ACHIEVEMENT #1:

The Automobile

Teacher's Guide

Introduction

The number one achievement! Did you guess it was the automobile? What an amazing machine. For centuries people tried everything to bring power to a vehicle – wind, fire, steam, alcohol, and electricity. Finally, Nicholas August Otto, a German engineer, perfected the four-piston gasoline internal combustion engine. However, automobiles were hand-made and very expensive. Only the wealthy could afford them. It took Henry Ford's development of mass production techniques in 1913 to make the automobile affordable.

In 1900 a handmade car cost about $1,550. The average person made $12.74 a week. Mr. Ford brought the cost per car down to $290. He sold 1 million cars by 1921 and 15 million by 1927. Ransom Olds actually gave Mr. Ford the idea. In Olds' factory, workers wheeled carts of car parts to each car frame to speed up production. Mr. Ford improved on this idea by setting up a conveyor belt that brought the *car frame* to *the worker*. He cut production time to 93 minutes per car. His motto was "fast and cheap" and that's why he painted all of his cars black – it was the color that dried the fastest.

Although it is men like Otto, Ford, and Olds who get credit for inventing the automobile – many women added to its development. Women went on to develop windshield wipers and electric starters as well as carburetor and brake linings. By 1925 women had invented over 150 things that improved its operation.

Lesson Focus: Product Testing and Redesign

Lesson Synopsis: Students consider the reasons for the continued redesign of the automobile during the last 100 years. They create, test, and redesign balloon-powered model Rocket Racers.

Related National Science Education Standards:

Content Standard B (Physical Science):

As a result of their activities in grades 5-8, all students should develop an understanding of Motions and Forces.

Fundamental concepts and principles that underlie this standard include:

- ♦ Unbalanced forces will cause changes in the speed or direction of an object's motion.

Content Standard E (Science and Technology):

As a result of activities in grades 5-8, all students should develop Abilities of Technological Design, including the ability to Identify Appropriate Problems for Technological Design, Design a Solution or Product, Implement a Proposed Design, Evaluate Completed Technological Designs and Products, and Communicate the Process of Technological Design.

Related Benchmarks from Benchmarks for Science Literacy:

Section 3C (Issues in Technology):

By the end of 5th grade, students should know that:

- ♦ Once an invention exists, people are likely to think up ways of using it that were never imagined at first.
- ♦ Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems.

By the end of 8th grade, students should know that:

> Technology … is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live.

Section 10J (Harnessing Power):

By the end of the 8th grade, students should know that:

> The steam engine was invented to solve the urgent problem of pumping water out of coal mines. As improved by James Watt, it was soon used to move coal, drive manufacturing machinery, and power locomotives, ships, and even the first automobiles.

Related Standards for Technological Literacy:

Standard 9 (Engineering Design):

In order to comprehend engineering design, students in grades 6-8 should learn that:

- ♦ Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.

Glossary:

- **Newton's Third Law of Motion** One of three fundamental principles of motion. It states that for every action there is an equal and opposite reaction.
- **action** A force exerted on a body.
- **reaction** The equal and opposite force which results when a force is exerted on a body.

Important Concepts:

- Modeling, testing, and modifying are important aspects of engineering design.
- For every action, there is an equal and opposite reaction.

Materials for Each Design Team:

4 Pins	Styrofoam meat tray or cardboard
Masking tape	Flexible straw
Scissors	Drawing (mechanical) compass
Marker pen	Small round party balloon
Ruler	Set of handouts

Safety Precautions:

As appropriate, remind students of guidelines for working with construction materials and tools and for handling balloons.

Procedure:

Engagement:

If you have not already shown the video, you may wish to do that at this time. Have students read and discuss the information related to the Timeline Handout.

Exploration and Explanation:

1. To standardize the testing process, have students agree upon as a class what the body and wheel dimensions of the original design will be or simply specify the dimensions. (Using the largest wheel pattern and beginning with a 4" by 8" rectangle for the body is one suggestion.)

2. Distribute the materials and construction tools to each student group. (If you are going to have them construct a second racer, tell them to save styrofoam tray scraps for later. Hold back the additional materials for the second racer until students need them.)

Teacher’s Guide (Continued)

3. Have students plan the arrangement of parts on the tray before cutting them out. (If you do not wish them to use scissors, students can trace the pattern pieces with the sharp point of a pencil or a pen. The pieces will snap out of the styrofoam if the lines are pressed deeply.)

4. Point out to students that the pins are serving as axles and that the wheels need to be able to rotate freely so the pins must not be pushed in snugly. (In their redesign, students may wish to explore using other types of axles.)

5. While students are constructing their cars, lay out a track on the floor approximately 10 meters long. Several metric tape measures joined together can be placed on the floor for determining how far the racers travel. (The students should measure in centimeters.)

6. Test the racers as they are completed. (Have students place a measured loop of string around the balloon and inflate the balloon inside the string loop each time you test the racers. This will increase the accuracy of the tests by helping to insure that each balloon inflates the same amount each time.)

7. Have students fill in the data sheets and create a report cover with a drawing of the racer they constructed.

Extension:

1. Distribute design pages so that the students can redesign their racers before starting construction.

2. Hold Rocket Racer speed races, in which racers compete against one another.

Evaluation:

Students will create "Rocket Racer Test Reports" to describe test runs and modifications that improved their racer's efficiency. Use these reports for assessment along with the design sheet and new racer.

Ideas for Further Exploration:

- Have students make a balloon-powered pinwheel by taping another balloon to a flexible straw. Push a pin through the straw and into the eraser of a pencil. Inflate the balloon and watch it go.
- Assign different Design Teams different problems to work on. One team might work on wheel size changes, while another works on traction, and a third works on types of axles.
- Have students research a list of products that claim to be “New and Improved”.

Additional Background Information for Teachers:

This activity can be done individually or with students working in pairs. Allow 40 to 45 minutes to complete the first part of the activity. The activity stresses technology education and provides students with the opportunity to modify their racer designs to increase performance. The optional second part of the activity directs students to design, construct, and test a new rocket racer based on the results of the first racer. Refer to the materials list and provide what is needed for making one rocket racer for each group of two students. Styrofoam food trays are available from butchers in supermarkets. They are usually sold for a few cents each or you may be able to get them donated. Students can also save trays at home and bring them to class.

If compasses are not available, students can trace circular objects to make the wheels or use the provided wheel and hubcap patterns. Putting hubcaps on both sides of the wheels may improve performance. If using the second part of the activity, provide each group with an extra set of materials. Save scraps from the first styrofoam tray to build the second racer. You may wish to hold drag or distance races with the racers. The racers will work very well on tile floors and carpeted floors with a short nap. Several tables stretched end to end will also work, but racers may roll off the edges.

Although this activity provides one rocket racer design, students can try any racer shape and any number, size, and placement of wheels they wish. Long racers often work differently than short racers.

While it is possible to demonstrate Newton's Law with just a balloon, constructing a rocket racer provides students with the opportunity to put the action/reaction force to practical use. In this case, the payload of the balloon rocket is the racer. Wheels reduce friction with the floor to help racers move. Because of individual variations in the student racers, they will travel different distances and often in unplanned directions. Through modifications, the students can correct for undesirable results and improve their racers' efficiency.

References:

- **Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology (EG-1999-06-108-HQ)**, a NASA-created curriculum supplement that can be downloaded from: http://spacelink.nasa.gov/products/Rockets/

ACHIEVEMENT #1:

The Automobile

Student Handout

My, How the Automobile has Changed!

In 1900, the typical automobile in the United States was box shaped, with little or no protection from the elements for either its parts or its passengers. Its solid rubber tires could not cushion bumps. Using the hand crank to start it sometimes resulted in injury. Its performance was so unreliable that owners were encouraged to carry a repair kit of over 60 items, ranging from extra parts to material to seal leaks. Kerosene side lamps provided crude lighting. Although there were 50 automobile-manufacturing companies in 1900, each car was hand made and cost twice the average worker's annual wage, so only the wealthy could afford to own a car.

As you examine the **Timeline** on the following page, you will find just some of the many innovations that have made automobiles more affordable and have improved automobile safety, comfort, and reliability.

The Importance of Automobile Safety

In the left hand margin of the **Timeline**, mark any safety improvements with the letter **S**. What other safety features can you identify in modern automobiles? Many improvements in safety are the result of deliberate testing of automobiles and their components. Crash testing provides important feedback to automotive engineers as they work to improve automobile safety.

The Importance of Mass Production

Although Henry Ford did not originate mass production of automobiles, his use of conveyer belts allowed him to cut production time from a day and a half per vehicle to just an hour and a half and to reduce the price of a Ford automobile by more than half.

