

The History and Physics of Flight

A curriculum for grades 5-8

The History and Physics of Flight curriculum was designed during the summer of 1998 in a one week curriculum development workshop sponsored by the Mn/DOT Office of Aeronautics. Close attention was paid to the Minnesota Graduation Standards during the development of this interdisciplinary curriculum.

To e-mail your comments about the curriculum or for more information about aviation education, please visit our website:

<http://www.mnaero.com/aved>



Minnesota Department of Transportation
Office of Aeronautics
Aviation Education Section
222 East Plato Boulevard
St. Paul, MN 55107-1618
(651) 297-1600

Contributors

Larry Disher

Brookside Elementary, Minneapolis

Mark Legvold

Ames Elementary, St. Paul

Tom Idstrom

Black Hawk Middle School, Rosemount–Apple Valley–Eagan

Robert Rasmussen

Museum Magnet School, St. Paul

Lolita Cox

Museum Magnet School, St. Paul

Marianne Portwood

Black Hawk Middle School, Rosemount–Apple Valley–Eagan

Roxanne Walter

St. Peter Middle School, St. Peter

Table of Contents

Overview.....	1
Time Line Project	3
Sample Evaluation Rubrics	10
Activities Matrix.....	14
Standards Matrices	15
Airplane Terminology	18
Balloons	21
Air Pressure and Flight	29
Jet Engines	43
Rockets.....	49
Internet Resources.....	62
Appendix A: History of Rockets.....	65
Appendix B: History of Jets.....	68
Daedalus and Icarus Play.....	71

Overview

This cross-curricular package of information addresses the history of human flight and the scientific concepts behind flight. The suggested grade levels are 5-8. It is designed for you to select the activities that would best fit into your school wide curriculum. Activities can be used individually or as a unit. Additional supplemental suggestions have been included, with supporting materials in the appendix.

Objectives

The student will gather information on the history of human flight. In addition, the student will investigate how the progress and development in aviation have and will impact the social, economic, technological and environmental aspects of our global community.

Background information for teacher

A time line of turning points, as well as many interesting facts in aviation history, is included in the time line lesson plan and a more detailed history of rockets and jets is located in the appendix.

A Brief History of Aerospace

A bird flies easily through the sky, I wonder, can I? Some of our ancestors undoubtedly had that thought. Step by step they gained the knowledge of flight. Thanks to their efforts, and at times sacrifices, we enjoy an ever expanding ability to fly higher, faster, and safer.

The first recorded ascension of a hot-air balloon was on June 4, 1783, in France. It was built by Joseph and Etienne Montgolfier. Three months later the Montgolfiers launched a hot-air balloon for King Louis of France, carrying a duck, a rooster, and a sheep. On November 21, 1783 Pilatre de Rozier and the Marquis d'Arlandes made the first manned balloon flight, lasting 25 minutes and traveling a little over 5 miles. On June 4, 1784, Marie Thible of France became the first female aeronaut.

In 1849 in England, Sir George Cayley built the first successful glider which carried his coachman safely down a hill. He formulated the basic principles of heavier-than-air flight and turned aviation from a fantasy into a science. Because of his contributions Sir George Cayley is called the "father of aerial navigation."

On the wind swept sand dunes of Kitty Hawk, North Carolina, in 1903, Orville Wright successfully flew the first recorded powered, heavier-than-air flight. It lasted 12 seconds and traveled 120 feet.

Fascinated by H.G. Wells' *War of the Worlds*, physicist Robert Goddard published *A Method of Reaching Extreme Altitudes* in 1919. In his experiments, Dr. Goddard pioneered the development of rockets that utilized liquid oxygen and liquid hydrogen as a fuel source. The funding of his work was supported by Charles Lindbergh and philanthropist Harry F. Guggenheim.

Charles Lindbergh became the first person to fly solo across the Atlantic Ocean in 1927. His flight of about 3,600 miles from New York to Paris lasted 33 hours. Just 49 years later, the Concorde made the same flight in 3 hours. It travels subsonic over land but over the ocean increases to Mach 2, approximately 1,400 mph.

In 1944, the first production jet powered aircraft, the ME 262, was introduced into combat by the Germans. Eight years later, the Comet, built by the de Havilland Aircraft Company, became the first commercial jet airplane. In 1954, two Comets, a couple of weeks apart, exploded in flight on clear days. All were grounded, and for the next year extensive research was conducted to solve the mystery. The conclusion: they were not built to stand the pressure changes. Jet powered aircraft fly at higher altitudes than piston powered ones and thus require different construction techniques. The Boeing Company watched and learned from the Comet experience and in 1958 rolled out their first commercial jet, the 707, and ushered in the jet age for commercial travel.

In 1957, the Soviet Union launched Sputnik, the first artificial satellite to orbit the earth. In 1961, Russia's Yuri Gagarin became the first person to orbit the earth in space. In 1969, Neil Armstrong became the first person to walk on the moon. Today, the space shuttle orbits 250 miles above the earth, traveling at 17,500 mph, and it takes just 90 minutes to complete a trip around the world.

In one life time we have expanded our powered flight capabilities from 120 feet in 12 seconds, to orbiting the earth in 90 minutes. What will flight be like 2098? What will the aircraft look like? What materials will be used to build them? Will they travel at warp speed? Will your students design tomorrow's aircraft, the engines that power it, or develop the materials to build it? Will they be the technicians who build and maintain it, the pilots who fly it, flight crew members, or simply passengers, whisked quickly, quietly, and safely to their destination?

Introduction of Time Line Project

A time line is a number line that shows important events in a period of history, or in a person's life. It is an effective way to organize information so that it can be understood at a glance. A straight time line shows events that have taken place, the order in which they occurred, and the relative amount of time between events. A Tiered Time line includes basic facts that connect with the date.

The following materials have been set up to meet the needs of a variety of students. For each middle school grade level, a time line project could be required. Grade levels are suggested in order to help you select a level of the project that will suit your classroom needs and/or the needs of your individual students. Sample evaluations in rubric form are included in for each grade level.

Procedures

Grade 5

1. Research 10 important events in the history of aviation.
2. Create a scaled time line of the information (scale would be optional; using appropriate scale may lead to logistical difficulties - see page 11).
3. One page essay on suggested topic: "How has the history of human flight affected our world socially, economically, technologically, or environmentally?"

Grade 6

1. Research 15 important events in the history of aviation.
2. Create a scaled time line of the information (scale would be optional; note: using appropriate scale may lead to logistical difficulties--see page 11).
3. Choose a person, place, or event related to aviation. Write an essay that addresses the social, economic, technological, and environmental effects of your choice (i.e. Charles Lindbergh, the Wright brothers' flight at Kittyhawk, or the creation of the 747 passenger jumbo jet).

Grade 7

1. Research 20 important events in the history of aviation.
2. Create a scaled time line of the information (scale would be optional; using appropriate scale may lead to logistical difficulties—see page 11).
3. Create an additional tier on the time line to incorporate the effect of the new technology on the social aspect of our global community (see page 11).
4. A possible essay question: "based on your opinion, what would our world be like if technology had not advanced beyond the 1940's level?"

Grade 8

1. Research 25 important events in the history of aviation.
2. Create a scaled time line of the information (scale would be optional; using appropriate scale may lead to logistical difficulties—see p. 11).
3. Create 4 tiers on the time line to incorporate the effect of the new technology on the social, economic, and environmental aspects of our global community (see p. 11).

4. Should we spend 2.5 billion dollars a year to advance space travel? Construct a persuasive paper to convince the reader of your opinion. You may use your Time line to find and list information that supports and verifies your opinion. Use at least five logical pieces of evidence to support your opinion. *An extension of this activity would be to have an in-class debate (see Extension Activities).

Extensions

Language Arts/Performing Arts

- I. Start with the story of Daedalus and Icarus (see appendix C). After traditional reading, have students consider the following questions in small or cooperative groups:
 1. Using your knowledge of physical concepts, would it truly be possible for the characters to fly with wax and feather wings? Explain your reasoning.
 2. Based on what you have learned, re-write the play using modern day materials and technology versus wax and feathers to build your wings.
 3. Perform the re-written play.
 4. Each group needs to come up with relevant questions for the audience which would lead to an explanation of air travel based on their re-designed wing structures.
- II. *Conduct an in-class debate, having students use the information they have collected for their time lines as evidence as they speak.
- III. Poetry writing and speaking.
- IV. The Black Eagles, a historical play based on a squadron of men that made a turning point in African-American history during WWII. This play not only incorporates language arts and performing arts, but is also historically-based and cross-cultural, and involves scientifically-based technology (NOT INCLUDED).

Mathematics/Science

- I. Demonstrate a grade level understanding of the following concepts: ratios, measurements, mass, lift, and wind flow.
 1. Write detailed, numbered steps to build a wing model.
 2. Write a detailed, comprehensive supply list for the model.
 3. Draw a scale model of the wing design (include dimensions in metric units).
 4. Build your model wing.
 5. Possible questions (adjust according to ability level): Given the mass of a plane and the mass of one of its wings, determine the following (show your work):
 - a. What percentage of the plane's mass is its wing?
 - b. What would be the mass of your plane?

Science/History/Art

Design and create a calendar of aviation which shows an event in aviation history for each day of the year (see appendix) The Aviation History Calendar is also an good source for dates in aviation history.

Sample Time Line

The points in time are listed below. To create a formal, visual time line, synchronous dates would have to be evenly spaced along a long sheet of paper/poster, etc. Then, the dates below would have to be placed in the correct position along the time line. Students should notice that there are large time gaps in early aviation history, and that the gaps become smaller as the 19th century approaches.

Myth and Legend

Ki Kung-shi—A Chinese prince, had a flying chariot

Kai Ka'us—A Persian king, had a flying throne

Khonsu—An Egyptian God, was winged

Assur—An Assyrian God, had eagle's wings

Arabic folk tales—Had flying carpets

Greek myth—Pegasus the flying horse, Icarus/Daedalus and the wax & feather wings

Roman myth—Mercury the winged messenger of the gods

Other Historical

400 B.C. — The first kites were invented by the Chinese

11th Century — Oliver of Malmesbury, a Benedictine Monk, is the first person to fly for some distance (125 paces) with the aid of wings.

1485 — Leonardo da Vinci designed the ornithopter, a wing-flapping aircraft that would use almost every muscle of the human body.

17th Century — The Royal Society of Great Britain passed out papers dealing with aeronautics to its members. After reading and discussing the papers, members were encouraged to produce new information. Robert Hooke and Sir Christopher Wren produced several notable papers.

1783 (June 5) — A duck, a sheep, and a rooster flew in a hot air balloon made of linen and paper by the Montgolfier brothers.

1783 (Aug. 27) — French chemist J.A.O. Charles launched an unmanned hydrogen balloon from the Champ de Mars in Paris.

1783 (Dec.) — J.A.O. Charles and assistant made the first manned flight in a hydrogen balloon from Paris to the village of Nesle.

1794 (June 26) — The French used a tethered balloon to observe the battlefield and direct artillery fire.

1797 — Andre-Jacques Garnerin became the world's first skydiver when he parachuted 2230 feet from a hot-air balloon.

1837 (April 16) — Canadian John Ray successfully launched a weight-carrying paper balloon. The balloon was blackened, which allowed the sun to heat the air within and thus provide lift.

1849 — A glider designed by Sir George Cayley lifted a ten year old boy briefly into the air.

1852 — Henri Giffard puts the first airship (equivalent to an airborne submarine) into flight.

1852 — Sir George Cayley invented the first airliner wing.

1879 — Victor Tatim, a French engineer, built two compressed air model airplanes which flew successfully.

1891 — Otto Lillenthal built the first practical glider for long flights. He is credited with establishing the superiority of curved versus flat wings.

1895 — Alexander Graham Bell began experiments with flight-rotors, wings, gliders, and kites. These experiments led to the Aerial Experiment Association (AEA) in 1907.

- 1896 (May 6)** — Samuel P. Langley launched a 9 pound steam driven model airplane, the Aerodome No. 5.
- 1903 (Dec. 8)** — Langley constructed a full size plane powered by an engine built by assistant Charles Manley. Manley attempted to fly the plane with Langley as a passenger. The flight plan involved catapulting the plane off the top of a houseboat on the Potomac River.
- 1903 (Dec. 17)** — In Kitty Hawk, North Carolina, Orville Wright became the first to achieve controlled powered flight. He stayed aloft for twelve seconds.
- 1905 (Dec. 28)** — A tetrahedral cell kite, the Frost King, built by A.G. Bell, carried Neil McDermid, a Baddeck, Nova Scotia native, into the air on a rope ladder.
- 1907** — Paul Cornu, a Frenchman, built the first free-flying helicopter.
- 1907 (Oct.)** — The Aerial Experiment Association (AEA) was formed.
- 1907** — The Cygnet, A.G. Bell's aircraft made of 3,393 tetra cells and 184 square meters of silk, was launched. It carried Lt. Thomas Selfridge as it launched from a raft towed behind the steamer Blue Hill. The kite was destroyed upon landing due to the crew's inexperience.
- 1908 (Mar. 12)** — The Red Wing, the first plane built by the AEA, made its first flight 97 meters above the ice over Lake Keuka in Hammondsport, New York. It was the first of four biplanes designed by Thomas Selfridge and had a 40 HP Curtiss engine. The name was acquired due to the red silk used to make its wings.
- 1908 (May 18)** — F.W. Baldwin flew the White Wing, the second biplane constructed by the AEA at Hammondsport, N.Y.
- 1908 (May 23)** — J.A.D. McCurdy flew the White Wing to its destruction.
- 1908 (July 10)** — With Glenn Curtiss as pilot, the June Bug, named due to its resemblance to the same named insect, was the first plane to make a complete turn.
- 1908 (Aug. 29)** — J.A.D. McCurdy completed the first figure 8 in the June Bug.
- 1908 (Sept. 17)** — Lt. Thomas Selfridge became the first passenger aviation fatality in a crash with pilot Orville Wright at Fort Meyers, Virginia.
- 1909 (Sept. 21)** — W.R. Turnbull obtained a U.S. patent for an aeroplane and hydroplane.
- 1909 (Oct. 27)** — First woman airplane passenger, Mrs. Henry Van Deman, flew with the Wright brothers.
- 1910** — Commercial Aviation began before WWI with the introduction of passenger carrying Zeppelin Airships; between 1910 and 1914, these airships carried more than 35,000 passengers between various German cities.
- 1912 (Mar. 9-17)** — Dr. Bell commissioned McCurdy to construct a tetrahedral flying machine, the Cygnet III. The machine never succeeded in flying.
- 1913 (July 31)** — Mrs. Alys McKey Bryant was the first woman to pilot a flight. She flew a Curtiss-type biplane at Vancouver, B.C.
- 1914** — Autopilot was invented by Elmer Sperry.
- 1915 (Jan.)** — First air-to-air combat and first German aerial bombing of Great Britain by Zeppelins. During WWI, 56 tons of aerial bombs were dropped on London, and 214 tons of aerial bombs were dropped on the rest of Britain.
- 1915** — The National Advisory Committee for Aeronautics, predecessor of NASA, was created by the U.S.
- 1916 (Sept. 2)** — Plane-to-plane radio transmission is successful at a distance of about 2 miles over North Island, California.

