater than drag, the plane speeds up. A pilot uses drag to land the plane. An airplane's **flaps** and **landing gear** help create drag. This slows the plane down for landing.

hand creating drag

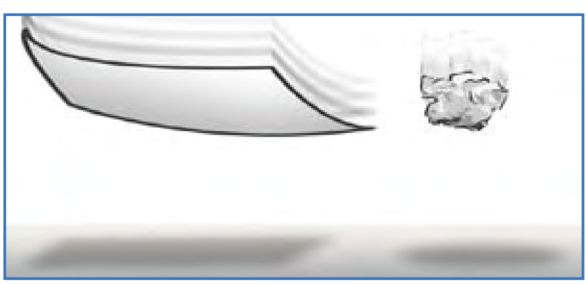
Paper Shape

Flaps on a plane help to create drag.

Do you remember the gravity experiment Paper Shape? Get two identical sheets of paper. Crumple one into a ball. Place the other sheet flat on your hand. Drop the two sheets of paper at the same time from at least 4 feet (1.2 meters) high. Which one will reach the floor first? The ball of paper will hit the floor first because its streamlined shape does not "ride on" the air. The flat sheet of paper has a larger leading surface area to meet more air resistance. So, it has more drag and moves more slowly through the air.

crumpled versus flat

When you are trying to move through the air, we think of drag as a bad thing. But we should be thankful for drag. If it were not for drag, rain drops would feel like bullets. Do you think a **parachutist** likes drag?



flat versus crumpled

parachutist

Lesson 19—Thrust and Drag Experiments

Materials—Lesson 19

- Student logs.
- Copies of the Thrust Experiments 1–3 and Drag Experiments 1–3 (teacher copies include a list of materials and answers for results and conclusions) for the teacher and each adult volunteer.
- Copies of the Thrust Experiments 1–3 (student copies) and Drag Experiments 1–3 (student copies) for each group (should be a total of 6 groups).

Materials for each of the following experiments:

Thrust Experiment 1—Balloon Jets

(Note: Blow up the balloons to the four different sizes and attach the straws for all six groups beforehand to save time.)

- Nylon fishing line. (About 40 feet (12 meters) will be needed.)
- Pack of elliptical (hotdog) shaped, helium quality balloons—all the same size. (24 are needed, but have extras on hand.)
- 4–10 strong plastic straws. (4 are needed, but have extras on hand.)
- Clear tape.
- 4 pairs of scissors.

Thrust Experiment 2—Moving Fan

- 1 electric fan.
- Wagon **or** replace the wagon with:
  - One 10- by 12-inch (25.4- by 30.5-centimeter) board large enough for the fan to sit on, and
  - 10–16 perfectly round pencils (or dowels).

Thrust Experiment 3—Pop the Cork

(Note: If you cannot find a plastic bottle with a cork, skip this experiment and go to the alternate experiment, **Flow Away**. A glass bottle could be used, but it is not recommended that young students work with glass.)

- Plastic soda bottle with a cork (1- or 2-liter size).
- A large container of vinegar (perhaps a gallon, enough to fill a soda bottle half full 6 different times).
- Baking soda.
- 1 teaspoon.
- Measuring cup (1 pint).
- Petroleum jelly (if needed).
- 10 perfectly round pencils or dowels.

Thrust Experiment 3 (Alternate)—Flow Away

- Strong plastic cup (about 10-12 ounce).
- 3 pieces of string, each about 10 inches (25.4 centimeters) long.
- Watering can (or something to pour water with).
- Dishpan.
- Hole punch.
- Scissors.
- Masking tape.
- Access to water (sink, spigot, etc.).

Drag Experiment 1—Run With It

(Note: An adult is needed at this station.)

- 1 large piece of poster board (18- by 24-inch or 45.7- by 61-centimeter or larger).
- String (about 2 feet or 0.6 meter).
- Hole punch.
- Stopwatch.
- Course for running (at least 25 yards or 23 meters).

Drag Experiment 2—Parachute Fun

(Note: Have a parent, student, or educational assistant construct these ahead of time. See Drag Experiment 2, teacher copy, for directions.)

- Tape.
- Ball of string.
- 3 different squares of the same fabric (about 8, 12, and 16 inches or 20, 30.5 and 40.6 centimeters).
- 3 identical, small plastic figures (teddy bear counters, action figures, or other miniature plastic figures) or 3 clothes pins.

Drag Experiment 3—It's A Drag

(Note: This experiment should be performed next to a sink for cleanup in between groups. An adult is needed at this station.)

- 1 tall clear container with a very wide mouth.
- Shish kabob skewer or tongs (or other device to retrieve clay shapes from corn syrup).
- Clear corn syrup (enough to fill ¾+ of the container).
- 6 bars of modeling clay (1 new bar for each group).
- Balance scale.
- Stopwatch.
- Pencil and paper to record times.

Pre-lesson Instructions—Lesson 19

1. Make sure that there are six sets of the Thrust Experiments 1–3 and Drag Experiments 1–3 (student copies), one set for each group.
2. Make sure that there are enough sets of the Thrust Experiments 1–3 and Drag Experiments 1–3 (teacher copies) for the teacher and each adult volunteer.
3. Make adjustments to the six groups, if necessary.
4. Check to see that all materials for the thrust and drag experiments have been gathered. Set up each experiment in its station. Change the station numbers. Renumber them 1–3 for the thrust experiments and 1–3 for the drag experiments. Name each station.
5. Set up a running course for Drag Experiment 1. This needs to be about 25 yards (23 meters) long for best results. An adult needs to be at this station.
6. See the teacher copy of Drag Experiment 2. Have a parent, student, or educational assistant make the parachutes ahead of time. Directions are given in the procedure section of that experiment.
7. Make sure adult volunteers are available and provide each one a set of the teacher copies of the Thrust Experiments 1–3 and Drag Experiments 1–3.

Procedure—Lesson 19

1. Tell the students that they will be conducting experiments on thrust and drag, the forces they read about in Lesson 18. Make any necessary changes to the groups at this time. Ask the recorder to get out the schedule for the reader and the scientist.
2. Distribute the sets of Thrust and Drag Experiments to the recorder of each group.
3. Remind the class of the instructions for conducting the experiments. (Adult volunteers should be present to hear these.)
   1) Only 7 minutes will be allowed at each station; so get right to work.
   2) After the reader reads the problem, discuss the hypothesis and decide as a group what this will be. Remember that the hypothesis is a good guess of what will happen. The recorder will write the hypothesis on the experiment worksheet. Then the reader reads the procedure as the scientist performs each step. Rotate the reader and the scientist at each station.
   3) After all steps are completed, the group should discuss the results and the conclusion. The group should help the recorder fill in the results and the conclusion.
   4) When your group has finished, wait for a signal (teacher preference) before proceeding to the next station.
4. Be sure that all adults have teacher copies of the Thrust Experiments 1–3 and Drag Experiments 1–3 and that they know to provide guidance for the result and the conclusion if the students are struggling or if they reach an incorrect result or conclusion.
5. Keep track of time and walk around the room giving assistance as needed. Allow longer periods of time at each station if necessary.
6. When all groups are finished, assemble together to discuss the results and conclusions of each experiment, making sure that they understand the properties of thrust and drag.

7. The following concepts should be grasped by the students:

   1) Thrust is the force that moves an airplane forward.

   2) Thrust in airplanes is provided with an engine (usually a piston engine) that turns a propeller or a jet engine.

   3) Newton's Third Law of Motion states that for every action there is an equal and opposite reaction.

   4) To produce thrust, the airplane engines push air backward (the action) causing the plane to go forward (an equal and opposite reaction).

   5) Drag is caused by air pushing against the airplane. This air resistance slows the forward motion of a plane.

   6) The larger the leading surface area of an object, the stronger the force of drag will be on that object.

   7) Streamline shaped planes (or objects) have less drag and are aerodynamic.

Thrust Experiments—Teacher Copies

Thrust Experiment 1—Balloon Jets

Problem:
If four balloons are blown up to different sizes, which balloon will travel the farthest when the air is released?

Materials:
- Nylon fishing line (about 40 feet or 12 meters will be needed).
- Pack of elliptical (hotdog) shaped, helium quality balloons—all the same size (24 are needed, but have extras on hand).
- 4–10 strong plastic straws (4 are needed, but have extras on hand).
- Clear tape.
- 4 pairs of scissors.
- 8 student chairs or desks.

Hypothesis:
The _________ balloon traveled the farthest.

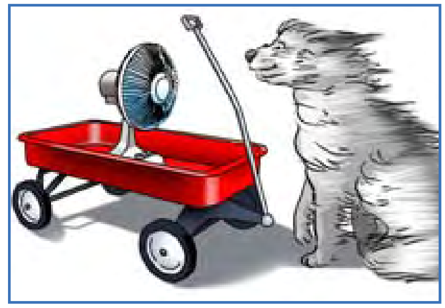
Procedure:
1. Inflate 4 balloons so that each is a different size, from barely inflated to fully inflated, and tie them shut.
2. Using tape, attach a straw lengthwise to each balloon.
3. Cut 4 equal lengths of fishing line, each about 10 feet (3 meters) long.
4. Thread each piece of fishing line through one of the straws and attach each end to a chair back.
5. Position the balloons at the end of each piece of string.
6. Snip the ends off of the balloons and observe.

Results:
The biggest balloon traveled the farthest.

Conclusion:
This happened because, for every action, there is an equal and opposite reaction. When the air is released from the balloon, the balloon moved in the opposite direction. When more air is released (the action), there is more push in the opposite direction (the equal and opposite reaction). More push caused the biggest balloon to travel the farthest.

Thrust Experiment 2—Moving Fan

Problem:
What will happen when you turn a fan on while it sits on a wagon (or on rollers)?



Materials:
- 1 electric fan.
- Wagon **or** replace the wagon with:
  - A 10- by 12-inch (25.4- by 30.5-centimeter) board large enough for the fan to sit on, and
  - 10–16 perfectly round pencils (or dowels).

Hypothesis:
The wagon (or board) will ______________________________
____

Procedure:
1. Place the fan in the wagon (or on the board lying across the pencils).
2. Turn the fan on.

Results:
The fan caused the wagon (or the board) to move in a backward motion, opposite the flow of the outward blowing air.

Conclusion:
This happened because, for every action, there is an equal and opposite reaction. The fan pushes the air out the front (action), which causes the fan to move in the opposite direction (an equal and opposite reaction).

Thrust Experiment 3—Pop the Cork

(Note: It would be best to perform this experiment outside, perhaps on a black top or other hard-surfaced area, because it will be messy.)

Problem:
What will happen to a bottle on rollers when it pops its cork?

Materials:
- Plastic soda bottle with a cork (1- or 2-liter size).
- A large container of vinegar (perhaps a gallon, enough to fill a soda bottle half full 6 different times).
- Baking soda.
- 1 teaspoon.
- Measuring cup (1 pint).
- Petroleum jelly (if needed).
- 10 perfectly round pencils (or dowels).

Hypothesis:
The bottle will ________________________________

Procedure:
1. Space the pencils about an inch apart on a table.
2. Grease the sides and bottom of the cork thoroughly with petroleum jelly and be ready to insert the cork quickly.
3. Fill the soda bottle half full with equal amounts of water and vinegar (50% water and 50% vinegar).
4. Pour 2 teaspoons of baking soda into the bottle and immediately insert the cork.
5. Lay the bottle on its side across the pencils.

Results:
The bottle rolled backward on the pencils when the cork was popped forward.

Conclusion:
This happened because, for every action, there is an equal and opposite reaction. The water, vinegar, and baking soda mixture in the bottle causes the air to expand. This increases the pressure and pushes the cork out. The force of the cork being pushed out (the action) causes an equal and opposite reaction on the bottle that forces it backward.

Thrust Experiment 3 (Alternate)—Flow Away

Problem:
What will happen to a cup filled with water that is suspended from a string when you open a hole in the side of the cup?

Materials:
- Strong plastic cup (about 10–12 ounces).
- 3 pieces of string, each about 10 inches (25 centimeters) long.
- Watering can (or something to pour water with).
- Dishpan.
- Hole punch.
- Scissors.
- Masking tape.
- Access to water (sink, spigot, etc.).

Hypothesis:
The cup will ___________________________________

Procedure:
(Note: The teacher or another adult should complete Steps 1–3 beforehand.)
1. Punch three holes around the top of the cup, equal distances apart.
2. Thread and knot each piece of string through a hole so that the cup is suspended and balanced.
3. Using the scissors, punch a hole in the side of the cup at a point where it intersects the bottom. Cover it with masking tape.
4. Fill the cup with water, hold it over the dishpan, and carefully remove the tape.

Results:
The cup moved in the opposite direction of the flow of water.

Conclusion:
This happened because, for every action, there is an equal and opposite reaction. The force of the water rushing out of the cup (the action) caused the cup to move in the opposite direction (the equal and opposite reaction).

Drag Experiments—Teacher copies

Drag Experiment 1—Run With It

Problem:
Can I run faster with or without a piece of poster board in front of me?

Materials:
- 1 large piece of poster board (18 by 24 inches or 45.7 by 61 centimeters or larger).
- String (about 2 feet or 0.6 meter).
- Hole punch.
- Stopwatch.
- Course for running (25 yards or 23 meters or more).

Hypothesis:
I will run faster ______________________________

Procedure:
(Note: The teacher or another adult should complete Step 1 beforehand.)
1. Punch two holes in the top (about 2 inches or 5 centimeters down) of the poster board and insert and knot the string so that it can be placed over a student's head.
2. Place the string around your neck with the poster board hanging in front of you. Hold the poster board next to your body and run the course while someone times you with a stopwatch.
3. Run the course without the poster board while being timed.
4. Compare the times.

Results:
I ran faster without the poster board.

Conclusion:
This happened because of drag, the air resistance against the poster board. The large leading surface of the poster board collided with more air molecules than when I ran without it. Its bulky shape was not as streamlined as my body.

Follow-up Activity:
If time allows, have the students race each other. Let the students take turns wearing the poster board.

Drag Experiment 2—Parachute Fun

Problem:
If you dropped three parachutes of different sizes to the floor from the same height, which one would hit the floor last?

Hypothesis:
The __________ parachute would hit the floor last.

Materials:
- Tape.
- Ball of string.
- 3 different size squares of the same fabric (about 8, 12, and 16 inches or 20, 30.5 and 40.6 centimeters).
- 3 identical, small plastic figures (teddy bear counters, action figures, or other miniature plastic figures) or 3 clothespins.

Procedure:
1. Cut 12 pieces of string, each about 12 inches (30.5 centimeters) long.
2. Tape a string to each corner of the 3 fabric squares, and then staple the corners to make the parachute stronger.
3. On each parachute, take the loose ends of the four strings and tape them together.
4. Attach a plastic figure to the taped strings of each parachute (or clip on a clothespin).
5. Find the highest point inside the building that is safe to drop the parachutes.
6. Drop all three at the same time, keeping the figures at the same height before the drop.

Results:
The biggest parachute hit the floor last.

Conclusion:
This happened because it had more drag than the other two. The larger the surface, the more air resistance there is to an object in motion. The larger surface collided with more air molecules so it had more air resistance, more drag. More drag slowed the parachute down so that it hit the floor last.

Drag Experiment 3—It's A Drag

(Note: This experiment should be performed next to a sink for cleanup in between groups. An adult is needed at this station.)

Problem:
What will happen to pieces of modeling clay of the same size, but different shapes when they are dropped into a bottle of corn syrup?

Materials:
- 1 tall clear container with a very wide mouth.
- Shish kabob skewer or tongs (or other device to retrieve clay shapes from corn syrup).
- Clear corn syrup (enough to fill ¾+ of the container).
- 6 bars of modeling clay (1 bar for each group).
- Balance scale.
- Stopwatch.
- Pencil and paper to record times.

Hypothesis:
The ________________ shape will hit the bottom first.

Procedure:
1. Fill the tall container ¾+ full with clear corn syrup and mark the outside of the container to show the fill-line.
2. Cut one bar of modeling clay into four same-size pieces. Use a balance scale to make sure that the pieces weigh the same.
3. Form various shapes with the pieces (one very streamlined, the others less streamlined to more bulky such as a teardrop, a cube, a sphere, a rectangular prism, etc.).
4. Drop the shapes, one at a time, into the bottle of corn syrup and time each drop. Record each time.
5. Retrieve the shapes with the shish kabob skewer. (Refill container to the fill-line to prepare for the next group.)

Results:
The more streamlined shapes dropped the quickest.

Conclusion:
This happened because streamlined shapes have less drag. In this case, the shapes traveled through a fluid other than air. But bulky shapes still collide with more molecules, whether air or liquid.

Thrust Experiment 1—Balloon Jets

Problem:

If four balloons are blown up to different sizes, which balloon will travel the farthest?

Hypothesis:

The ___________ balloon traveled the farthest.

Procedure:

1. Inflate 4 balloons so that each is a different size, from barely inflated to fully inflated, and tie them shut.
2. Using tape, attach a straw lengthwise to each balloon.
3. Cut 4 equal lengths of fishing line, each about 10 feet (3 meters) long.
4. Thread each piece of fishing line through one of the straws and attach each end to a chair back so that there are 4 equal lines spanning 4 sets of chairs.
5. Position the balloons at the end of each piece of string.
6. Snip the ends off of the balloons and observe.

Results:

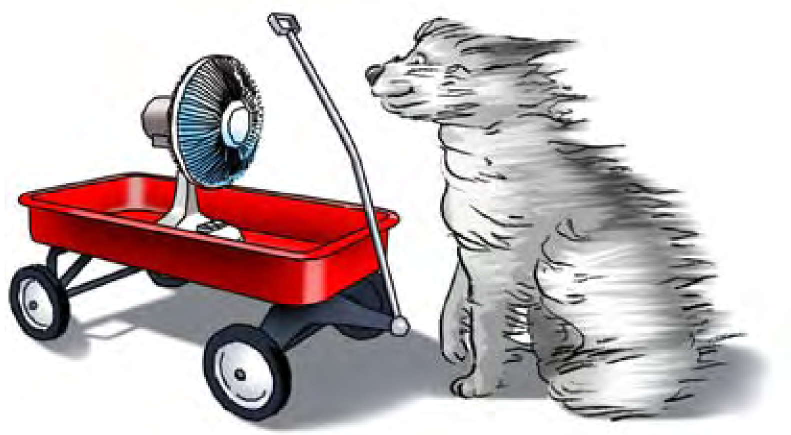
The __________ balloon traveled the farthest.

Conclusion:

This happened because ____

____

Thrust Experiment 2—Moving Fan



Problem:

What will happen when you turn a fan on while it sits on a wagon (or on rollers)?

Hypothesis:

The wagon (or board) will ______
____
____

Procedure:

1. Place the fan in the wagon
(or on the board lying across the pencils).
2. Turn the fan on.

Results:

The fan ______________________________

Conclusion:

This happened because ______________________________
____
____
____
____

Thrust Experiment 3—Pop the Cork

(Note: It would be best to perform this experiment outside, perhaps on a black top or other hard-surfaced area, because it will be messy.)

Problem:
What will happen to a bottle on rollers when it pops its cork?

Hypothesis:
The bottle will ______________________________

Procedure:
1. Space the pencils about an inch apart on a table.
2. Grease the sides and bottom of the cork thoroughly with petroleum jelly and be ready to insert the cork quickly.
3. Fill the soda bottle half full with equal amounts of water and vinegar (50% water and 50% vinegar).
4. Pour 2 teaspoons of baking soda into the bottle and immediately insert the cork.
5. Lay the bottle on its side across the pencils.

Results:
The bottle ____

Conclusion:
This happened because ____

____

Thrust Experiment 3 (Alternate)—Flow Away

Problem:

What will happen to a cup filled with water that is suspended from a string when you open a hole in the side of the cup?

Hypothesis:

The cup will ______________________________

Procedure:

(Note: The teacher or another adult should complete Steps 1–3 beforehand.)

1. Punch three holes around the top of the cup, equal distances apart.
2. Thread and knot each piece of string through a hole so that the cup is suspended and balanced.
3. Using the scissors, punch a hole in the side of the cup at a point where it intersects the bottom. Cover it with masking tape.
4. Fill the cup with water, hold it over the dishpan, and carefully remove the tape.

Results:

The cup ____

Conclusion:

This happened because ____

____

Drag Experiment 1—Run With It

Problem:

Can I run faster with or without a piece of poster board in front of me?

Hypothesis:

I will run faster ______________________________

Procedure:

(Note: The teacher or another adult should complete Step 1 beforehand.)

1. Punch two holes in the top (about 2 inches or 5 centimeters down) of the poster board and insert and knot the string so that it can be placed over a student's head.
2. Place the string around your neck with the poster board hanging in front of you. Hold the poster board next to your body and run the course while someone times you with a stopwatch.
3. Run the course without the poster board while being timed.
4. Compare the times.

Results:

I ran ____

Conclusion:

This happened because ____

____

Follow-up Activity:

If time allows, have the students race each other. Let the students take turns wearing the poster board.

Drag Experiment 2—Parachute Fun

Problem:

If you dropped three parachutes of different sizes to the floor from the same height, which one would hit the floor last?

Hypothesis:

The __________ parachute would hit the floor last.

Procedure:

1. Cut 12 pieces of string, each about 12 inches (30.5 centimeters) long.
2. Tape a string to each corner of the 3 fabric squares, and then staple the corners to make the parachute stronger.
3. On each parachute, take the loose ends of the four strings and tape them together.
4. Attach a plastic figure to the taped strings of each parachute (or clip on a clothespin).
5. Find the highest point inside the building that is safe to drop the parachutes.
6. Drop all three at the same time.

Results:

The __________ parachute hit the floor last.

Conclusion:

This happened because ____

____

Drag Experiment 3—It's A Drag

(Note: This experiment should be performed next to a sink for cleanup in between groups. An adult is needed at this station.)