The Impact of the Automobile on Society

The United States has more automobiles per person than virtually any other country in the world. The availability of reliable, affordable automobiles has changed how we vacation and how we build our cities, and is a major force in our economy. Its basic design has been adapted to produce vehicles ranging from trucks to jeeps to ambulances. From traffic jams to rising gasoline prices to drunk driving to acid rain, the automobile is at the heart of many of the challenges facing our society today. Considering both the positive and negative impacts, how do you think that Henry Ford would feel about the influence his innovations have had, if he were alive today?

Student Handout (continued)

Timeline of Events Related to Achievement #1:

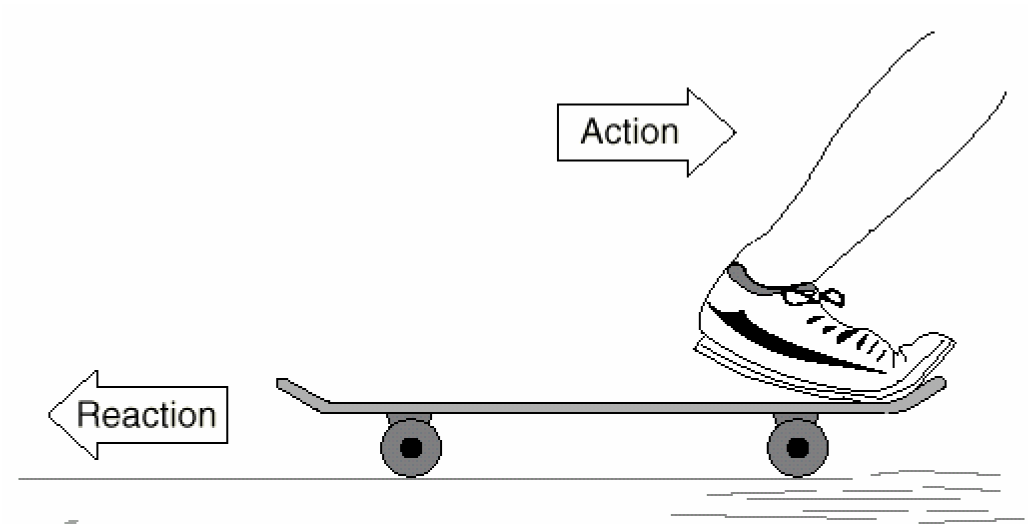
1900	Packard is the first U.S. car to feature three-speed and reverse gear box.
1901	Ransom E. Olds originates mass production techniques.
1901	British designer Frederick William Lanchester patents disc brakes.
1901	Frederick Simms invents first car fender, based on railway engine buffers.
1908	Henry Ford begins mass production of the Model T.
1908	Henry Ford adds conveyor belt to improve mass production of Model T.
1911	Charles Kettering invents the electric starter.
1911	First mechanically operated windshield wipers.
1911	Interchangeable parts are introduced by Henry M. Leland.
1915	Cadillac introduces the V-8 engine.
1916	Dodge mass-produces first car body made entirely of steel.
1926	First power steering system, installed in the Pierce-Arrow.
1934	Chrysler Airflow becomes the first mass-produced streamlined car.
1940	Karl Pabst designs the Jeep, workhorse of WWII.
1947	B. F. Goodrich Co. introduces the first tubeless tire.
1948	Disc brakes are introduced by Chrysler.
1953	First car whose body is made of fiberglass-reinforced plastic.
1967	Safer car bumpers absorb some of the energy of an impact or collision.
1970	Gary Gabelich travels over 600mph in a rocket-powered car.
1980-90s	Continuing research and experimental work with alternative fuels, electric and solar-powered vehicles, seat belts, airbags, mapping systems, etc.

Student Handout (continued)

Building and Testing a Balloon-powered Rocket Racer

A Rocket Racer is a simple way to observe **Newton's Third Law of Motion**. This law states that **every action has an equal and opposite reaction**. This is an important principle in both automotive engineering and aerospace engineering.

Imagine that a skateboard and rider are in a state of rest (not moving). The rider jumps off the skateboard. In the Third Law, the jumping is called an **action**. The skateboard responds to that **action** by traveling some distance in the opposite direction. The skateboard's opposite motion is called a **reaction**. (When the distance traveled by the rider and that traveled by the skateboard are compared, it would appear that the skateboard has had a much greater **reaction** than the **action** of the rider. This is not the case. The reason the skateboard has traveled farther is that it has less mass than the rider.)



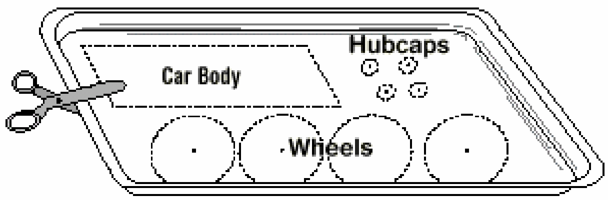
With rockets, the **action** is the expelling of gas out of the engine. The **reaction** is the movement of the rocket in the opposite direction. Constructing a balloon-powered Rocket Racer will provide you with the opportunity to put the **action/reaction** principle to practical use and to use test data to improve an engineering design.

Materials for Each Design Team:

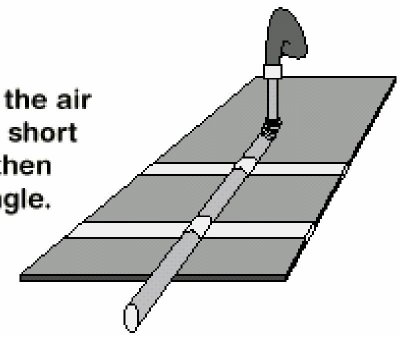
4 Pins	Styrofoam meat tray or cardboard
Masking tape	Flexible straw
Scissors	Drawing (mechanical) compass
Marker pen	Small round party balloon
Ruler	Set of handouts
String	Clothespins or Clamps

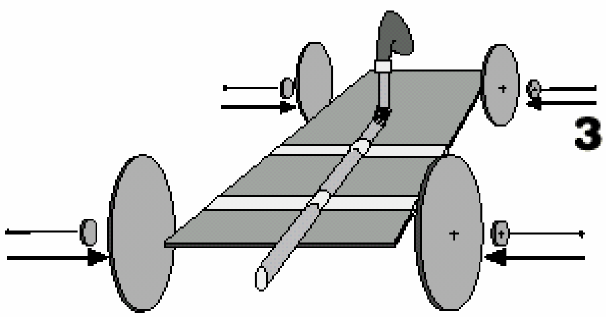
How To Build A Rocket Racer

1. Lay out your pattern on a styrofoam tray. You need **1** car body, **4** wheels, and **4** hubcaps. Use a compass to draw the wheels.



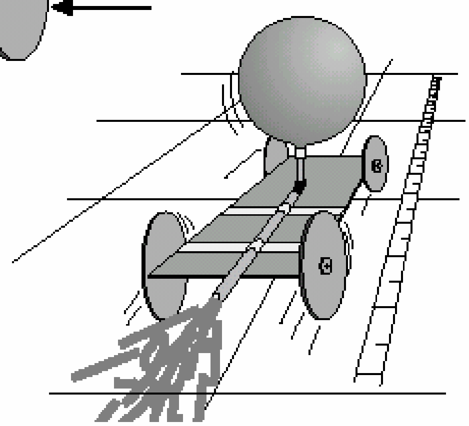
2. Blow up the balloon and let the air out. Tape the balloon to the short end of a flexible straw and then tape the straw to the rectangle.