- 1916** — Professor Givson developed air cooling of aircraft engines by means of spacing, depth, and thickness of fins, and studied the effects of airflow at the Royal Aircraft Factory at Farnborough.
- 1917 (Feb. 13)** — Aircraft Manufacturers Association (AMA) formed.
- 1917** — U.S. declared war on the Central Powers.
- 1918 (May)** — Army pilots began the Post Office's first regular airmail route (Washington to New York).
- 1918** — Weather reporting instruments, developed by Lt. W.F. Reed, were carried aloft by a kite balloon to take upper atmosphere weather soundings.
- 1919** — Deutsche Luftreederei, the first civil airline with passenger service, operated between Berlin, Leipzig, and Weimar.
- 1919 (May)** — Lieutenant-Commander A.C. Read and crew, in the Curtiss Flying Boat, were the first to fly over the Atlantic.
- 1919 (June 28)** — Treaty of Versailles signed, leaving Germany disarmed of a military air force except rockets as potential weapons.
- 1920-22** — Robert Goddard performed multiple experiments to determine the most efficient combination of rocket fuels.
- 1921** — Bessie Coleman became the first licensed African-American pilot
- 1926** — Robert Goddard worked with rockets as a means of air travel.
- 1927** — Charles Lindbergh flew nonstop and solo across the Atlantic.
- 1932** — Amelia Earhart solos across the Atlantic.
- 1933** — The first modern airliner, the Boeing 247, made its initial flight. Its capacity is 10 passengers and 400 pounds of luggage. Luxuries included armchair seats, a flight attendant, and a bathroom.
- 1935** — Amelia Earhart flew solo across the Pacific Ocean from Hawaii to California.
- 1937** — The jet engine was invented by Frank Whittle.
- 1939** — Igor Sikorsky was credited for the first modern helicopter.
- 1943-45** — The Tuskegee Airmen were a prominent, all black squadron during WWII.
- 1947** — Chuck Yeager flew 670 mph, faster than the speed of sound.
- 1957** — Russians launched Sputnik I, the first man-made satellite.
- 1959** — Hovercraft invented by Christopher Cockerell.
- 1960** — By pointing engine nozzles downward, Michel Wibault tested the first Jump Jet. Very little runway was needed as a result.
- 1961** — Russian Yuri Gagarin was the first person in space.
- 1963** — Russian Valentina Tereshkova was the first woman in space. She orbited earth 48 times, traveling 1.2 million miles.
- 1969** — United States Apollo11 astronauts landed on the moon.
- 1973** — The first United States space station, Skylab, proved that people can live in space for extended time periods.
- 1977** — The Gossamer Condor was the first human-powered craft to fly successfully.
- 1981** — Columbia, the first Space Shuttle, was launched.
- 1984** — An astronaut maneuvering unit for space movement was put into use by NASA.
- 1986** — Jeana Yeager and Dick Rutan were the first to circle the world without refueling. They started with 1,240 gallons of fuel aboard the Voyager.
- 1993** — At only 11 years old, Victoria Van Meter became the youngest girl to fly across the United States.

Time line examples

Fifth and Sixth Grade: 1941

Working in different countries and unaware of each other's work, Frank Whittle in Britain, and Pabst von Ohain in Germany, developed the first jet engines. Whittle's engine was the first used on a plane called the Gloster E28/39.

Seventh Grade: 1941

Working in different countries and unaware of each other's work, Frank Whittle in Britain, and Pabst von Ohain in Germany, developed the first jet engines. Whittle's engine was the first used on a plane called the Gloster E28/39.

Social Aspects: With the ability to travel at 500 mph, the jet engine revolutionized the way humans travel. Military jets flying at an excess of 1500 mph changed the way we fight wars.

Eighth Grade: 1941

Working in different countries and unaware of each other's work, Frank Whittle in Britain, and Pabst von Ohain in Germany, developed the first jet engines. Whittle's engine was the first used on a plane called the Gloster E28/39.

Social Aspects: With the ability to travel at 500 mph, the jet engine revolutionized the way humans travel. Military jets flying at an excess of 1500 mph changed the way we fight wars.

Economic Aspects: The Boeing Company, the largest aerospace company in the world, had a revenue of \$45.8 billion in 1997. Boeing employees more than 237,000 people in 60 different countries.

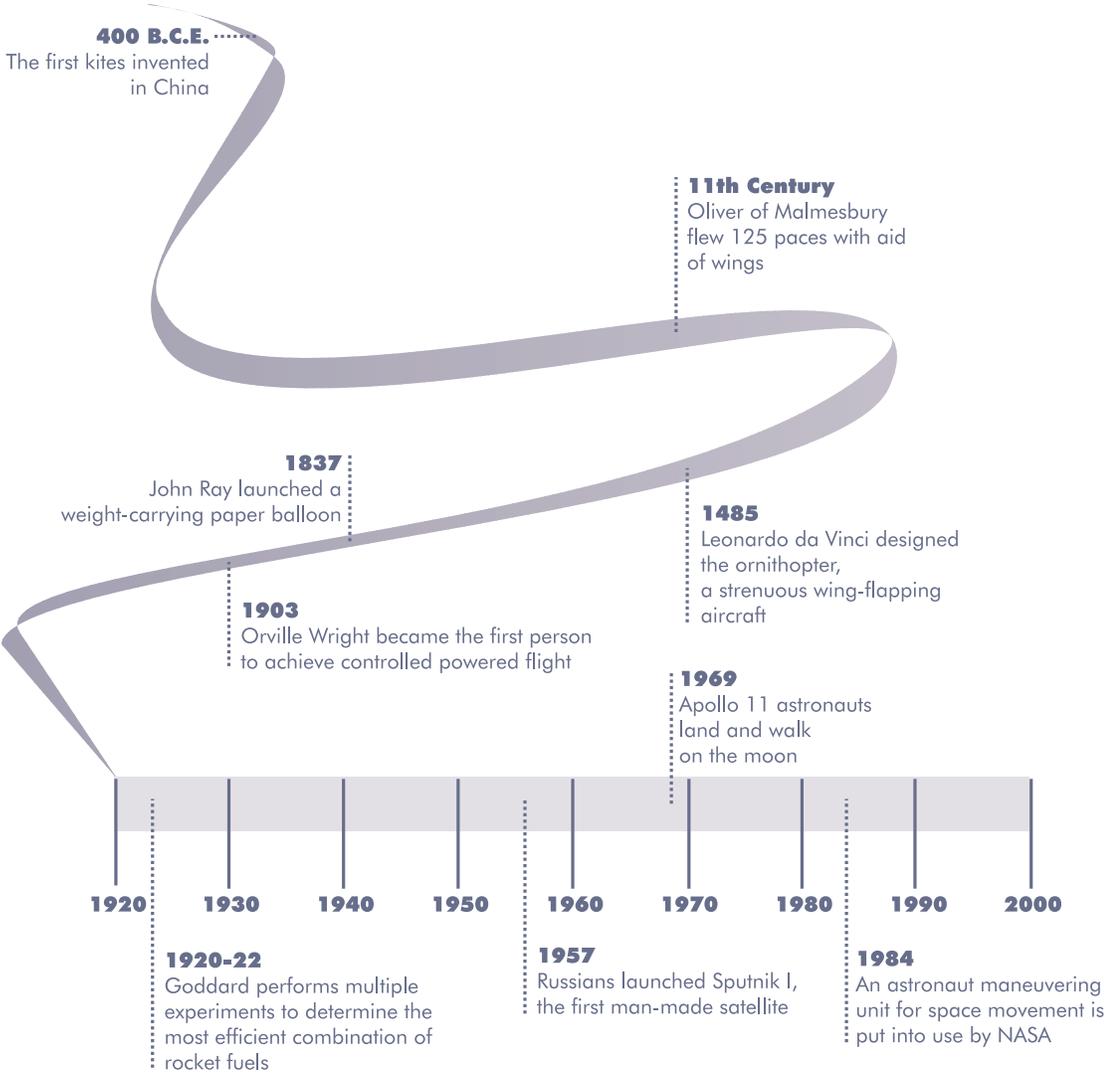
Environmental Impacts: The increased use of jet engines has directly impacted the environment. Noise pollution is a major concern in areas of close proximity to airports. Jet engines burn large amounts of fossil fuels in order for jets to fly. Volume of jet fuel is measured in pph (pounds per hour). A loaded 747 consumes 60,000 pph (8955 gph) at takeoff, and 26,000 pph (3881 gph) while cruising.

Time Line Hints

It is probably not feasible for students to make a scale time line that would include Greek mythology in their individual project. In order for the students to see how long ago the story of Daedalus and Icarus is in relation to the recent advancements in aviation, the following are suggested:

- A. Class time line to scale.
 1. Determine a time line ratio (1cm = 1 year)
 2. Work in the hallway or outside and measure from the current year by placing masking tape on the major aviation events in the last 50 years.
 3. Have the students predict how far down the string you would plot the story of Daedalus and Icarus.
 4. Measure and plot for 1000 B.C. (30 meters).
- B. Ribbon time line. Have the students extend a "ribbon" at the beginning of their time line to show the dates before the 1780's (see T1).

Ribbon Timeline Example (T1)



Sample Evaluation Rubrics

Grade 5

ITEM	POINTS	
	Possible	Actual
10 Events in Aviation History		
Time Line Chronological Order Drawn to Scale		
Essay Content Relevant to Topic Paragraph Structure Sequencing Topic Sentence Main Idea Supporting Sentences Closing Sentence Grammar Punctuation Spelling		

Sample Evaluation Rubrics

Grade 6

ITEM	POINTS	
	Possible	Actual
15 Events in Aviation History		
Time Line Chronological Order Drawn to Scale		
Essay Person, Place or Event Social Effect Economic Effect Environmental Effect Paragraph Structure Sequencing Topic Sentence Main Idea Supporting Sentences Closing Sentence Grammar Punctuation Spelling		

Sample Evaluation Rubrics

Grade 7

ITEM	POINTS	
	Possible	Actual
20 Events in Aviation History		
Time Line Chronological Order Social Aspect of New Technology (Tier Two) Drawn to Scale		
Essay Descriptive Adjectives/Adverbs Maintains Position on Topic Paragraph Structure Sequencing Topic Sentence Main Idea Supporting Sentences Closing Sentence Grammar Punctuation Spelling		

Sample Evaluation Rubrics

Grade 8

ITEM	POINTS	
	Possible	Actual
25 Events in Aviation History		
Time Line Chronological Order (Tier One) Social Aspect (Tier Two) Economic Aspect (Tier Three) Environmental Aspect (Tier Four) Drawn to Scale		
Essay Persuasive Use Five Supporting Pieces of Evidence Maintains Position on Topic Paragraph Structure Sequencing Topic Sentence Main Idea Supporting Sentences Closing Sentence Grammar Punctuation Spelling		

Activities Matrix

ACTIVITY	GRADE LEVEL			
	5	6	7	8
Timeline	•	•	•	•
Essay	•	•	•	•
Perform Greek play "Daedalus and Icarus"	•	•	•	•
Rewrite play using modern day materials instead of wax and feathers	•	•	•	•
Perform rewritten play	•	•	•	•
Write a list of discussion questions for rewritten play (groups)	•	•	•	•
Debate of essay discussion questions				•
Write poetry about flight	•	•	•	•
Write detailed, numbered steps to build a model wing	•	•	•	•
Draw a scale model of a wing design (inc. dimensions in metric units)			•	•
Build model wing			•	•
Paper rockets	•	•	•	•
Parts of an airplane	•	•	•	•
The hovering ball	•	•	•	•
Ballooning activities	•	•	•	•
Balancing balloons	•	•	•	•
Rising and falling temperatures	•	•	•	•
Creative Aircraft	•	•	•	•
Up, up and away balloon project	•	•	•	•
Design and create a calendar of events for each day of the year	•	•	•	•
Jet gas engine	•	•	•	•
Jet propulsion	•	•	•	•
Making a wing	•	•	•	•
Air pressure demonstration (vacuum hose)	•	•	•	•
Table tennis ball pressure	•	•	•	•
Wind tunnel	•	•	•	•
Balloon staging	•	•	•	•
Balloon rocket	•	•	•	•
Effervescent rocket	•	•	•	•

Standards Matrix: Science

Intermediate Level

INQUIRY		
Media (a student shall demonstrate the ability to):		
1. Answer a question by gathering information		
2. Answer a question by recording, displaying & comparing information		
3. Record & organize information; report findings in written, oral, or visual presentation		
MATHEMATICAL APPLICATIONS		
Space, Shape, & Measurement (a student shall):		
1. Describe and analyze two- and three-dimensional shapes using metric units to measure length		
2. Represent a three-dimensional space in a two-dimensional view		
3. Measure, including identifying types of measurement req.; select appropriate tools and units of measurement; measure accurately		
Chance Handling Data (a student shall):		
1. Answer questions by collecting and organizing data, represent the data, and communicate results		
2. Describe patterns, trends, or relationships in data displayed in graphs tables, or charts		
READ , LISTEN & VIEW		
Literal Comprehension (a student shall demonstrate):		
1. Comprehension of literal meaning		
Interpretation & Evaluation (a student shall):		
1. Interpret & evaluate information from fiction and non-fiction selections		
THE ARTS		
Writing (a student shall demonstrate the ability to write a story based on a direct experience including):		
1. Interpret and perform an existing story by adapting plot, characters and language for theatrical purposes		

Standards Matrix: Science

Middle Level

SCIENCE		
Physical Systems (students should understand the fundamental laws & concepts of the physical world, including):		
1. Properties of matter		
2. Physical and chemical changes		
3. Transfer of energy and work		
4. Concept of the force of motion		
5. Historical significance of major scientific advancements		
INQUIRY		
Direct Observation (students shall demonstrate an ability to):		
1. Gather information to answer a scientific question		
2. Gather information to answer a social science question		
3. Collect and record data		
Accessing Info. (students shall demonstrate an ability to):		
1. Use a variety of sources to answer a question or support a position		
2. Use electronic media to access relevant information		
3. Support a position by synthesizing information		
Controlled Experiments (a student shall):		
1. Design and conduct a controlled experiment or investigation		
2. Interpret the experiment or investigation		
MATHEMATICAL APPLICATIONS		
Chance & Data Handling (a student shall):		
1. Formulate a question & design an appropriate data investigation		
2. Analyze data by applying appropriate data measurement concepts		
3. Predict future results based on experimental results		
4. Measuring to the appropriate accuracy using approp. tools & units		

Standards Matrix: Science

Middle Level (cont.)

READ, LISTEN & VIEW		
Non-fiction (a student shall demonstrate the ability to):		
1. Comprehend, interpret, evaluate information from a variety of non-fiction formats		
2. Comprehend information that addresses complex ideas by comparing & contrasting		
Fiction (a student shall demonstrate the ability to comprehend, interpret & evaluate by):		
1. Retelling a story, including major characters, settings, sequence of events & conflicts		
2. Categorizing events, behavior or characters		
Technical Reading (a student shall demonstrate the ability comprehend technical information by):		
1. Knowing relevant tech. vocab.: use of tools & safety procedures		
2. Applying step-by-step directions		
3. Showing an understanding of info. from visual or graphic data		
THE ARTS		
Artistic Interpretation (a student shall interpret & evaluate a variety of art by):		
1. Explaining connections between artwork and its social, cultural & historical context		
WRITE & SPEAK		
Writing (students shall demonstrate an ability to write a narrative, including):		
1. A description of events from direct experience or observation		
2. Use of relevant detail and figurative language to create an image of setting, characters, and events		
3. Dialogue between characters		
4. A sequence of events or ideas leading to a logical ending		
Writing (students shall demonstrate an ability to write an opinion or idea that):		
5. Argues effectively why the idea should be supported or opposed		
6. Uses evidence that supports the idea		
7. Has correct spelling and mechanics		

Airplane Terminology



Jet Aircraft Terminology



Demonstrations and Experiments for Ballooning

Ballooning Activities

A balloon “floats” because the air inside of it weighs less than the air around it. To prove that air does have weight, show the following demonstrations to your class.