Problem:
What will happen to pieces of modeling clay of the same size, but different shapes when they are dropped into a bottle of corn syrup?

Hypothesis:
The ________________ shape will hit the bottom first.

Procedure:
1. Fill the tall container ¾+ full with clear corn syrup.
2. Cut one bar of modeling clay into four same-size pieces. Use a balance scale to make sure that the pieces weigh the same.
3. Form various shapes with the pieces (one very streamlined, the others less streamlined to more bulky such as a teardrop, a cube, a sphere, a rectangular prism, etc.).
4. Drop the shapes, one at a time, into the bottle of corn syrup and time each drop. Record each time.
5. Retrieve the shapes with the shish kabob skewer.

Results:

The _______________ shapes dropped the quickest.

Conclusion:

This happened because ____

____

____

____

____

____

Activity Nine — Controlling the Plane

Lessons 20–21

Activity (Lessons 20–21) prep time:
45 minutes–1 hour
(for gathering materials and following pre-lesson instructions)

Teaching time:

Lesson 20: 1½ hours
(Science, Language Arts)

Lesson 21: 1½–2 hours
(Science, Math)

Objectives—Lessons 20 and 21

1. The students will identify the major parts of an airplane.
2. The students will describe the function of each of the major parts of an airplane.
3. The students will explain how the ailerons, rudder, and elevator control the direction of the airplane.
4. The students will identify the movements of roll, pitch, and yaw.
5. The students will construct an airplane and demonstrate how the ailerons, rudder, and elevator affect the direction of the plane.
6. The students will conduct test flights of their planes to predict and verify information.
7. The students will graph the results of their test flights and calculate the range, mean, and median distances of the flights.
8. The students will design a Super Plane, make a labeled drawing of the plane, and deliver a presentation detailing its capabilities to the class.

National Standards—Lesson 20 and 21

Science

- Abilities necessary to do scientific inquiry—S2Ea, S2Ma.
- Understandings about scientific inquiry—S2Eb, S2Mb.
- Properties of objects and materials—S3Ea.
- Position and motion of objects/Motion and forces—S3Eb, S3Mb.
- Objects in the sky—S5Eb.
- Abilities of technological design—S6Ea, S6Ma.
- Understanding about science and technology—S6Eb, S6Mb.
- Risks and benefits—S7Md.
- Science and technology in local challenges/in society—S7Ee, S7Me.
- Science as a human endeavor—S8Ea, S8Ma.

Mathematics

- Compute fluently and make reasonable estimates—M3.
- Understand patterns, relations, and functions—M4.
- Use mathematical models to represent and understand quantitative relationships—M6.
- Analyze change in various contexts—M7.
- Use visualization, spatial reasoning, and geometric modeling to solve problems—M11.
- Understand measurable attributes of objects and the units, systems, and processes of measurement—M12.
- Apply appropriate techniques, tools, and formulas to determine measurements—M13.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them—M14.
- Select and use appropriate statistical methods to analyze data—M15.
- Develop and evaluate inferences and predictions that are based on data—M16.
- Understand and apply basic concepts of probability—M17.
- Problem solving—M18.
- Reasoning and proof—M19.
- Communication—M20.

Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12. (See Language Arts Matrix on page 8.)

Technology

- Students are proficient in the use of technology– I2.
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works—I7.
- Students use technology to locate, evaluate, and collect information from a variety of sources—I10.
- Students employ technology in the development of strategies for solving problems in the real world—I14.
- Relationships among technology and other fields—T3.
- Role of society in the development and use of technology—T6.
- Influence of technology on history—T7.
- Attributes of design—T8.
- Engineering design—T9.
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving—T10.
- Apply the design process—T11.
- Use and maintain technological products and systems—T12.
- Transportation technologies—T18.

Lesson 20—It's All About Control

Materials—Lesson 20

- Student logs.
- A copy of the student text for Lesson 20, "It's All About Control," for each student.
- A copy of "The Parts of an Airplane" diagram for each student.
- A copy of the homework assignment, "Design Your Own Super Plane," for each student.
- A picture of the *Wright Flyer I.*
- Pictures of modern aircraft.
- An empty plastic wrap box or any long slender box.
- Cutaway pictures (cross sections) of planes.
- Imaginary Planes poster to be used at the discretion of the teacher to motivate the Super Plane designs.
- Materials for making a straw plane:
  - A copy of the instructions, "Making a Straw Plane," for each pair of students or group of no more than three students. (Each student will construct a plane, but grouping allows students to help one another.)
  - A 12-inch (30.5-centimeter), strong, plastic straw for each student.
  - A 12- by 18-inch (30.5- by 45.7-centimeter) sheet of heavy card stock or other stiff paper for each student. (If possible, allow students to choose different colors. This helps with identifying their planes.)
  - Clear tape.
  - Paper clips.
  - Scissors.
  - A 12-inch (30.5-centimeter) ruler.

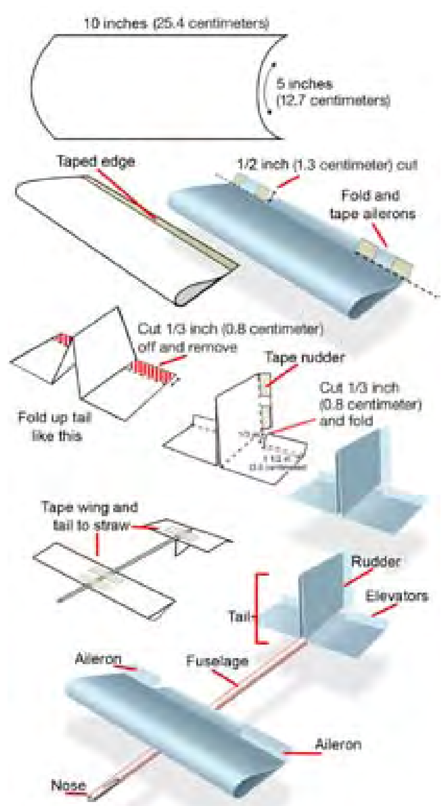
Pre-lesson Instructions—Lesson 20

1. Duplicate enough copies of the student text for Lesson 20, "It's All About Control," for each student. Punch holes.
2. Duplicate enough copies of the diagram of "The Parts of an Airplane" for each student. (This diagram is included on page 237.) Punch holes.
3. Duplicate enough copies of the homework assignment, "Design Your Own Super Plane," for each student. (This homework assignment is included on page 238.) Punch holes.
4. Duplicate enough copies of the instructions, "Making a Straw Plane," for each pair or group. (These instructions are included on page 235.)
5. Have a teacher assistant or a parent cut the parts for the straw plane ahead of time. This is especially helpful for younger students and even for older students when there are time restraints. Use card stock, tag board, or other stiff paper. For each student, cut a 10- by 5-inch (25.4- by 12.7-centimeter) piece for the wing, and an 8- by 1½-inch (20.3- by 3.8-centimeter) piece for the tail. Prepare several extra parts for students who may make mistakes.
6. Lay the straws, wings, and tail assembly pieces out so students can pick them up cafeteria-style.
7. Assign each student to a partner or a small group (no more than three students in a group) for constructing and flying their planes.
8. Teachers may want to ask a few parents to come in to help with the construction of the straw planes. Be sure they are there to watch you demonstrate how to make one at the beginning of the lesson.
9. Enlarge the diagram, "The Parts of an Airplane," to be used as a chart.
10. Find pictures of the *Wright Flyer I* and modern airplanes. Pictures of these should be available in the books that have been gathered.

Procedure—Lesson 20

1. Display the enlarged diagram, "The Parts of an Airplane." Point out the five main parts of an airplane: fuselage, wings, tail assembly, engine, and landing gear. Explain that all airplanes have these five main parts. Tell them that today they will be making their own plane and, in the next lesson, they will conduct test flights with the plane.

2. Distribute the instructions, "Making a Straw Plane." Explain that this aircraft will have a fuselage, wings, and a tail assembly, but will not have an engine or landing gear. Tell them that they will be learning about all of these parts as they read the student text.



3. Read through the instructions and demonstrate each step by making your own straw plane. Repeat often the names of the parts (fuselage, wings, tail assembly, ailerons, rudder, and elevator) as you make the plane so that students will start to identify these names and their locations on the plane. <u>Keep your own straw plane. You will need it as a demonstrator in the Straw Plane Experiments.</u>
4. Assign each student to their partner or group so that they can help one another as they assemble the planes. If parents are present, assign them to several groups so that they can oversee the construction of the straw planes and make sure that the wings and tail assemblies are on straight and firm.
5. Instruct the students to collect the parts they need to assemble their straw plane.
6. Allow about 20 minutes for the students to construct their planes. Have them write their names on their planes and let them keep the planes as they read the student text.
7. Distribute copies of the student text for Lesson 20, "It's All About Control," so students can insert these copies in their logs.
8. Distribute copies of the "Parts of an Airplane" diagram. Do not have the students insert this in their logs yet. They will need to have it available as they read the student text.
9. Display the picture of the *Wright Flyer I*, and the pictures of modern aircraft. Compare the *Wright Flyer I* to the modern aircraft. Note the dimensions and weight of each if these are available. Compare the capabilities of each.
10. Introduce and teach the vocabulary. Use the, "Parts of an Airplane," diagram to locate the parts on the plane. There are many words on this list, and most are identified within the text. They were included so that students will be somewhat familiar with them before reading the text, and to let them know that pilots use many instruments to control the plane. Students should know the five main parts of a plane. They should also know the words ailerons, elevator, and rudder because these are parts of the straw plane and they will need to know the location and function of these for experiments. Make sure that students understand the movements of roll, pitch, and yaw when they read the text. Do not expect students to recall the rest of the words.

11. Read and discuss the student text, "It's All About Control," as you would any guided reading activity. As the class discusses the text, question their understanding and encourage their questions.
12. Read the section, "Planes Today and Yesterday, Big and Small." As the students identify the different kinds of planes, make a list on the board. The three general kinds of aviation are commercial, military, and private. Planes built for specific uses include cargo, weather (including those used by hurricane hunters), spy, crop duster, sightseeing, fire fighting, mail, stunt, float (to land on water), ski (to land on ice), fighter, bomber, and Air Force One. Some planes are equipped as hospitals to fly to remote areas of the world.
13. Make sure the students have "The Parts of an Airplane" diagram on their desks. They will be referring to it throughout the next section.
14. When reading the section, "Learning Which Parts Do What," tell the students to identify the parts on their straw plane as well as on their diagrams. Continue reading this section, stopping to locate each part as you discuss its function.
15. When discussing roll, pitch, and yaw, have the students pick up their planes and demonstrate these movements. Have them move the part of the plane that causes these movements (ailerons—roll, rudder—yaw, elevator—pitch). Tell them not to throw their planes but move them while holding them in their hands.
16. In the last paragraph of the text, the term "wing warping" is used. Remind the students that they read about this in the Wrights' biography. Use the long slender box to demonstrate this concept by taking hold of each end and twisting the ends in opposite directions.
17. Have the students place their planes on a shelf or counter for safekeeping and insert the diagram in their logs.
18. Distribute copies of the homework assignment, "Design Your Own Super Plane." Discuss the assignment and fill in the due date. Students should be ready to present their designs as a part of Lesson 23. Also, tell the students to ask their parents to clock the distance from their homes to school. They could write this request on the homework sheet. This distance will be used for Lesson 22.

Vocabulary—Lesson 20

ailerons – surfaces on the outer trailing edge of the wing that move up and down to roll the plane and bank the wings into a turn

ailerons

cargo – goods carried by a large vehicle

century – a period of 100 years

cockpit

cockpit

cockpit – control center where the pilot, instrumentation, and navigational aids used in flying are located

elevator – surface on the horizontal part of the tail section that moves up or down to control the up and down motion (pitch) of the plane

elevator

engine – part of the airplane that provides the power (thrust) for sustaining flight and for takeoff and landing

engine


flaps

flaps – part of the trailing edge of the wing that is lowered to increase lift and also to slow the aircraft down for landing by increasing drag


fuselage

fuselage – the long, narrow, part of the aircraft going down the center that contains the main systems of the plane and space for the cockpit, passengers, and cargo and to which the wings and tail are attached


horizontal stabilizer

horizontal stabilizer – the horizontal wing-like part of an aircraft's tail assembly that is fixed, and to which the elevator is hinged

landing gear – wheels, floats, or skis of an aircraft


landing gear


leading edge

leading edge – the front edge of a wing

pitch – the act of moving the nose of a plane up or down, controlled by the elevators

retractable – capable of being drawn back in


roll


pitch

roll – the act of banking a plane left or right, controlled by the ailerons

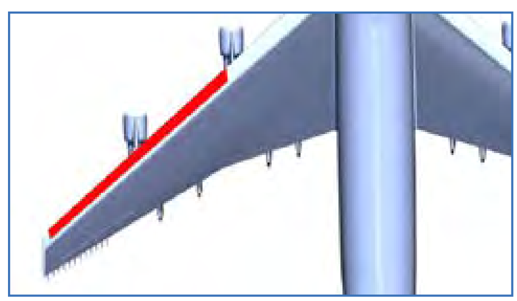
rudder – a vertical part usually hinged to the vertical stabilizer and used to move the aircraft left or right (yaw)

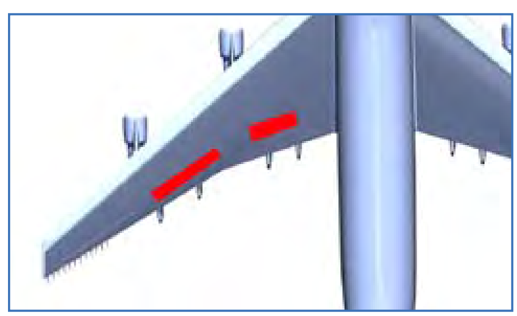

rudder

slats – a movable part of the leading edge of the wing of an airplane used to increase lift

spoilers – a long, narrow, hinged plate on the upper surface of an airplane wing that reduces lift and increases drag when raised

stability – the ability of an object, such as a ship or aircraft, to maintain balance or continue in its original, upright position


slats


spoilers

tail assembly

stabilizer – a device for making something stable (i.e., making it resistant to change of position or not easily moved)

tail assembly – also called the empennage; the rear part of an aircraft, including the horizontal and vertical stabilizers, elevators, and rudder

trailing edge – the back edge of a wing

trailing edge

vertical stabilizer – the vertical wing-like part of an aircraft's tail assembly that is fixed, and to which the rudder is hinged

vertical stabilizer

wings – long areas of the plane extending from the fuselage that produce lift as the plane moves through the air

yaw – the act of turning an aircraft to the left or right, controlled by the rudder

wings

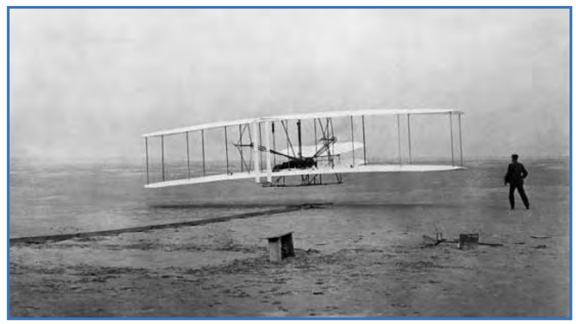
yaw

Student Text—Lesson 20

It's All About Control

Planes Today and Yesterday, Big and Small

Airplanes have changed a lot in the last **century**. The *Wright Flyer* was tiny and slow. The little plane could hold only one person. Today's planes are huge and fast. They can carry hundreds of people and cross the ocean in just a few hours. The *Flyer* used a propeller. Today, most planes use jet engines. But even with all of the changes, modern planes have the same basic parts as the early planes did.



Wright Flyer I

Boeing 777

Airplanes are designed to do two things. Some are made to move people from place to place. Others are made to take **cargo** from one place to another. Planes come in many shapes and sizes. The shape and size depend on how the airplane will be used. Think of the many uses of planes. See how many you can name.

cargo plane

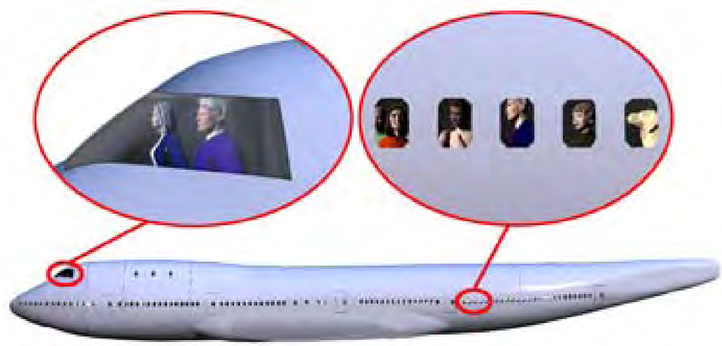
passenger plane

But no matter what a plane is used for, they all have five basic parts. Each one has a **fuselage**, **wings**, a **tail assembly**, **engines**, and **landing gear**.

the five basic parts of a plane

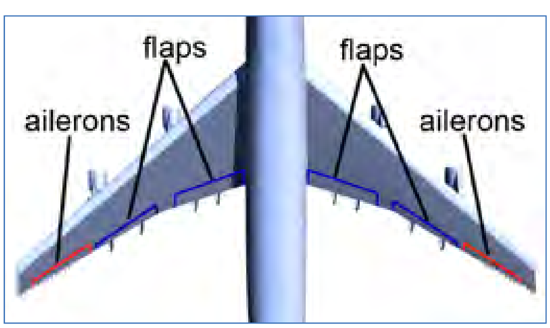
Learning Which Parts Do What

The **fuselage** is the main body of the aircraft. All of the other parts are attached to it. The fuselage is streamlined to decrease drag. It has a long tube shape so that air can flow smoothly around it. The **cockpit** is at the front of the fuselage. This space is for the pilot and crew. It has the instruments and controls for flying the airplane. The rest of the fuselage has space for the passengers and cargo.


the fuselage

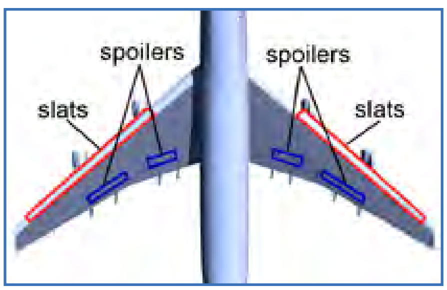

instruments in the cockpit

The **wings** of the plane provide most of the lift. They support the weight of the plane while in flight. In most planes, they also carry the fuel. The wings can have several movable parts. These parts are attached to the wing with hinges, and they help to steer and control the plane. Almost all planes have **flaps** and **ailerons**. The flaps are hinged to the back edge (**trailing edge**) of each side of the wing near the fuselage.



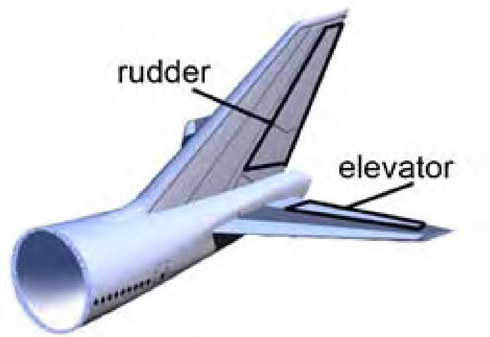
The plane rolls, or banks, because one aileron is up and one aileron is down.

They move together at the same time. Flaps move down to increase lift. This helps with lift on takeoff. The lowered flaps also increase drag. This slows the plane down for landing. Ailerons are also hinged to the trailing edge of the wing. But they are located near the tip of the wing. When they are moved in opposite directions (one up, one down), they **roll**, or bank, the airplane. This means the plane will go left or right while going up or down.

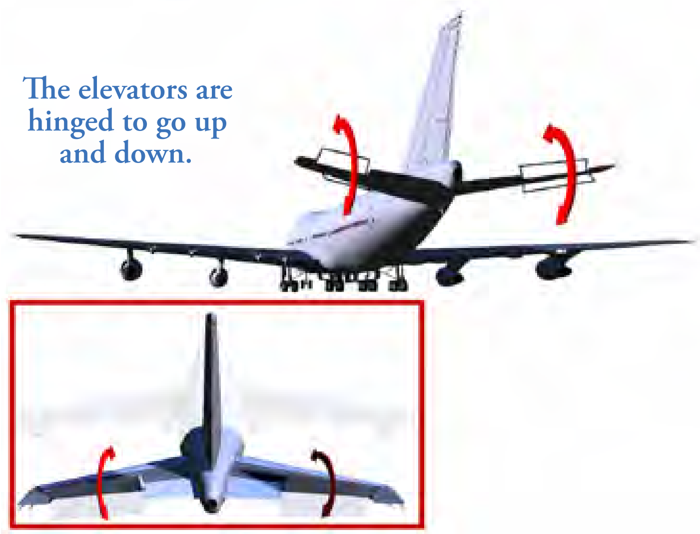


Some planes also have **slats** and **spoilers** on the wings. Slats move out from the front of the wing (the **leading edge**). This makes the wing area larger to increase lift. Spoilers are on the top surface of the wing. After landing, spoilers reduce lift and slow the plane down. They can also be used to roll the plane.