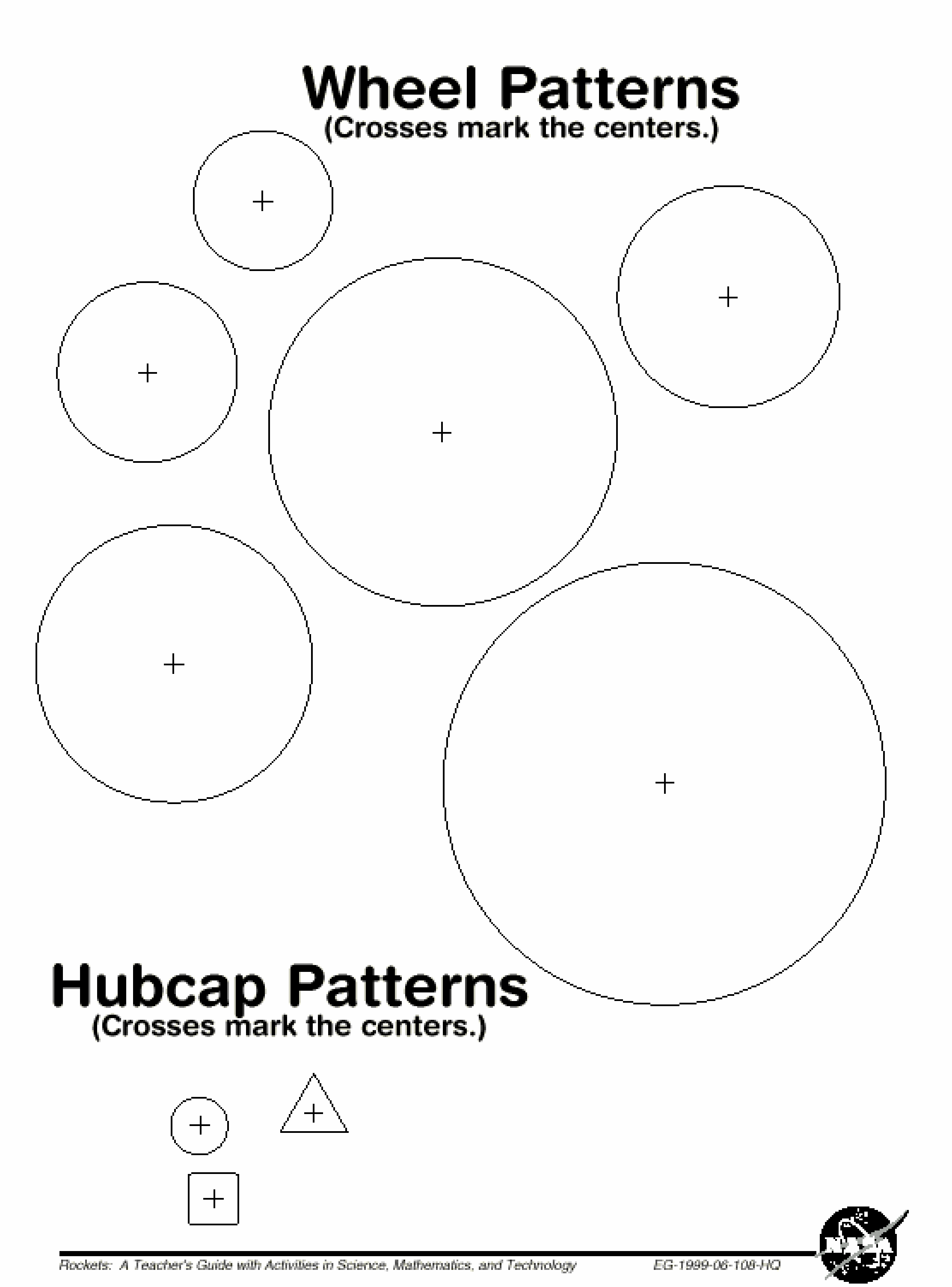




3. Push pins through the hubcaps into the wheels and then into the edges of the rectangle.

4. Blow up the balloon through the straw. Squeeze the end of the straw. Place the racer on floor and let it go!




Wheel Patterns
(Crosses mark the centers.)
Hubcap Patterns
(Crosses mark the centers.)
Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology
EG-1999-06-108-HQ

Rocket Racer Test Report

Draw a picture of your rocket racer.

BY

____

____

DATE: ____________________________

Rocket Racer Test Report

Place your rocket racer on the test track and measure how far it travels.

1. Describe how your rocket racer ran during the first trial run.
   (Did it run on a straight or curved path?)

   ____

   How far did it go? ____________ centimeters

   Color in one block on the graph for each 10 centimeters your racer traveled.

2. Find a way to change and improve your rocket racer and test it again.

   What did you do to improve the rocket racer for the second trial run?

   ____

   ____

   How far did it go? ____________ centimeters

   Color in one block on the graph for each 10 centimeters your racer traveled.

3. Find a way to change and improve your rocket racer and test it again.

   What did you do to improve the rocket racer for the third trial run?

   ____

   ____

   How far did it go? ____________ centimeters

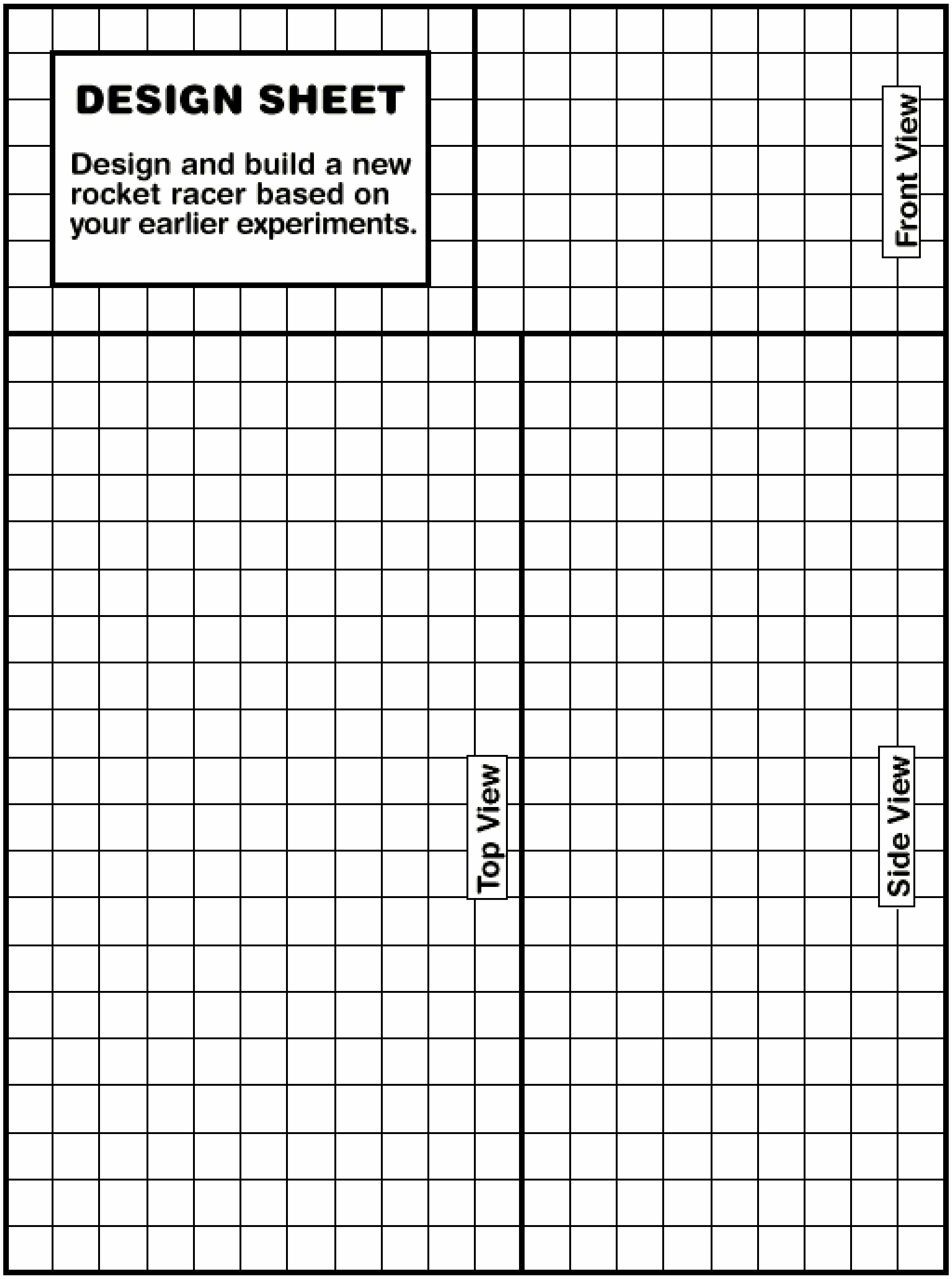
   Color in one block on the graph for each 10 centimeters your racer traveled.