Activity	Page
Balancing balloons	22
Rising and falling temperatures	23
Balloon project	25

Balancing Balloons

The student will predict what will happen when the air is let out of a balloon on one side of a balance. This will allow the student to observe that air does have mass.

Grade Level

5-8

Time Needed

30 minutes

Materials

1. Meter stick
2. Tape
3. 2 balloons of the same size
4. Clothespin

Procedure

1. Blow up two balloons and secure the openings with a clothes pin.
2. Tape the balloons to each end of a meter stick.
3. Have a student volunteer balance the meter stick on their finger (see diagram).
4. Have the students predict what will happen if some of the air is let out of one of the balloons.
5. Carefully let some of the air out of one balloon. Replace the clothes pin.
6. Record observations.



Principles Observed

Because the balloons became unbalanced after some of the air was let out, there must have been a loss of mass. The only thing that was lost was air, thereby showing that air does have mass.

Extension Activities

1. Have the students predict what will weigh less, an inflated basketball or a deflated basketball. Then determine the answer.
2. Since a difference in weight is required for an object to float, have students answer the question: What allows a hot air balloon to float in the air? Why doesn't a balloon that you blow up with your air float? What makes a helium balloon float?

Rising and Falling Temperatures

Objectives

The students will observe that a difference in temperature causes a change in density. This will model how a hot air balloon achieves altitude.

Grade Level

5-8

Time Needed

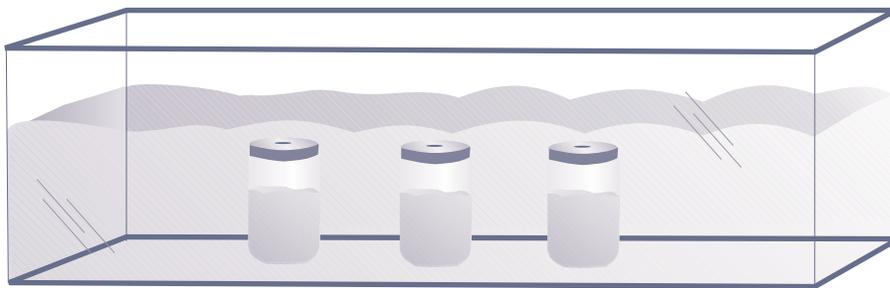
1 class period

Materials

1. Ten-gallon aquarium that holds water
2. Three baby food jars with lids
3. Nail
4. Hammer
5. Hot water
6. Cold water
7. Room temp water
8. Food coloring
9. Modeling clay

Procedure

1. Punch a hole in the lids of the jars.
2. Fill one of the jars to the top with warm water, one with cold water and one with room temperature water.
3. Add a different color of food coloring to each jar.
4. Screw the lid on and cover the hole with the modeling clay. Be sure that the clay is easy to remove.



5. Set the three jars on the bottom of the aquarium that is filled with room temperature water (see diagram).
6. Have the students predict what will happen when the clay is removed. They can easily draw their predictions on a piece of paper.
7. Remove the clay.
8. Record the observations.

Principles Observed

The hot water will rise quickly, the cold water will remain in the jar and the same temperature jar's water will come out slowly. This is due to the fact that as water (or any fluid, including air) warms up, it becomes less dense. As it becomes less dense, it starts to rise. This concept can clearly be illustrated with the use of a lava lamp.

Balloonists use this theory to gain altitude. They heat the air inside the balloon so that it becomes less dense than the surrounding air. Just like the warmer water rose in the aquarium, so the balloon rises in the atmosphere.

Extension Ideas

1. Float a food-colored ice cube in an aquarium and observe that as it melts, colored streams of water go to the bottom of the aquarium. This shows that a cool fluid is more dense than a warmer fluid.
2. Compare the rate at which the streams of water reach the top if there is only a slight difference in the temperature between the aquarium and the jar. Then try a bigger temperature difference.
3. Use the results to answer the question: When is the best time to balloon, winter or summer?

Cross-curricular Activities**Language arts**

1. Have the students write a paragraph of their observations.

Art

1. Have students draw a picture of a balloon and design the graphics to go on it.

Social Studies

1. Have the students research the Montgolfier brothers of France, credited with the first balloon flight.
2. Have the students research the attempts at ballooning around the world non-stop.
3. Have the students research the importance of ballooning during the Civil War, the Boer War in South Africa, and during the time of Napoleon's reign.

Biology

1. Research the process of lake water turn over when the seasons change (Why don't lakes freeze from the bottom up if cold water goes to the bottom of the lake?).

Up, Up and Away Balloon Project

After students have spent some time researching balloons and discovering the principles of flight that are behind them, they should be ready to build their own. The following activity is only a brief description of what a teacher could do with the students. It should be modified to fit the age and experience of the students.

Objectives

1. Students will learn to construct and float their own hot air balloon.
2. Students will use the scientific method to test and modify their design.
3. Students will efficiently use class time, as well as work productively as a group.

Grade level

5-6

Time Needed

To be determined by the teacher; although, a few days are recommended.

Procedure

The Research Project

1. Explain to the students that they need to design a balloon that will float using a hair dryer as the hot air source. They will need to supply the materials to build the balloon (or the teacher can supply the resources) from home.
2. The group needs to draw the design out before construction can begin. If the balloon needs to be modified, the group needs to also redraw the sketch. They must give reasons for the modification. The sketches will be turned in as part of the final assessment.

The Lab Activity

1. If you are short on time, you can provide the students with the template (see next activity) for the tissue paper balloon. Then all the students have to do is cut it out and glue the panels together. Grading would then consist of the ability to work together and possibly the quality of the design on the balloon itself.

Extensions

1. Vary the size of the panels to see how that affects the time aloft.
2. Vary the type of paper used to see how that affects the time aloft.

Hot air balloon

Courtesy of Sharon Lovell

A good introduction to this project is talking about the hot air balloons students have seen and how they work. There are also a lot of good books on the subject. For fifth and sixth graders, *Hot Air Henry*, by Mary Calhoun, is a good one to read first.

Materials (for one 5ft. Balloon)

1. Six panels of jewelers' tissue*, dimensions below. (Jewelers' tissue is 20" wide, so you don't have to piece it together. If unavailable, gluing regular tissue paper together will work.)
2. Markers
3. Elmer's glue or 4-5 gluesticks
4. Hot air popcorn popper or hair dryer may be used for the five foot balloon. The nine foot pattern requires a commercial hot air balloon launcher. They are available from companies such as PITSCO, use propane, are safe, and cost around \$80.
5. A place to launch—a gym is best. The cooler the room, the better. Outdoors, a calm day and an open field away from power lines and traffic are needed. A commercial launcher removes the difficulties involved when using an extension cord for the hair dryer/popcorn popper.
6. Rubber bands
7. String

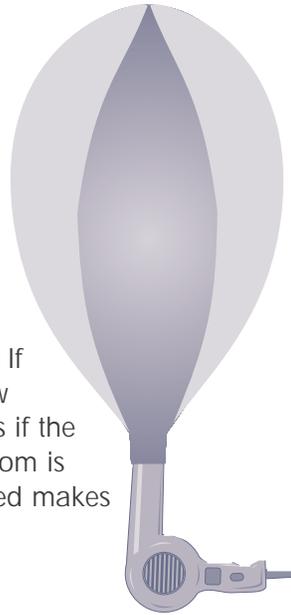
**Johnson Paper and Supply Co., 806 14th Avenue N.E., Minneapolis, MN (612) 333-6308 (20"x1500' roll, approximately \$21.48 plus \$5-10 postage) is one source of jewelers' paper.*

Procedure

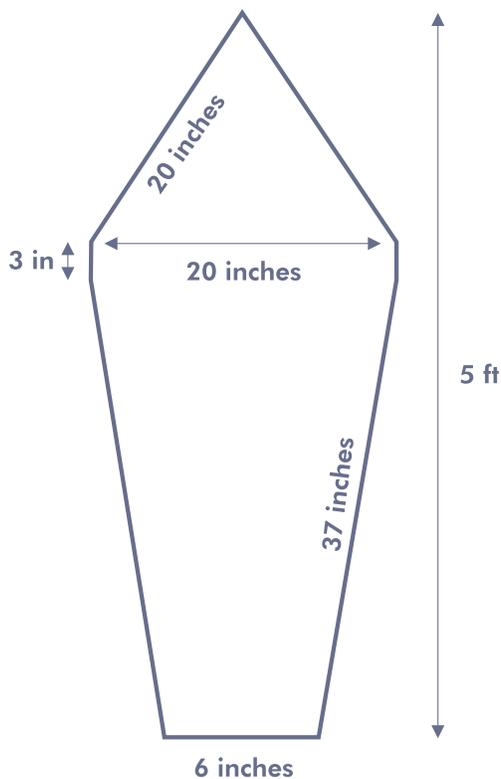
1. Create a tagboard template for students to use to trace the shape of the panels onto the tissue (pattern information is on the next page). Students can trace and cut their own panels, or panels can be cut and ready to decorate for younger students.
2. Students can work in small groups to design and color their panels. It is helpful to avoid letters and numbers because when the panels are put together, some may be backwards. They only have to color one side because the markers bleed through. Put newsprint under the panels before coloring.
3. The six panels go together like an accordion. First lay one down and put a continuous thin line of glue along the entire left side. Younger children could use glue sticks. It's very important that the glue line does not stop and start, which makes a hole for air to escape.
4. Put another panel right on top. Now you have the left side glued together. Put a thick glue line along the right side of this panel.
5. Lay another panel on top. Put the thin glue line on the left side. Continue laying panels on top and putting glue on alternate sides till the six panels are all on the pile. Glue the two open sides together.
6. To seal the top, tie the string or thread about two inches down. Leave bottom open.

7. To launch, hold bottom down over hot air popper/hair dryer or launcher and let the balloon inflate. It'll feel hot and start tugging. At that point, take the bottom, squish it together, wrap the rubber band around it, and let it go quickly. An adult should do most of the holding because these appliances become very hot (with the exception of the commercial launcher) and could cause burns.

If you're inside, the balloon will rise and stay up until the air inside has a temperature (and weight) equal to the room air. If the room is cool, it will stay up longer. Students can time how long it's up. They can talk about variables, comparing results if the balloon is launched at different times of the day when the room is warmer or cooler, or if the length of time the balloon is heated makes a difference.

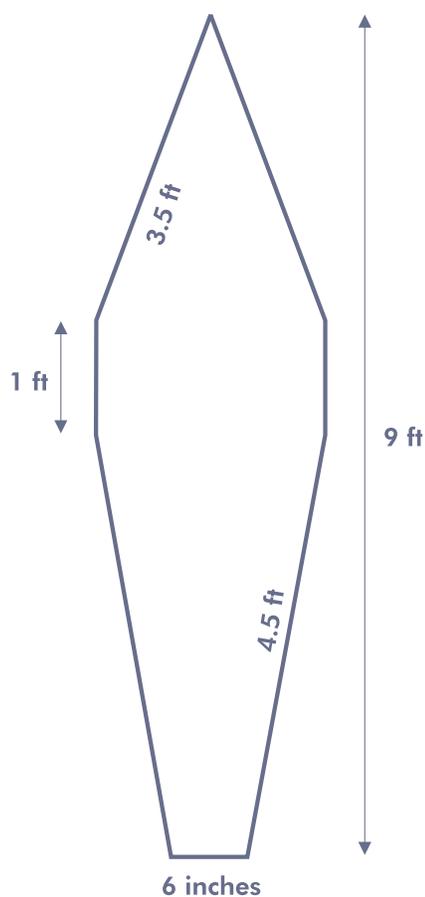


Five Foot Balloon Pattern



Nine Foot Balloon Pattern

(use 9 ft panels; requires commercial launcher)



Hot air balloon (cont.)

Grade level

7-8

Time needed

To be determined by the teacher, although a few days are recommended.

Objective

The students will design a hot air balloon that is self-sufficient; it is capable of carrying its fuel source as it ascends. This project contains more safety issues than the one for the fifth and sixth grade. For this reason, care must be used during the experiments. The students should each have a role in the process: fuel source researcher, balloon designer, materials manager, etc.

The students could be graded on:

1. How well they worked as a group.
2. How well they met deadlines.
3. How close the final product is to the original sketch.
4. The time it stayed aloft.
 - a. Contest version with the top time getting the most points.
 - b. All things fair version: if it stays up for "x" amount of time, the student receives "y" amount of points.
5. How well they used class time
6. Use of materials

Possible things to research before construction begins:

1. Type of material used for the balloon (plastic, nylon, paper, etc.).
2. Shape of the balloon.
3. Type of fuel source (tea candle, rubbing alcohol, wood, etc.).
4. Students can research the exothermic nature of fuels (the temperature at which it burns).
5. Type of carrier for the fuel (wire basket, tuna can, etc.).
6. How to attach the safety tether to the balloon.

The teacher is encouraged to create an assessment tailored to the style of project that will be conducted.

Flow chart for the project

1. Form groups (teacher chosen or student chosen).
2. Research.
 - a. Type of material.
 - b. Type of carrier.
 - c. Type of fuel.
 - d. Shape of the balloon.
3. Sketch the first prototype to scale.
4. Construct prototype.
5. Attempt to get prototype aloft.
6. Revise and redraw.

Demonstrations and Experiments for Air Pressure and Flight

Activity	Page
The Hovering Ball	30
Air Pressure Demo	34
Tennis Ball Pressure	35
Wind Tunnel Experiment	37
Wind Tunnel Construction	38
Making a Wing	39
Creative Aircraft	41

The Hovering Ball (Grades 5-6)

Objectives

Students will construct a model that illustrates Bernoulli's Principle which states that pressure in a moving stream of fluid is less than the surrounding pressure. They will investigate the effects of pressure by getting a table tennis ball to "hover."

Grade Level

5-6

Materials

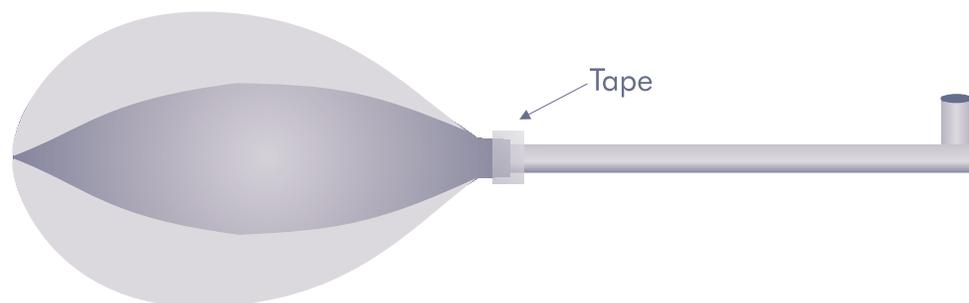
1. Flexi straw
2. Large balloon
3. Tape
4. Table tennis ball

Time needed

1 class period

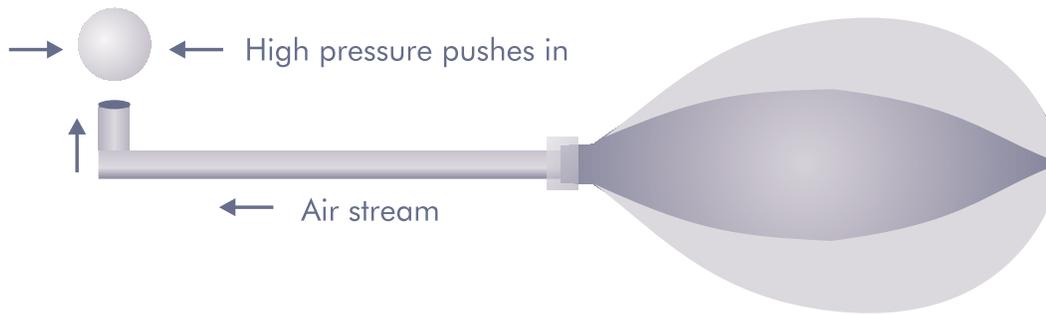
Procedure

1. Have students prepare the straw by placing the opening of the balloon around the long end of the straw.
2. Seal the end of the balloon around the straw by taping over the mouth of the balloon (see diagram).
3. The students will then blow up the balloon and pinch the neck of the balloon to keep the air inside.
4. Have students predict what will happen to the ball if it is placed over the bent-up portion of the straw in the moving stream of air.
5. Then have the students release the neck of the balloon while holding the straw horizontally with the short end pointing up.
6. Place the ball in the moving stream of air.
7. Observe what happens.