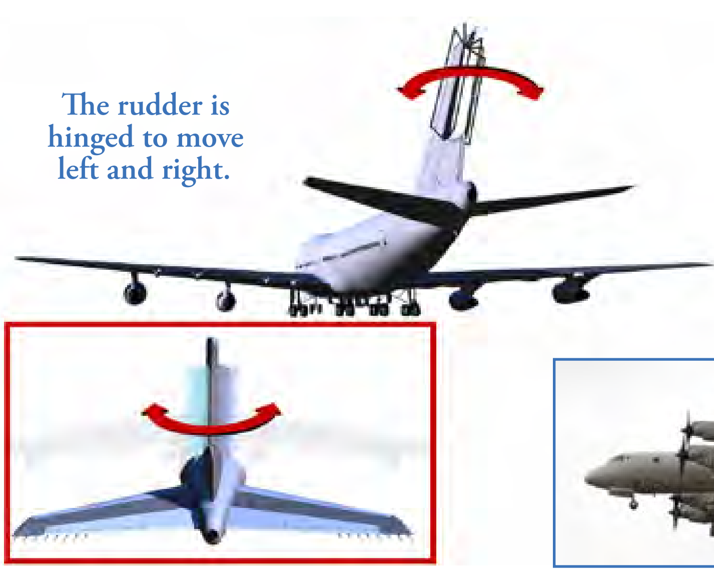
The **tail assembly** is attached to the back of the fuselage. It has four parts. Two of the parts are fixed and two are movable. The two fixed parts are called **stabilizers**. They give the plane **stability** and keep it flying straight. Think about a car with the wheels not bolted on tightly. The car will wobble and feel unsafe. If you tighten the bolts, it will not wobble any more. It becomes stable. That is what these parts do to a plane. The **horizontal stabilizer** looks like a small wing on the back. It keeps a plane from pitching, or rocking up and down. The **vertical stabilizer** is also called a fin. It keeps a plane from yawing, or swinging side to side.



The tail assembly also has two parts that are movable. They are the **elevator** and the **rudder**. The elevator is hinged to the horizontal stabilizer. The pilot moves it to control the up and down motion (**pitch**) of the airplane's nose. Pitch describes the forward and back tilting motion of the plane. The rudder is hinged to the vertical stabilizer. It is used to turn the aircraft left or right (**yaw**) without going up or down.

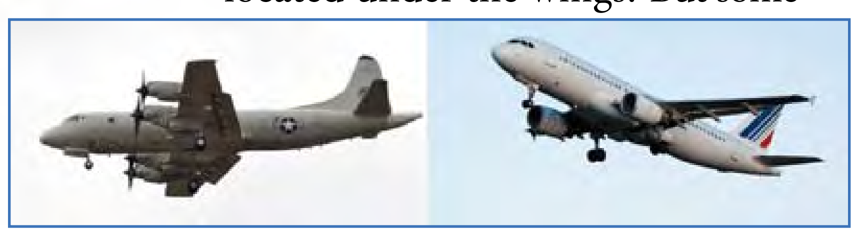


The elevators are hinged to go up and down.



The rudder is hinged to move left and right.

A plane's **engines** give it thrust. This is the force needed for taking off. But it is also needed to keep the plane flying in the air and to land. The engine can be a propeller or a jet. Propellers are placed on the front of the plane. Most jet engines are located under the wings. But some



propeller plane

jet plane

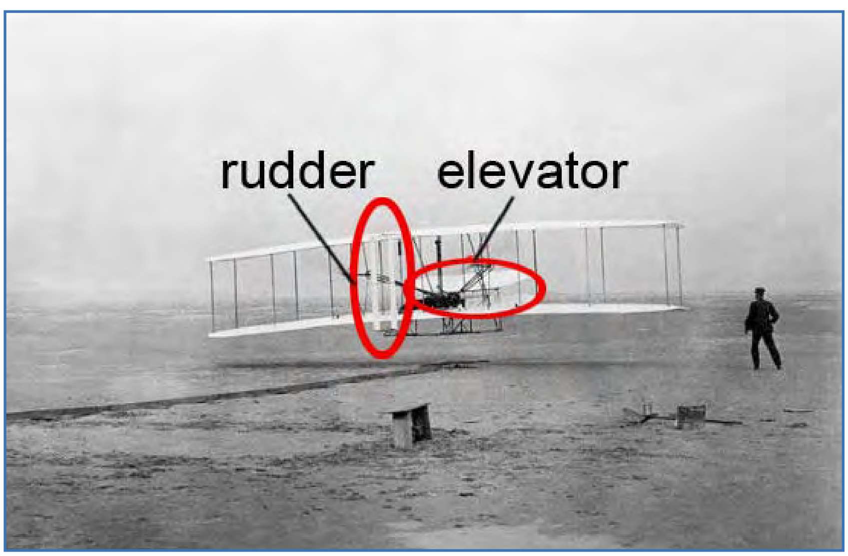
planes, like fighter jets, will have the engines in the fuselage.

The **landing gear** is the wheels. They support the weight of the plane when it is on the ground. They also reduce the shock on landing. The brakes for the wheels are like brakes for cars.

F-22A Raptors have their engines in the fuselage.

ready for landing

The wheels may be fixed or **retractable** (pulled up into the fuselage). Instead of wheels, a plane may have skis, skids, floats, or pontoons.



Wright Flyer I

Wouldn't Wilbur and Orville Wright be amazed at the aircraft seen in the skies today? The Wright Brothers were the first to figure out that it was all about control. Their first plane, the *Wright Flyer*, used an elevator and a rudder for pitch and yaw. They used a technique called "wing warping" for roll. Aircraft design has come a long way, but the Wrights got us started in the right direction.

Lesson 21—Experiments and Test Flights

Materials—Lesson 21

- A straw plane for every student and the teacher.
- A copy of the Straw Plane Experiments 1–4 (teacher copy which includes a list of materials and answers for results and conclusions) for the teacher and each adult volunteer.
- Copies of the Straw Plane Experiments 1–4 (student copy) for each student.
- Calculator.
- Overhead projector.
- A graph transparency.
- A free-flying area and a measured area for test flights.

Pre-lesson Instructions—Lesson 21

1. Duplicate and collate enough student copies of the Straw Plane Experiments 1–4 so that each student has a set. Punch holes.
2. Duplicate and collate enough teacher copies of the Straw Plane Experiments 1–4 so that each adult (teacher and volunteers) has one set of each. Volunteers are helpful, but not necessary for these experiments.
3. Choose an inside or outside area to fly the Straw Planes. Three of the experiments need only a free-flying area such as a playground, open field, or large inside space.
4. Experiment 4 needs a measured area for flying. Mark off an area to be used for measuring flight distances. Mark a starting line for students to stand behind. Then secure a tape measure down one side to measure the distance of each flight. If possible, make three areas (three wide lanes) for measured flights. This will cut down on time and keep the students more involved. If it is extremely windy outside, it is recommended that an inside area be used for the measured flights so that the wind is not a variable and all flight conditions are the same.
5. Make adjustments to the partners or groups as necessary.

Procedure—Lesson 21

1. Distribute the student copies of the Straw Plane Experiments 1–4 for students to insert in their logs.
2. Distribute the planes. Review and identify the ailerons, elevator, and the rudder.
3. Remind students that they will once again be working with a partner (or a group). If changes are necessary, make them at this time.
4. Read over Straw Plane Experiment 1—Ailerons with the students. Allow time for the students to complete their hypotheses.
5. Use your own straw plane to demonstrate each step of the procedure in Experiment 1. Emphasize the importance of keeping the elevator and rudder in the same position and only moving the ailerons as instructed. Remind them to record the direction of the plane after each flight. Tell them that they will have about 10 minutes to finish their flights and fill in the results and the conclusion.
6. Have the students gather their logs, pencils, and planes and proceed to the free flight (not measured) area. Let the students go through the procedure independently. Allow about 10 minutes. Walk around giving assistance as needed.
7. Assemble the students together to go over the results and the conclusion. Allow them to make changes so that each student has the correct answers.
8. Read through Straw Plane Experiment 2—Elevators. Allow time for the students to write their hypotheses. Demonstrate each step of the procedure for Experiment 2. Emphasize the importance of keeping the ailerons and rudder in the same position and only moving the elevator as instructed. Remind them again to record the data after each flight. Allow about 10 minutes for the students to complete their flights and record their results and conclusions. Go over the results and conclusion and allow students to make corrections.
9. Repeat the above procedure for Straw Plane Experi ment 3—Rudders. Change part names as necessary and emphasize the importance of keeping the ailerons and the elevator in the same positions.
10. Have the students move to the measured flight area. Read through Straw Plane Experiment 4—Test Flights. Allow students time to write their hypotheses. Demonstrate each step of the procedure in Experiment 4. Actually throw the plane 5 times, measure and record

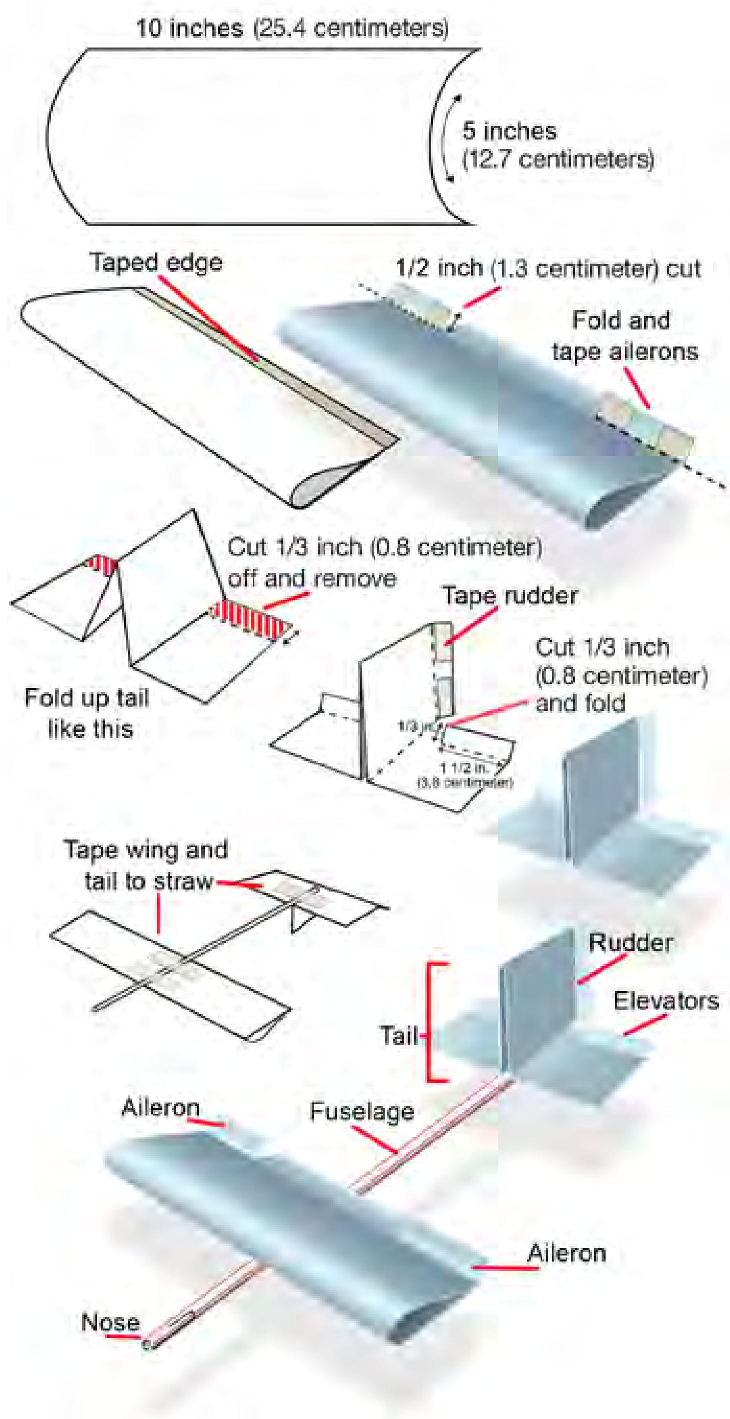
each distance, and note the position of each of the movable parts. **Save this data to be used as a demonstration for filling in the graph and computing the range, mean, and median distances for these flights**.

11. If only one measured field (lane) is used, give each group a number. Then, fly in that order. If more than one field is used, assign each group to a field and give them a number so they will know when to fly. As each student flies, let the other members of his/her group help with the measuring. Have them rotate flights within a group. That way, while one student is recording his/her own data, another student will be conducting his/her own flight.
12. Go back inside to fill in the bar graph and compute the range (the difference between the longest and shortest flights), the mean (the average distance of the flights), and the median (the middle distance of the flights).
13. Distribute the calculators. Model each step using the data from the teacher demonstration for Experiment 4. Use the overhead projector with the graph transparency and fill in the graph. Then compute the range, mean, and median distances of the flights. Demonstrate how to calculate each one. Complete each step together as a class, with each student using their own set of flight test data to make their own calculations.
14. Discuss the test flights and allow the students to share their individual experiences, results, and conclusions. Identify the longest flight. Ask the student who made it to describe the position of the movable parts and why he/she thinks it went that far. Put this plane on display for a few days as the Winner of the Long Distance Flight Test, or recognize this achievement in some other way.
15. Remind the students that their Super Plane designs and presentations are due on ___ (whenever the next lesson will be taught). Ask if there are any questions or concerns.

Making a Straw Plane

Materials

- 1 strong plastic straw (About 12 inches or 30.5 centimeters long. Bendable straws will not work.).
- 1 sheet of 12- by 18-inch (30.5 by 45.7-centimeter) card stock (or other stiff paper).
- Clear tape.
- Scissors.
- Paper clips (4-6 per student).
- A ruler.



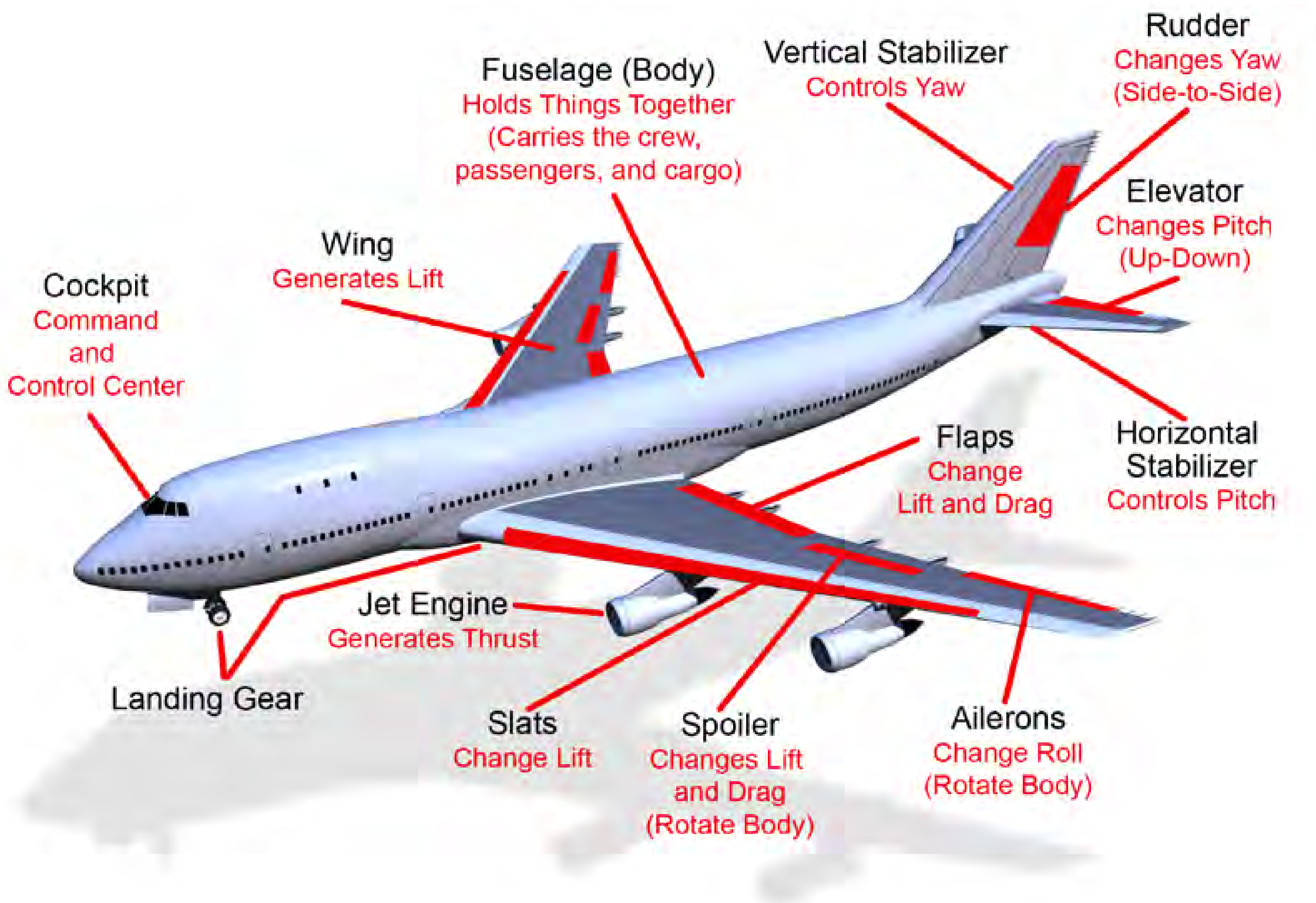
Directions for Assembling

1. Cut a 10- by 5-inch (25.4- by 12.7-centimeter) piece of card stock (or other stiff paper). Fold it over to make an airfoil, or wing, about 2½ inches (6.4 centimeters) wide. **DO NOT CREASE**. Using 10 inches (25.4 centimeters) of clear tape, tape the two edges together to form an airfoil. You may have to work on this a little to get an airfoil

that is not too fat, but also not creased.

2. Make a ½-inch (1.3 centimeter) cut into the taped edge of the wing at about 2 inches (5 centimeters) in, on both ends, to form an aileron. While holding the top and bottom of the aileron together, tape both ends of each aileron shut.
3. Cut an 8- by 1½-inch (20.3- by 3.8-centimeter) sheet of card stock for the tail assembly. Fold in the middle to make a tight crease. Open and then fold either side in half again so that both edges come up to the crease.
4. Tape the crease in place so that it sticks up. Let the two outer panels lay flat.
5. Cut ⅓ inch (0.8 centimeter) off the back of the two outer panels. The piece that is sticking out from the vertical stabilizer will be the rudder.
6. Make a ⅓-inch (0.8 centimeter) cut into the horizontal stabilizer to form two elevators about 1½ inches (3.8 centimeters) long from either end.
7. Ask another student to help you attach the wing and tail assembly onto the straw. Measure the wing to find the center of the wingspan and mark it with a pencil. Tape the center of the wing to the straw so that the leading edge of the wing is about 3½ – 4 inches (8.9 – 10 centimeters) back from the front of the straw. One student should hold the wing in place on the straw while the other student affixes two or three strips of tape to firmly hold the wing onto the straw.
8. Next, firmly tape the tail assembly onto the end of the straw as shown in the diagram.
9. Weight the end of the nose with several paper clips.
   (Try different amounts to ensure a nose-forward flight.)
10. Crease and bend the ailerons, elevators, and rudder.

The Parts of an Airplane



Design Your Own Super Plane

The aviation company you work for has asked its aeronautical engineers (you) to submit ideas for a new super plane. This plane must be able to travel in the atmosphere and take off and land on a runway. It should have special capabilities in addition to the ones found on planes being used today. Your job will be to:

1. Research some of the most modern planes such as the *F–22 Raptor*, the *F–35 Joint Strike Fighter*, the *C–17 Globemaster III*, the *Boeing 777*, the *Airbus 380*, the *Cessna Citation CJ3*, and the *Gulfstream G550*.

2. Write a short presentation (one paragraph) to be presented to your company's board of directors (your classmates) describing your super plane. Be sure to include the following information:
   - Is it military, commercial, or private?
   - Purpose—How will it be used?
   - Capacity—How many passengers or how much cargo can it carry?
   - Range—How far can it fly before refueling?
   - Speed.
   - Special capabilities and equipment.
   - A name for the plane.

3. Design a poster. Draw a diagram of your super plane and label the important parts.

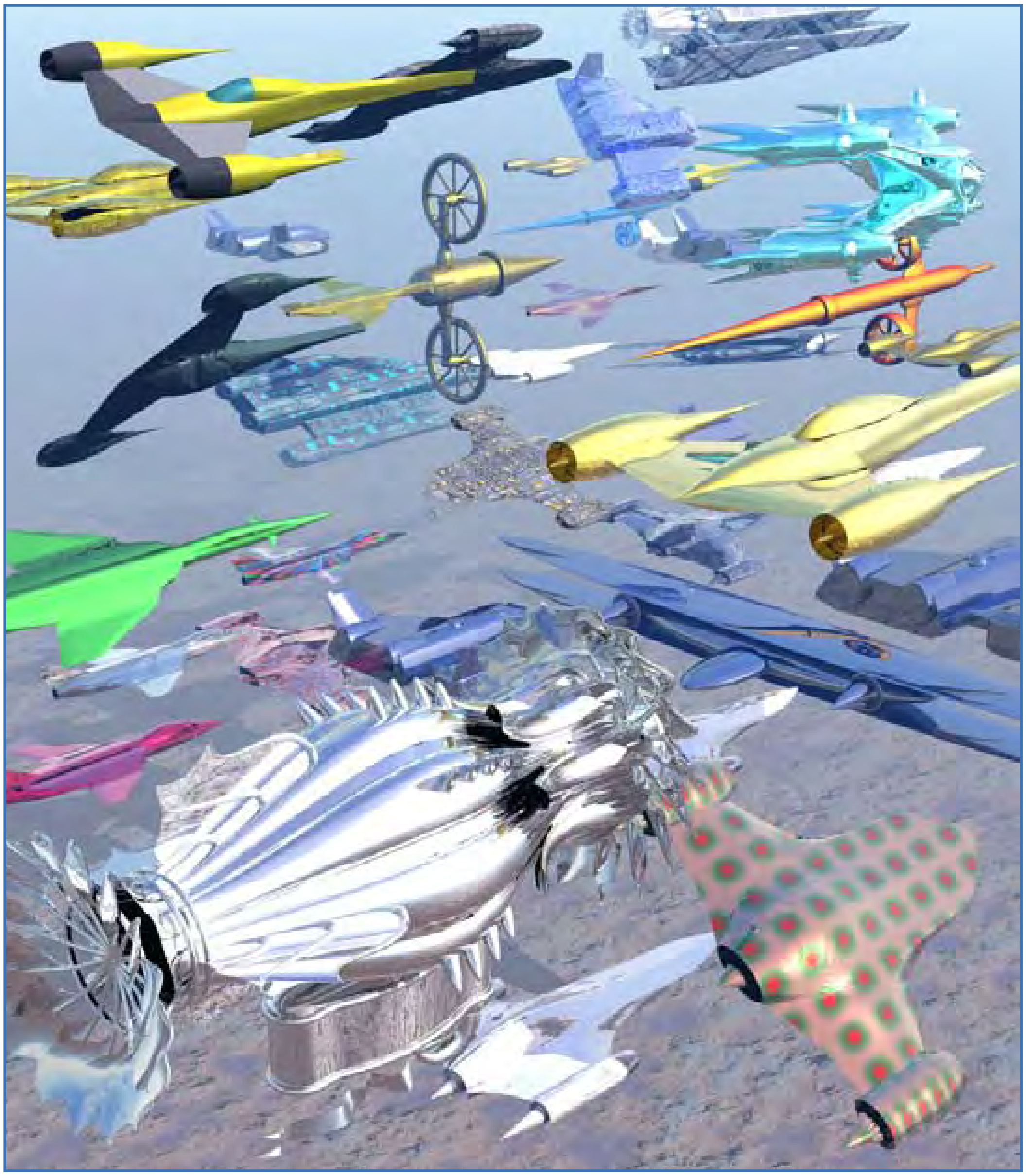
DUE DATE: ______________________

Parents, please sign this slip and return it to school. Thank you.