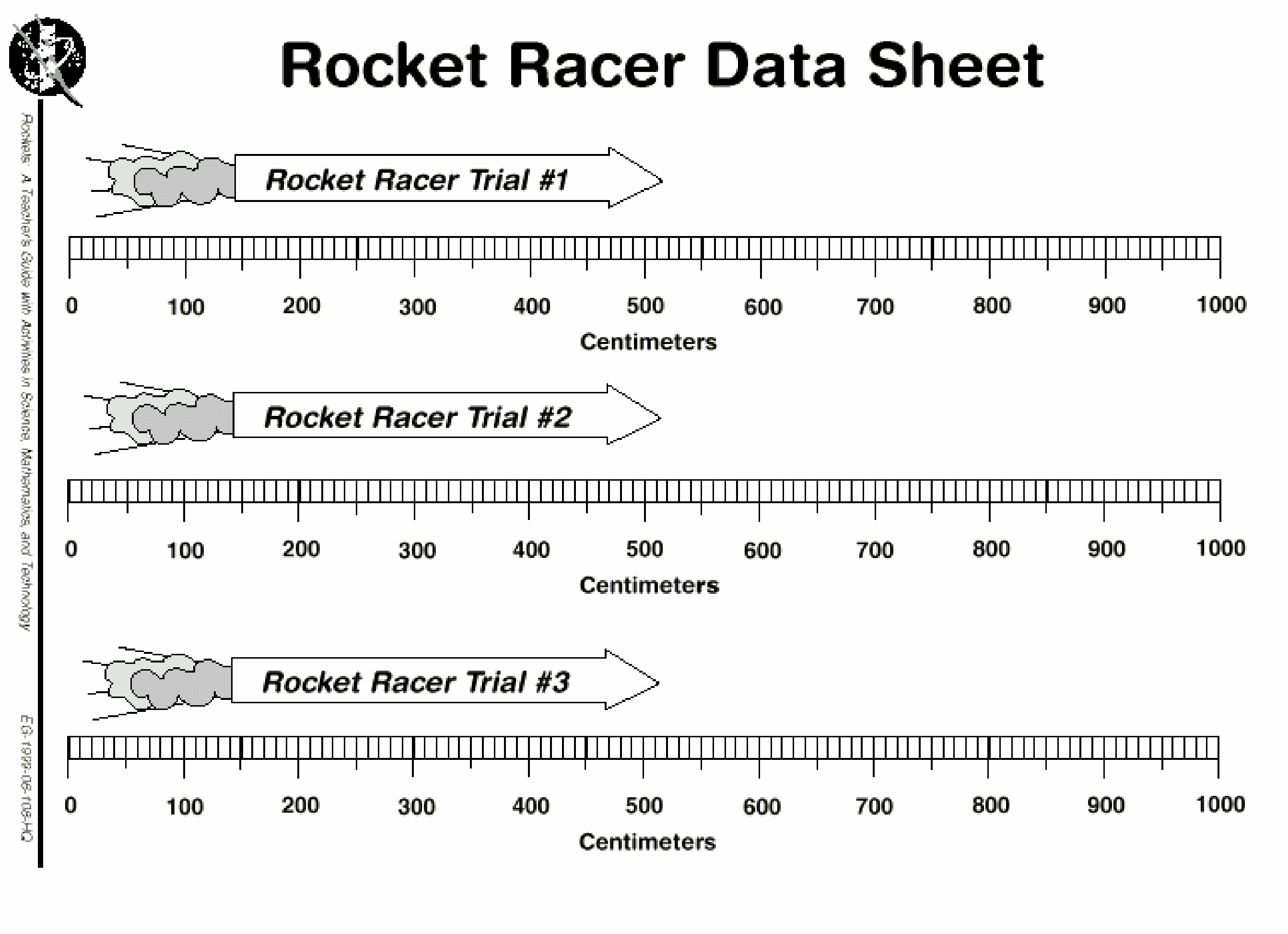
4. In which test did your racer go the farthest?____________

   Why? ____

   ____

Student Handout (continued)




Rocket Racer Data Sheet
Rocket Racer Trial #1
0 100 200 300 400 500 600 700 800 900 1000
Centimeters
Rocket Racer Trial #2
0 100 200 300 400 500 600 700 800 900 1000
Centimeters
Rocket Racer Trial #3
0 100 200 300 400 500 600 700 800 900 1000
Centimeters
Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology
EG-1999-06-108-HQ

ACHIEVEMENT #2:

Apollo Moon Landing

Teacher's Guide

Introduction

Since the beginning of time, people looked into the night sky and wondered what was out there. In the last century engineers began looking at the same sky, planning how to get there. Engineers like Robert Goddard and Werner von Braun experimented with rockets. They understood that a major force would be necessary to escape Earth's gravity - but how much force?

The engineers who worked on the Apollo mission had a huge challenge. The ship that took Neil Armstrong and his crew to the moon weighed 40 tons. They had to make sure they had enough fuel to launch it and bring it back. The first stage rocket alone burned 15 tons of fuel per second.

Engineers had a lot of detective work to do before the Apollo missions could be launched. They had to develop new materials, communications systems, energy supply systems and life support systems. Sensors so doctors could monitor the health of the astronauts, and computers that would fit on a spacecraft. And they did it all in less than a decade.

More than 60,000 products were developed from the space program that have improved life for all of us. These materials are now being utilized in more commercial ways, like making skateboards and snowboards more light weight, helmets more durable. Apollo set us on a course that would continue to bring us knowledge of the universe. Perhaps, most importantly, Apollo allowed us to become explorers in outer space - thanks to the efforts of thousands of engineers who believed nothing was impossible.

Lesson Focus: Spinoff Technologies

Lesson Synopsis: Students explore paper rockets, learn about the Apollo Program and Apollo spinoffs, and use simple office supplies to design and create a new useful product.

Related National Science Education Standards:

Content Standard B (Physical Science):

As a result of their activities in grades 5-8, all students should develop an understanding of Motions and Forces. Fundamental concepts and principles that underlie this standard include:

- Unbalanced forces will cause changes in the speed or direction of an object's motion.

Related Benchmarks from Benchmarks for Science Literacy:

Section 3C (Issues in Technology):

By the end of 5th grade, students should know that:

- Once an invention exists, people are likely to think up ways of using it that were never imagined at first.
- Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems.

By the end of 8th grade, students should know that:

- Technology … is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live.

Related Standards for Technological Literacy:

Standard 1 (Characteristics and Scope of Technology):

In order to comprehend the scope of technology, students in grades 6-8 should learn that:

- The development of technology is a human act and is the result of individual or collective need and the ability to be creative.
- Technology is closely linked to creativity, which has resulted in innovation.

Glossary:

spinoffs Products and services in such areas as health and medicine, environment, public safety, consumer/home/recreation, transportation, computer technology and industrial productivity that incorporate a technology developed in a different area or for a different reason.

fin A projection shaped like a fish fin, attached to a rocket to increase control over the direction the rocket moves.

Important Concepts:

Many technological achievements are ultimately applied in ways different from those first imagined.

Materials for Each Inquiry Team:

Materials for Engagement:

Scrap bond paper
Cellophane tape
Scissors
Sharpened fat pencil
Milkshake straw (slightly thinner than pencil)
Eye protection
Metric ruler

Materials for the Extension (Engineering Challenge):

Cellophane tape
Index Cards
Paper clips
Variety of other office supplies

Suggested Materials for Further Exploration:

Masking tape
Pictures of the Sun and planets

Materials for Setting up Target Range:

10-meter tape measure
Copies of planet drawings

Safety Precautions:

Because the rockets are projectiles, make sure students wear eye protection.

Procedure:

Engagement: Have students make and test Paper Rockets as follows:

1. Demonstrate a completed paper rocket to the students.
2. Distribute the materials and construction tools to each student. (Students may work individually or in pairs.)
3. Have students each construct a rocket as shown in the instructions on the student sheet.
4. While students are constructing their rockets, select a location for flying the rockets. (A room with open floor space or a hallway is preferable.) Prepare the floor by marking a 10-meter test range with tape measures or meter sticks laid end to end.
5. Tell students to predict how far their rocket will fly and record their estimates in the test report sheet.
6. When students complete the rockets, distribute straws.
7. Have students record data from each launch on the Paper Rocket Launch Record Report form. (The form includes spaces for data from three different rockets.)
8. After the first launches, and as time allows, have students construct new and "improved" paper rockets and attempt a longer journey through the solar system. (Encourage the students to try different sized rockets and different shapes and number of fins. After test flying the rocket and measuring the distance it reached, students should record the actual distance and the difference between predicted and actual distances on the Paper Rockets Test Report.)

Teacher's Guide (Continued)

Exploration, Explanation: Have students use the **Student Handout** to read about the Apollo Program and some of its spinoffs. Have them use the **NASA Spinoff Database** online to research additional Apollo Spinoffs.

Extension: Have students complete the **Engineering Challenge**.

Evaluation:

- Have students complete test reports that will describe the rockets they constructed and how those rockets performed. Ask the students to create bar graphs on a blank sheet of paper that show how far each of the three rockets they constructed flew. Have students write a summarizing paragraph in which they pick which rocket performed the best and explain their ideas for why it performed as it did.
- Have students reexamine the Timelines in this unit for other examples of spinoffs.