Principles Observed

The steady stream of upward air is enough to overcome gravity. The ball becomes centered in the stream due to Bernoulli's Principle which states that the pressure in a moving stream of fluid is less than the pressure of the surrounding fluid. The surrounding fluid thereby "pushes" toward the ball causing it to remain centered in the stream of air (see diagram). The ball remains in the stream of air even if the direction of the stream is altered slightly (gravity takes over if it is altered too much).



Extension Ideas

1. Change the size of the balloon used and determine if that makes a difference in the height that the table tennis ball hovers in the air stream.
2. Change the size of the straw used and determine if the results are altered.
3. Place some small strips of modeling clay randomly on the ball to see how that affects its behavior in the air stream.
4. Place a beach ball in the stream of air produced by a leaf blower to illustrate the concept on a larger scale.

Cross-Curricular Activities

Language arts

1. Have the students pretend their table tennis ball is a rocket ship blasting off to another world.
2. Have the students write a story about their trip.
3. Have the students write a paragraph of their observations.

Art

1. Have the students draw pictures of their adventures.

Math

1. Have the students measure the height the ball hovers above the straw.

Social Studies

1. Have the students research Daniel Bernoulli using the library or the Internet.

Meteorology

1. The effects of high and low pressure on air movement can be observed by studying the wind and other weather events (tornadoes, hurricanes, etc.).

Sports

1. Study how Bernoulli's Principle gives a curve ball the curve, a basketball lift, and a drop on a volleyball serve (see diagram).

The Hovering Ball (Grades 7-8)

Objectives

Students will construct a model that illustrates Bernoulli's Principle which states that pressure in a moving stream of fluid is less than the surrounding pressure. They will investigate the effects of pressure by getting a table tennis ball to "hover."

Grade Level

7-8

Time Needed

1 class period

Materials

Per Student

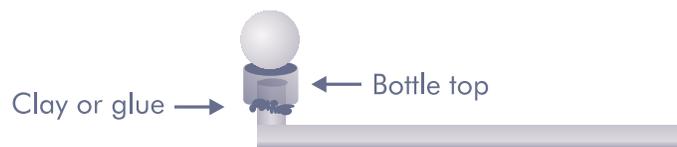
1. Plastic cap from a pop bottle
2. Flexi-straw
3. Table tennis ball

Per Class

1. Drill bit with the same diameter as the straw
2. Glue gun or modeling clay

Procedures

1. Drill a hole in the top of the cap.
2. Push the short end of the flexed straw through the hole so that it will contact the ball when the ball is placed on the open end of the cap (see diagram).



3. Hold the end with the cap on it. Put the long end in your mouth. Place the table tennis ball on the cap and balance it there. Blow steadily through the straw.
4. When you have the cap properly adjusted so the ball stays in place above the cap in the air stream, hot glue around the straw so that it will maintain its position or place the modeling clay around the straw (hot glue or place the modeling clay on the flat side of the cap).
5. Have the students record their observations.

Principles Observed

The steady stream of upward air is enough to overcome gravity. The ball becomes centered in the stream due to Bernoulli's Principle which states that the pressure in a moving stream of fluid is less than the pressure of the surrounding fluid. The surrounding fluid thereby "pushes" toward the ball causing it to remain centered in the stream of air (see diagram on top of p. 33). The ball remains in the stream of air even if the direction of the stream is altered slightly (gravity takes over if it is altered too much).

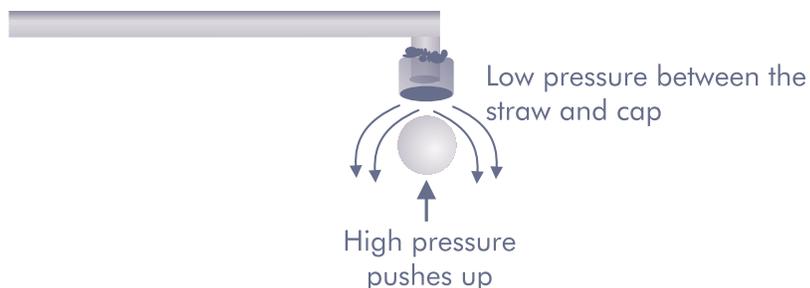
High pressure



Extension Ideas

1. Have the students record their observations if the placement of the cap on the straw is varied. They could measure the height the straw is in the cap and compare that to the height of ball in the airstream.
2. Have the students hold the ball in place and rotate the straw so that the cap opening faces downward. The students should start blowing through the straw and then let go of the ball.

The ball should not fall as long as the student continues to blow. The movement of air creates a low pressure area behind the ball. The higher pressure of the surrounding air pushes the ball into the cap (see diagram below).



Cross-curriculum Activities

Language arts

1. Have the students write a scientific lab report on their hypothesis, results and conclusion.

Math

1. Have the students measure the height the ball hovers above the straw. They can construct a data table and graph the results when they add variables.

Social Studies

1. Have the students research Daniel Bernoulli in the library or on the Internet.

Meteorology

1. The effects that high and low pressure have on air movement can be observed by studying the wind and other weather events (tornadoes, hurricanes, etc.).

Sports

1. Study how Bernoulli's Principle gives a curve ball the curve, a basketball lift, and a drop on a volleyball serve.

Air Pressure Demo

Objectives

The student will observe the principles of air pressure.

Grade Level

5-8

Time needed

30 minutes

Materials

1. Hose from a vacuum cleaner or other flexible, wide tubing
2. Ice cream bucket
3. Confetti, or similar light weight substance

Procedure

1. Place the confetti, bird seed, etc. in the bucket.
2. Hold one end of the hose just above the substance in the bucket.
3. Have students hypothesize what will happen when the loose end is swung in a circle.
4. Start to swing the hose in a circle above your head.
5. Have students record observations.

Principles Observed

As the hose is swung in a circle, it creates an area of low pressure at the end of the hose above your head. This low pressure area causes the confetti to be pulled up and out of the hose. This is an example of Bernoulli's Principle which states that pressure is lower in a moving fluid. Have students answer the question: How does a vacuum cleaner work? What creates the suction?

Extension Ideas

1. The length the hose that swings could be varied.
2. The speed at which the hose rotates could be varied.
3. The type of substance in the bucket could be varied to see how much "lift" could be produced.

Cross-Curricular Ideas

Math

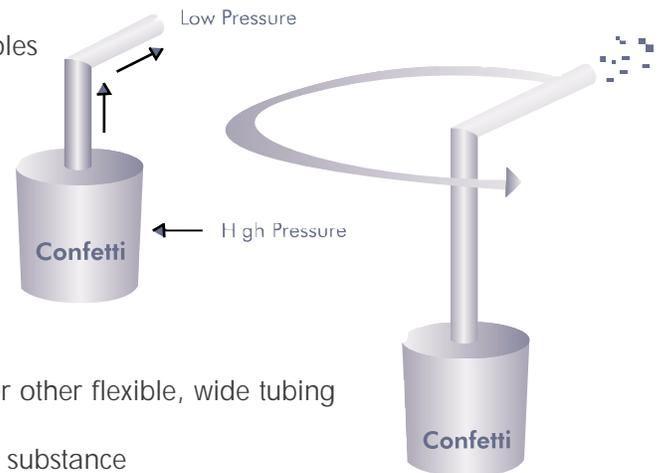
1. The hose swings in a circular path, so radius and diameter could be discussed.
2. The students could measure the distance the substance landed from the bucket.

Earth Science

1. This demonstrates how a tornado pulls things (houses, small pets) into the vortex.

Social Studies

1. Students could research Daniel Bernoulli in the library.
2. Students could research the inventor of the vacuum cleaner.



Tennis Ball Pressure

Objectives

Students will observe how different air pressures around an object affect the behavior of the object. Students will hypothesize and test how shapes of objects affect the behavior of the air around it and the object itself.

Grade Level

5-8

Time Needed

1 Class Period

Materials Needed

1. Table tennis balls
2. Hair dryer
3. Tape and paper

Procedure

1. Demonstrate the principles of lift and air pressure by placing a table tennis ball in the air stream of a blow dryer.
2. Have the students hypothesize about what would happen if we modified the ball in some way such as weighing down one end with tape or clay or by putting wings on the sides of the ball.
3. Working in groups, have the students modify their own table tennis ball and test it on the dryer.
4. Have the students adjust their design modification in order to maintain the ball in the stream of air.

Inquiry

1. How do airplanes use the principle of air pressure to move up and down? What would we need to do in order to create an object that would float horizontally, not vertically like the ping pong ball?
2. Could we design a way to "float" an object horizontally?
3. What would we need to change in order to achieve this?

Principles

The table tennis ball will float above the blow dryer because the air moving around the ball is at a lower pressure than the air pressure above the ball. Also, the air meeting the ball spreads out to surround the ball. This explains why the ball does not blow to one side or the other even when the blow dryer is tilted to the side.

Extension Ideas

1. Allow the students to try different light-weight objects in the air stream to see if they will float.

Cross-curricular ideas**Writing**

1. Have the students write about the stream of air flowing around the ball and why the ball does not move out of the stream. Have them hypothesize in their writings about different variables that could have been added to this experiment and write down the results (a stronger fan or bigger ball).

Meteorology

1. Study high and low pressure areas.

Math

1. Have students measure the maximum angle that the hair dryer can be tipped before the ball falls out of the air stream.

Art

1. Students can visualize the airstream and create a multi-color poster or picture illustrating the principle.

Wind Tunnel

Objectives

Students will design and test their own wing structure in order to directly observe the Bernoulli Effect, air pressure, lift, and drag.

Grade Level

5-8

Time Needed

2 class periods

Materials needed

1. Wind tunnel (see directions on page 38)
2. 3 x 5 Cards
3. Popsicle sticks
4. Balance
5. Clay (or that left over chewing gum!)

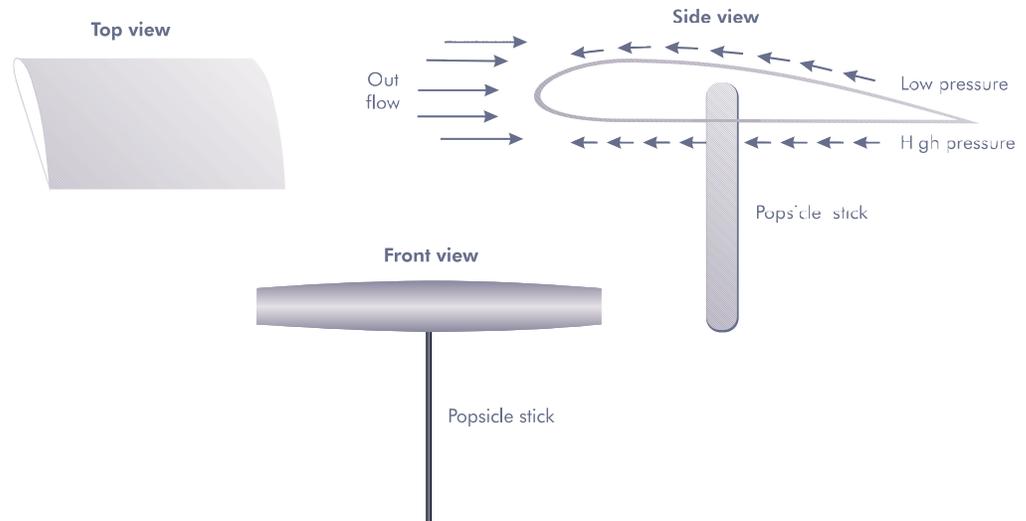
Procedure

1. Have students draw their idea of what a wing looks like from both a top and side view.
2. As the students finish their own diagram, draw the same views on the board as shown below.
3. Using the diagrams on the board, explain how the shape of the wing has been developed to maximize the principle of air flow; using the faster moving air over the wing to “lift” it.
4. Using the principle of air flow and wing design, have the students construct their own wings using 3 x 5 cards and tape. They must incorporate the popsicle stick into the center of their wing in order to complete the experiment (see diagram on p. 38).
5. Once designs are completed, the students can test them by attaching the popsicle stick to clay found on the balance. Make sure that students balance out their wing design to zero by placing weights on the opposite side of the balance so that both sides are equal. By placing the wing in the wind tunnel, the students will be able to see how much lift was created by their wing’s design by adding more weight to the wing’s side again so that both sides are equal.*

**This activity can be adapted into a contest to see who can produce the wing with the most lift.*

Principles observed

Lift is created by air moving around an object. When air is forced over the wing it moves at a higher rate of speed than the air below the wing. Because of this difference the wing tends to move in an upward direction, toward the higher pressure. If the surface area is increased, there will be a greater area of high pressure and lift will be increased. This explains the need for larger and longer wings on larger aircraft.



Cross-curricular ideas

Math

1. Have students make a chart of the results for each wing design and compare them to the surface area for that wing. Students could also hypothesize about the amount of lift created by a wing the length and width of a football field.

Art

1. Have students color their wing designs and display them.

Biology

1. Have students compare and contrast their wing and the shape of a bird's wing.

Wind Tunnel Construction

This activity can either be accomplished by the teacher or by a small group of students.

Materials needed

1. A wind source: fan, blower, hair Dryer.
2. Semi-ridged paper stock (any size).
3. Tape.

Procedure

1. Adjust the fan so that it faces straight and level.
2. Create a funnel apparatus that surrounds the fan and brings the diameter of the fan down by approximately 50%.
3. Extend the funnel into a tube that can blow directly across the top of the balance apparatus.

Making a Wing

Objectives

Students will build an airfoil that will demonstrate the principle of lift. Students will predict and observe the behavior of their airfoil and record their observations.