I have read my child's Super Plane assignment.

Signature ____

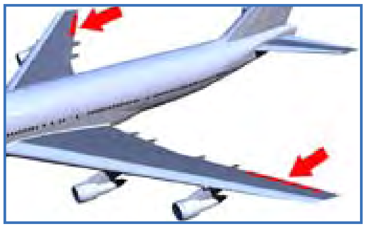
Imaginary Planes



Straw Plane Experiments—Teacher Copies

Straw Plane Experiment 1—Ailerons

Problem:
How do ailerons affect the direction an airplane flies?



ailerons

Materials:
- 1 straw plane for each student.
- A free flying area such as a playground or field (no measurements needed).

Hypothesis:
The ailerons will cause the plane to ____________________

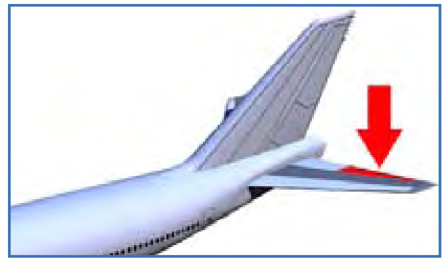
Procedure:
1. Keep the elevators and the rudder in the same neutral position each time you fly the plane.
2. Fly the plane with both ailerons up.
   Record the direction of the plane. ___________________
3. Fly the plane with both ailerons down.
   Record the direction of the plane. ___________________
4. Fly the plane with the left aileron up and the right aileron down.
   Record the direction of the plane. ___________________
5. Fly the plane with the right aileron up and the left aileron down.
   Record the direction of the plane. ___________________

Results:
The ailerons caused the plane to roll, or bank, to the right or left.

Conclusion:
This happened because this is the function of ailerons on the plane. They allow the pilot to control the direction in which he/she wants to roll the plane. When the left aileron is up and the right aileron is down, the plane will roll to the left. When the right aileron is up and the left aileron is down, the plane will roll to the right.

Straw Plane Experiment 2—Elevators

Problem:
How do elevators affect the direction an airplane flies?



elevator

Materials:
- 1 straw plane for each student.
- A free flying area (no measurements needed).

Hypothesis:
The elevators will cause the airplane to ________________

Procedure:
1. Keep the ailerons and the rudder in the same neutral position each time you fly the plane.
2. Fly the plane with both elevators up.
   Record the direction of the plane. ___________________
3. Fly the plane with both elevators down.
   Record the direction of the plane. ___________________

Results:
The elevators caused the plane to pitch up or down.

Conclusion:
This happened because the function of the elevators is to tilt the nose up or down. This allows the pilot to control the pitch of the plane to ascend or descend.

Straw Plane Experiment 3—Rudders

Problem:
How does the rudder affect the direction of the airplane?

rudder

Materials:
- 1 straw plane for each student.
- A free flying area (no measurements needed).

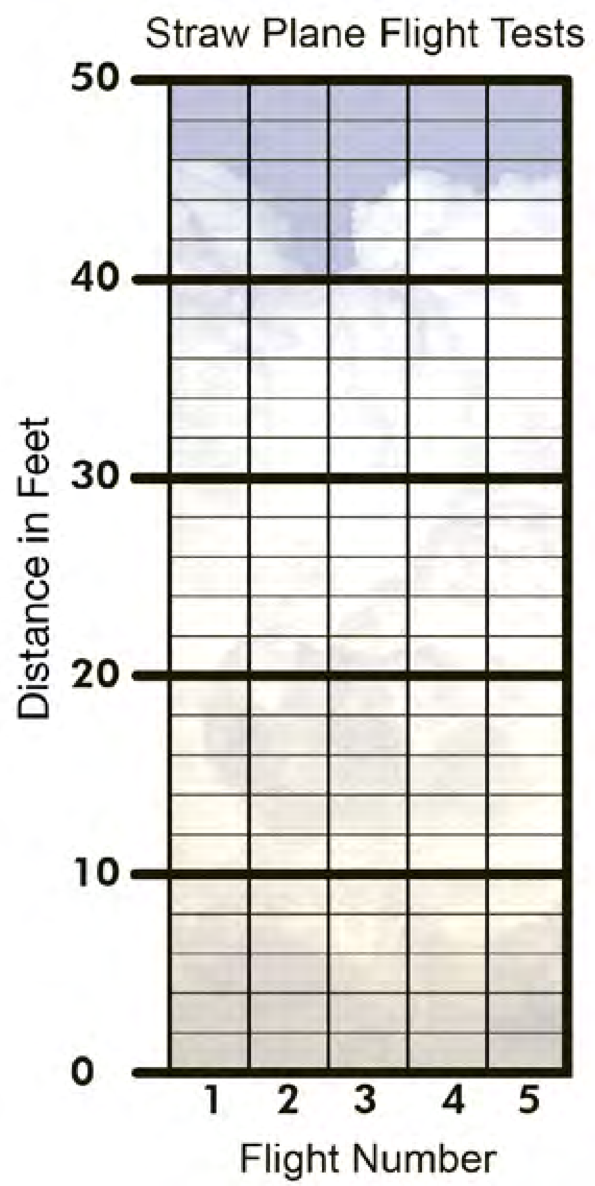
Hypothesis:
The rudder will cause the plane to____________________

Procedure:
1. Keep the ailerons and the elevator in the same neutral position each time you fly the plane.
2. Fly the plane with the rudder turned to the right. Record the direction of the plane. ___________________
3. Fly the plane with the rudder turned to the left. Record the direction of the plane. ___________________

Results:
The rudder caused the airplane to turn left or right.

Conclusion:
This happened because the function of the rudder is to turn the plane left or right. The pilot is able to control the yaw (left or right turn) of the plane by moving the rudder left or right. Moving the rudder to the right causes the plane to turn right because the airflow pushes the tail to the left. Moving the rudder to the left causes the plane to turn left because the airflow pushes the tail to the right.

Straw Plane Experiment 4—Flight Tests



Problem:
In what positions do I put the ailerons, elevator, and rudder to make my plane fly the greatest distance?

Materials:
- 1 straw plane for each student.
- A measured flight field, or wide lane, up to 50 feet (15 meters) long. (Have 3 fields, or wide lanes, if possible.)

Hypothesis:

My plane flew the greatest distance with the ailerons ____________________, the elevator____________________, and the rudder _____________ ______________________.

Procedure:

1. Standing on the measured field, you will make five test flights with your plane.
2. After each flight, measure and record the distance your plane flew in the Flight Test Data table.
3. For each flight, you may adjust the ailerons, elevator, and rudder of the plane to any position you think will make it fly the greatest distance—up, down, flat, or straight. Record their position for each flight in the Flight Test Data table.
4. You may not want to make any changes or adjustments at all in between flights. Just be sure to measure and record the distance of each flight as well as the position of the movable parts.
5. When all five flights are completed, fill in the bar graph. Remember that each block is worth 2 feet.

Follow-up Activity:

Compute the range, mean, and median distances of the flights. Arrange the flight distance numbers in order from least to greatest. The range is the difference between the longest and shortest flights. Use a calculator here, if necessary. The mean is the average distance of the flights. Use a calculator to add up the distances of the five flights, and then divide that sum by 5, the number of flights taken. The median is the middle distance of the flights. Look at the numbers you arranged in order from least to greatest. The median is the middle number of that group.

RANGE _______ MEAN _______ MEDIAN _______

Flight test data

Flight no.	Distance	Ailerons	Elevator	Rudder
1				
2				
3				
4				
5				

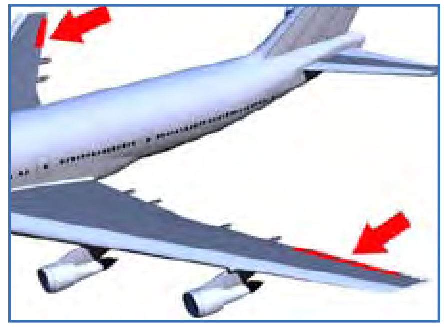
Results:

My plane flew the greatest distance with the ailerons flat, the elevator flat, and the rudder straight.

Conclusion:

This happened because the ailerons and the elevator in a flat position gave the wing and the horizontal stabilizer more surface area. This increased lift and allowed the plane to stay in the air longer. The rudder in a straight position kept the plane flying straight rather than turning. The greater distance was achieved by going straight ahead.

Straw Plane Experiment 1—Ailerons



ailerons

Problem:

How do ailerons affect the direction an airplane flies?

Hypothesis:

The ailerons will cause the plane to_______________

Procedure:

1. Keep the elevators and the rudder in the same neutral position each time you fly the plane.
2. Fly the plane with both ailerons up. Record the direction of the plane.
3. Fly the plane with both ailerons down. Record the direction of the plane.
4. Fly the plane with the left aileron up and the right aileron down. Record the direction of the plane.
5. Fly the plane with the right aileron up and the left aileron down. Record the direction of the plane.

Results:

The ailerons cause the plane to ____

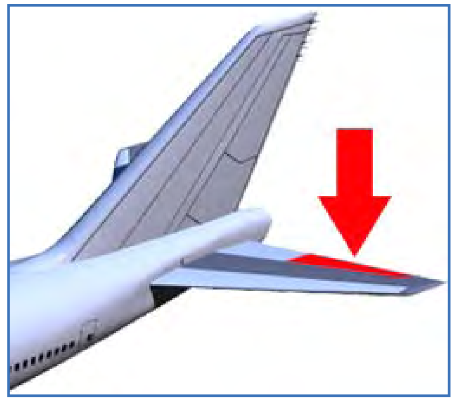
____

Conclusion:

This happened because ____

____

Straw Plane Experiment 2—Elevators



elevator

Problem:

How do elevators affect the direction an airplane flies?

Hypothesis:

The elevators will cause the airplane to ____________

____

Procedure:

1. Keep the ailerons and the rudder in the same neutral position each time you fly the plane.
2. Fly the plane with both elevators up.
   Record the direction of the plane.
3. Fly the plane with both elevators down.
   Record the direction of the plane.

Results:

The elevators caused the plane to ________________________________

____

____

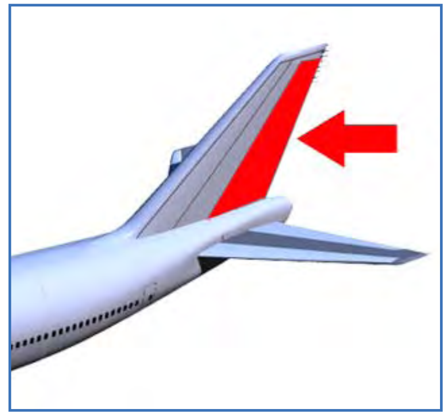
Conclusion:

This happened because ____

____

____

Straw Plane Experiment 3—Rudders



rudder

Problem:

How does the rudder affect the direction of the airplane?

Hypothesis:

The rudder will cause the plane to _______________

Procedure:

1. Keep the ailerons and the elevator in the same neutral position each time you fly the plane.
2. Fly the plane with the <u>rudder turned to the right</u>. Record the direction of the plane.
3. Fly the plane with the <u>rudder turned to the left</u>. Record the direction of the plane.

Results:

The rudder caused the airplane to ____

____

Conclusion:

This happened because ____

____

____

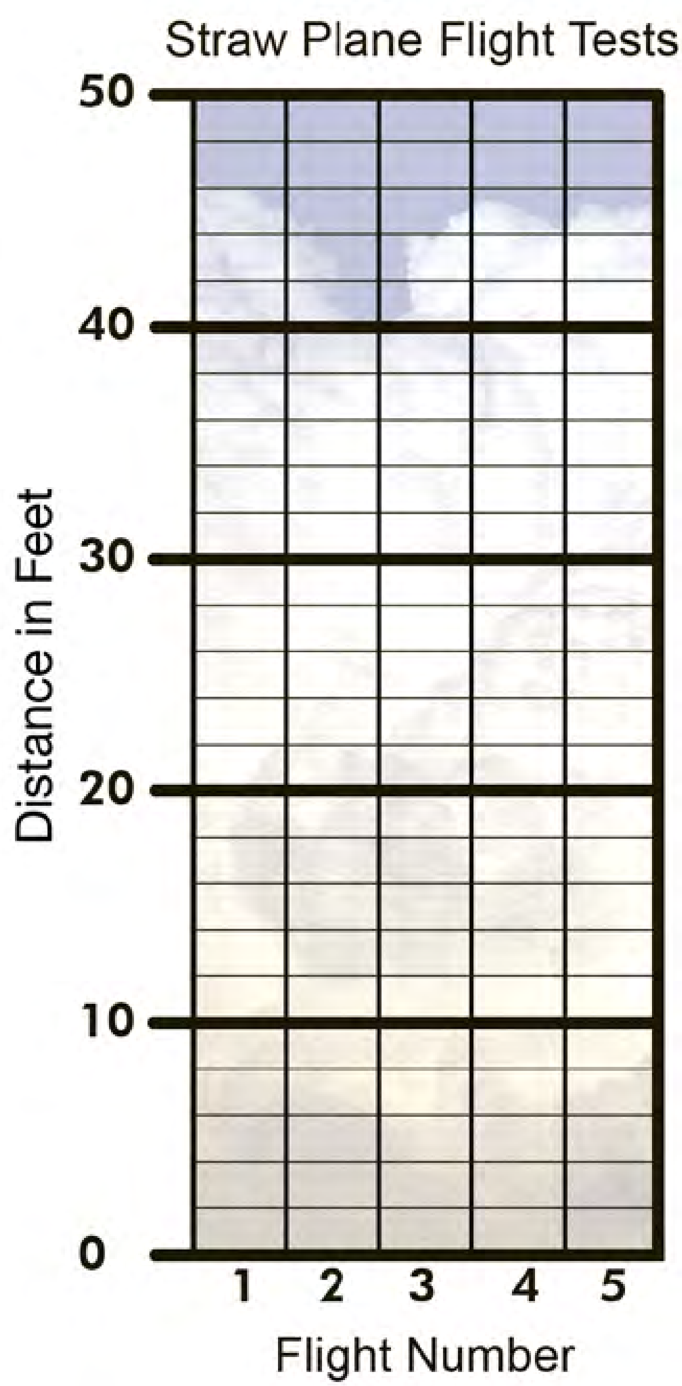
____

Straw Plane Experiment 4—Flight Tests

Problem:
In what positions do I put the ailerons, elevator, and rudder to make my plane fly the greatest distance?

Hypothesis:
My plane flew the greatest distance with the ailerons ________________, the elevator________________________, and the rudder ___________________

Procedure:
1. Standing on the measured field, you will make five test flights with your plane.
2. After each flight, measure and record the distance your plane flew in the Fight Test Data table.
3. For each flight, you may adjust the ailerons, elevator, and rudder of the plane to any position you think will make it fly the greatest distance—up, down, flat, or



straight. Record their position for each flight in the Flight Test Data table.

4. You may not want to make any changes or adjustments at all in between flights. Just be sure to measure and record the distance of each flight as well as the position of the movable parts on the table below.
5. When all five flights are completed, fill in the bar graph. Remember that each block is worth 2 feet (0.6 meters).

Flight test data

Flight no.	Distance	Ailerons	Elevator	Rudder
1				
2				
3				
4				
5				

Results: My plane flew the greatest distance with the ailerons _____________, the elevator _____________, and the rudder _____________.

Conclusion: This happened because ____
____
____
____
____
____

Follow-up Activity:

Compute the range, mean, and median distances of the flights. Arrange the flight distance numbers in order from least to greatest. The range is the difference between the longest and shortest flights. Use a calculator here, if necessary. The mean is the average distance of the flights. Use a calculator to add up the distances of the five flights, and then divide that sum by 5, the number of flights taken. The median is the middle distance of the flights. Look at the numbers you arranged in order from least to greatest. The median is the middle number of that group.

RANGE ______________ MEAN _____________ MEDIAN ____________

Activity Ten—Soaring Higher

Lessons 22–23

Activity (Lessons 22–23) prep time: 1 hour
(for gathering materials and following pre-lesson instructions)

Teaching time:

Lesson 22: 2–2¼ hours
(Science, Math, Language Arts, Technology)

Lesson 23: 2 hours
(Science, Language Arts, Technology)

Objectives—Lessons 22 and 23

1. The students will calculate their own rates of speed while walking and running and compare this to the speeds of vehicles described in the reading selection.
2. The students will recognize a general progression of the improvements and changes in transportation.
3. The students will identify some of the people and events that led to the development of modern aircraft.
4. The students will become familiar with some of the contributions of the National Advisory Committee for Aeronautics (NACA) and the National Aeronautics and Space Administration (NASA).
5. The students will use a line graph to plot the speeds of various aircraft representing the progress of increased speed in the development of aircraft.
6. The students will share the knowledge they have learned about flight as they complete the KWL chart.
7. The students will present their designs of a Super Plane and give an overview of its capabilities to the class.
8. The students will follow instructions to construct a glider model of the *X–43* scramjet aircraft.

National Standards—Lessons 22 and 23

Science

- Abilities necessary to do scientific inquiry—S2Ea, S2Ma.
- Understandings about scientific inquiry—S2Eb, S2Mb.
- Position and motion of objects/Motion and forces—S3Eb, S3Mb.
- Objects in the sky—S5Eb.
- Abilities of technological design—S6Ea, S6Ma.
- Understanding about science and technology—S6Eb, S6Mb.
- Risks and benefits—S7Md.
- Science and technology in local challenges/in society—S7Ee, S7Me.
- Science as a human endeavor—S8Ea, S8Ma.
- History of science—S8Mc.

Mathematics

- Compute fluently and make reasonable estimates—M3.
- Understand patterns, relations, and functions—M4.
- Use mathematical models to represent and understand quantitative relationships—M6.
- Analyze change in various contexts—M7.
- Use visualization, spatial reasoning, and geometric modeling to solve problems—M11.
- Understand measurable attributes of objects and the units, systems, and processes of measurement—M12.
- Apply appropriate techniques, tools, and formulas to determine measurements—M13.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them—M14.
- Select and use appropriate statistical methods to analyze data—M15.
- Develop and evaluate inferences and predictions that are based on data—M16.
- Understand and apply basic concepts of probability—M17.
- Problem solving—M18.
- Reasoning and proof—M19.
- Communication—M20.

Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective—G1.
- How to use mental maps to organize information about people, places, and environments in a spatial context—G2.
- The physical and human characteristics of places—G4.
- How culture and experience influence people's perceptions of places and regions—G6.
- The patterns and networks of economic interdependence on Earth's surface—G11.
- The processes, patterns, and functions of human settlement—G12.
- How human actions modify the physical environment—G14.
- How physical systems affect human systems—G15.
- How to apply geography to interpret the past—G17.
- How to apply geography to interpret the present and plan for the future—G18.

Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12. (See Language Arts Matrix on page 8.)

Technology

- Students are proficient in the use of technology—I2.
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works—I7.
- Students use technology to locate, evaluate, and collect information from a variety of sources—I10.
- Students employ technology in the development of strategies for solving problems in the real world—I14.
- Relationships among technology and other fields—T3.
- Cultural, social, economical, and political effects—T4.

- Effects of technology on the environment—T5.
- Role of society in the development and use of technology—T6.
- Influence of technology on history—T7.
- Attributes of design—T8.
- Engineering design—T9.
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving—T10.
- Apply the design process—T11.
- Use and maintain technological products and systems—T12.
- Assess impact of products and systems—T13.
- Transportation technologies—T18.

Lesson 22—Faster, Farther, Higher

Materials—Lesson 22

- Student logs.
- A field for the 100- or 50-yard (91- or 46- meter), run and walk.
- A stopwatch for each timer.
- A calculator for each student.
- Access to computers.
- A copy of the student text for Lesson 22, "Faster, Farther, Higher," for each student.
- Picture books for children on the history of transportation, the history of airplanes, future planes, and other books on airplanes.
- Pictures of the *Wright Flyer III*, WWI and WWII planes, stunt planes, the *Spirit of St. Louis*, the *X–1, X–15, F–15, B–2, SR–71, F–22* and the *X–43.*
- A sheet of large-lined graph paper for each student.
- Overhead projector.
- Large-lined graph paper transparency (same as students' graph paper).