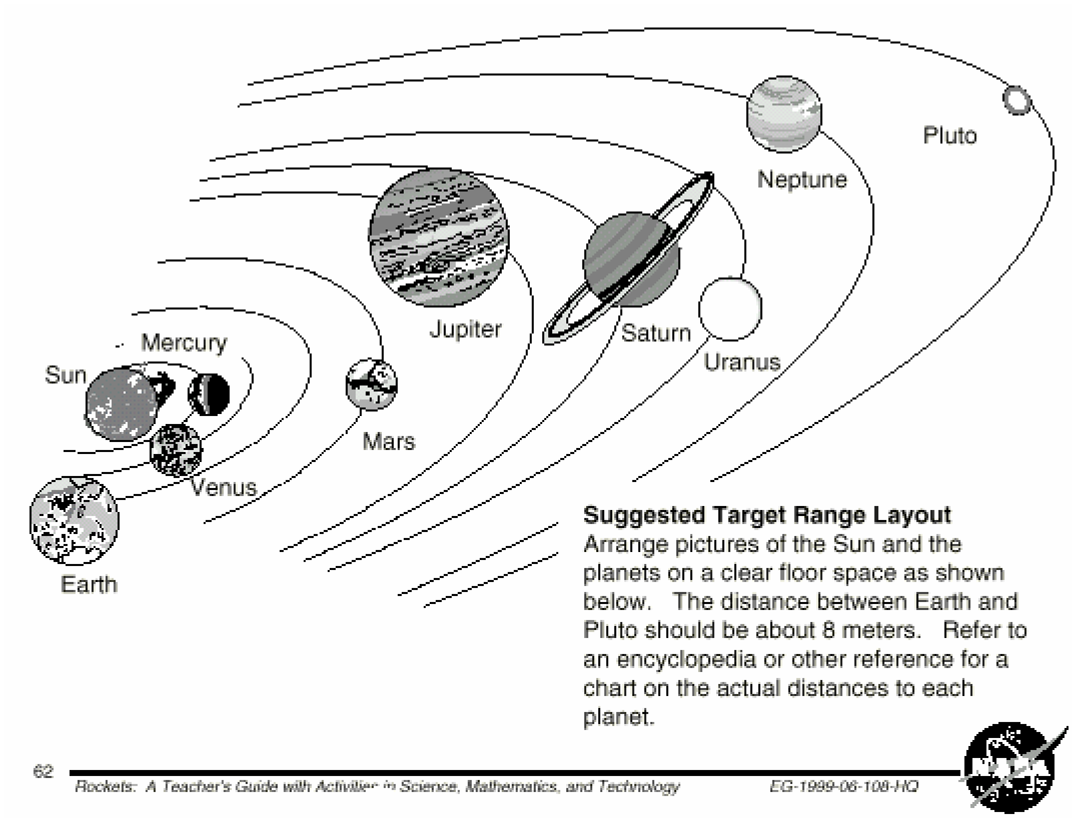
Ideas for Further Exploration:

For younger students, create a chart listing how far each planet target actually is from Earth and have them arrange the pictures to scale. (Older students can look up these distances for themselves.)

Have students try to determine how high the rockets fly. (To do so, place masking tape markers on a wall at measured distances from the floor to the ceiling. While one student launches the rocket along the wall, another student compares the height the rocket reached with the tape markers. Be sure to have the students subtract the height from where the rocket was launched from the altitude reached. For example, if students held the rocket 1.5 meters from the floor to launch it, and it reached 4 meters above the floor, the actual altitude change was 2.5 meters.)

As an alternative to the 10-meter test track, lay out a planetary target range and have students launch from planet Earth, telling them to determine the farthest planet they are able to reach with their rocket. Use the planetary arrangement shown below. (Pictures for the planets are found at the end of the Teacher's Guide. Enlarge as desired.)

Teacher's Guide (Continued)



Additional Background Information for Teachers:

Although the activity suggests using a solar system target range, the Paper Rockets activity actually demonstrates how rockets fly through the atmosphere. An important improvement in rocketry came with the replacement of sticks by clusters of lightweight fins mounted around the lower end. Fins could be made out of lightweight materials and be streamlined in shape. They gave rockets a dart-like appearance. A rocket with no fins is much more difficult to control than a rocket with fins. The placement and size of the fins is critical to achieve adequate stability while not adding too much weight. Some experimenters even bent the lower tips of the fins in a pinwheel fashion to promote rapid spinning in flight. With these "spin fins," rockets become much more stable in flight, but this design also produces more drag and limits the rocket's range.

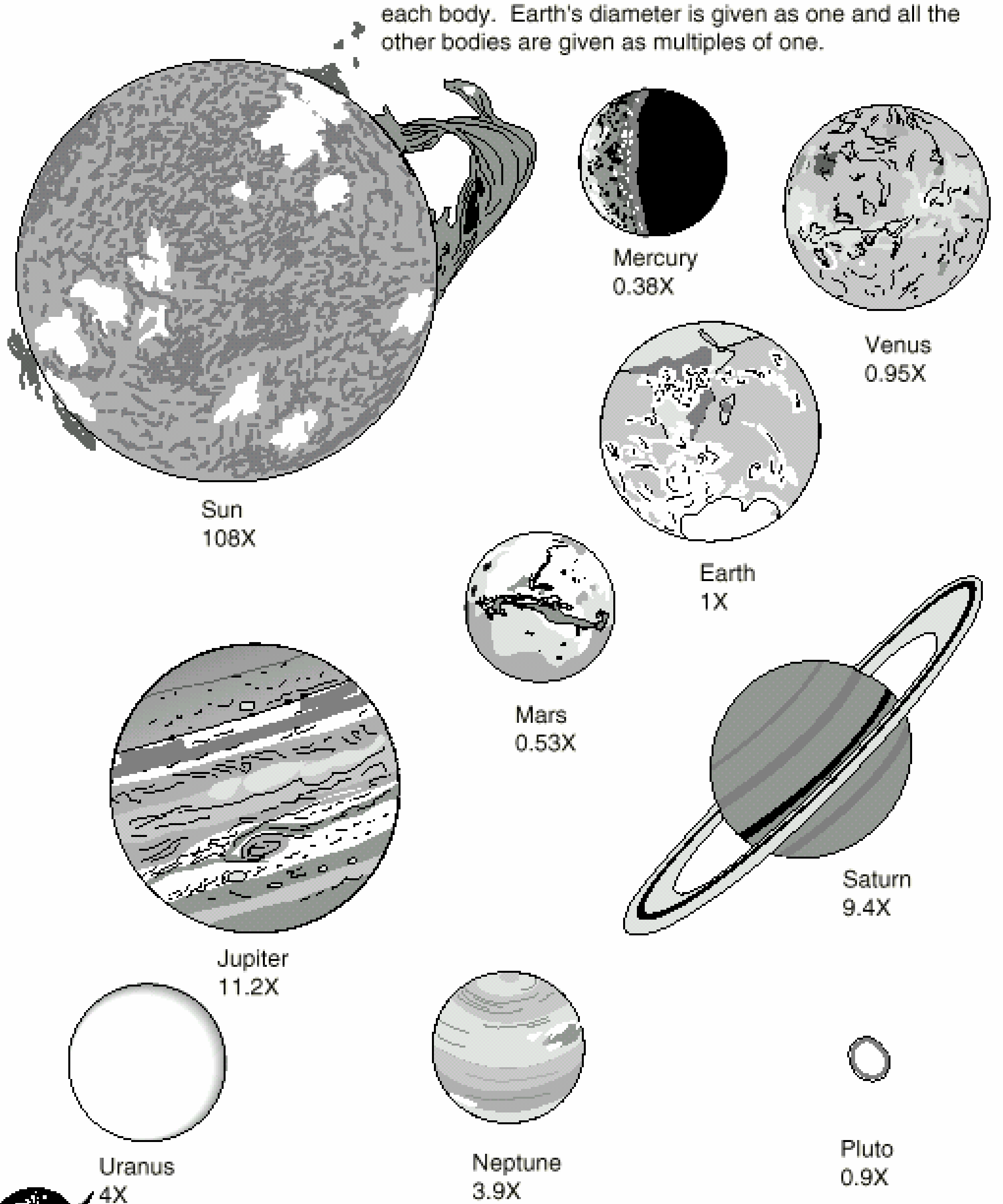
References:

- **I Have the Heart of a Rocket**, online article of the development of the Ventricular Assist Device, available at: http://www.nasaexplores.com/lessons/01-005/fullarticle.html (The student reading in this lesson is based on this article.)
- **Spinoff**, NASA online publication on NASA spinoff technologies, available at: http://www.sti.nasa.gov/tto/spinoff.html
- **NASA Spinoff Database**, online at: http://www.sti.nasa.gov/tto/spinselect.html
- **Rockets: A Teacher's Guide with Activities in Science, Mathematics, and Technology (EG-1999-06-108-HQ)**, a NASA-created curriculum supplement that can be downloaded from: http://spacelink.nasa.gov/products/Rockets/ (The background on the Apollo Program and the Rocket Activity used in this lesson are taken from this publication.)