Materials Needed

1. Paper
2. Drinking straw
3. Tape
4. Thread

Grade Level

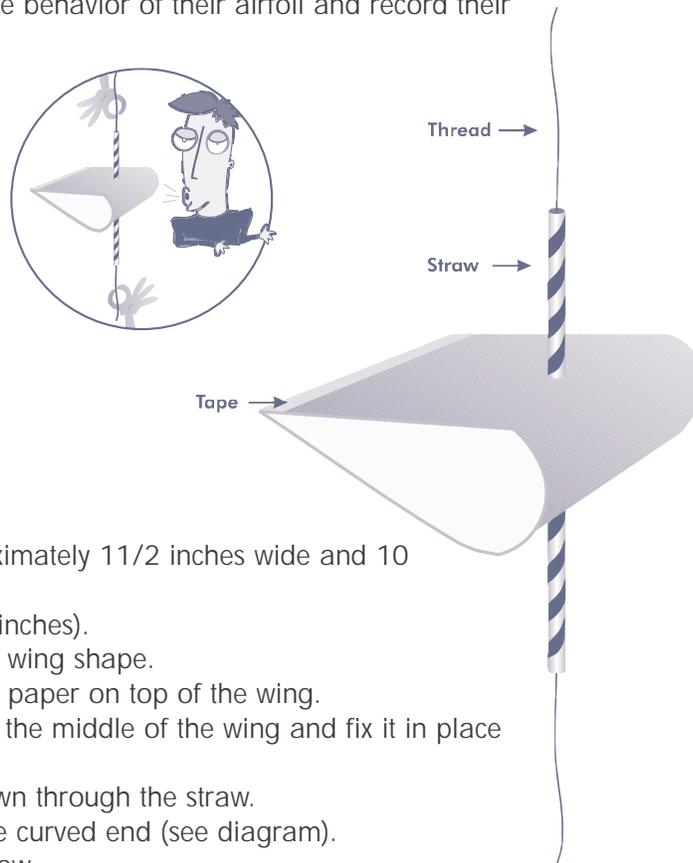
Grades 5-8

Time Needed

One class period

Directions

1. Cut a thin strip of paper approximately 1 1/2 inches wide and 10 inches in length.
2. Cut a short piece of straw (3-4 inches).
3. Fold and bend the paper into a wing shape.
4. Use tape to join the ends of the paper on top of the wing.
5. Push the straw through holes in the middle of the wing and fix it in place with the tape.
6. Push a long piece of thread down through the straw.
7. Hold the thread and blow at the curved end (see diagram).
8. Students will record what they saw.



Principles observed

Students will observe that air going over the top of the wing moves faster, and faster air means lower air pressure on the top of the wing. Consequently, the slower air under the wing has high pressure and pushes the wing up the thread. The upward push is the force called lift.

Extensions

1. Students can add flaps to the wing. They can then test for lift and drag by manipulating the flaps up or down. What effect does this have on the behavior of the wing?
2. Students can change the size of the wing by making the surface area greater or less. They can then test the lift of these wings. They can observe, compare, and contrast these observations with the original wing activity.

Cross Curriculum Activities**Language arts**

1. Have students write their observations in a journal.
2. Students can speak about their predictions, observations and conclusions to the class.

Mathematics/Science

Demonstrate a grade level understanding of the following concepts: ratios, measurements, mass, lift, and wind flow.

1. Write detailed, numbered steps to build a wing model.
2. Write a detailed, comprehensive supply list for the model.
3. Draw a scale model of the wing design.
 - a. Include dimensions in metric units.
4. Build your model wing.
5. Possible questions (adjust according to ability level): Given the mass of a plane and the mass of one of its wings, determine the following (show your work):
 - a. What percentage of the plane's mass is its wing?
 - b. What would be the mass of your plane?

Creative Aircraft

Objective

Students will use the concepts they have learned about flight to design their own aircraft.

Grade Level

5-8

Time Needed

1-2 class periods

Procedure

1. Explain to the students that they will be constructing their own flying machines.
2. They will be able to use any materials they wish as long as they do not spend any more than a set amount of money that is set by the teacher.
3. Use of common household items is encouraged.
4. Students can construct any type of flying machine: balloon, plane, glider, etc. The teacher can set up categories for judging such as distance, time aloft, or most creative.
5. Students must present their design to the class to explain which scientific concepts they used in the development and utilization of their craft (We used Bernoulli's Principle by creating a high pressure area under the wing of our glider).

Principles Observed

Students will determine which principles they use and will need to explain them.

Extension Ideas

1. Have the students write a hypothesis about how they would re-design their models after the first run and the effect the change would have on their aircraft.

Cross-curricular activities

History:

1. Have the students research inventors in the field of aviation and flight. What procedures did they use when inventing their own aircraft?

Art:

1. Students can be assessed on the aesthetics of their flying craft.

Demonstrations and Experiments for Jet Engines

Activity	Page
Jet Engine	44
Jet Propulsion	46

Jet Engine

Objective

Students will observe the power of expansion in the jet cycle.

Special Note

Because of the heat used, this activity is meant to be done as a demonstration while explaining the way a jet engine works. There are extension activities listed below that the teacher may use to reinforce this concept.

Grade Level

5-8

Time Needed

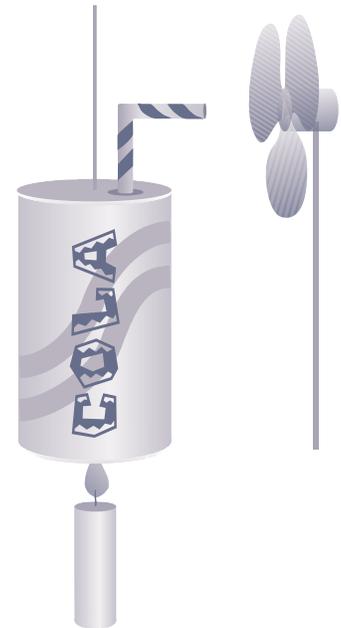
1 class period

Materials

1. Candle or small heat source
2. Pop can
3. Water
4. Flexi straw
5. Clay
6. Pinwheel

Procedure

1. Fill the pop can with approximately 30 ml of water.
2. Insert the straw so that the bottom of the straw is just inside of the can.
3. Seal the mouth of the can around the straw so that the can is now air tight.
4. Hold the can with a string attached to the tab over a candle or heat source.
5. Wait for the steam to start to escape. Use the steam to turn a pinwheel or move other objects.
6. Change the size of the hole to experiment or demonstrate thrust from the gas jet.



Principles Observed

A gas jet, or any standard engine, works by taking in air and expanding it rapidly, usually by burning a type of fuel. This experiment shows how plain water expands when it goes into a gaseous state and channels that energy into one smaller area, producing thrust energy. You can demonstrate that this energy can be used to do work in several different ways such as the pinwheel.

Extension Ideas

1. Fix the gas jet apparatus to a wheeled object and use the power to move it.
2. Research the properties of water to find out how much water expands when it turns into steam.
3. Use other materials to produce a gas and thrust such as baking soda and vinegar.
4. Calculate the thrust using the pinwheel and rotations per minute. Do different materials give us better thrust?

Cross-Curricular Activities**History**

1. Have students research the jet engine and the idea of using jets for power.

Language Arts

1. Write a creative story about how life would be different if we never entered the “jet” age.

Art

1. What would a jet powered car look like? Write an advertisement for the first jet car and illustrate it.
2. Draw a cross section of a jet engine and label its parts.

Industrial Tech

1. Have students design and create their own simple jet engine that can support combustion as a means of expansion.

Jet Propulsion

Objective

The students will be able to demonstrate and describe how a basic jet engine works while working with the concept of thrust and compression.

Grade Level

5-8

Time Needed

1 class period

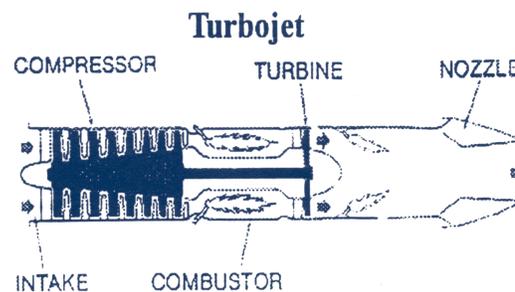
Materials needed

1. Balloons
2. Wire or fishing line
3. Tape

Procedure

1. Diagram a jet engine using the figure below. Have students note that a jet engine is divided into three different parts:
 - A: The Compressors
 - B: The Combustion Chambers
 - C: The Turbines

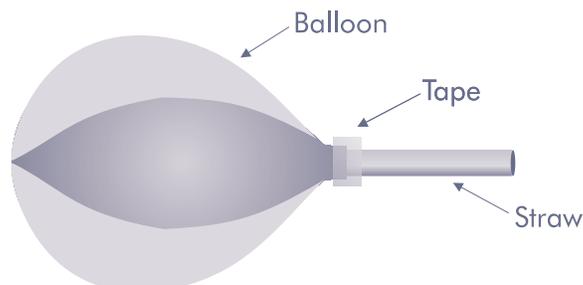
This experiment will deal mainly with the thrust created by compressing a gas and letting it expand out of a smaller area.



2. Run fishing line through a straw and attach a balloon to the straw.
3. Blow up the balloon and let the "jet" go.

How could we increase the thrust of this balloon?

4. Allow students to attach a small piece of straw to the mouth of the balloon to create a smaller hole (see diagram). The smaller hole will result in a greater amount of thrust because the compressed gas escaping from a smaller hole.



5. Have the students repeat step 2 and 3, letting the straw propel the balloon.
6. Students can experiment with different sizes of holes, amount of breaths in the balloon, and angle of the fishing line.

Principles Observed

Sir Isaac Newton stated the principle that for every action there is an equal and opposite reaction. A jet engine uses this principle by taking in air, a gas, on one side, energizing it by compression and rapid expansion, and using that energy to create a reaction, namely thrust out the opposite side. The balloon is simulating the idea of compression and thrust, or rapid expansion. This experiment also shows the efficiency a jet engine has by channeling all reactive energy in one pointed direction.

Extension Ideas

1. Have the students experiment with different sizes or types of balloons and straws. Make a chart recording which variables give the most powerful engine.
2. Move the string from a horizontal to a vertical position. Which jet goes the highest? What forces are working against the jet?
3. Use energy from balloon to power non-fixed aircraft that students could design & build.
4. Discuss the concepts of energy, potential energy, and equilibrium in balloons.

Cross-curricular Activities

History

1. Have students research the jet engine and the idea of using jets for power. List other areas that prove Sir Isaac Newton's principle of action/reaction.

Language Arts

1. Write a creative story about how life would be different if we never entered the "jet" age.

Art

1. What would a jet powered car look like? Write an advertisement for the first jet car and illustrate it. Draw a cross section of a jet engine and label its parts.

Math

1. Calculate the amount of energy lost to gravity when the string is slanted. Measure the degrees that the string is tilted and the length traveled.

Industrial Tech

1. Have students design and create their own simple jet engine that can support combustion as a means of expansion.

Demonstrations and Experiments for Rockets

Activity	Page
Paper Rockets	50
Balloon Rocket.....	52
Balloon Staging	54
Balloon Rocket Stabilizer	56
Air Expansion Demonstration	58
Effervescent Rocket.....	60

Paper Rockets

Objectives

Students will design, build and fly paper rockets. The students will predict the flight behavior of their rockets and record their observations.

Grade Level

5-8

Time Needed

Two class periods may be needed.

Materials

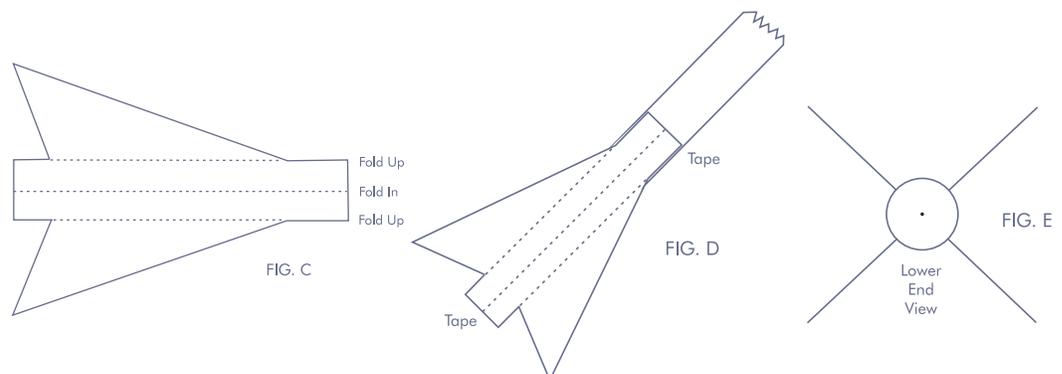
1. Large plastic straws, the kind used in fast food restaurants (one per student)
2. Sharpened pencils (same size as the straws, one per student)
3. Paper (8 in. by 10 in., two sheets per student)
4. Cellophane tape (one roll per 2 or 3 students)
5. Scissors (one per student)

Procedure

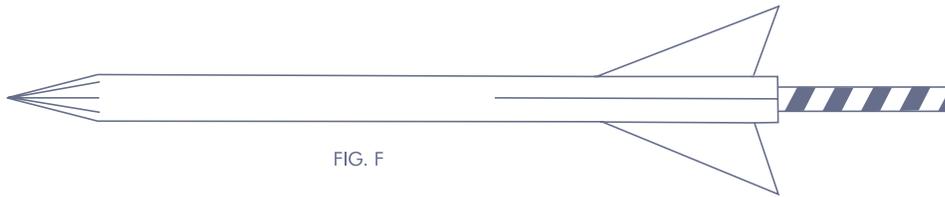
1. Cut a strip of paper 8 inches long and 1^{1/2} to 2 inches wide.
2. Roll the paper strip lengthwise around the pencil and tape it.
3. Make several pointed cuts at one end of the tube. See figure A.
4. Slide the sharpened end of the pencil toward the pointed cuts. Fold the points around the sharpened end of the pencil and tape to form the nose cone.



5. Cut out two sets of fins. Use the pattern in Fig. C. Fold the fins on the dashed lines in the manner shown in Figure C.
6. Using two pieces of tape, fix the fins to the opposite end of the tube from the nose cone. Insert the pencil for support in taping. See Figure D.
7. Place the rocket over the soda straw. See Fig. F.



8. Pick a location in the school for a firing range to launch the rocket. One side of

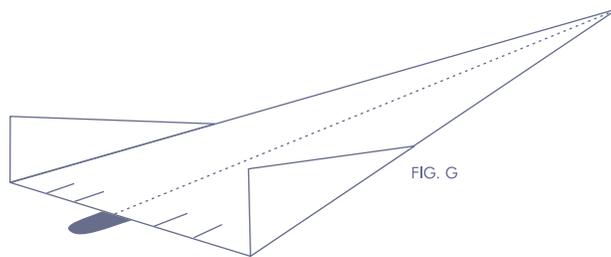


the classroom or a hallway are examples of possible sites. Also, a room with a high ceiling like a gymnasium or auditorium would work the best. An outdoor site may also work well.

9. Launch the rocket by blowing sharply on the straw. Make sure to aim the rockets in the desired direction.
10. The students will observe what happens and record their observations. They then will compare their prediction with what actually happened and write comparisons based on the prediction/observation process.

Principles Observed

The students will observe the principle of action/reaction (Newton's third principle). Thrust is the force that hurls the rocket into the air/space.



Extension Ideas

1. Students should be encouraged to change the shape and size of the fins and the length of the tube. They also vary the shape of the nose cones. Students could place the fins at different places and predict, observe and record the results. Creating larger fins could turn the rocket into a glider.

Competitions could be organized to find out which rocket design can go the highest, the farthest, or land closest to a target zone. See Figure G..

Cross Curriculum Activities

Math

1. Measure rocket using customary measures.
2. Measuring angles of the fins.

Language Arts

1. Journaling, writing predictions, contrasts, comparisons, and observations.

Balloon Rocket

Objectives

The students will build a balloon rocket. They will predict what will happen and will test their prediction by observing what actually happens. The students will then record their observations. They will discover that air has weight (air pressure). The students will observe that a force (air pressure) in one direction results in a corresponding force (thrust) in the opposite direction (action-reaction).