Pre-lesson Instructions—Lesson 22

1. Teachers could ask several parents to volunteer to help time the 100- or 50-yard (91- or 46- meter), run and walk, but it is suggested that students learn to use a stopwatch and time one another. Provide a class roll for recording times to each volunteer. Provide a stopwatch for each timer. Ask the P.E. teacher and the students for extra stopwatches.
2. Prepare an area for the 100- or 50-yard (91- or 46-meter), run and walk.
3. Calculate (or use your car to determine) a few distances so the students can use these to determine how long it would take to walk or run there. Use the distance from the school to nearby businesses or other landmarks as examples. Also, determine a few longer distances, perhaps from one town to another.
4. Duplicate enough copies of the student text for Lesson 22, "Faster, Farther, Higher," for each student. Three-hole punch.
5. Find and mark a few pictures from a children's book on the history of transportation that support the section, "From Foot Power to Steam Power." Find and mark pictures from several airplane books that contain the pictures of planes mentioned in the text. (See the materials list.)
6. Find pictures in books and on the Internet of the planes mentioned in the materials list. Go to Google and type in the name of the plane.

Procedure—Lesson 22

1. Begin this lesson by letting each child compute their own rate of speed when running and walking. (Teachers are encouraged to compute their own speeds.) Take the class to the pre-measured area and time each child as they run and then walk the course. Have the students take their logs to write down the times. Teachers should provide a class roll for recording times to those who are timing the students.
2. Return to the classroom and distribute the calculators. Write the formula for calculating rate on the board (Rate = Distance/Time). Demonstrate using the formula to compute your own speed. Have each child compute their rate of speed for running and walking by using the formula.
3. Once the students have computed their rates in yards (meters) per second (or minute), have them convert each rate into miles (or kilometers) per hour. Use a computer for these conversions at **http://www.sciencemadesimple.net**. Click on "Unit Conversions" and then click on "Speed." The students should type in their rate and then chose yards (meters) per second or yards (meters) per minute to convert to miles (kilometers) per hour.
4. Once the students know their rates of speed in miles (kilometers) per hour, engage them in a short discussion about how long it would take them to walk or run to a certain place. Remind them that they probably would not be able to sustain their running rates for long distances. Use the distances from their homes as well as the distances suggested in the Pre-lesson Instructions.

5. Introduce and teach the vocabulary as you would any guided reading. Locate some of the places mentioned in the vocabulary on the map. For the vocabulary word "naval base," locate, on a U.S. map, the naval bases at Norfolk, VA, San Diego, CA, and Pearl Harbor, HI. Also, locate Tuskegee, AL. On a world map locate some of the countries involved in WWI and WWII. Find a Jetsons website if time allows.
6. Before distributing the student text, ask the students what they think the first mode of transportation was. Then ask them what they think came next, then next, etc., to form a brief outline on their thoughts about how transportation evolved. Write this short list on the board. Help them to understand that the wheel was an invention. Remind them that an invention is a new thing on Earth created by man, which has not existed before. A discovery is something that has always been on Earth, has always existed, and man has found it for the first time. Early man invented the wheel. Early man discovered fire.
7. Distribute copies of the student text for Lesson 22, "Faster, Farther, Higher," and have the students insert these in their logs. Read and discuss this selection as you would any guided reading. As the class discusses the text, question their understanding and encourage their questions.
8. Read the first section, "From Foot Power to Steam Power." Compare the information in the text to the list on the board. Show the students the pictures, from a book on the history of transportation, that support the text.
9. Continue reading through the text. Share pictures that support the text as you read. Allow the students to share their thoughts on the material as you read through the text.
10. When the students finish the section, "The Impact of World War II," they may wonder why the U.S. used the atomic bomb on Japan. There are several answers to this question, but the main one was that the U.S. felt that it would save many American lives. The history of this war reveals that the Japanese killed thousands of Americans from April to August 1945, the last few months of the war. Germany had already surrendered in May.
11. After reading the section, "Future Aircraft," teachers should ask the students why they think the U.S. Government needs to keep secrets. Help them to understand that, as a superpower, the U.S. needs to have military superiority. It also needs to maintain its technological superiority for economic purposes. These advances represent time, effort, and money that the U.S. is not willing to just give away.
12. Distribute the graph paper. Using the overhead projector and the graph paper transparency, demonstrate how to mark increments of 100s on the left-hand side. Label this side, "Rate of Speed in mph" or "Rate of Speed in kilometers per hour." Allow a few minutes for the students to complete this part of their graphs.
13. Along the bottom of the graph, write the names of aircraft from the text and then plot the speeds on the graph. Let the students choose these names from the text and other sources too, if available. Try to list them in chronological order. Underneath the names of the aircraft, write a P for Propeller, J for Jet, R for Rocket, or S for Scramjet. Demonstrate this on the overhead and allow time for the students to complete this step.
14. Remind the students that they will be presenting the designs for their Super Planes in the next lesson. Also tell them that they will be completing the KWL chart and that they should be thinking about the things they have learned.

Vocabulary—Lesson 22

airline – a business providing a system of scheduled air transport

airliner – an airplane operated by an airline for carrying passengers

British Airways is an airline company.
This airliner (airplane) is waiting for take off.

modern artillery

artillery of the past

artillery – large weapons, such as cannons, howitzers, and missile launchers, that are operated by crews

barnstormer – a pilot who travels around the country giving exhibits of stunt flying and parachuting

Barnstormers walk on the wings of the planes to entertain the crowds.

bush pilot

bush pilot – a person who flies a small airplane to and from areas that cannot be reached by larger aircraft or other means of transportation

crucial – of extreme importance; necessary to the resolution (solving) of a crisis

hypersonic – capable of speed equal to or exceeding five times the speed of sound

The Jetsons – a space-age cartoon show. This futuristic show first aired in 1962. It featured a family with two children, a dog, and a robot maid in a home that could produce almost everything you could wish for at the touch of a button. Family members of age had their own personal spaceships for travel. Viewers were led to believe that this would be like life in the year 2062.

Mach – a very high speed can be expressed by a Mach number; named for Ernst Mach, an Austrian physicist. It is a number representing the ratio of the speed of a body, like an aircraft, to the speed of sound, usually in air. Mach 1 is the speed of sound; Mach 2 is twice the speed of sound, etc. The speed of sound at high altitudes is about 660 mph (1,062 kilometers per hour).

NASA – the National Aeronautics and Space Administration; an independent agency of the United States Government responsible for aviation and spaceflight.

NASA Logo

naval base – a base for U.S. Navy operations that houses U.S. Navy personnel and ships

navigation – the guidance of ships, airplanes, or land vehicles from place to place

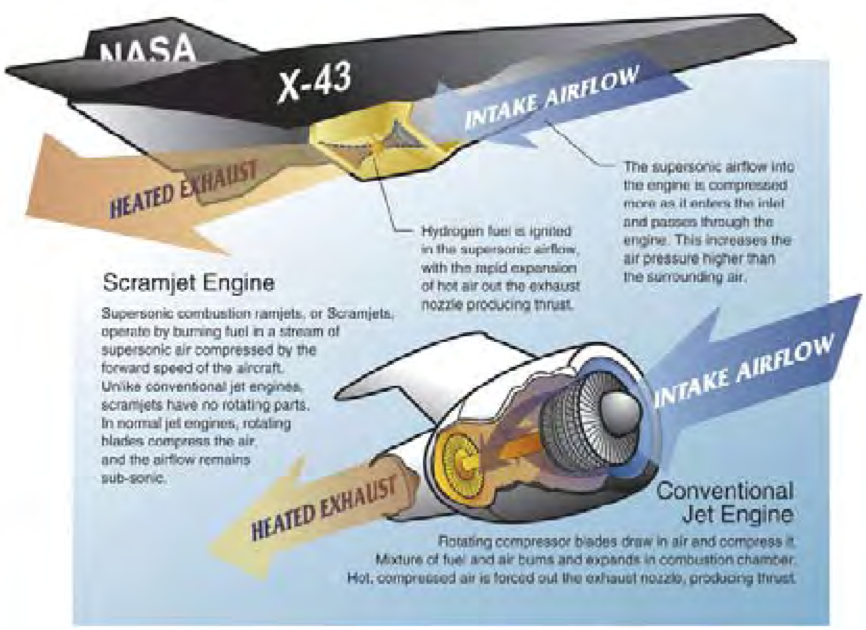
Norfolk Naval Base

navigation system for a car

paddlewheel boats

paddlewheel – a large wheel fitted with paddles and driven by an engine in order to propel a boat

scramjet – a ramjet airplane engine designed for hypersonic flight that burns fuel in the supersonic airstream produced by the plane. A ramjet is a jet engine that propels aircraft by burning fuel mixed with air taken in and compressed by the engine in a way that produces a greater exhaust speed than intake speed.



scramjet

stealth – avoiding detection; an aircraft design that has the ability to prevent detection by radar


steam engine

steam engine – an engine that runs on boiling water. The force of steam pushes a piston up and down. Gears or rods change the piston motion into the turning motion of the wheels.

supersonic – speeds from one to five times the speed of sound in air


Tuskegee Airmen

Tuskegee – The Tuskegee Institute was one of the first important schools to provide adequate education for African-Americans. The military selected Tuskegee Institute to train African-American pilots because of its commitment to aeronautical training. Tuskegee Airmen included pilots, navigators, bombardiers, maintenance and support staff, instructors, and all the personnel who kept the planes in the air. In WWII, they flew more than 15,000 sorties (a flight of one combat aircraft on a mission).

World War I (WWI) – A war fought from 1914 to 1918, in which the Allies (Great Britain, France, Russia, Belgium, Italy, Japan, the United States, and other countries) defeated the Central Powers (Germany, Austria-Hungary, Turkey, and Bulgaria).

World War II (WWII) – A war fought from 1939 to 1945, in which the Allied Forces (Great Britain, France, the Soviet Union, the United States, China, and other countries) defeated the Axis Forces (Germany, Italy, and Japan).

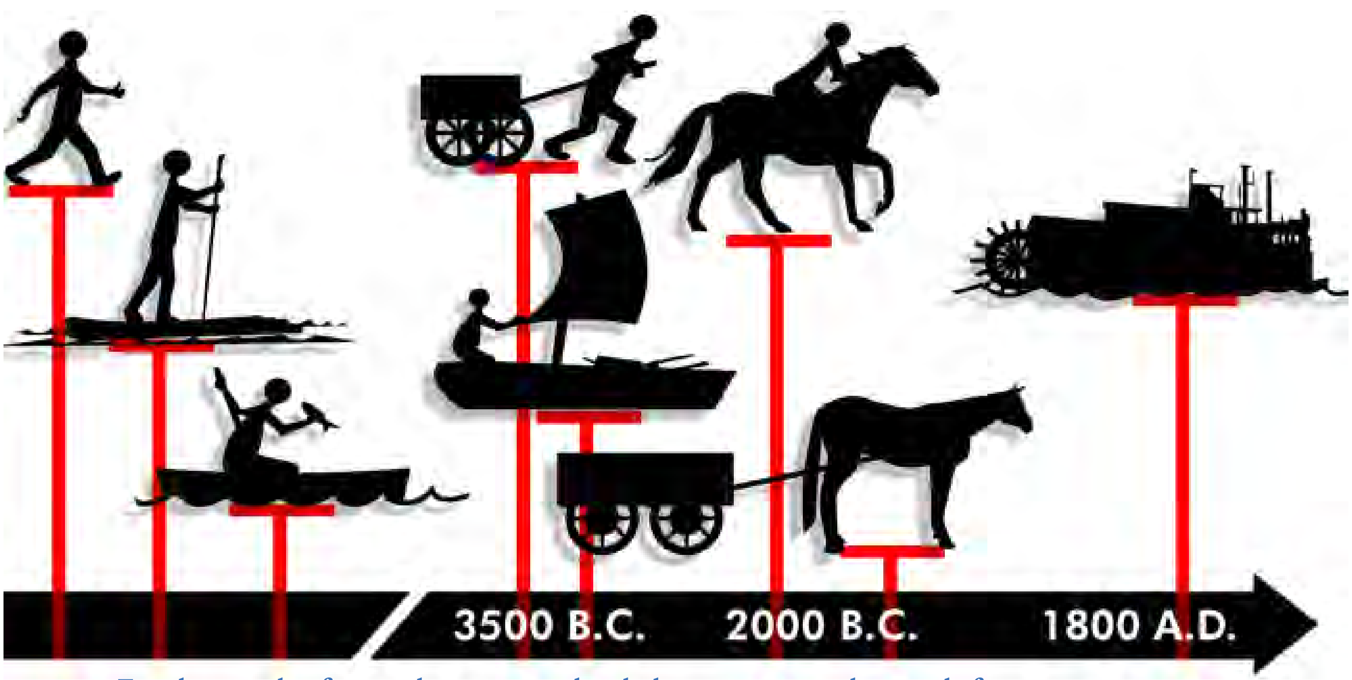
Student Text—Lesson 22

Faster, Farther, Higher

From Foot Power to Steam Power

How do you think humans got from place to place a long time ago? Well, at first they just walked. If they wanted something moved, they could carry or drag it. So they did not travel very far from home. They also did not try to move many goods. Then, early humans began to travel by water. At first, they made a simple raft by tying logs together. We do not know exactly when the first boats were used. But most people believe that humans used water for travel thousands of years ago.

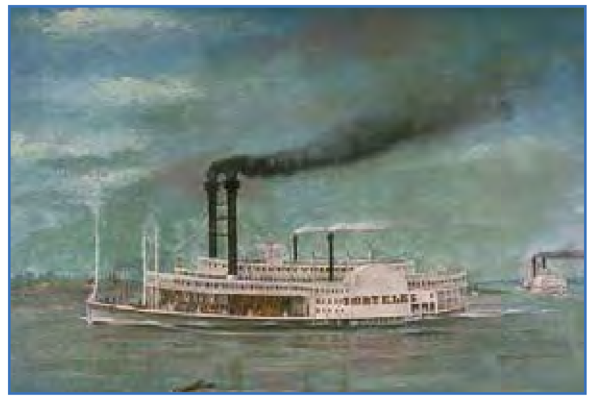
A new way to travel came in 3500 B.C. This is when we think the wheel was invented. So, humans were able to make a cart with two wheels. About the same



For thousands of years, humans used only boats, carts, and animals for transportation.

time, oars and sails were added to boats. Then in 2000 B.C., horses were tamed. They could be ridden from place to place and they were also used to do work. Later, horses pulled carts with four wheels. For thousands of years, humans used boats, carts, and animals to go from place to place, and that was all they had. Travel was slow, hard, and dangerous.

In the early 1800s, boats began to use steam power. A **steam engine** turned a big **paddlewheel** or a propeller. These pushed the boat on the water. Now, humans did not have to rely on the wind to sail on the water, nor did they have to use oars. Boats could now be built bigger, and they could carry much heavier loads.


a steam-powered paddlewheel

Then, trains with steam engines were invented. Before trains, most cities and towns were built near water. Boats would bring people what they needed. But now, cities and towns could be built inland. Trains could carry very heavy loads, so all kinds of goods could be taken to almost any place. By the end of the 19th century, travel was much faster. One train set a speed record of 100 mph (160 kilometers per hour)! The way people and goods were moved had changed forever.


a steam-powered locomotive

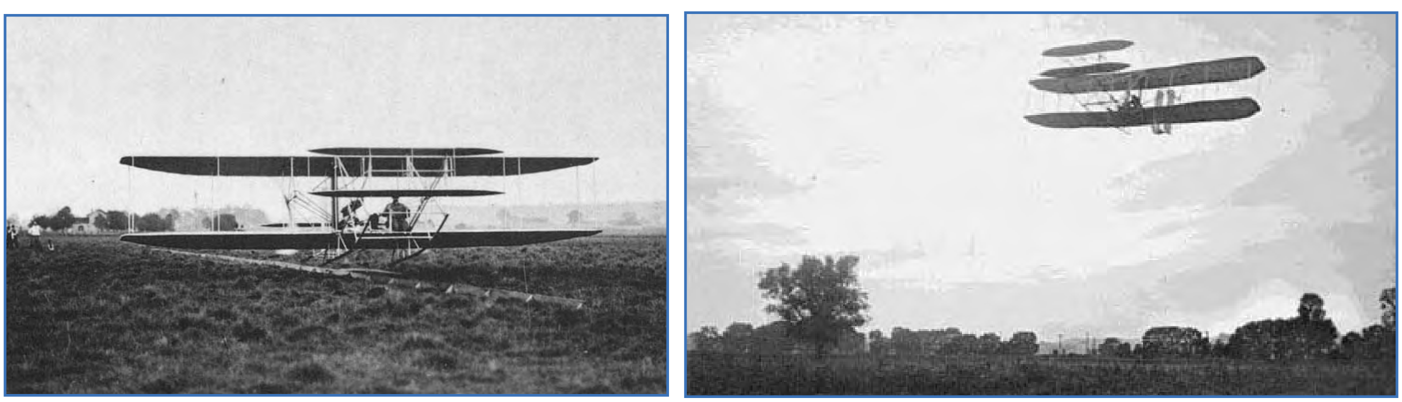
By this time, many people had their own cars. So, roads had to be paved because cars would often get stuck in the mud. People could go anywhere they wanted to go, and a car was faster and safer.

Karl Benz and his patent motor car

A Century of Flight—From Kitty Hawk to World War I

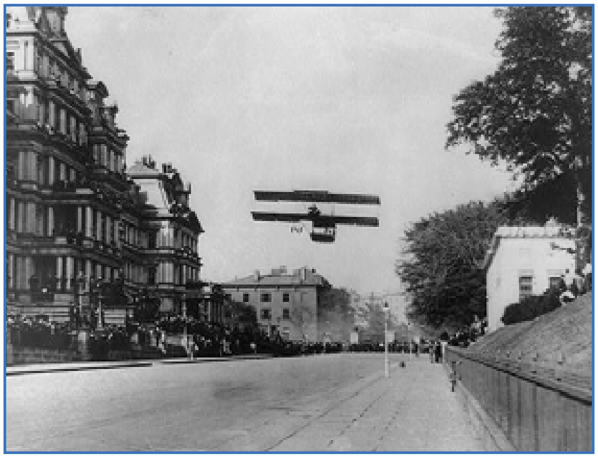
Then, in 1903, the Wrights flew an airplane for the first time. The longest flight that day had an air speed of 31 mph (50 kilometers per hour). Some birds could fly faster! But this was just the beginning. Two years later, the Wrights flew what they called the first practical plane. It could stay in the air for over half an hour. It could turn, bank, and fly in figure eights. Yet, it wasn't until 1909 that the Wrights sold the first plane to the U.S. military.

The *Wright Flyer I* made the first flight in 1903.



The Wrights flew the first practical airplane, the *Wright Flyer III,* in 1905.

For the next few years, pilots entered their planes in races and air meets. They were always improving their planes, as they tried to go faster, fly higher, and stay in the air longer.



After Claude Grahame-White won the Gordon Bennett speed race at the Belmont Air Meet in 1910, he flew to Washington, DC and landed on a street next to the White House.

Four planes were in the air at the same time in this photo from the Reims, France Air Meet in August 1909.

In 1914, **World War I** (WWI) began. For the first time, planes were used to fight a war. At first, the planes were used to spy on the enemy. They were sent up to take pictures that showed the size and strength of the enemy. They could also see exactly where the enemy was camped. Then, the big **artillery** guns could hit their targets.

Justin Gruelle paid tribute to the early aviation pioneers in his mural, "The Early Birds." The painting depicts the pilots and the aircraft that flew in the early years of flight.

This led to each side trying to protect itself from these spy flights. So, planes were equipped with guns to fire at the enemy planes. These were the first fighter planes. Some pilots were known as "flying aces." This meant they had shot down five or more enemy planes. The best pilot was a German, called the "Red Baron," who shot down 80 planes during the war. As the war went on, planes were used as bombers. At first, pilots just tossed the bomb from the cockpit. Later, bigger planes were able to carry bigger bombs. During the war, the average speed of a plane went from 50 mph to 125 mph (80 to 201 kilometers per hour).

Eddie Rickenbacker was America's Ace of Aces during WWI.

a replica of the "Red Baron's airplane"

Vickers Vimy, WWI bomber

A Century of Flight—The Time Between World War I and World War II

After WWI, the use of planes expanded. The U.S. made some of its war planes into mail planes, and pilots flew bags of mail from city to city. One of these mail pilots was

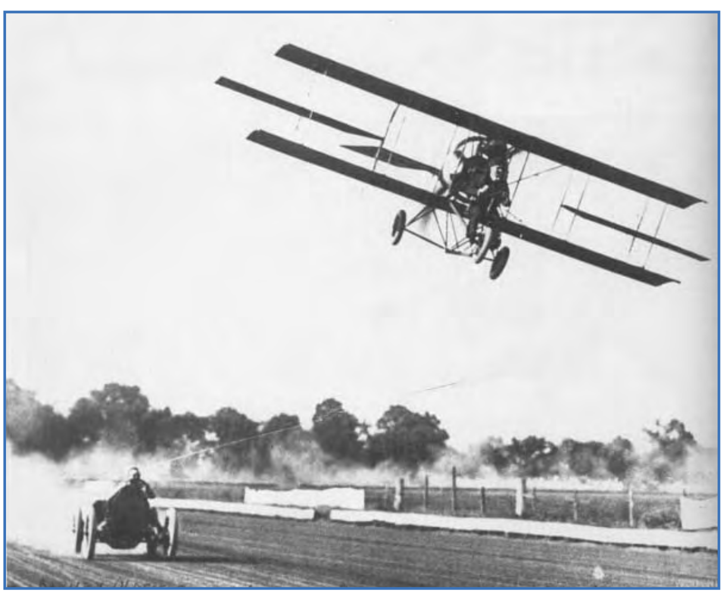
May 15, 1918. Mechanics help U.S. Army Lt. George Boyle position a *Curtiss JN4–H "Jenny"* for takeoff during the inauguration of U.S. airmail service in Washington, DC.