Planet Targets

(Not Drawn To Scale)

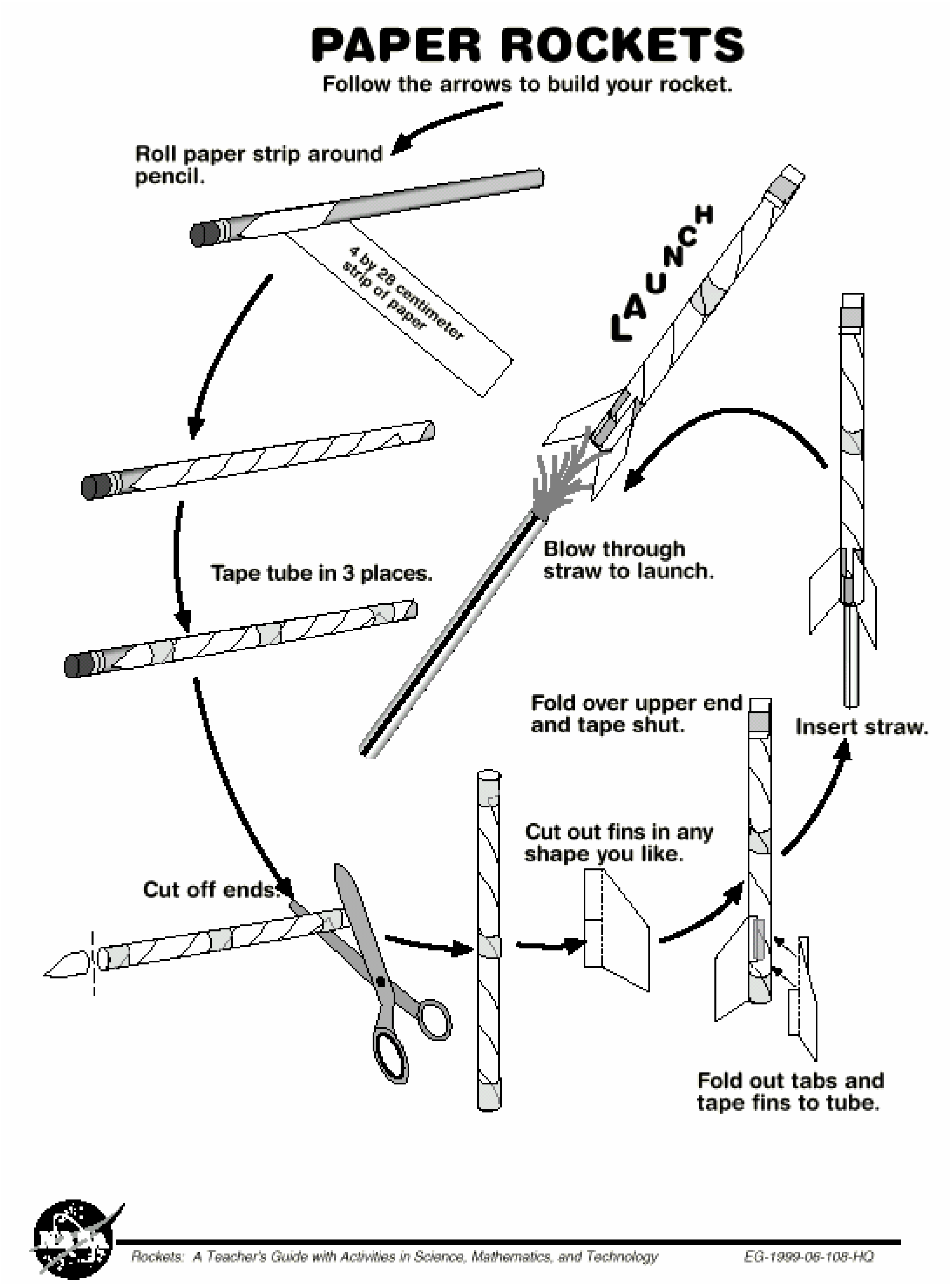
Enlarge these pictures on a copy machine or sketch copies of the pictures on separate paper. Place these pictures on the floor according to the arrangement on the previous page. If you wish to make the planets to scale, refer to the numbers beside the names indicating the relative sizes of each body. Earth's diameter is given as one and all the other bodies are given as multiples of one.



ACHIEVEMENT #2:

Apollo Moon Landing

Student Handout



Paper Rocket Test Report

Names:

____

____

1. Launch your rocket three times. How far did it fly each time. What is the average distance your rocket flew? Write your answer in the spaces below.
2. Build and fly a rocket of a new design. Before flying it, predict how far it will go. Fly the rocket three times and average the distances. What is the difference between your prediction and the actual average distance?
3. Build a third rocket and repeat step 2.
4. On the back of this paper, write a short paragraph describing each rocket you built and how it flew. Draw pictures of the rockets you constructed.

Rocket 1

		Make notes about the flights here.
How far did it fly in centimeters?	1. ______ 2. ______ 3. ______	
Average distance in centimeters?	______	

Rocket 2

		Make notes about the flights here.
Predict how many centimeters your rocket will fly.	______	
How far did it fly in centimeters?	1. ______ 2. ______ 3. ______	
Average distance?	______	
Difference between your prediction and the average distance?	______	

Rocket 3

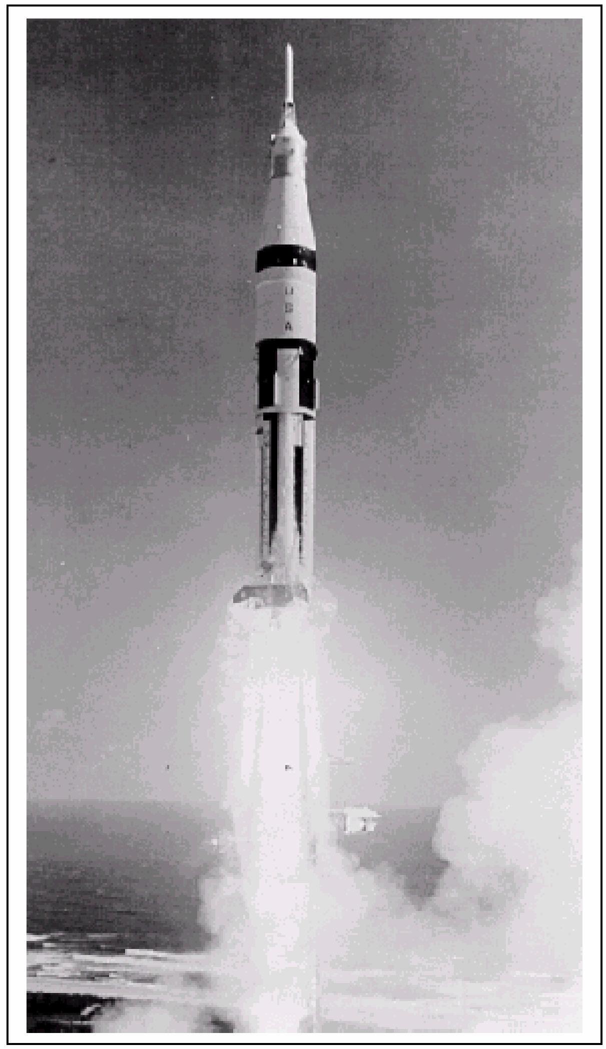
		Make notes about the flights here.
Predict how many centimeters your rocket will fly.	______	
How far did it fly in centimeters?	1. ______ 2. ______ 3. ______	
Average distance?	______	
Difference between your prediction and the average distance?	______	

Student’s Handout (continued)

The Apollo Program

The Gemini was the second manned capsule developed by the United States. It was designed to carry two crew members and was launched on the largest launch vehicle available - the Titan II rocket. President Kennedy’s mandate significantly altered the Gemini mission from the general goal of expanding experience in space to preparing for a manned lunar landing on the Moon. It paved the way for the Apollo program by demonstrating rendezvous and docking required for the lunar lander to return to the lunar orbiting spacecraft, the extravehicular activity (EVA) required for the lunar surface exploration and any emergency repairs, and finally the ability of humans to function during the eight day manned lunar mission duration. The Gemini program launched ten manned missions in 1965 and 1966, eight flights rendezvoused and docked with unmanned stages in Earth orbit and seven performed EVAs.

Launching men to the moon required launch vehicles much larger than those available. To achieve this goal the United States developed the nearly 7-meter tall Saturn launch vehicle, shown in the picture. The Apollo capsule, or command module, held a crew of three. The capsule took the astronauts into orbit about the Moon, where two astronauts transferred into a lunar module and descended to the lunar surface. After completing the lunar mission, the upper section of the lunar module returned to orbit to rendezvous with the Apollo capsule. The Moonwalkers transferred back to the command module and a service module, with an engine, propelled them back to Earth.



After four manned test flights, Apollo 11 astronaut Neil Armstrong became the first man on the moon. The United States returned to the lunar surface five more times before the manned lunar program was completed. After the lunar program the Apollo program and the Saturn booster launched Skylab, the United State's first space station. A smaller version of the Saturn vehicle transported the United States' crew for the first rendezvous in space between the United States and Russia on the Apollo-Soyuz mission.