Grade level

5-8

Time needed

One class period

Materials

Each student will need:

1. A balloon
2. A straw
3. Strong tape
4. Scissors
5. Strong thread

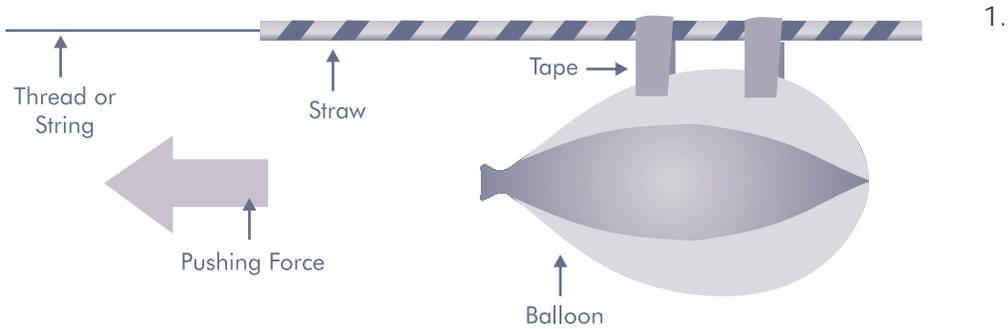
Procedures

1. Cut a straw in half and push one end of a long piece of thread through the straw.
2. Stretch the thread across a room and tie it tightly.
3. Cut two pieces of tape
4. Blow some air into the balloon.
5. Tightly hold the end of the balloon so the air can't escape and ask a classmate to help you tape the balloon firmly to the straw.
6. Blow some more air into the balloon.
7. Let the balloon go.
8. Observe what happens and record your observations. Write a comparison of your prediction and what actually happened. Write a statement that explains what you saw.

Principles Observed

The air inside the balloon is crammed into a small space so it is at a high pressure. As it escapes out of the opening in the balloon, it pushes the balloon in the opposite direction. In other words, the balloon fills with air creating pressure inside of it. This caused the unbalanced force to push the balloon forward. The principle of action-reaction is at work here. As air is forced out of the balloon through the nozzle/opening, it creates thrust, the force that propels the balloon (rocket) through the air.

Extensions



Students can measure the time the balloon takes to travel the distance of the line.

2. Students can then calculate the approximate speed.
3. Students can think of ways to slow the balloon down.
4. Students can change the size of the balloon and observe the changes that take place.
5. Students could set up two balloons side by side and have a race.

Cross Curriculum Activities

Language Arts

1. Students can research the history of rocketry and write a research report.

Science, Art, Language Arts

1. Students can design and build a model rocket. Then they can write an adventure story using the rocket as the setting.

Balloon Staging

Objectives

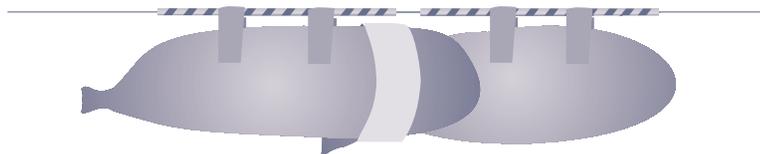
The students will create a multi-stage balloon rocket. They will observe the behavior of the multi-stage rocket and compare and contrast the behavior of the balloons in relation to their experiences with the single stage (one balloon) set.

Grade Level

5-8

Time Needed

One class period



Materials Needed

1. Two long party balloons
2. Nylon monofilament fishing line (any weight)
3. Styrofoam coffee cup
4. Masking tape
5. Scissors

Procedures

1. Thread the fishing line through the two straws.
2. Stretch the fishing line tightly across a room and secure its ends. Make sure the line is just high enough for people to pass safely underneath.
3. Cut the coffee cup in halves so that the lip of the cup makes a continuous ring.
4. Loosen the balloons by inflating them beforehand. Inflate the first balloon about 3/4 full of air and squeeze its nozzle tight.
5. Pull the nozzle through the ring. While someone helps you, inflate the second balloon. The front end of the second balloon should extend through the ring a short distance. As the second balloon inflates, it will press against the nozzle of the first balloon and take over the task of holding it shut. It may take a bit of practice to accomplish this.
6. Take the balloons to one end of the fishing line and tape each balloon to a straw. The balloons should be pointed along the length of the fishing line.
7. Write a prediction of what you think will happen.
8. Let the nozzle of the first balloon go.
9. Observe and record the results of the activity. Make a comparison between your prediction and what actually took place. Write a paragraph that communicates the comparison.

Principles Observed

The students will observe Newton's Third Law of Motion in action. In this application the balloons travel forward with a force that is equal and opposite to the backward force propelling the balloon.

Extensions

1. The students can experiment to discover a way to slow down the speed of the balloons.
2. The students can vary the size and shape of the balloons and observe and record the results.
3. The students can measure the distance traveled by this two-stage set-up compared to a single stage set-up.
4. The students can measure the distance the balloons traveled and measure the elapsed time from start to finish.
5. The students can calculate the approximate speed the balloon rockets traveled at in miles per hour and feet per second.

Cross Curriculum Activities**Language Arts**

1. Students can write observations in their science journals.

Math

1. Students can measure distance, time, and speed.

Social Studies

1. Students can research the history of rocketry. They can then use this research information to create a tri-folded display.

Balloon Rocket Stabilizer

Objectives

The students will create a balloon rocket. They will observe the action-reaction principle of motion. The students will create a stabilizer to control the flight of their balloon rocket. The students will observe the effects of the force of drag on their balloon rocket. They will make predictions, observations, and conclusions and record them.

Grade Level

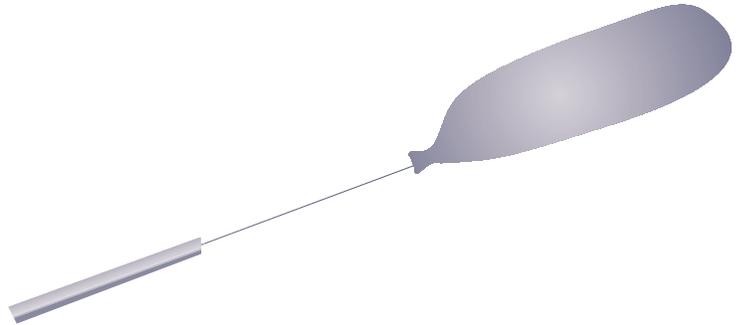
5-8

Time Needed

One class period

Materials

1. Long party balloon
2. String
3. Paper napkin
4. Scissors
5. Cellophane tape



Procedure

1. Take about a two or three-foot-long length of string and loop one end around the nozzle of the balloon. The loop should be large enough to provide a strong “rocket thrust” when the balloon is inflated and released.
2. Cut a 1 to 2 inch wide strip of paper from the napkin to form a streamer.
3. Use a short piece of tape to attach the other end of the string to the paper streamer.
4. Make a prediction about what you think will happen and record it.
5. Inflate the balloon and point it in the direction you want. The balloon should fly in a reasonably straight path.
6. Adjust the length of the string and the size of the streamer to achieve the best flights.
7. Observe the flight of the balloon and record the results.
8. Compare the flight of the stabilized balloon with the flight of an unstabilized balloon.
9. Observe and record results.

Principles observed

A balloon flies as a rocket due to the action-reaction principle (Newton’s Third Law of Motion), when its nozzle is released. Normally, the flight would be erratic and the balloon would fly about wildly. By attaching a string with a streamer to the balloon, the balloon’s flight is stabilized. The string and streamer provides drag, which is a force in the opposite direction from the thrust produced by the air rushing out of the balloon’s nozzle. This drag prevents the balloon from tumbling by keeping the nozzle pointed reasonably towards the rear during flight.

Extensions

1. Change the shape of the balloon. Compare and record the results.
2. Change the size of the streamer.
3. Change the materials the streamer is made of.
4. Draw a diagram of the flight pattern of each trial exhibit. How are they different?
Why?

Cross Curriculum Activities**Math**

1. Measure the distance of each trial flight. Measure the height each balloon rocket flew.

Language Arts

1. Journal all predictions, observations, and conclusions.

Art

1. Design and color streamers with bright interesting patterns.

Air Expansion Demonstration

Objective

Students will observe air that is heated expand and produce thrust.

Grade Level

5-8

Time Needed

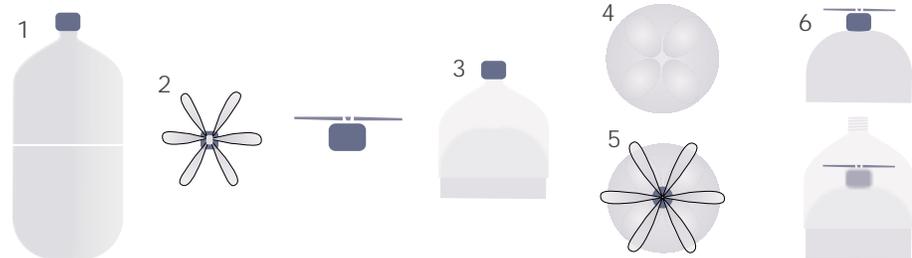
1 Class Period

Materials

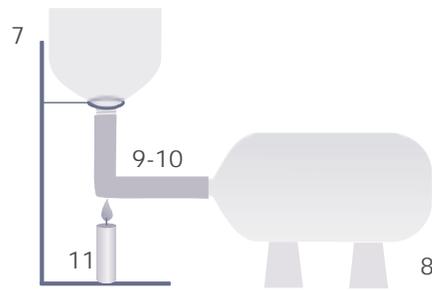
1. 2 Two liter bottles
2. 2 Balsa wood airplane propellers or pinwheels
3. Aluminum foil
4. 2 Rubber bands
5. 2 Paper or Styrofoam cups
6. Large paper clips
7. Candle or heat source

Procedure

1. Cut the two liter bottles in half.
2. Attach the propellers or windmills to the caps of the bottles as shown.
3. Cut the bottom of each bottle off so that the bottom will fit into the wide part of the top section.



4. Make several large holes in the bottom of the bottle, being careful not to damage the structural integrity of the piece.
5. Attach the propeller and cap in the middle of the bottom piece making sure that the propeller will turn freely.
6. Attach this section to the top section of each bottle with the propeller inside.
7. Using a ring stand, put one of the bottle sections with the mouth of the bottle down, into the ring.
8. Lay the other bottle on the Styrofoam cups and attach with glue or tape.
9. Roll aluminum foil into a 1 inch tube approximately 1.5 feet long.
10. Attach each end of the tube to the bottles using rubber bands.
11. Place candle or heat source under the foil tube and light. The air movement will turn the props, indicating air entering, expanding, and exiting at a higher rate of speed.

**Principles Observed**

The air that enters the tube is compressed through the mouth of the bottle, heated (11), which causes it to expand, and sent up through the upper part of the apparatus at a higher rate of speed. This is comparable to a jet engine in that the air flows through the engine. Comparisons can also be made to the way one propeller turns at the beginning, causing air to be pushed in, & another turns at the end, creating a higher amount of thrust.

Extension Ideas

1. Hold a lit match in front of the apparatus to see the airflow, then hold it at the end to see the thrust. Blow smoke through the apparatus to observe the air pattern.

Effervescent Rocket

Objectives

The students will build a rocket that will show the application of Newton's Third Law of Motion. They will predict, observe, and draw conclusions based on their observations.

Grade Level

Grades 5-8

Time Needed

1 class period

Materials

1. Heavy paper (60-110 index stock or construction paper)
2. Plastic 35mm film canister. Fuji canisters work the best. The film canister must have an internal-sealing lid.
3. Student sheets
4. Cellophane tape
5. Scissors
6. Effervescent antacid tablet
7. Paper towels
8. Water
9. Eye protection for students (goggles)

Procedure

See diagram on p. 61.

For the teacher

Students should work in pairs for best results. Make samples of rockets in various stages of completion available for students to study. This will help some students visualize the construction steps.

A single sheet of paper is sufficient to construct a rocket. Be sure to tell the students to plan how they're going to use the paper. Let the students decide whether to cut the paper the short or long direction to make the body tube of the rocket. This will result in rockets of different lengths for flight comparison.

The most common mistakes in building the rocket are: forgetting to tape the film canister to the rocket body, failing to mount the canister with the lid end down, and not extending the canister far enough from the paper tube to make snapping the lid easy. Some students may have trouble forming the cone. To make the cone see pattern on page 60. Cones can be any size.

Extensions

1. Hold an altitude contest to see which rockets fly the highest. Launch the rockets near a wall in a room with a high ceiling. Stand back and observe how high the rockets travel upward along the wall. Let all students take turns measuring rocket altitudes.
2. Students can list the geometric shapes that are present in a rocket.
3. Students can test to see how the amount of water placed in the cylinder affects how high the rocket will fly.

- Students can test to see how the temperature of the water affects how high the rocket will fly and how quickly it launches.
- Students can vary the amount of the tablet used to see what affect it has on how high the rocket will fly and how quickly it launches.
- Students could try to create a two-stage rocket.

Cross Curriculum Activities

Math

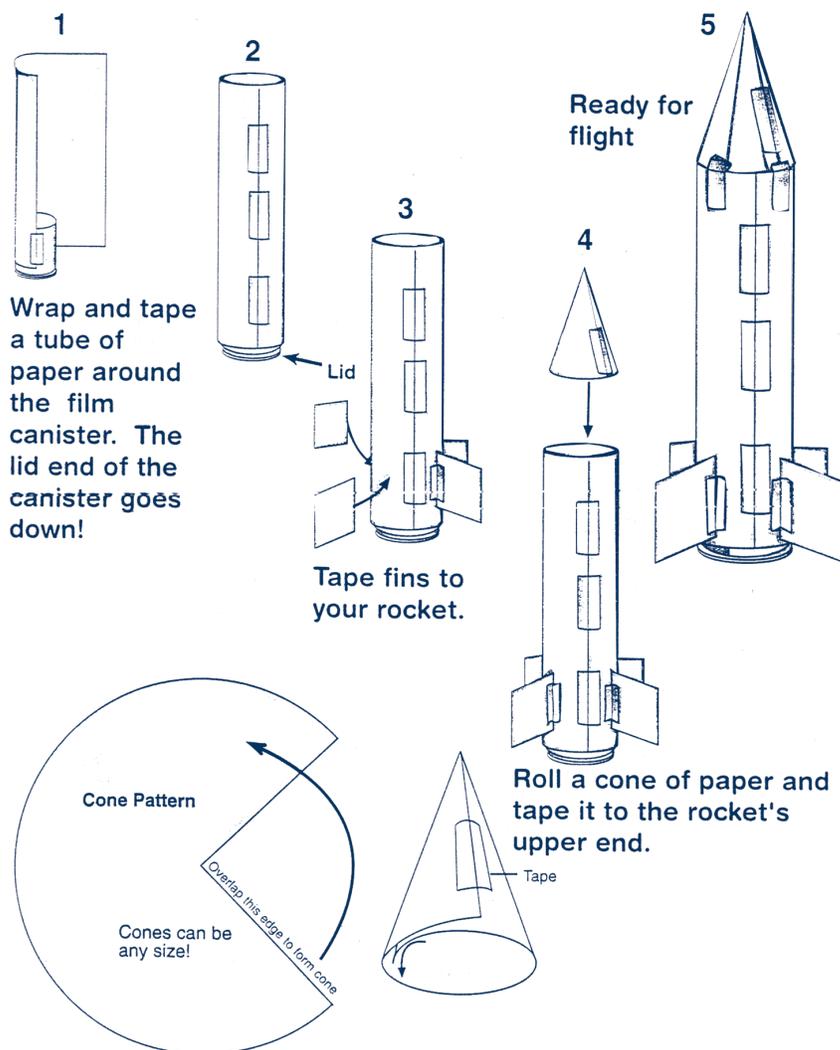
- Students can measure the distance and height the rockets fly in the various trials.
- Students can brainstorm their own strategy for measuring the height the rockets fly.