Charles Lindbergh. Charles loved to fly, and, in 1927, he became famous by making the first nonstop solo flight across the Atlantic Ocean. The trip from New York to Paris took 33½ hours.

Charles Lindbergh completed the first trans-Atlantic flight on May 21, 1927.

Another group of pilots were known as **bush pilots**. They brought food and mail to people who were snowed in. They picked up sick people and flew them to doctors, and brought help to people who lived far from towns and cities.

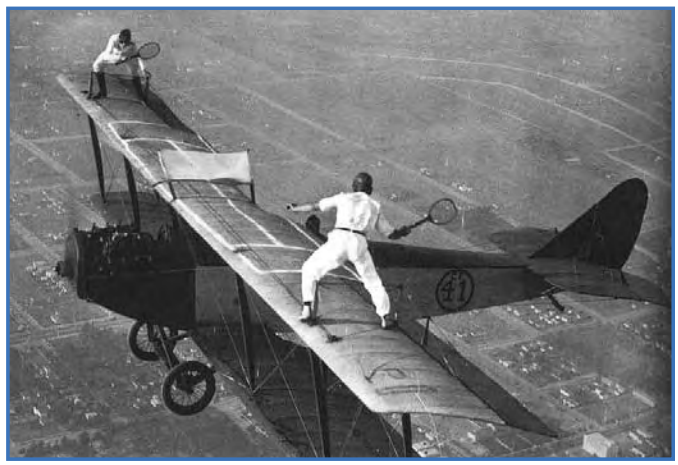
Many people in the U.S. saw their first plane after WWI. That was when air shows came to town. Pilots could win cash prizes for how fast and how high they could fly. So, pilots improved their planes to set new records. By 1931, a plane could fly 340 mph (547 kilometers per hour). The air shows also had stunt pilots. This is what the people really came to see. Planes would spin, dive, and fly upside down. The pilots were called **barnstormers**. Some of these daredevils even walked on the wings. Some hung from under the wing while the plane was in the air. After the show, the pilots gave rides for a small fee.



Lincoln Beachey was one of the most widely performing exhibition flyers. Here he is racing his plane against a car. He usually beat the car.

One of these pilots was Bessie Coleman. She was the first African-American woman pilot in the U.S. She flew stunts at air shows all over the U.S. She wowed the crowds as she looped the plane and flew upside down. Gladys Ingle was also famous at air shows. She would shoot arrows at a target while standing on a wing. She would also change planes in mid-air! Amelia Earhart was another famous woman pilot. She set many world records for speed and long distance flight. When she attempted to make the first flight around the world, her journey was reported on the front page of newspapers all over the world. But after 22,000 miles (35,406 kilometers), with 7,000 miles (11,265 kilometers) to go, her plane went down over the Pacific and was never found.

Bessie Coleman, first African-American woman pilot and stunt pilot



Admission to a barnstorming show was between 25 and 50 cents.

The time between the wars saw a rise in the use of passenger planes. The first **airline** service was actually started before the war, but it was just a short hop between two cities. After WWI, some war planes were made into passenger planes. The planes that flew from Paris to London could carry 11 people. By the 1930s, Pan Am flew a flying boat. This plane took people to places that were far away. Many of these places had no runway, so

Amelia Earhart stands in front of her custom Lockheed *Electra Model 10E* in 1937. This was the plane that she flew when she attempted her around-the-world flight.

the plane just landed on the water. In 1936, planes began to fly across the U.S. from New York to Los Angeles. But the trip took 18 hours. By the end of the decade, Pan Am was flying across the Atlantic Ocean.

Contract airmail service was launched between Washington and Nevada, marking the true beginning of U.S. commercial air transportation and the birth of United Airlines. Image courtesy of United Airlines Archives.

In the decades between the wars, airplanes began to be used in many different ways. Each new plane was better than the ones before it. Planes were now constructed of metal instead of wood and cloth. The cockpit was closed so that pilots were no longer hit in the face by rain or snow. The controls and instruments for flying the plane were improved. New **navigation** aids could help pilots know which way to go. A lot of these improvements came about because of the National Advisory Committee for Aeronautics (NACA). NACA was formed by the U.S. Congress in 1915 to study the problems of flight. Its first laboratory, the Langley Laboratory, was built in Hampton, Virginia. Some of the best engineers and scientists in the U.S. came

This Pan Am flying boat, a *Sikorsky S–42* seaplane, was the world's first big luxury airliner. Image courtesy of panamair.org.

The Douglas Sleeper Transport-the overnight version of the famous DC-3.

to work for NACA. Wind tunnels were built to test the planes. These tests helped to improve the materials used to build planes. The wind tunnel tests also helped to design the planes. The research allowed planes to be made safer and go faster.

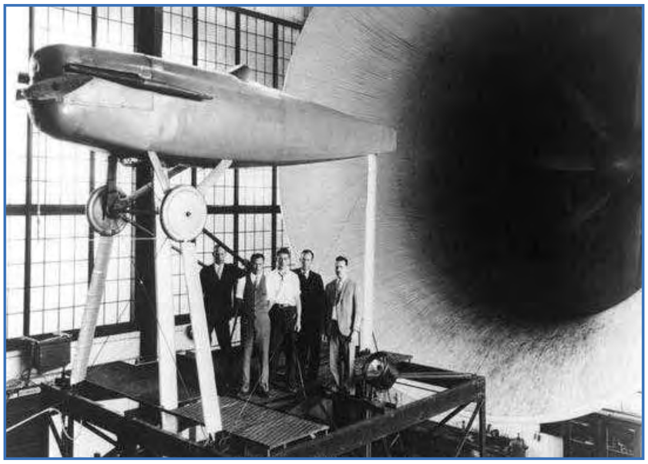
By 1958, NACA research had helped every aircraft made during the previous four decades. In that year, NACA was transformed into **NASA**. Today, NASA still works to improve the planes that fly in our skies.

Langley's Variable Density Tunnel could predict how aircraft would perform under flight conditions (1922).

Lawrence Clousing with a *Lockheed P–80* in1948

Langley Laboratory's first wind tunnel was built in 1920.

Langley's full-scale tunnel became operational in 1931. Notice the man standing just inside the tunnel.



NACA's Propeller Research Tunnel

A Century of Flight—The Impact of World War II

Air power was **crucial** to both sides in **World War II (WWII)**. Many kinds of planes were used, but both sides relied on the fighters and bombers. The roar of the bombers brought terror to the people on the ground. At first, the U.S. was not a part of this war. But in 1941, Japan made a surprise attack. It sent its planes to bomb the U.S. **naval base** at Pearl Harbor. The next day, the U.S. declared war. Many battles were won because of air power. Bombs were used to destroy railroads, factories, and weapons plants. They helped to clear the way for ground forces.

Spitfire Fighters 1943

The U.S. trained the first African-Americans to be pilots in WWII. They came to be known as the

bombers 1945

The Japanese attacked Pearl Harbor on December 7, 1941.

Tuskegee Airmen. These men came home as heroes. Many were given awards for their bravery. Women were pilots in the war, too. They were used to ferry planes back and forth, but they did not take planes into combat.

The Tuskegee Airmen were pilots of the all-African-American 332nd Fighter Group.

By the end of WWII, planes had been greatly improved. Some jets were now flying at nearly 500 mph (805 kilometers per hour). They could carry 3 tons (2.7 metric tons) of bombs nearly 2,000 miles. Due to the bombing, much of Europe and Japan was in ruins. Air power was used to bring the war to an end. But it took two U.S. planes dropping two atomic bombs on Japan to force the Japanese to surrender.

women pilots of WWII

The *Enola Gay*, a Boeing *B–29*, was the first of two planes to drop atomic bombs on Japan. This photo shows the *Enola Gay* returning from the bombing mission against Hiroshima.

Faster and Farther with Jet Engines

The world's first operational jet fighter was the *Messerschmitt Me-262 Schwalbe.*

The first jet plane was built by the Germans in 1939. They also built the first jet fighter. By the end of WWII, both sides were building jet planes. The first jet in the U.S. could not go as fast as a propeller plane, but that soon changed. In 1952, the British flew the first jet **airliner**. Later, a Boeing jet gave people in the U.S. an even faster ride. In 1969, a Boeing jumbo jet could fly over 600 mph (966 kilometers per hour) and carry 550 people. That same year, Britain and France built the *Concorde*. This was also a passenger jet. Flying at Mach 2.2, or 1,674 mph (2,695 kilometers per hour), it could travel from London to New York in about 3 hours. It took the *Mayflower* over 2 months to cross the Atlantic Ocean! The *Concorde* flew its last flight in 2003. Can you guess why?

Boeing 747

Concorde

Faster and Farther with Rocket Engines

In 1947, Chuck Yeager went so fast that he broke the sound barrier. His *Bell X–1* flew at **Mach** 1.06, or 806 mph (1,299 kilometers per hour). Mach 1 is the speed of sound. This was the first **supersonic**, or above Mach 1, flight. The *X–1* did not use a

Chuck Yeager was the first pilot to fly above Mach 1.

jet engine to go this fast. It used a rocket. A rocket is different from a jet engine. A jet engine mixes air with fuel. The hot air expands and blows out the back to push the plane forward. Rockets do not use air, but they carry their own oxygen. The rocket fuel is burned, forcing flaming gases to escape from the open end of the rocket. This huge force coming out of one end pushes the plane in the opposite direction.

The *Bell X–1* was the first aircraft to break the sound barrier.

The *B–52* carried the *X–15* under its wing until it reached a high altitude. Then, the *X–15* was dropped, and its rocket engines took over.

And Higher

A few years later, NACA began high speed research. This is known as **hypersonic** flight. This type of aircraft can travel at speeds of Mach 5 or above. In 1958, NASA took over this work from NACA. In 1959, NASA joined with the Air Force and the Navy to build the *X–15*. This plane was powered by a rocket, but it had to be air launched. It was put under the wing of a *B–52* and dropped. For the next 10 years, the *X–15* made 199 flights and set two records. The speed record

The *X–15* was capable of traveling at Mach 6.7.

was set when the *X–15* flew at Mach 6.7. This is 5,100 mph (8,208 kilometers per hour)! The plane could go anywhere on the Earth in less than 3 hours! (Of course, it would have to have enough fuel on board.) The *X–15* set the altitude record when it flew 67 miles high. Do you know what that meant? The pilot had to wear a suit to protect him because he went into space. NASA used the data from this plane to help with the space program. The *X–15* held both of these records until 2004. In that year, *SpaceShipOne* flew 69.6 miles (112 kilometers) above the Earth. The *X–15* record for speed has still not been broken by a piloted aircraft.

SpaceShipOne in flight

In the 1960s, the U. S. Air Force built the *SR–71 Blackbird*. The *SR–71* flew at Mach 3, or three times the speed of sound. This was the fastest jet in the world. The *SR–71* was an air-breathing jet, not a rocket. It could go any place on Earth in 4 hours, and it flew higher than any jet in the world. It set a record at 85,000 feet (25,908 meters). It flew so fast and so high that the pilot had to wear a spacesuit! The *SR–71* was also a spy plane. Its cameras could identify a golf ball from 16 miles (26 kilometers) high.

the *SR–71 Blackbird*

Future Aircraft

The planes of the future will be hard for us to imagine. It will be years before we fly in planes that go above Mach 5. But in March 2004, NASA made aviation history with an unpiloted aircraft. NASA flew the *X–43* at almost Mach 7. That is about 5,000 mph (8,047 kilometers per hour)! And it did not use a rocket. The *X–43* used a jet engine called a **scramjet**. Three years earlier, the first test of the *X–43* had failed. So, for the next 3 years, the Hyper-X team worked to fix all of the problems.

The *X–43* was launched from a *B–52* and flew at 7,000 mph (11,265 kilometers per hour) under its own power.

the *X-43*

A B–52 carried the X–43, riding on the tip of a Pegasus rocket, to 40,000 feet where the Pegasus was launched. At 95,000 feet, the X–43 was released from the rocket and flew under its own power to reach an altitude of 110,000 feet at almost Mach 9.6, or nearly 7,000 miles (11,265 kilometers) per hour.

Does this remind you of another team who worked to solve the problems on a plane that would not fly 100 years ago? With the same spirit as the Wright brothers long ago, the Hyper-X team tried again. This time, the plane soared. In November 2004, the *X–43* flew again. This time it flew at just under Mach 10. That is a speed of about 7,000 mph (11,265 kilometers per hour)!

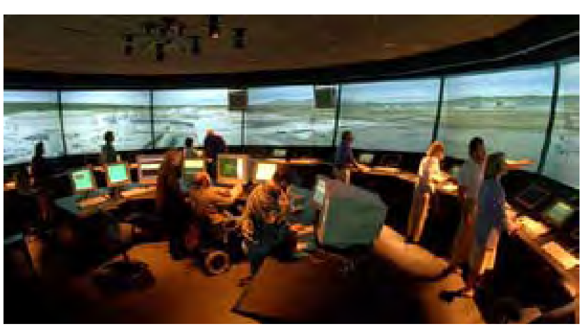

F–22 Raptors

F–35 Joint Strike Fighter "Lightning II"

MQ–1 Predator unmanned aerial vehicle (UAV)

Who knows what a scramjet may be used for in the future? For now, the new military planes are focused on three things. They must be designed for **stealth**, speed, and weapons. Look for the *F–22 Raptor* and the *F–35 Joint Strike Fighter*. Both travel above Mach 1, and both are stealth planes. The public is still wondering about what will replace the *SR–71*. Much of this is kept secret. A lot of research is being done on unmanned aerial vehicles, or UAVs. They are like flying robots with cameras and other tools on board. These planes fly very high to take pictures and collect data. Many of them are used as spy planes. We could call them spy sky robots!

The airline industry is looking at faster planes, too. But they need to fix some other problems first. NASA is trying to help them. NASA built a virtual air traffic control tower to help the airlines plan better airports. It will help find safer ways to handle the



NASA "FutureFlight Central," the world's first full-scale virtual airport control tower, is located at NASA Ames Research Center. The facility is designed to test ways to solve potential air and ground traffic problems at commercial airports. Twelve rear projection screens provide a seamless 360-degree, high-resolution view of the airport or other scenes being depicted. The imaging system, powered by supercomputers, provides a realistic view of weather conditions, environmental and seasonal effects, and the movement of up to 200 active aircraft and ground vehicles. Image courtesy of NASA Ames.

planes in the sky. NASA is also doing research in another area. They are looking at small jet planes. The jets would go from one local airport to another, so many travelers could avoid the big airports in big cities. One day we may all fly our own planes.

This is a futuristic view of how a jetport might look.

Lesson 23— Our Super Planes

Materials—Lesson 23

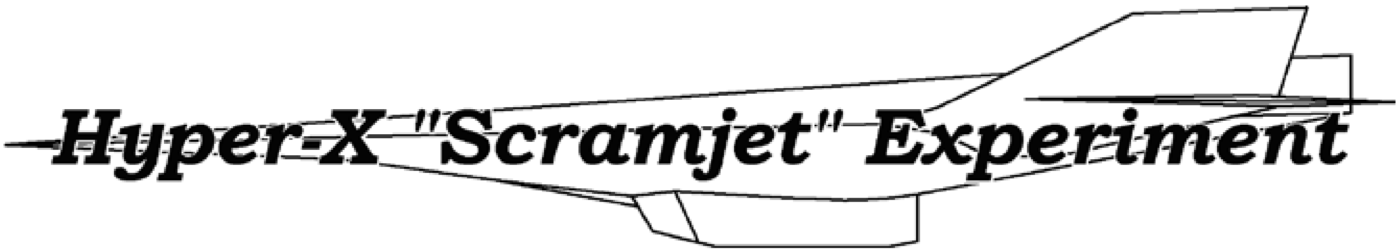
- The KWL chart on flight.
- A stand or place for the students to display their posters as they make their presentations.
- The book, *Icarus Swinebuckle,* by Michael Garland.
- *X–43* Scramjet pattern and Information Page.

Pre-lesson Instructions—Lesson 23

1. Duplicate and collate enough copies of the *X–43* Scramjet Glider and the Information Page for each student.
2. Teachers are encouraged to invite the school principal, a pilot, or an engineer from the community to listen to the Super Plane presentations. An invited guest adds a tone of seriousness to these presentations and helps to prepare students for real-life situations.
3. Teachers may want to plan a special way to end the unit on flight. This could include a paper airplane contest followed by an airplane snack such as pretzels and a drink! A paper airplane book by Peter Clemens is listed in the Suggested Reading. Students may also use the following websites for paper airplane models or make their own. Use **http://www.grc.nasa.gov/WWW/K-12/aerosim/LessonHS97/paperairplaneac.html** for a basic paper airplane or **http://www.grc.nasa.gov/WWW/K12/WindTunnel/Activities/foldairplane.html** for the paper jet model.

Procedure—Lesson 23

1. Ask the students why they think this unit was titled *The Courage to Soar*. Ask them to recall the people who demonstrated the courage to soar.
2. Direct the students' attention to the KWL chart on flight. Review what the students wanted to know about flight. Let the students share these answers first, and begin to fill in the What We Learned column. Then, proceed to write the other facts that the students have learned through this study on flight. Use student logs, maps, and charts for review.
3. Prepare the class for listening to the Super Plane presentations. Tell them that when they become adults they will probably have to present their research on many occasions. Encourage them to pretend that they are in front of a board of directors and competing for their plane to be chosen. Encourage the class to be professional as they listen to the presentations.
4. Introduce any guests and begin the presentations.
5. Find a place in the room or hall to display the Super Plane Designs.
6. **Homework:** Distribute the *X–43* Scramjet pattern and the *X–43* Information Page. Read and discuss the Information Page. Tell the the students to construct and decorate the *X–43* gliders and return them the next day.
7. Read the fictional story, *Icurus Swinebuckle,* by Michael Garland as a way to end the unit. Tell the students that even Icarus the pig had some of the same characteristics as the early aviation pioneers. Ask the students to identify some of these characteristics.



The NASA Hyper-X team designed and built the fastest "air-breathing" experimental "X-plane" ever. Known as the *X–43*, it flew almost 10 times the speed of sound, which is Mach 10 or 7,200 mph (11,587 kilometers per hour)!

The goal of Hyper-X was to demonstrate "scramjet" engine technology in flight. A scramjet is an air-breathing engine, or one that uses oxygen from the air that it captures. Scramjets mix and burn oxygen and fuel, such as hydrogen, at speeds inside the engine faster than the speed of sound (Mach 1). Because the vehicle does not need to carry large tanks of heavy oxygen, it can be a lighter and smaller vehicle or it can carry a heavier payload than a rocket.

The design of the *X–43* is that of a flying engine. The lower body (fuselage) compresses air entering the scramjet engine and expands the exhaust behind the engine to create thrust. The "lifting body" shape also gives the *X–43* lift so that it does not need large wings. The sharp shape of the nose, engine, wings and tails reduce drag so that the *X–43* can cut through the atmosphere at such high speeds.

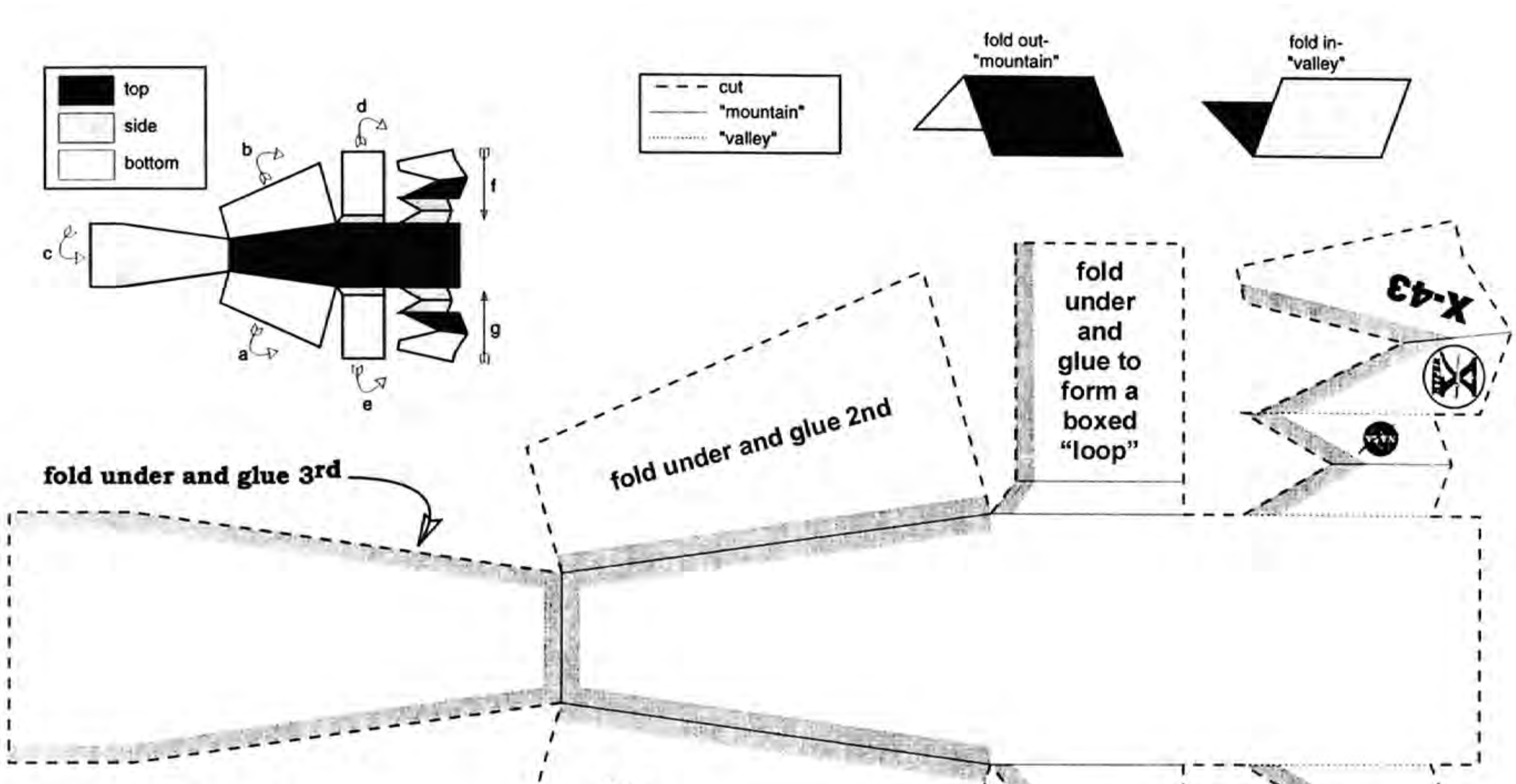
Flying at "hypersonic" speeds—faster than Mach 5—can really get an aircraft hot! Thermal Protection Systems (TPSs) will keep the *X–43* from getting too hot. Some TPS materials will act like Space Shuttle tiles by insulating the vehicle from the intense heat of hypersonic flight. Other TPS can use water, hydrogen, or some other fuel to take away heat from the hottest parts of the vehicle before being released overboard.