Timeline of Events Related to Achievement #2:

1926	Goddard launches first liquid-fuel rocket engine.
1932	Wernher von Braun begins experimenting with rocket engines.
1934	Von Braun builds his first successful rocket, the A-2.
1950	A two-stage bumper rocket is launched from Cape Canaveral.
1957	Sputnik I is launched by liquid-fueled rocket built by Sergei Korolev.
1958	The U.S. launches Explorer 1, beginning of the US space program.
1959	Russia lands a probe on the moon and takes the first pictures of its far side.
1961	Russian Yuri Gagarin orbits Earth one time.
1961	Alan Shepard is launched 115 miles into space, lands 15 minutes later in Atlantic Ocean.
1962	John Glenn orbits Earth three times in a Mercury capsule, Friendship 7.
1962	Mariner 2 flies past Venus, the first probe to fly beyond another planet.
1963	The first communications satellite to reach synchronous orbit is launched.
1964	First space walk, U.S. Gemini program.
1969	Apollo 11 moon landing, Neil Armstrong is first person to walk on moon.
1971	Earth-orbiting space station, USSR.
1973	Skylab is placed in orbit.
1976	Mars space probes, NASA's Viking I and Viking II, launched.
1977	U.S. Space Shuttle program begins.
1981	Columbia Space Shuttle, the first reusable winged spaceship, is launched.
1997	The robotic explorer, Sojourner, lands on Mars.
1997	Discovery Shuttle mission with John Glenn aboard at age 77.

Spinoffs from the Apollo Program

Many product and services incorporate NASA technology, in such areas as health and medicine, environment, public safety, consumer/home/recreation, transportation, computer technology and industrial productivity. These are called **spinoffs**. Here are some of the contributions of the Apollo program:

CAT Scanners and MRI technology (Computer-Aided Tomography and Magnetic Resonance Imaging) used in hospitals world wide, came from technology developed to computer-enhance pictures of the moon for the Apollo program.

Cool suits, which kept Apollo astronauts comfortable during moon walks, are today worn by race car drivers, nuclear reactor technicians, shipyard workers, people with multiple sclerosis and kids with a congenital disorder known as hypohidrotic ectodermal displasia.

Kidney dialysis machines were developed as a result of a NASA developed chemical process that could remove toxic waste from used dialysis fluid.

A cardiovascular conditioner developed for astronauts in space led to the development of a physical therapy and athletic development machine used by football teams, sports clinics and medical rehabilitation centers.

Cordless power tools and appliances are one of the most successful commercial spinoffs of space-based technology.

Athletic shoe design and manufacture also benefited from Apollo. Space suit technology is incorporated into a shoe's external shell.

Insulation barriers made of aluminum foil laid over a core of propylene or mylar, which protected astronauts and their spacecraft's delicate instruments from radiation, is used to protect cars and trucks and dampen engine and exhaust noise.

Exploring Apollo Spinoffs

The NASA Spinoff Database at http://www.sti.nasa.gov/tto/spinselect.html is easy to search. Just enter the word Apollo and press the Submit Query button. The database contains nearly 150 examples of products developed based on technologies originally created for the Apollo Program. (To see the entire list, select Display a maximum of 150 reports.)

Select a product different from those described below and be prepared to give a brief oral description of it to the class. Try to imagine how someone got the idea of applying NASA technology outside of the space program.

Student's Handout (continued)

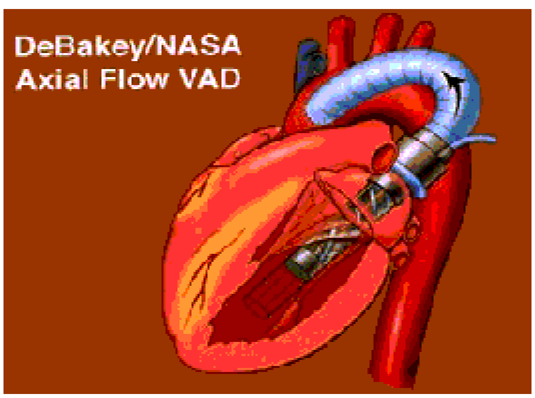
The Heart of a Rocket?

(Information courtesy of NASA'S Aerospace Technology Enterprise)

The last place you'd expect to find part of a rocket engine is attached to the human heart. Rocket engines are notoriously fickle and demand pampering to pump strange fluids like liquid hydrogen for even just a few minutes of pump life. The human heart, on the other hand, is a durable device, changing its output to meet new demands and enduring a range of stresses for decades.

Merging the two was the brainchild of NASA engineer David Saucier of the Johnson Space Center, who received a heart transplant in 1984 after a wait of several months. Why not borrow some space technology, he asked his doctor, to give a failing heart a boost while a patient is waiting for a heart? In response to this question, his doctor, Dr. Michael DeBakey (a pioneer in heart transplants), DeBakey's team at Baylor College, and biomedical experts at MicroMed Technology, worked together to develop a **Ventricular Assist Device** (VAD).

The human heart (like those of all mammals and birds) has four chambers. The right auricle and ventricle receive blood from the body and pump it into the lungs to exchange carbon dioxide for oxygen. The left auricle and ventricle receive blood from the lungs and pump it out to the body. Because it has to push blood out to the entire body, the left ventricle is under the greatest strain and often fails first. The VAD was designed to reduce the left ventricle's load while keeping blood flowing to the rest of the body.



On paper it looked great. In clinical trials with animals, it only worked two days. Longer life of the pump was needed to give longer life to patients. Such differences between planning and testing are not unusual in engineering development work. Soon, design changes increased pump life to an impressive 120 days. In practice, it has operated for five to six months, thus giving patients a longer time to wait for a donor.

For now, the U.S. Food and Drug Administration classifies the VAD as "an experimental device". One day soon it may be approved for general use.

This story illustrates one way that spinoffs occur – when someone's past and present experiences combine with their creativity to trigger new ideas.

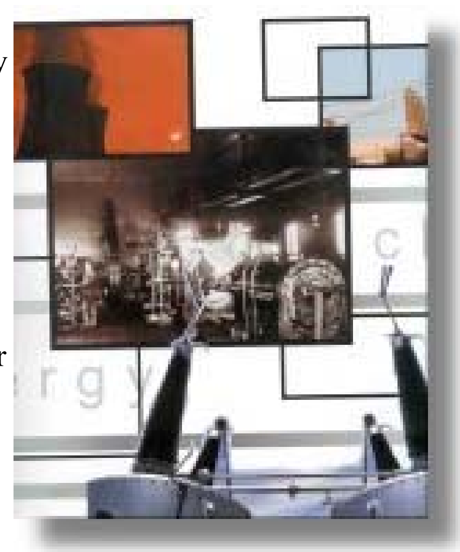
Engineering Challenge: Design and make a new useful product using only paper clips, index cards, transparent tape, and other standard office supplies.

ACHIEVEMENT #3:

Power Generation

Teacher's Guide

Introduction



For centuries people had been aware of the phenomenon of electricity. But they didn't understand it well enough to put it to any use. Once they did, they began inventing motors, generators, telephones, appliances, and so on. The engineer's role was learning to unlock the power of natural resources hidden throughout the planet. They figured out how to design the machinery to extract or collect it, the processes to convert it to fuel, and the systems to transmit this power into our homes, schools and factories.

By the end of the century, electricity has become so important to our life style, we cannot imagine life without it. Engineers found the clues that made it possible. Finding energy sources, developing economical ways to make them useful and environmentally safe are challenges that will always be part of the future, because modern society cannot exist without electricity. Maybe you'll be one of the engineers who will continue to revolutionize the world's energy supply.

Lesson Focus: Reducing Energy Costs and Environmental Impacts

Lesson Synopsis: Students brainstorm a list of the ways they use electricity in their home, explore how to reduce home energy costs using the Energy Saver Website, consider the environmental impacts of power generation, and evaluate the potential effectiveness of roof overhang in reducing home cooling costs.

Related National Science Education Standards:

Content Standard B (Physical Science):

As a result of their activities in grades 5-8, all students should develop an understanding of Transfer of Energy. Fundamental concepts and principles that underlie this standard include:

- Energy is… associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical.
- Energy is transferred in many ways.
- Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

As a result of activities in grades 5-8, all students should develop Understandings About Science and Technology.

Fundamental concepts and principles that underlie this standard include:

- Scientists propose explanations for questions about the natural world, and Engineers propose solutions relating to human problems, needs, and aspirations.
- Technological solutions … have side effects … and carry risks…

Related Benchmarks from Benchmarks for Science Literacy:

Section 8C (Energy Sources and Use):

By the end of 8th grade, students should know that:

- Energy can change from one form to another, although in the process some energy is always converted to heat. Some systems transform energy with less loss of heat than others.
- Different ways of obtaining, transforming, and distributing energy have different environmental consequences.
- Electrical energy can be produced from a variety of energy sources and can be transformed into almost any other form of energy. Moreover, electricity is used to distribute energy quickly and conveniently to distant locations.