Art

- Students can create colorful patterns to cover the rockets' fuselages.

Social Studies

- Students can research the history of rocketry or the history and development of NASA and write a research report. Students can also use this research to make an oral presentation to the class.



Some interesting science and aviation web sites

Aviation History sites

A detailed timeline of aviation events

<http://highlander.cbnet.ns.ca/cbnet/educatio/schools/riverview/bell1.html>

Aviation History On-Line Museum

<http://www.aviation-history.com/>

NASA History Home Page

<http://www.hq.nasa.gov/office/pao/History/>

Landings: Aviation Museums/History

http://www.landings.com/_landings/pages/museums.html

Confederate Air Force's information and history

<http://avdigest.com/caf/gcw/>

Historical WWI information

<http://www.geocities.com/CapeCanaveral/7749/ww1links.htm>

Statistical data on all military aircraft

http://www.csd.uwo.ca/~pettypi/elevon/gustin_military/index.html

A complete list of the statistical data on all military aircraft from around the world including detailed time lines. Contains many interactive sites.

Ballooning links

<http://www.euronet.nl/users/jdewilde/index.html>

This web site offers a vast assortment of other ballooning links. Everything under the sun, from history of ballooning to the future of ballooning.

A short history of ballooning

<http://www.bris.ac.uk/Depts/Union/BUHABS/first.html>

Balloons during the Civil War

http://www.thehistorynet.com/CivilWarTimes/articles/1096_text.htm

Aviation sites

Aviation web links

<http://www.beapilot.com/hotlist/>

B-29 and other WWII aircraft

<http://www.nasm.edu/GALLERIES/GAL103/gal103.html>

Photographs and information on the B-29 and other WWII aircraft.

Aircraft and aerospace information

http://www.landings.com/_landings/pages/images.html

Provides links to many different sites related to aircraft and aerospace information.

Aerospace industry and technology

[http://www1.drive.net/evird.acgi\\$pass*9499895!_h-www.landings.com/_landings/pages/simulators.html](http://www1.drive.net/evird.acgi$pass*9499895!_h-www.landings.com/_landings/pages/simulators.html)

This site links to many other sites dealing with aerospace industry and technology.

Flight and aeronautic control

<http://members.aol.com/tserve24/private/flt123.html>

A great site containing terms associated with flight and aeronautic control.

Noise distribution as a plane takes off

<http://www.scican.net/~sos/jetNoise.html>

Shows the noise distribution as a plane takes off. Actual movement!

Supersonic test flights

<http://www.thehistorynet.com>

See "Light the fuse and go" for supersonic test flights.

Technology sites**Cross section of a jet**

<http://www.ge.com/aircraftengines/feature.htm>

This site shows a cross section of a jet while it is working.

Aircraft design and new technology

http://aa.stanford.edu/~frl/FRL_Projects.html?62,15

This site gives information on aircraft design and new technology.

How a jet engine works

[http://www1.drive.net/evird.acgi\\$pass*9499895!_h-www.landings.com/_landings/pages/simulators.html](http://www1.drive.net/evird.acgi$pass*9499895!_h-www.landings.com/_landings/pages/simulators.html)

Shows cross sections and explains how a jet engine works.

Aerospace industry and technology

[http://www1.drive.net/evird.acgi\\$pass*9499895!_h-www.landings.com/_landings/pages/simulators.html](http://www1.drive.net/evird.acgi$pass*9499895!_h-www.landings.com/_landings/pages/simulators.html)

This site links to many other sites dealing with aerospace industry and technology.

Balloon related sites**Ballooning links**

<http://www.euronet.nl/users/jdewilde/index.html>

This web site offers a vast assortment of other ballooning links. Everything under the sun, from history of ballooning to the future of ballooning.

A brief history of ballooning

<http://www.u-net.com/icarus/history.ballooning/>

A brief history of ballooning with pictures of the first balloon.

A short history of ballooning

<http://www.bris.ac.uk/Depts/Union/BUHABS/first.html>

Use of balloons during the Civil War

http://www.thehistorynet.com/CivilWarTimes/articles/1096_text.htm

Science of ballooning

<http://www.pbs.org/wgbh/nova/balloon/>

An informative and interactive site that allows you to experience the science of ballooning as well as take a virtual balloon flight.

Variations possible in the shapes of balloons

<http://www.geocities.com/CapeCanaveral/Launchpad/2595/index.html>

If you want to see the variations possible in the shapes of balloons, this is the site for you. It has balloon shapes from around the globe.

Principles of ballooning

<http://www.launch.net/>

A very informative site that answers frequently asked questions and looks at the principles of ballooning.

Weather related sites**Weather with satellite images**

http://www.weather.com/weather/us/cities/MN_Rochester.html

This site offers an up-to-date view of the weather with satellite images included.

Weather resources

<http://www.geocities.com/CapeCanaveral/Launchpad/2503/wx.html>

Upcoming air events in Minnesota

<http://www.geocities.com/CapeCanaveral/Launchpad/2503/>

This site lists upcoming air events in Minnesota as well as links to weather sites.

Weather concepts

<http://www.aviators.net/weather.html>

This site explains weather concepts such as cloud formation as well as how weather relates to aviation.

Appendix A: History of Rockets

The earliest form of solid rocket fuel was a type of gunpowder used in China in the late third century B.C. Bamboo tubes filled with saltpeter, sulphur and charcoal were tossed into ceremonial fires during religious festivals in hopes the noise of the explosion would frighten evil spirits. A few of the bamboo tubes were not completely sealed, and so instead of exploding they would skitter out of the fire propelled by rapidly burning gunpowder.

- 1045** — The Chinese are using this concept to create missile rockets in their military. These rockets are said to have carried incendiary material and iron shrapnel and are said to have caused devastation for 2,000 feet around the area of impact.
- 1241** — The Europeans start to use rocket-like weapons. Mongols against Magyar forces at the battle of Sejo which preceded the capture of now Budapest, December 25, 1241.
- 1258** — The Mongols use the rocket technology to capture Baghdad.
- 1268** — Arabs adopt the technology and use it against the French Army of King Louis IX in the seventh crusade.
- 1500** — The Italians, Germans and British have all adopted the technology.
- 1600** — Rockets are used for things other than warfare. A German fireworks maker, Johann Schmidlap invented the “step rocket”; a vehicle that lifted fireworks to higher altitudes. A Chinese legend tells about a high ranking Chinese official, Wan-Hu, who designed a rocket-powered flying chair. Attached to the chair were two large kites, and forty-seven fire-arrow rockets. There was a roar, a puff of smoke, and they were never seen again.
- 1720** — A Dutch professor, Willem Gravesande, built model cars propelled by jets of steam. German and Russian scientists start working with rockets which weigh more than 99 Pounds.
- 1812** — The Congreve rockets created by William Congreve for the British Military are highly successful. They were used by British ships to pound Fort McHenry in the war of 1812. They inspired Francis Scott Key to write “By the rockets’ red glare, as the bomb burst in air” in his poem that later became The Star-Spangled Banner.
- 1818** — An official rocket brigade was created in the British Army.
- 1898** — A Russian schoolteacher, Kostantin Tsiolkovsky (1857-1935) proposed the idea of space exploration by rockets. In a report he published in 1903, he suggested the use of liquid propellants for rockets to get greater range. The speed and range of the rocket was limited only by the exhaust velocity of escaping gas. He was later named the father of astronautics.
- 1926** — On March 16th, 1926 Goddard achieved the first successful flight with a liquid propellant rocket. It flew only two and half seconds, climbed 12.5 m, and landed 56.1 meters away; flying 152 ft fueled by liquid oxygen and gasoline. He later developed bigger and faster rockets that had flight control and payload compartments for scientific instruments. For his achievements he was named the father of modern rocketry.
- 1934** — Werner Von Braun creates the A2. A rocket powered by ethanol and liquid oxygen. The A2 grew into the A-4 or V-2. It was the first successful long range ballistic missile.

- 1937** — The V-2 rocket is used in WWII, which could destroy a whole city block.
- 1956** — The Army Ballistic Missile Agency was established at Redstone Arsenal under Von Braun to build the intermediate range ballistic missile.
- 1957** — In October, the Soviet Union launches the first earth-orbiting artificial satellite called Sputnik I.
- 1958** — In January, the United States launches its first satellite, Explorer I. The National Aeronautics and Space Administration (NASA) is founded in October of that year.
- 1961** — April 3rd, Yuri Gagarin became the first human to travel in space, making a complete orbit of the earth in 108 minutes (Vostok 2).
- May 5, 1961** — Alan Shepard becomes the first American in space making a suborbital flight aboard the Freedom 7 Mercury Spacecraft.
- February 20, 1962** — John Glenn became the first American to complete three orbits in the "Friendship Seven" Mercury spacecraft. It took 4.5 hours. Glenn, now a U.S. Senator from the State of Ohio, returned to space on the Space Shuttle in October, 1999.
- July 20, 1969** — Neil A. Armstrong lands on the moon in Apollo 11.
- May 14, 1973** — America's first space station, Skylab, was placed in orbit. It was 118 feet long, weighed 200,000 pounds and was manned by three crew members. It completed its 28 day mission not without technical difficulties fixed by later crews. There were three more missions after that one. The second mission being 59 days and the third one 89 days. Skylab four became unstable and impacted the earth's surface July 11, 1979.
- 1975** — Venera 9 and 10 land and photograph Venus. Venera 9 lasts for 53 minutes in the high pressure and temperature of Venus. Three days later, Venera 10 lasts for 63 minutes.
- 1976** — Viking I was launched August 20th, 1975, and arrived at Mars on June 19th, 1976. The first month was spent scanning and imaging the surface to find suitable landing sites for the Viking landers. So on July 20th, 1976, Viking 1 lands on Mars. The results from the Viking experiment gave a very detailed view of Mars including volcanoes, lava plains, large canyons, cratered areas, wind formed features and evidence of surface water.
- 1977** — August 20, 1977, Voyager II is launched on its way to Jupiter (July 9, 1979), by Saturn (August 26, 1981), by Uranus (January 24, 1986) and Neptune (August 24, 1989).
- 1986** — On January 28, the space shuttle Challenger Exploded 73 seconds after liftoff killing seven astronauts and the first school teacher to be sent into space (Scobee, Smith, Resnik, Onizuka, Mc Nair, Mc Auliffe, and Jarvis).
- February 19, 1986** — The Soviet Union launches the Mir space station.
- 1990** — Hubble Space Telescope returns high-resolution images of Mars and other outer planets of the Solar System.
- 1994** — Clementine, or Deep Space Probe Science Experiment (DSPSE), was a new design in lightweight structure and propellant systems. It spent 70 days in Lunar orbit mapping the surface of the moon. It also used a laser to gather altimeter data generating the first lunar topographic map.

- 1996** — The Mars Pathfinder, a lander and surface rover, landed on Mars and gave us 2.6 billion bits of information, 16,000 images, 15 chemical analysis of rock and extensive data on wind and weather. The flight time from Earth to Mars took six to seven months, arriving on Mars July 4th, 1997. The flight team began preparation for landing the Pathfinder 45 days before entry into Mars orbit (M-45). A final check of the instruments and rover were conducted on M-30. The fourth and final trim maneuver was done on M-10. At M-5, the spacecraft turned to entry attitude. For entry, the roll thrusters increased the spacecraft spin rate from 2 to 10 rpm, the navigation team produced orbit solutions on a regular basis and adjustments were made to the computer programs that determined when the parachute should be deployed. Final adjustments were made six hours before entry. Entry into Mars' atmosphere ended the cruise phase of the mission. Entry, landing, and surface operations then began.
- 1996** — On May 18, the X Prize was officially announced in St. Louis. The X Prize is designed to stimulate the development of commercial space tourism by awarding a \$10 million prize to the first private team who safely launches and lands a vehicle capable of transporting three people on two consecutive suborbital flights to 100 kilometers altitude. The X Prize Foundation was established in 1994 as an educational nonprofit organization dedicated to inspiring private, entrepreneurial advancements in space travel. The X-PRIZE has been created for one purpose: to realize the dream of spaceflight for the general public.
- 1997** — On October 13th, the Cassini Space Mission left from Kennedy space station in the Titan IV/Centaur to orbit Saturn and retrieve information from one of its moons (Titan). It will take 6 years for it to reach Saturn. The planned trajectory of the rocket uses the gravity of the other planets to launch it to its final destination. The planned course is two flybys of Venus (April 1998, June 1999), a flyby of Earth (August 1999) and one of Jupiter (December 2000) before arriving at Saturn (2007).
- 1998** — Planet B is a Japanese space probe that was launched July 4th and orbited the Earth for 4 months before setting off for Mars. It was launched with an M-V rocket at Kagosima Space Center. The M-V launcher is the largest solid propellant rocket ever built in Japan with a diameter of 2.5 m and weight of a 140 tons. It was built to enable increase payload for interplanetary missions by using a newly developed maraging steel for the motor casing that is light but strong. On board Planet B, or Nozomi, is a Neutral Mass Spectrometer (NMS) built by the Atmospheric Experiment Branch. The NMS will be used to study the structure and dynamics of the atmosphere and ionosphere of Mars, including interaction with the solar wind.
- 2001** — The Pluto Express mission is scheduled for launch in 2001 and will return in 2013. The mission will consist of a pair of small, fast, relatively cheap spacecrafts weighing less than 220 pounds each. The spacecraft will pass within 15,000 kilometers of Pluto and Charon and will map the composition and structure of Pluto's atmosphere and landscape. Studies of this two planet system are to begin 12-18 months prior to closest approach.
- 2003** — Rosetta will investigate comet Wirtanen. The spacecraft will orbit the comet and drop two probes on it. Mars Surveyor 2003 is launching a series of probes to the red planet, which will return soil samples for analysis in 2005.

Appendix B: History of Jets

- 1937** — On April 12, 1937, a young British engineer, Frank Whittle, initiated the first successful operation of a practical jet engine. Simultaneously, in a different part of the world, a young German engineer named Pabst von Ohain came up with his own version of the jet engine in September. Whittle's idea, however, did not get government support or funding, and so the Germans, with funding, became the first to fly a jet-engined aircraft, the Heinkel HE 178, in August 1939. The British version of the jet-engined aircraft was not flown till May 15, 1941. It was named the Gloster E.28/39 Pioneer.
- 1944** — The first production jet powered aircraft, the ME 262, was introduced into combat by the Germans. It had a swept wing, a pressurized cockpit and was a versatile fighter-bomber.
- 1952** — The Comet, built by the de Havilland Aircraft Company, became the first commercial jet airplane.
- 1954** — Two Comets, a couple of weeks apart, exploded in flight on clear days. All were grounded, and for the next year extensive research was conducted to solve the mystery. The conclusion: they were not built to stand the pressure changes that occur when the plane rapidly climbs and descends to its normal flight level. Jet powered aircraft fly at higher altitudes than piston powered ones and thus require different construction techniques.
- July 15, 1954** — The model 367-80 marked Boeing's arrival in the commercial jet age. The Model 367-80 was strictly a prototype for the 707. Its main purpose was to test new technology and was retired to the Smithsonian Institution, National Air and Space Museum collection in the early 70's.
- 1955** — In Toulouse, France, the Sud-Aviation Caravelle was the first jet-powered airliner to have its engines placed in pods attached to the rear of the fuselage. This design put all the jet noise behind the aircraft, gave the Caravelle a quieter cabin, and improved aerodynamics. The closely packed tail-engine design also provided better control in the event of an engine failure. This design was used with a number of other aircraft that would follow, like the BAC 1-11, the DC-9, the Boeing 727 and the Trident. 1955 also saw Russia's first jet airliner, the Tu-104. It was based on their Tu-16 jet bomber.
- 1957** — The Vought Crusader was the first US Navy fighter capable of sustained supersonic speed in level flight.
- 1958** — Boeing rolled out their first commercial jet, the 707. Simultaneously, the McDonnell-Douglas DC-8 was brought out causing serious competition for Boeing.
- 1963** — Boeing's 727 was flight tested to begin operating within two years.
- 1965** — 1965 saw the development of the McDonnell-Douglas DC-9/MD-80 series. The DC-9 twinjet proved more popular than the four-engine DC-8, and resulted in the DC-8 being discontinued. The MD-80 replaced it. Also in 1965, the Boeing 737 rolled off the manufacturing line creating competition for McDonnell-Douglas. The 737 is a smaller twinjet. It was made in two main versions, the 737-100 and the longer 737-200, which carried more passengers.