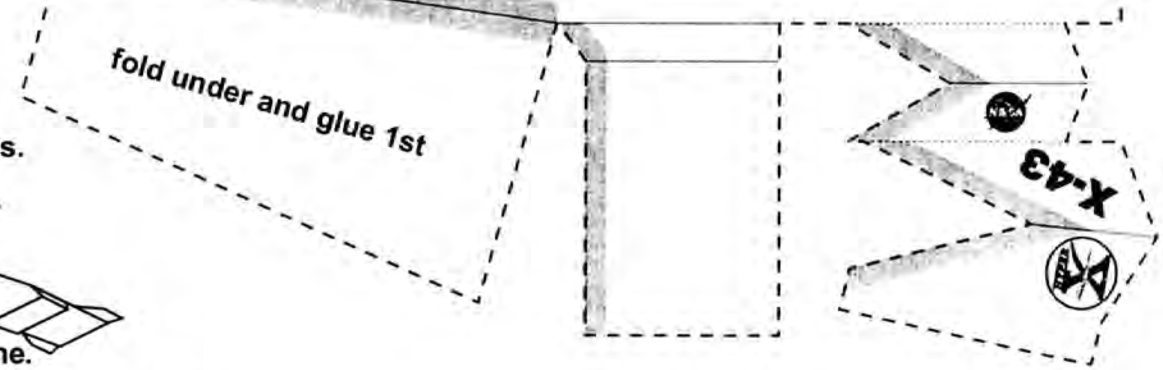
The history of X-planes is a great one! The rocket-powered *X–1*, flown in 1947 by Chuck Yeager, was the first aircraft to fly faster than the speed of sound—breaking the sound barrier with a sonic boom. Several other X–planes have explored high-speed flight. Pete Knight set the record of Mach 6.7 in the rocket-powered *X–15* in 1967.

On March 27, 2004, the unpiloted *X–43* was launched at 40,000 feet (12,192 meters) by the NASA *B–52* aircraft and boosted by a Pegasus rocket to 95,000 feet (28,956 meters) and a speed near Mach 7. The *X–43* then separated from the booster and made an eleven-second hypersonic run under its own power. This set a new speed record for an air-breathing aircraft at Mach 6.83. After the fuel ran out, the *X–43* conducted a series of flight maneuvers to record how a lifting body flies at hypersonic speeds down to subsonic speeds (below Mach 1). On November 16, 2004, the last flight of the *X–43* set a new speed record by flying under power at about Mach 9.6 and 110,000 feet (33,528 meters).

The knowledge gained from these flights will help accelerate U.S. aerospace technology into the 21st century. In the future, scramjet-powered vehicles could be used to launch satellites, visit space stations, or travel from New York to Tokyo in under three hours! Log on to **http://www.nasa.gov/missions/research/x43-main.html** for more information.

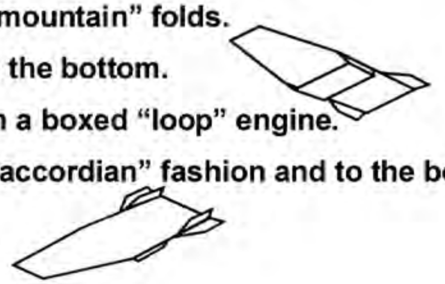
the *X–43*





DIRECTIONS

1. Cut out the model along the dashed lines.
2. Make the four "valley" folds on the tails.
3. Make the eleven "mountain" folds.
4. Glue a, b, and c to the bottom.
5. Glue d to e to form a boxed "loop" engine.
6. Glue f and g in a "accordian" fashion and to the bottom.
7. Happy Flying!



Print or copy on 67# paper for best results!

"The Early Birds"

by Justin Gruelle

From Left to Right: Lieut. H.H. Arnold, Lieut. John H. Towers, Clarence deGiers, Glenn H. Curtiss, Thomas Baldwin, Frank T. Coffyn, Wilbur Wright, Orville Wright, Glenn L. Martin, Charles L. Lawrence, Octave Chanute.

Left to Right: Octave Chanute, Grover C. Loening, Edson F. Gallaudet, George A. Page, Jr., Lieut Thomas E. Selfridge, Earle Ovington, Robert J. Collier.

Resources

General Links Related to Aeronautics and Aviation

NASA Multimedia Gallery contains video, audio, and photo imagery.
http://www.nasa.gov/multimedia/highlights/index.html

NASA Image eXchange (NIX) is a Web-based tool for searching several NASA image archives on the Internet.
http://nix.nasa.gov/

Great Images in NASA (GRIN) is a collection of over 1,000 images of significant historical interest.
http://grin.hq.nasa.gov/

The NASA Portal serves as the gateway for information regarding content, programs, and services offered by NASA. The collection of educational information has been divided into categories for kids, students, educators, and the media. The students' and educators' categories are further divided to give an overview of resources available for K–4, 5–8, 9–12, and post-secondary users.
http://www.nasa.gov/home/index.html?skipIntro=1

PlaneMath is an interactive Web site for students and teachers to learn about math and aeronautics as they participate in the activities and lessons. It was designed for children with physical disabilities, but it is a valuable teaching tool for all students. **http://www.planemath.com/**

The Aeronautics Learning Laboratory for Science, Technology, and Research (ALLSTAR) is a Web site for students and teachers. Lesson plans and experiments on the principles of aviation and aerospace, and the history of aeronautics are available on this site. Clearly established levels of understanding for different age-ranges are a strength of this site. **http://www.allstar.fiu.edu/**

The National Coalition for Aviation Education Web site was created as a one-stop clearinghouse for aviation education materials.
http://aviationeducation.org/

The U.S. Centennial of Flight Commission Web site contains a comprehensive collection of educational essays, multimedia, and links regarding the history of flight.
http://www.centennialofflight.gov/index.cfm

The K–8 Aeronautics Internet Textbook contains lesson plans, student text, activities, experiments, demonstrations, information on aerospace careers, and other links that relate to aeronautics.
http://wings.avkids.com/

Re-Living The Wright Way focuses on the Wright Brothers while teaching math and science.
http://wright.nasa.gov/

Virtual Skies is a Web site that helps teachers to explore the world of aeronautics as they learn the principles of flight and see large wind tunnels in operation.
http://virtualskies.arc.nasa.gov/

NASA Quest is a rich resource for educators, kids, and space enthusiasts who are interested in meeting and learning about NASA people and the national space program.
http://quest.arc.nasa.gov/index.html

The National Air and Space Museum (NASM) of the Smithsonian Institution was established to memorialize the development of aviation and spaceflight and to provide educational materials for the study of aviation.
http://www.nasm.si.edu/

The National Museum of the United States Air Force near Dayton, Ohio, is the oldest and largest military aviation museum in the world.
http://www.nationalmuseum.af.mil/

The Air Museum Planes of Fame Web site is an excellent source of aviation links.
http://www.planesoffame.org/

The Academy of Model Aviation (AMA) is a national organization that organizes, promotes, and insures model aviation.
http://www.modelaircraft.org

Links Related to Activities

Activity One—Kite Flight

Ellis, Dave. "Kites, Kids, and Education." *Kansas City Kite Club*.
http://kckiteclub.org/DaveEllis/TOC.htm

Cheek, Jerrie S. "Jerrie's Curriculum Hotlist." Educational Technology Center, Kennesaw State University, Kennesaw, GA.
http://webtech.kennesaw.edu/jcheek3/kites.htm

NASA Glenn Research Center.
http://www.lerc.nasa.gov/WWW/K-12/airplane/kite1.html

Activity Three—Aviation Pioneers

U.S. Centennial of Flight Commissioners. "Kid's Fly Zone." U.S. Centennial of Flight Commission.
http://www.centennialofflight.gov/user/kids.htm

Activity Four—Having the Right Stuff—The Wrights and Bleriot

U.S. Centennial of Flight Commissioners. "Kid's Fly Zone." U.S. Centennial of Flight Commission.
http://www.centennialofflight.gov/user/kids.htm

Wright Brothers Aeroplane Company. "A virtual museum of pioneer aviation." Wright Brothers Aeroplane Company.
http://www.first-to-fly.com/

Benson, Tom. "Re-Living The Wright Way." NASA Glenn Research Center.
http://www.grc.nasa.gov/WWW/Wright/airplane/shortw.html

Activity Seven—The Matter of Air

Science Club Monthly. "Find Experiments."
http://www.scienceclubmonthly.com

Spangler, Steve. "All About Air." Steve Spangler Science, Steve Spangler, Inc.
http://www.stevespanglerscience.com/experiments/

Activity Eight—The Four Forces of Flight

The National Museum of the United States Air Force near Dayton, Ohio, is the oldest and largest military aviation museum in the world. *The Discovery Hangar*.
http://www.nationalmuseum.af.mil/

The Franklin Institute Science Museum & The Science Museum London. "Your Own Flight." *Flights of Inspiration*.
http://www.fi.edu/flights/index.html

NASA Glenn Research Center. "PlaneMath Enterprises Training." *PlaneMath, a place to learn cool things about math and aeronautics!*
http://www.planemath.com/activities/pmenterprises/training.html

Activity Nine—Controlling the Plane

NASA Glenn Research Center. "Ultra-Efficient Engine Technology Kid's Page." *Airplanes*.
http://www.ueet.nasa.gov/StudentSite/airplanes.html#partsofplane

Cornish, Jim. "Science of Flight." *Parts of an Airplane*, *Controlling an Airplane*.
http://www.cdli.ca/CITE/flightsc.htm#Parts

Activity Ten—Soaring Higher

The National Museum of the United States Air Force near Dayton, Ohio, is the oldest and largest military aviation museum in the world.
http://www.nationalmuseum.af.mil/

The National Air and Space Museum (NASM) of the Smithsonian Institution was established to memorialize the development of aviation and spaceflight and to provide educational materials for the study of aviation.
http://www.nasm.si.edu/

Suggested Reading

Ardley, Neil. (1991), *The Science Book of Air.* Harcourt Brace and Jovanovich, New York. ISBN: 0–15–200578–1. Simple experiments demonstrate basic principles of air and flight.

Asimov, Isaac. (1993), *How Do Airplanes Fly? (Ask Isaac Asimov)* Gareth Steven's Inc., Milwaukee, WI. ISBN: 0–8368–0800–2. Describes the forces of flight.

Barrett, Norman. (1994), *Visual Guides, Flying Machines.* Franklin Watts, New York. ISBN: 0–531–14301–5. Includes the history and development of flight.

Bendick, Jeanne. (1992), *Eureka! It's an Airplane!* The Millbrook Press, Brookfield, Connecticut. ISBN: 1–56294–058–9. Describes the development of the airplane and some of the inventions that have made it a more common means of transportation.

Biesty, Stephen and Richard Platt. (1992), *Stephen Biesty's Incredible Cross-Sections.* Alfred A. Knopf, New York. ISBN: 0–679–81411–6. Cross-sectional illustrations explore the inner working of real machines and buildings including a galleon, a steam train, an ocean liner, a submarine, a helicopter, a jumbo jet, and the Space Shuttle.

Burleigh, Robert. (1991), *Flight, The Journey of Charles Lindbergh*. Philomel Books, New York. ISBN: 0–440–84704–4. Describes how Charles Lindbergh achieved the remarkable feat of making the first nonstop, solo, flight from New York to Paris in 1927.

Busby, Peter. (2003), *First to Fly: How Wilbur and Orville Wright Invented the Airplane*. Crown, New York. ISBN: 0–375–812–873. A look at the lives of the Wright Brothers, from their childhood interest in flight, through their study of successful gliders and other flying machines, to their triumphs at Kitty Hawk and beyond.

Clemens, Peter. (1991), *Super Wings the Step-By-Step Paper Airplane Book*. RGA Publishing Group, Lowell House Juvenile, U.S.A. ISBN: 0–929923–87–1. This guide to making and flying paper airplanes features 19 fun and easy models.

Cole, Joanna. (1997), *The Magic School Bus Taking Flight*. Scholastic, Inc., New York. ISBN: 0–590–7371–2. Ms. Frizzle and her class find out about how things fly.

D. K. Direct Limited. (1992), *What's Inside? Planes.* Dorling Kindersley, Inc., New York. ISBN: 1–56458–135–7. Describes some of the external and internal workings of such aircraft as an airship, a helicopter, a jumbo jet, a fighter plane, and an ultralight plane.

Darling, David. (1991), *Up, Up, and Away, The Science of Flight*. Dillon Press, New York. ISBN: 0–87518–479–0. Explains and demonstrates the principles of flight through experiments and provides information on different types of aircraft.

Freedman, Russell. (1991), *The Wright Brothers, How They Invented the Airplane.* Holiday House, New York. ISBN: 0–8234–0875–2. Follows the lives of the Wright Brothers and describes how they developed the first airplane.

Garland, Michael. (2000), *Icarus Swinebuckle.* Albert Whitman & Company, Morton Grove, IL. ISBN: 0–80753–495–1. Fiction – Although he knows that his ambition to fly is silly, Icarus the pig sets out to design, build, and test a set of wings.

Gibbons, Gail. (1986), *Flying*. Holiday House, New York. ISBN: 0–8234–0599–0. Presents a brief history of flight from balloons evolving into more sophisticated means of air transportation such as helicopters, jet planes, and space shuttles.

Gross, Ruth Belov. (1977), *Dangerous Adventure! Lindbergh's Famous Flight*. Scholastic Book Services, New York. ISBN: 0–80276–309–8. A brief biography of Lindbergh including his famous flight.

Gunning, Thomas G. (1992), *Dream Planes*. Dillon Press, New York. ISBN: 0–87518–556–8. Describes planes of the future.

Hansen, Ole Steen. (2003), *The Story of Flight, Modern Military Aircraft*. Crabtree Publishing Company, St. Catherines, Ontario. ISBN: 0–7787–1204–4. Depicts modern military aircraft in story and pictures.

Hart, Phillip S. (1992), *Flying Free, America's First Black Aviators.* Lerner Publications Company, Minneapolis, Minnesota. ISBN: 0–8225–1598–9. Surveys the history of black aviators from the early black aviation communities in Los Angeles and Chicago in the 1920s through World War II to modern times.

Jacobs, Marion B. (1999), *The Library of Why, Why Can Airplanes Fly?* Rosen Publishing Group Inc., New York. ISBN: 0–8239–5274–6. Provides answers to flight-related questions such as, "What is air pressure?," "What is lift?," and "What is thrust?"

Jefferis, David. (1987), *Epic Flights.* Franklin Watts, New York. ISBN: 0–531–105–075. Stories about daring flights.

Jennings, Terry. (1992), *How Things Work, Planes, Gliders, Helicopters, and Other Flying Machines*. Kingfisher Books, New York. ISBN: 1–85697–870–2. Examines, in text and labeled diagrams and illustrations, how various types of airplanes and other flying machines work and the kinds of functions they perform. Includes instructions for related projects and experiments.

Kelley, Steve. (1990), *Airplanes and Other Things That Fly.* A Golden Book, New York. ISBN: 0–307–17867–6. Identifies different kinds of aircraft through pictures and stories.

Kerrod, Robin. (1992), *Eyewitness Juniors, Amazing Flying Machines*. Alfred A. Knopf, New York. ISBN: 0–679–92765–4. Text and photographs present flying machines throughout history, including hot-air balloons, helicopters, and the Space Shuttle.

Mayer, Mercer. (1999), *Shibumi and the Kitemaker.* Marshall Cavendish, New York. ISBN: 0–7614–5054–8. Fiction – After seeing the disparity between the conditions of her father's palace and the city beyond its walls, the emperor's daughter has the royal kitemaker build a huge kite to take her away from it all.

Michael, David. (1993), *Step-By-Step Making Kites*. Kingfisher Books, New York. ISBN: 1–85697–923–7. Provides an introduction to kite construction and directions for making various kinds of kites, including a two-stick kite, box kite, superstunter, and wind sock.

Miller, David and Wilfred Hardy. (1992), *I Can Be An Airplane Pilot.* Derrydale Books, New York. ISBN: 0–517–06990–3. Describes the job of an airplane pilot, the training, the practice, learning about the flight deck, and how to control the plane.

Moser, Barry. (1993), *Fly! A Brief History of Flight Illustrated*. Willa Perlman Books. ISBN: 0–06–022894–6. Highlights 16 episodes in the development of aviation ranging from balloons to the Space Shuttle.

Nahum, Andrew. (1990), *Eyewitness Books, Flying Machine*. Alfred A. Knopf, New York. ISBN: 0–679–80744–6. A photo essay tracing the history and development of aircraft from hot-air balloons to jetliners. Includes information on the principles of flight and the inner workings of various flying machines.

Old, Wendie. (2002), *To Fly, The Story of the Wright Brothers*. Clarion Books, New York. ISBN: 0–618–13347–X. Traces the lives and the work that the two Wright Brothers did together to develop the first machine-powered, heavier-than-air airplane.

Pallota, Jerry. (1999), *The Jet Alphabet Book*. Scholastic Inc., New York. ISBN: 0–439–21019–4. An ABC book of different types of jets.

Pallotta, Jerry and Fred Stillwell. (1997), *The Airplane Alphabet Book*. Charlesbridge Publishing, Watertown, MA. ISBN: 0–88106–907–8. An ABC book of different types of aircraft.

Parker, Steve. (1995), *? What If….Airplanes*. Copper Beech Books, Brookfield, Connecticut. ISBN: 1–56294–946–2. An imaginative look at airplanes through such questions as "What if airplanes didn't have air?" and "What if airplanes could go into space?"

Parker, Steve. (1997), *High in the Sky*. Candlewick Press, Cambridge, MA. ISBN: 0–7636–0128–4. Identifies different kinds of aircraft.

Peet, Bill. (1974), *Merle the High Flying Squirrel.* Houghton Mifflin, Boston. ISBN: 03951–845–25. Fiction – Unhappy about the noise and clutter of the city, a squirrel travels by kite out west to find peace and quiet in the forest of giant trees he has heard about.

Provensen, Alice and Martin. (1983), *The Glorious Flight*. The Viking Press, New York. ISBN: 0–670–34259–9. A biography of the man whose fascination with flying machines produced the *Blériot XI,* which made the first air crossing of the English Channel in 37 minutes in 1909.

Robins, Jim. (1986), *Do You Know? The Story of Flight.* Warwick Press, New York. ISBN: 0–531–19022–6. Gives some of the history and milestones of flight.

Sabin, Louis. (1983), *Wilbur and Orville Wright, The Flight to Adventure.* Troll Associates, U.S.A. ISBN: 0–89375–851–5. Focuses on the childhood of the Wright Brothers and the inventiveness they displayed in their youth.

Schmidt, Norman. (1999), *Great Paper Jets.* Sterling Publishing Company. ISBN: 1–895569–46–X. Descriptions of different jet airplanes, each accompanied by a pattern and directions for assembly.

Scholastic Voyages of Discovery. (1994), *The Story of Flight*. Scholastic, Inc., New York. ISBN: 0–590–47643–2. A voyage of discovery through time from Leonardo da Vinci's designs for flying machines to the Wright Brothers to the Concorde and planes of the future.

Sobol, Donald J. (1961), *The Wright Brothers at Kitty Hawk*. Scholastic Inc., New York. ISBN: 0–590–42904–3 Describes the work, the trials, and the perseverance of the Wright Brothers from the first glider at Kitty Hawk in 1900 to the first powered flight in 1903.

Wallner, Alexandra. (1996), *The First Air Voyage in the United States*. Holiday House, New York. ISBN: 0–8234–1224–5. Recounts the voyage of an eighteenth-century French aeronaut by hot air balloon from Philadelphia to Woodbury, New Jersey, in 1793.

Weiss, Harvey. (1995), *Strange and Wonderful Aircraft.* Houghton Mifflin Company, Boston. ISBN: 0–395–68716–0. A lively history of the folklore and science of flight from Daedalus to Mariner.

White, Larry. (1995), *Air, Simple Experiments for Young Scientists*. The Millbrook Press, Brookfield, Connecticut. ISBN: 1–56294–471–1. Through simple experiments, readers explore air and its properties, including motion, weather, and flight.

Wilson, Anthony. (1995), *Visual Timelines of Transportation.* Dorling Kindersley, London. ISBN: 1–56458–880–1. More than 500 different forms of transportation are featured. Each spread is divided vertically into time columns, and horizontally into bands of transportation. An illustrated chronology of new technologies and innovations running beneath each time chart explains the context of each new development.