- 1966** — Gulfstream starts to produce big business jets that are almost as large as jetliners.
- 1968** — In Russia, the Tu-154 is made to replace the Tu-104, Antonov An-10 and Ilyushin 11-18. It resembles the 727 with its trijet layout but is slightly larger with downward anhedral (drooping) wings.
- 1969** — The largest commercial transport aircraft, the Boeing 747, rolled off the production lines. It was a serious economic gamble for the Boeing company but ended up being a huge success.
- 1977** — On January 21, the Concorde (Air France flight 085) took its inaugural flight from Paris to Rio de Janeiro via Dakar. At the same time, a British Airways Concorde took off from Heathrow bound for Bahrain. A month earlier in Washington, D.C., Congress had banned the Concorde from landing in the United States, the reason being that they believed it would cause damage to buildings from the engine noise.
- February 4, 1976** — The Concorde was given the go ahead to fly to New York and Washington for a trial period of twelve months, but the Port Authority of New York and New Jersey put on their own ban. So on May 24, two Concorde took off, one from Paris and one from London, to make a coordinated parallel approach landing at Washington D.C., on 01 right and 01 left touching down together. It wasn't till November 22, 1977, that the ban was finally lifted from landing in New York's JFK airport. The Concorde is the world's only operational commercial supersonic transport. Traveling at twice the speed of sound, it routinely flies from London and Paris to New York and Washington in three hours carrying about a 100 passengers.
- 1981-2** — In 1981 Boeing comes out with the 767 followed by the 757 in 1982. The wide-body 767 is a state-of-the art design with a glass cockpit in which all information is presented on small television screens. The narrow body 757 received a reputation of being one of the companies best performers. It has a rapid rate of acceleration on take-off even when heavily loaded.
- 1990** — The MD-11 trijet first flew on January 10, 1990. The MD-11 is about 18.6 ft. longer than the earlier DC-10 trijet. It has a highly sophisticated flight deck and advanced automatic system controls that significantly reduces the pilot's work load. Advances in aerodynamics such as a redesigned wing trailing edge, a smaller horizontal tail, fuel tanks in the wing and an extended tail cone help reduce drag, save fuel and add range.
- 1994-5** — The 777-200 rolled off the production line on April 9, 1994. Its first delivery is made to United Airlines on May 17, 1995. Then on June 14, 1995, Boeing announces the 777-300X which is a stretched version of the 777-200. The fuselage would be extended 10 meters to a total of 242ft, 4 inches making it the world's longest jetliner, and increasing the

capacity to 368 passengers in a three class configuration or 451 passengers in a two- class configuration. In other words, this aircraft would have the same capacity as the 747-100/-200, but would burn one-third less fuel and would have a forty percent lower maintenance cost than the 747. The 777's have a number of new features, for example, an improved aluminum alloy (7055) is used in the upper wing skin and stringers which offers greater compression strength enabling designers to save weight and improve corrosion and fatigue resistance. More lightweight composite materials were also used for similar purposes. The six-wheel system reduces weight and operating cost. All fuel is stored in the wings and carries about 31,000 gallons of fuel. The longer range 777's will carry 44,700 gallons.

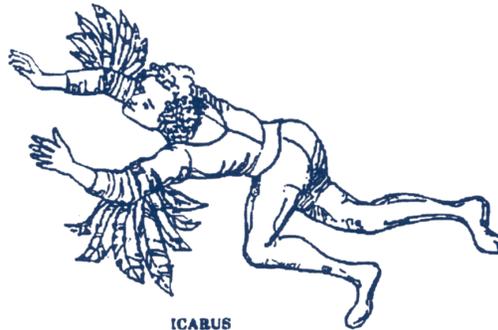
- 1996** — NASA started a multi-year hypersonic flight-test program to create a Hypersonic Flight Experimental vehicle that will fly ten times the speed of sound. The first Hyper-X is scheduled to fly at Mach 7 in late 1998. This is faster than any air-breathing aircraft has ever flown. The SR-71 was able to fly Mach 3, and the highest speed attained by NASA's rocket-powered X-15 was Mach 6.7 in 1967. Now, with the use of the scramjet engine, the Hyper-X will be able to test speeds above Mach 8.
- 1997** — Boeing 777-300 first flew in October 1997.
- 1998** — On August 3rd, 1998, the new Boeing model 717, previously the MD-95-30, made its first flight. It resembles the DC-9 in size, range, performance and reliability, with an addition of flexible cabin arrangements, a modern cockpit with computerized flat-panel displays, and low maintenance costs. Delivery of these twinjets for commercial use is not expected till mid-1999. Also expected in the upcoming future is the 737- 600. It is the smallest member in the Next Generation family of twinjets. It received FAA certification on August 18, 1998, and the first delivery of the new model was made on September 19 to SAS. In addition to the 737-600 version, there are the 737-700, 737-800 and 737-900. The 737-700 is already in service, and the 737-800 made its first delivery in April. The Boeing 737-900, with room for 177 passengers in a two class configuration, is a new project where Alaska Airlines is the first customer. Flying in late 1998, the X-34 reusable launcher will test improvements and attain a flight speed of Mach 8.

Appendix C

Daedalus and Icarus: A High Flying Duo

Characters

Athena (goddess of wisdom)
 Carpenter
 Daedalus (inventor)
 Fisherman
 Icarus (Daedalus' son)
 Guard
 Minos (King of Crete)
 Narrator
 Polycasta (Daedalus' sister)
 Sheperd
 Talos (Daedalus' nephew)



Narrator: Daedalus was an inventor who lived in the city of Athens. Athena, the goddess of wisdom, had given Daedalus special powers in appreciation of a statue of her that Daedalus had made. Daedalus became the greatest inventor in Athens. Even Aegeus, the King of Athens, counted on Daedalus for advice and problem solving. However, Daedalus wasn't content to be the greatest inventor in Athens, he wanted to be the only inventor in Athens. He was even jealous of his nephew Talos, a budding inventor.

Daedalus enjoyed the praise he received, especially from family members.

Polycasta: Who would have thought that my own brother would be a genius?

Daedalus: Don't be jealous of me. My ideas benefit the entire city. If I can be of help to you, just let me know.

Polycasta: Now that you mention it, my son Talos loves to build things. He built a doghouse that is so comfortable that the dog refuses to come out. And mice are lined up to try out his attractive mousetrap. Please take him, and teach him something useful.

Daedalus: I don't need anyone right now.....

Polycasta: He works for free, cleaning up, taking out the garbage. Athena didn't give you a special talent for that.

Daedalus: All right all ready. Having him around will allow me more time for my work. He can start tomorrow. But I'm busy with very important people. He needs to stay out of my way. And remember, he works for free.

Narrator: Twelve year old Talos came to stay with his uncle, quietly going about his chores. One day an Athenian came to Daedalus for help.

Carpenter: I need a tool that can cut through wood quickly and neatly. I need a tool that is quicker and neater than an axe. Do you have something that I could use?

Daedalus: Maybe a bigger axe or a spear. Hmmmmmm. Let me think about it. Come back in a day or two and I may have thought of something.

Narrator: When the carpenter left, Talos spoke up.

Talos: Uncle, look at my plan for a tool—I call it a saw. It will cut through wood more easily than an axe.

Daedalus: Hmmmmmm. How does it work?

Talos: These sharp teeth cut the wood when you move them back and forth across the wood. I saw a fish skeleton in the garbage and it made me think of this saw.

Daedalus: Shhhhhhh. Didn't I tell you not to disturb me. Give me that silly drawing and go back to your chores.

Narrator: But Daedalus didn't throw the drawing away. He used Talos' drawing to make a saw out of metal. Then he brought the saw to the carpenter.

Carpenter: You are a genius. How did you think of this saw?

Daedalus: Oh, it just came to me one night as I was taking out the garbage.

Narrator: Daedalus took all of the credit, but Talos was not discouraged. He felt that someday his uncle would recognize his talent.

Talos: Uncle, Uncle! Look at what I have made. I call it a compass. You can use it to draw perfect diagrams and to measure things exactly.

Daedalus: Give me that and stop fooling around! You've got work to do. (To himself) I've got to do something about this boy, or I'll become the second best inventor in Athens.

Narrator: Daedalus was so angry and jealous that he couldn't sleep. He thought up a plan that made him feel better. He jumped out of bed and rushed to Talos' room.

Daedalus: Talos! I was too harsh with you earlier. Please forgive me. Come, help me with a project on top of Athena's temple. I could use your advice.

Talos: Wow! That would be great. But right now? In the middle of the night? It's so dark!

Daedalus: This shouldn't take long.

Narrator: When they arrived at the roof of the temple, Daedalus carried out his evil plot.

Daedalus: I have been asked to build a statue for that side of the tower. Lean over edge and tell me if you think that it's possible.

Talos: Well, it sure looks dangerous, but if you say so.

Narrator: As Talos leaned over, Daedalus gave the youth a swift push which sent him hurdling toward the stones. But before he hit the ground, he began flapping his arms and miraculously began to move skyward. You see, Athena had watched the plot unfold and stepped in to save the youth. She turned the boy into a bird (a partridge), and then she had a few words with her former favorite.

Athena: I am tempted to take back all the powers I have given you. But I won't. Instead, I'm going to vanquish you from Athens. You must wander through the world, praying that someone will take you in. We'll let the three fates determine your punishment.

Narrator: Daedalus wandered from country to country until he came to the country of Crete, ruled by the evil King Minos. Daedalus settled here, married and had a son, whom he named Icarus. Daedalus loved his son very, very, very, very much.

Daedalus worked for years for King Minos. Finally, Minos gave Daedalus the job of designing the Labyrinth to house Minos' evil pet, the Minotaur. Theseus escaped from the Labyrinth, taking Minos' daughter Ariadne with him. Someone was going to have to take the heat from Minos. That person was Daedalus.

Minos: Guards, bring me the inventor!

Narrator: The palace guards bound Daedalus and Icarus and brought them to the king.

Minos: What shall I do with you? Theseus killed the Minotaur and escaped from the Labyrinth. Only you could have helped him. To make matters worse, he has run off with dear Ariadne.

Guard: Let's execute them now, your Highness!

Minos: No. I've thought of a better punishment. Take the inventor and his son to the maze to be trapped by his own invention.

Narrator: Daedalus' face became a mask of terror. Even he would get lost in the Labyrinth, unless he had his master plans with him

Daedalus: (Thinking only about his son) I have one request you Highness. My son is afraid of the dark. Can we have a supply of candles, so that his last hours will be a little less frightening?

- Minos:** Fine! Have your candles. You can watch each other starve!!!
- Narrator:** Daedalus and Icarus were blindfolded and taken to the center of the maze and set free. They were held there by the guards' threats with arrows and spears while the guards retraced their steps.
- Icarus:** Father, I'm already hungry. What will we do! You must think of some way out of this!
- Daedalus:** I'm thinking as fast as I can. Even if we escape, Minos' army will catch us. If we make it to the sea, the king's navy will capture our ship.
- Narrator:** Daedalus stayed awake all night. He regained his hope when the chirping of birds signaled the rising sun.
- Daedalus:** You would have to be a bird to escape from Minos. That's it! Wake up my son! We've got work to do.
- Icarus:** What! Father, have you lost your mind?
- Daedalus:** Just listen! Use your bird calls to call down as many birds as you can. Quickly!
- Narrator:** Icarus made sounds that imitated all the birds in the sky. Hearing the calls, the birds swooped down toward the inventor and his son. The two grabbed as many feathers as they could. The lucky birds lost only a few feathers.
- Daedalus:** We will use the wax from the candles to hold the feathers.....
- Icarus:** Father, please tell me what you are making.
- Daedalus:** I'm making wings! With these feathers and wax, I'll make wings to carry us out of this maze and away from this island. Minos may control the land and the sea, but he doesn't rule the sky. We'll fly away.
- Narrator:** Daedalus made sets of wings for himself and his son in just a day. Then they practiced with the wings until they knew they could fly.
- Daedalus:** Pay attention to my words, Icarus. Fly right behind me! Do you hear? Don't fly too low or the spray from the sea will wet your wings and pull you down. Don't fly too high either. If you fly too close to the sun, the wax that keeps the wings together will melt and you will fall into the sea.
- Icarus:** Father, I promise I will obey you.
- Narrator:** The two set out at the break of day. They flapped above the walls of the Labyrinth and over Minos' kingdom. The people below didn't know what to think of what they saw in the early morning sky.

Fisherman: That's the strangest pair of birds that I've ever seen.

Shepard: No, it must be two gods visiting earth.

Fisherman: I think I'd better go back to sleep.

Narrator: Once they were safely away from Minos' island, the father and son whooped and shouted.

Icarus: We're as free as birds!

Daedalus: Just remember my words son. Be careful!

Icarus: It feels great to fly, gliding, soaring. Look at my dive, look at how high I can go.

Daedalus: (alarmed) This is no time for fun, son, Just stay close behind me. We must get to land as soon as we can.

Narrator: When Daedalus turned his back, Icarus spread his wings and soared as high as he could. He felt the warm rays of the sun on his body. He let the air currents take him higher, just as the tide will sometimes carry a swimmer deeper and deeper.

Icarus: (To himself) I'll catch up with Dad in a second. It's great to be flying, the sun feels so good. That old Labyrinth was so cold.

Narrator: But something began to go terribly wrong. Icarus' wings began to get heavier and heavier. He started to feel the melting wax warming his arms. He turned to look and saw a feather drop from his wings. Now he remembered his father's warning!

Icarus: Oh No! Father, help me!

Narrator: But Daedalus was far ahead and he could not hear the words of his son.

Before long, hundreds of feathers fell from the wings. Icarus was dropping to the blue sea below. He frantically waved his arms, but it did no good.

Flying ahead, Daedalus was lost in thought.

Daedalus: It would be something if I could build wings for an entire army. I could fly my army back to Crete, surprise Minos and become king. Icarus, how long do you think it would take me to.....

Narrator: Turning around, he saw that he was alone in the beautiful, cloudless sky. His heart pounded as he circled back. What he feared the most appeared before his eyes. Icarus was floating, lifeless, in the sea.

Daedalus landed on the first island he saw and convinced the fishermen to bring in the body of his son. He buried Icarus on that island. He noticed a bird sitting in a tree as he said goodbye to his son. The bird was a partridge. The same bird that Talos became when Daedalus pushed him off of Athena's temple so many years before. At last, Daedalus understood how wrong and cruel that plan had been....now that his own son's life had been taken from him.

For the remainder of his life, Daedalus lived quietly on the island of Sicily, making toys for the children there. The death of Icarus caused the inventor to hang up his wings and his desire for fame and fortune.

THE END