Zaunders, Bo. (2001), *Feathers, Flaps, & Flops.* Dutton Children's Books, New York. ISBN: 0–525–46466–2. A collection of short biographies of some famous fliers/pilots and their epic flights.

Materials List

Pre-unit Instructions

A list of materials is given at the beginning of each activity or, in some cases, each lesson. It is recommended that teachers begin to gather materials in advance of teaching the unit. **It may be helpful to duplicate the materials lists and pre-lesson instructions and give them to a team of parent volunteers.** As materials are collected, have a predetermined way to organize and store them. Labeled tubs or boxes make it easier to plan and prepare each lesson. **Use a color printer for printing pictures and laminate each one if possible.** Keeping and storing the materials will be helpful for teaching the unit again to future classes and will greatly reduce the prep time for each lesson.

In addition to gathering the materials ahead of time, teachers should try to fill their classrooms with a variety of picture books on airplanes and other aircraft, flight, the lives of famous aviators, the history of aviation, and planes of the future. Use the city or county library as well as the school library to find books on these subjects. These books will be needed for student research in Lessons 9–12. A list of suggested books is provided in the Resources section. The Resources section also lists related websites for students to explore.

Bulletin board

A week before beginning the unit, teachers should prepare a "Take Flight" bulletin board and ask the students to bring in pictures of man-made objects that fly in the atmosphere (not spacecraft). This should be an ongoing project as students continue to bring in pictures throughout the unit.

Student needs

Students will need a binder with three 1-inch diameter rings. This will be used as a student log as well as a place to store student text, experiments, and homework assignments.

Activity One—Kite Flight

Lessons 1 and 2

- The book, *Merle the High Flying Squirrel,* by Bill Peet or *Shibumi and the Kitemaker* by Mercer Mayer, or another appropriate fictional story about kites. (See Suggested Reading list.)
- KWL chart on flight.
- The "Take Flight" bulletin board for students to post pictures of man-made objects that fly.
- A copy of the student text for Lessons 1 and 2, "Kites in Flight," for each student.
- A copy of the Sled Kite Instructions (or Alternate Sled Kite Instructions and template) for each group of 3–4 students.
- World map.
- Student logs—A loose-leaf binder with three rings, each about 1 inch in diameter. The students should insert about 10 sheets of notebook paper. A braded folder will also work.

Making a Sled Kite

- Plastic garbage bag at least 24 by 30 inches (61 by 76 centimeters).
- 2 wooden dowels—24 inches (61 centimeters) long and ⅛ inch (3 millimeters) in diameter.
- Scissors.
- 1 yardstick or meter stick.
- Marking pen or pencil.
- Small ball of string.
- Roll of duct tape or packing tape.

Alternate Sled Kite Materials

- Alternate sled kite template.
- 2 drinking straws.
- Clear tape.
- Scissors.
- String—two 18-inch (45.7-centimeter) lengths and a 1-yard (0.9-meter) length.
- 1 hole punch.
- 1 paper clip.
- Selection of paper (tissue, newspaper, crepe).
- Markers, crayons, pencils.

Lesson 3—Go Fly a Kite

- 8- by 11-inch (20.3- by 28-centimeter) white drawing paper—1 sheet for each student.
- Drawing and coloring materials such as magic markers, colored chalk, oil crayons, etc.
- Sled kites and personal kites brought from home.
- 12- by 18-inch (30.5- by 45.7-centimeter) multi-colored construction paper—1 sheet for each student.
- Kite-flying field.

Activity Two—The Flight Timeline

Lesson 4—Creating the Flight Timeline

- Blue bulletin board paper—about 3 by 6 feet (0.9 by 1.8 meters) long. (The length depends on the number of entries. Six feet is sufficient for 25 students.)
- White construction paper or other white paper to be used as a cloud border around the timeline.
- Drawing paper (white) squares—about 4 by 4 inches (10 by 10 centimeters), 2 per student.
- Multi-colored construction paper—about 5 by 6 inches (13 by 15 centimeters), 2 per student.
- Drawing and coloring materials such as magic markers, colored chalk, oil crayons, etc.
- Black pens for bold writing.
- Access to a computer to complete or verify information.

Activity Three—Aviation Pioneers

Lesson 5—They Never Gave Up

- Student logs.
- Pictures of early aviation pioneers and their flying machines.
- A color picture of the Montgolfier balloon.
- A copy of the student text for Lesson 5, "They Never Gave Up," for each student.
- A copy of the Rotor Motor Instructions for each student.
- Several sheets each of different weights of paper such as heavy construction paper, cardstock, light cardboard, tissue paper, notebook paper, etc.
- Scissors—1 pair for each student.

Activity Four—Having the Right Stuff—The Wrights and Blériot

Lessons 6 and 7—The Wright Brothers and Louis Blériot

- Pictures of early aviation pioneers and their flying machines. (See the Resources section at the end of this guide and Pre-lesson Instructions for Lessons 6 and 7.)
- Pictures of the Wright Brothers—as many as possible showing their planes and different events in their lives. (See Resources and Pre-lesson Instructions.)
- A copy of the student text for Lesson 6, "The Wright Brothers," for each student.
- A copy of the student text for Lesson 7, "Louis Blériot," for each student.
- Picture books and biographies on the Wright Brothers and Louis Blériot.* (See Resources.)
- Chart paper – four sheets.
- A U.S. map.
- Student logs.

* At the time of this writing, there is only one children's biography of Louis Blériot. *The Glorious Flight Across the Channel With Louis Blériot,* by Alice and Martin Provensen, published in 1983 by Viking Penguin, Inc.

Activity Five—Flying a Styrofoam® Plane

Lesson 8—Will it Fly?

- The book, *The First Air Voyage in the United States,* by Alexandra Wallner.
- Student logs.
- A Styrofoam® tray or plate for each student.
- Scissors for each student.
- Clear tape dispensers (about 4).
- A 25-foot (7.6-meter) tape measure for each group—Ask the students to bring these in if needed.
- An inside flying field (gymnasium or cafeteria) or outside if no wind is blowing.
- Picture books and other trade books on flight, airplanes, famous aviators, the history of flight, and aircraft of the future. (See Resources.)
- Access to computers.
- White 9- by 12-inch (22.9- by 30.5-centimeter) construction or drawing paper—several sheets for each team.
- Multi-colored 12- by 18-inch (30.5- by 45.7-centimeter) construction paper to be used as the pages for the book.
- Drawing and coloring materials such as magic markers, colored chalk, oil crayons, etc.
- Student logs.

Activity Six—Looking for Answers—A Research Project

Lessons 9–12—Modeling the Research Process and the Writing Process, Conducting Research, The Finished Product, and Presenting the Research

- Picture books and other trade books on flight, airplanes, famous aviators, the history of flight, and aircraft of the future. (See Resources.)
- Access to computers.
- White 9- by 12-inch (22.9- by 30.5-centimeter) construction or drawing paper—several sheets for each team.
- Multi-colored 12- by 18-inch (30.5- by 45.7-centimeter) construction paper to be used as the pages for the book.
- Drawing and coloring materials such as magic markers, colored chalk, oil crayons, etc.
- Student logs.

Activity Seven—The Matter of Air

Lessons 13 and 14—Air Works for Me and Discovering the Properties of Air

- Student logs.
- Pictures of how air works for us (homework assignment from Lesson 12).
- A copy of the student text for Lesson 13, "Air Works for Me" for each student.
- Copies of the Air Experiments 1–10 (teacher copies), which include a list of materials and answers for results and conclusions for the teacher.
- Copies of the Air Experiments 1–10 (student copies) for each student.
- A golf ball.
- A ping-pong ball.
- Clear plastic cup—8-ounce size or larger.
- 1 index card (5 by 8 inches or 12.7 by 20.3 centimeters)
- "The Scientific Process" chart.
- A "Three States of Matter" chart.
- A transparency of the Demonstration Experiment.
- Materials for the optional activities Hot Air Balloons and Air Cubes are listed with those activities.

Optional Activity—Hot Air Balloon

- 7 sheets of 24- by 36–inch (61- by 91.4-centimeter) tissue paper. (Use 2 or 3 colors.)
- 1 glue stick.
- Scissors.
- 4 pennies.
- A copy of the "Instructions for Assembling Hot Air Balloons."

Optional Activity—Air Cubes

- A piece of 12- by 18-inch (30.5- by 45.7-centimeter) tag board (or other stiff paper) per student.
- Glue or clear tape.

Launching Hot Air Balloons

- One or two camp stoves (Coleman, etc.); usually parents can help with this.
- For each stove, purchase a 2-foot (0.6-meter) length of regular stovepipe.
- Pot holder mitts (4 per stove).

Demonstration Experiment—Air Power

- Pie pan or other shallow pan (or dish).
- Candle.
- Modeling clay.
- A tall, clear, glass jar (taller than candle and flame).
- 1½ cups of water.

Air Experiment 1—Perfume Spray

- 1 bottle of inexpensive, strong-smelling perfume.

Air Experiment 2—No Way In

- 1 paper towel.
- 1 plastic cup.
- 1 small bucket or pan filled with water.

Air Experiment 3—Blow Hard

- 1 clear plastic bottle (2-liter soda bottle).
- 1 balloon (helium quality).

Air Experiment 4—Balancing Act

- 2 balloons inflated to the same size.
- 3 pieces of string, each about 14 inches (35.6 centimeters) long.
- A 12-inch (30.5-centimeter) ruler.
- Balance scale for Follow-up Activity.

Air Experiment 5—The Real Paper Weight
- A 12-inch (30.5-centimeter) ruler.
- A 12- by 18-inch (30.5- by 45.7-centimeter) piece of newsprint.

Air Experiment 6—Brrrrrrr
- 1 balloon.
- A cloth or soft plastic measuring tape.
- Access to a refrigerator.

Air Experiment 7—Money Freeze
- 1 soda bottle (glass is best).
- 1 nickel.
- Water.
- Access to a freezer.

Air Experiment 8—Balloon Magic
- 1 balloon (helium quality).
- 1 plastic soda bottle.
- 1 pan of very hot water.

Air Experiment 9—Thermometer Reading
- 2 thermometers.

Air Experiment 10—Bottle It Up
- A 1-gallon plastic milk bottle with a cap.
- Very hot water.

Activity Eight—The Four Forces of Flight

Lesson 15—The Four Forces of Flight at Work
- Student logs.
- The book, *The Airplane Alphabet Book,* by Jerry Pallotta.
- A copy of the student text for Lesson 15, "The Four Forces of Flight at Work," for each student.
- Diagram of a plane shown in the center of the four forces of flight.
- Frisbees® – 1 for each pair of students if possible.
- 2 natural fiber, long, heavy ropes for tug of war (Ask the P.E. teacher for these. Do not use ropes made out of synthetic fiber.) Tie a piece of cloth at the center of each rope.
- 4 nametags labeled WEIGHT, LIFT, THRUST, and DRAG on strings made to be put around a student's neck.
- Toy airplane – about 12 inches (30.5 centimeters) long.
- An empty egg carton (or other lightweight, bulky item).

Lesson 16—The Pull of Gravity
- Student logs.
- A copy of the student text for Lesson 16, "The Pull of Gravity," for each student.
- Copies of the Gravity Experiments 1–6 (Teacher copies, which include a list of materials and answers for results and conclusions) for the teacher and each adult volunteer.
- Copies of the Gravity Experiments 1–6 (Student copies) for each group (should be 6 groups).

Gravity Experiment 1—Is There A Heavyweight Champion?
- 1 tennis ball.
- 1 baseball.
- 1 football.
- 1 golf ball.
- 1 basketball.
- 1 soccer ball.
- Access to a slide or other high, safe structure.

Gravity Experiment 2—Which One Wins?
Note: Choose objects that will not be susceptible to air resistance.
- Objects of different weights and shapes (e.g., pencil, book, shoe, shoe box, paper clip, tack, rubber band, etc.).

Gravity Experiment 3—Colliding Marbles
- 2 marbles—same size, but different colors.
- A 12- or 18-inch (30.5- or 45.7-centimeter) ruler with a groove down the center.
- 3 books.
- Several marbles of different sizes.

Gravity Experiment 4—Flip the Coins
- 1 yardstick or meter stick.
- 4 different coins.
- Balance scale or small scale.
- Small objects such as a magnet, eraser, crayon, paintbrush, counter, cork, marble, or things volunteered by the students.

Gravity Experiment 5—Cup Stacking
- 4 paper cups. (Have a few extra in case some are damaged.)
- 4 playing cards.

Gravity Experiment 6—Paper Shape
- 12 sheets of notebook paper (2 for each group).
- 1 golf ball.

Lesson 17—It Lifts Me Up—The Force of Lift

- Student logs.
- A copy of the student text for Lesson 17, "It Lifts Me Up—The Force of Lift," for each student.
- Copies of the Lift Experiments 1–6 (teacher copies, which include a list of materials and answers for results and conclusions) for the teacher and each adult volunteer.
- Copies of the Lift Experiments 1–6 (student copies) for each group (should be 6 groups).
- A copy of the optional activity, "Airfoil on a String," for each student, if used.
- Scissors for each student.
- 1 sheet of notebook paper for each student.
- A thick textbook such as math or science for each student, the same for every student.
- Diagram of an airfoil.
- Tug of war rope.
- Toy airplane.
- LIFT and GRAVITY nametag necklaces.

Lift Experiment 1—Chin Ups

- 1 piece of 6- by 2-inch (15- by 5-centimeter) paper.

Lift Experiment 2—Paper Pull

- 2 strips of 2- by 12-inch (5- by 30.5-centimeter) paper.

Lift Experiment 3—Can It

- 2 empty soda cans.
- 2 pieces of 14-inch (35.6-centimeter) string.
- A 12-inch (30.5-centimeter) ruler.
- Tape.

Lift Experiment 4—Ping-pong Funnel

- 1 small plastic funnel 4- or 5-inch (10- or 13-centimeter) diameter.
- 1 ping-pong ball.

Lift Experiment 5—Air Dance

- 1 hair dryer.
- 1 ping-pong ball.

Lift Experiment 6—Wing It

- A 5- by 8-inch (13- by 20-centimeter) index card.
- A 6-sided pencil.
- A 12-inch (30.5-centimeter) ruler.
- Tape.
- Hair dryer.

Optional Activity—Airfoil on a String

- Lightweight paper (notebook paper).
- Scissors.
- Straw - 1 straw for every 2 students.
- String - 18 inches (45.7 centimeters) for each student.
- Fan.

Lesson 18—The Opposing Forces of Thrust and Drag

- Student logs.
- A copy of the student text for Lesson 18, "The Opposing Forces of Thrust and Drag," for each student.
- An electric fan (small room-size).
- A 12- by 18-inch (30.5- by 45.7-centimeter) piece of poster board, tag board, or thin cardboard.
- Roller skates or roller blades for an adult. (If you're brave!)
- A large ball such as a soccer ball, basketball, or volley ball.
- 2 sheets of notebook paper for each student.

Lesson 19—Thrust and Drag Experiments

- Student logs.
- Copies of the Thrust Experiments 1–3 and Drag Experiments 1–3 (teacher copies, which include a list of materials and answers for results and conclusions) for the teacher and each adult volunteer.
- Copies of the Thrust Experiments 1–3 (student copies) and Drag Experiments 1–3 (student copies) for each group (should be 6 groups).

Thrust Experiment 1—Balloon Jets

Note: Blow up the balloons to the four different sizes and attach the straws for all six groups beforehand to save time.

- Nylon fishing line (about 40 feet or 12 meters will be needed).
- Pack of elliptical (hotdog) shaped, helium quality balloons—all the same size (24 are needed, but have extras).
- 4–10 strong plastic straws (4 are needed, but have extras).
- Clear tape.
- 4 pairs of scissors.

Thrust Experiment 2—Moving Fan

- 1 electric fan.
- Wagon or replace the wagon with one 10- by 12-inch (25.4- by 30.5-centimeter) board large enough for the fan to sit on, and 10–16 perfectly round pencils (or dowels).

Thrust Experiment 3—Pop the Cork

(Note: If you cannot find a plastic bottle with a cork, skip this experiment and go to the alternate experiment, Flow Away. A glass bottle could be used but it is not recommended that young students work with glass.)

- Plastic soda bottle with a cork (1- or 2-liter size).
- A large container of vinegar (perhaps a gallon, enough to fill a soda bottle half full 6 different times).
- Baking soda.
- 1 teaspoon.
- Measuring cup (1 pint).
- Petroleum jelly (if needed).
- 10 perfectly round pencils or dowels.

Thrust Experiment 3 (Alternate)—Flow Away

- Strong plastic cup (about 10-12 ounces).
- 3 pieces of string, each about 10 inches (25.4 centimeters) long.
- Watering can (or something to pour water with).
- Dishpan.
- Hole punch.
- Scissors.
- Masking tape.
- Access to water (sink, spigot, etc.).

Drag Experiment 1—Run With It

(Note: An adult is needed at this station.)

- 1 large piece of poster board (18- by 24-inch or 45.7- by 61-centimeter or larger).
- String (about 2 feet or 46 centimeters).
- Hole punch.
- Stopwatch.
- Course for running (25 yards, or 23 meters, or more).

Drag Experiment 2—Parachute Fun

(Note: Have a parent, student, or educational assistant construct these ahead of time. See Drag Experiment 2 teacher copy for directions.)

- Tape.
- Ball of string
- 3 different squares of the same fabric (about 8, 12, and 16 inches or 20, 30.5, and 40.6 centimeters).
- 3 identical, small plastic figures (teddy bear counters, action figures, or other miniature plastic figures) or 3 clothes pins.

Drag Experiment 3—It's A Drag

(Note: This experiment should be performed next to a sink for cleanup in between groups. An adult is needed at this station.)

- 1 tall clear container with a very wide mouth.
- Shish kabob skewer or tongs (or other device to retrieve clay shapes from corn syrup).
- Clear corn syrup (enough to fill ¾+ of the container).
- 6 bars of modeling clay (1 new bar for each group).
- Balance scale.
- Stopwatch.
- Pencil and paper to record times.

Activity Nine—Controlling the Plane

Lesson 20—It's All About Control

- Student logs.
- A copy of the student text for Lesson 20, "It's All About Control," for each student.
- A copy of "The Parts of an Airplane" diagram for each student.
- A copy of the homework assignment, "Design Your Own Super Plane," for each student.
- A picture of the *Wright Flyer I*.
- Pictures of modern aircraft.
- An empty plastic wrap box or any long slender box.
- Cutaway pictures (cross sections) of planes.
- Imaginary Planes poster to be used at the discretion of the teacher to motivate the Super Plane designs.
- Materials for making a straw plane.
- A copy of the instructions, "Making a Straw Plane," for each pair of students or group of no more than three students. (Each student will construct a plane, but grouping allows students to help one another.)
- A 12-inch (30.5-centimeter), strong, plastic straw for each student.
- A 12- by 18-inch (30.5- by 45.7-centimeter) sheet of heavy card stock or other stiff paper for each student. (If possible, allow students to choose different colors. This helps with identifying their planes.)
- Clear tape.
- Paper clips.
- Scissors.
- A 12-inch (30.5 centimeter) ruler.

Lesson 21—Experiments and Test Flights

- A straw plane for every student and the teacher.
- A copy of the Straw Plane Experiments 1–4 (teacher copy, which includes a list of materials and answers for results and conclusions) for the teacher and each adult volunteer.
- Copies of the Straw Plane Experiments 1–4 (student copy) for each student.
- Calculator.
- Overhead projector.
- A graph transparency.
- A free-flying area and a measured area for test flights.

Straw Plane

- A copy of the instructions, "Making a Straw Plane," for each pair of students or group of no more than three students. (Each student will construct a plane, but grouping allows students to help one another.)
- A 12-inch (30.5-centimeter), strong, plastic straw for each student.
- A 12- by 18-inch (30.5- by 45.7-centimeter) sheet of heavy card stock or other stiff paper for each student. (If possible, allow students to choose different colors. This helps with identifying their planes.)
- Clear tape.
- Paper clips.
- Scissors.
- A 12-inch (30.5-centimeter) ruler.

Straw Plane Experiment 1—Ailerons

- 1 straw plane for each student.
- A free flying area such as a playground or field (no measurements needed).

Straw Plane Experiment 2—Elevators

- 1 straw plane for each student.
- A free flying area (no measurements needed).

Straw Plane Experiment 3—Rudders

- 1 straw plane for each student.
- A free flying area (no measurements needed).

Straw Plane Experiment 4—Flight Tests

- 1 straw plane for each student.
- A measured flight field, or wide lane, up to 50 feet or 15 meters long. (Have 3 fields, or wide lanes, if possible.)

Activity Ten—Soaring Higher

Lesson 22—Faster, Farther, Higher

- Student logs.
- A field for the 100- or 50-yard (91- or 46-meter), run and walk.
- A stopwatch for each timer.
- A calculator for each student.
- Access to computers.
- A copy of the student text for Lesson 22, "Faster, Farther, Higher," for each student.
- Picture books for children on the history of transportation, the history of airplanes, future planes, and other books on airplanes.
- Pictures of the *Wright Flyer III*, WWI and WWII planes, stunt planes, the *Spirit of St. Louis*, the *X–1*, *X–15*, *F–15*, *B–2*, *SR–71*, *F–22* and the *X–43*.
- A sheet of large-lined graph paper for each student.
- Overhead projector.
- Large-lined graph paper transparency (same as students' graph paper). Our Super Planes.

Lesson 23—Our Super Planes

- The KWL chart on flight.
- A stand or place for the students to display their posters as they make their presentations.
- The book, *Icarus Swinebuckle,* by Michael Garland.
- X–43 Scramjet pattern and Information Page.

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