Related Standards for Technological Literacy:

Standard 5 (Effects of Technology on the Environment):

In order to discern the effects of technology of the environment, students in grades 6-8 should learn that:

- Decisions to develop and use technologies often put environmental and economic concerns in direct competition with one another.

Standard 16 (Energy and Power Technologies):

In order to select, use, and understand energy and power technologies, students in grades 6-8 should learn that:

- Much of the energy used in our environment is not used efficiently.

Teacher's Guide (Continued)

Glossary:

energy efficiency Using advanced and state-of-the-art technologies to provide better quality energy services with less energy, getting the most productivity from every unit of energy, getting the desired energy services - comfortable homes, profitable businesses, convenient transportation - with less energy use, less air pollution, and lower total cost.
Using energy wisely and eliminating energy waste.

upgrade An improvement in performance resulting from an addition or change.

retrofit To add new features such as new/better pollution controls to an existing device, manufacturing plant, or power plant.

Important Concepts:

- By increasing energy efficiency, it is possible to maintain the same standard of living while decreasing cost and pollution.

- Current power generation technologies have environmental impacts.

Materials for Each Inquiry Team:

Materials for Each Engineering Team:

Shoebox
Black construction paper
Thermometer
Lamp (optional)
Poster board
Scissors
Ruler

Procedure:

Engagement: Pass out page 1 of the student handouts and the Timeline and have students brainstorm a list of all the ways electricity is used in their homes.

Exploration:

1. Either have students take the Survey home and complete it for their own homes, or decide as a class on a "typical" home to investigate.
2. Have students use the Energy Saver Website to explore the factors contributing to energy costs in your area and ways to reduce these costs. (If online access is not available during class, information could be downloaded and photocopied ahead of time.)

Teacher's Guide (Continued)

Explanation: Have students examine the suggested home upgrades and rank them according to their cost, ease of change, etc.

Extension (Engineering Challenge): Have students do the activity "Using Roof Overhang to Reduce Home Cooling Costs."

Evaluation: Have students reexamine the Survey form and explain why each item makes a difference in home energy costs.

Ideas for Further Exploration:

Have students use the data shown on factors contributing to energy costs to create pie charts.

References:

- **The Energy Sourcebook (High School Unit)**, published in 1990 by TVA (out of print). (The activity **Using Roof Overhang to Reduce Home Cooling Costs** is taken from the activity Energy Efficient Structures.)

- **Middle School Lessons from the Alliance to Save Energy** are downloadable at: http://www.ase.org/educators/lessons/download.htm The Alliance to Save Energy is a nonprofit coalition of prominent business, government, environmental, and consumer leaders who promote the efficient and clean use of energy worldwide to benefit the environment, the economy, and national security. Founded and co-chaired in 1977 by Senators Charles H. Percy (R-IL) and Hubert H. Humphrey (D-MN).

- **The Home Energy Saver Website**, sponsored by the Department of Energy and the EPA, online at http://HomeEnergySaver.lbl.gov/

- **Consumer Energy Information, online at:** http://www.eren.doe.gov/consumerinfo/ Sponsored by the Department of Energy's Energy Efficiency and Renewable Energy Network. Provides links to fact sheets, a glossary, and information related to home, business, school, and transportation energy issues. The "Ask an Energy Expert" feature allows students to send in a question and receive a response by email in 2-3 weeks.

ACHIEVEMENT #3:

Power Generation

Student Handout

The History of Electricity

Amber is fossilized tree sap, in which one occasionally finds embedded insects. When ancient people attempted to polish pieces of amber, for use as amulets or adornments, they would have discovered that rubbing the amber caused it to attract bits of fur and feathers, a phenomenon we now call static electricity. In fact, our word **electricity** comes from the word **elektron**, the Greek word for amber. By the early 1700's, "friction machines", which generated static electricity as you turned a handle to rapidly rub the surface of a polished sphere, were a common entertainment among wealthy people.

Ben Franklin's famous 1752 kite experiment was the result of his fascination with static electricity and with the Leyden jar, a device invented in Leyden, Holland, and that allowed storing up of electricity generated with a friction machine. The study of electricity continued for the next 100 years, but, as you can see by examining the Timeline for this lesson, it was Thomas Edison's work on the light bulb that created a need for power stations.

How Many Ways to Do Use Electricity?

Make a list of all the uses of electricity in **your** home. (It may help if you imagine walking from room to room, taking note of what items you plug into the various outlets.) Don't forget those uses that do not require you to plug something in, such as electric stoves, water heaters, central heating, and dishwashers. You may want to survey older relatives to determine how many of the items on your list were things they had when they were your age.

Ways to Save on Home Energy Costs

It is estimated that the use of electric appliances accounts for about 10% of the average person's electric bill. In Texas and other Southern states, 25-40% of annual home energy costs are spent on air conditioning.

To find out how various energy uses affect the average energy bill for homes in your area, go to the Home Energy Saver website at: **http://HomeEnergySaver.lbl.gov/.** Type in your zip code and then click on Go! (To customize the information for your own home, you will need to first complete the **Survey** sheet.)

Using the results for an average home in your zip code, your own home, or a set of values provided by your teacher, examine the list of Suggested Upgrades. Click on an upgrade to get more information. Attempt to rank the suggestions in terms of which would be the easiest or cheapest.

Environmental Impacts of Power Generation

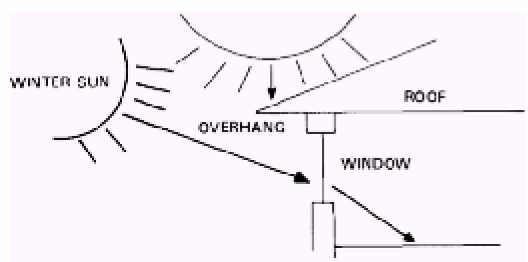
Electric power plants are the country's largest industrial source of the pollutants that cause acid rain (NO_x and SO_2), smog (NO_x), mercury poisoning in lakes and rivers, and global warming (CO_2). According to a 1998 report, U.S. electric generators are responsible for 28% of NO_x, 67% of SO_2, 36% of CO_2, and 33% of mercury emitted annually nationwide.

Pre-1980, coal-fired power units, which continue to rely on 20-40 year old emissions control and other technology, account for only 52% of national electricity generation but for over 80% of pollutant emissions from the utility industry. This is the case because older plants are less efficient than modern generating facilities and because most of these plants are exempted from the emissions limitations that apply to newer plants utilizing cleaner technologies and fuels.

Because power plants often have very tall smoke stacks, the pollution they release may be carried many miles from the plant. More than half of the acid deposition in eastern Canada originates from emissions in the United States.

As you can see, reducing home energy use not only saves money, but also can reduce pollution.

Engineering Challenge:
Using Roof Overhang to Reduce Home Cooling Costs



Using the sun's heat in the winter and avoiding it in the summer can help reduce heating and cooling costs. A roof overhang can help shade windows in the summer.

Materials for Each Engineering Team:

Shoebox
Black construction paper
Thermometer
Lamp (optional)
Poster board
Scissors
Ruler

Student Handout (continued)

1. Cut a hole in one side of a cardboard box. This will be a window. Make sure the window is placed closer to the top of the box than it is to the bottom.

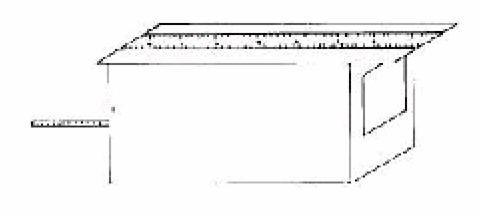
2. Paint all the inside surfaces of the box flat black or cover them with black construction paper.

3. Cut a piece of white poster board for the roof, long enough to make sure the roof covers the entire box and extends over the edge to completely shade the window.

4. Use plastic wrap to cover and seal the hole in the side of the box. Tape the plastic around the edges.

5. Make a small hole toward the back of the box. The hole should be large enough to insert the thermometer. Make sure the bulb of the thermometer is measuring the air temperature in the box. It should not be in direct sunlight.

6. Tape a ruler to the "roof" piece. This will allow you to easily measure the amount of roof overhang. Your model should look like this:



7. Set this model "house" up outside in direct sunlight around midday. The window should be facing south. Alternatively, use a lamp (shade removed) with a 100-W bulb.

8. Place the roof so that the window is completely shaded. Wait about 5 minutes (until the temperature has stabilized) and record the temperature in the box. Also record the air temperature outside the box.

9. Move the roof a few centimeters at a time so that the window is only half shaded and record the temperature after it stabilizes. Be sure to measure and record the outside air temperature, too.

10. Move the roof and measure the temperature of the box when its window is in full sun. Be sure to measure and record the outside air temperature, too.

11. Based on your data, would you recommend that roof overhang completely shade south-facing windows in the summer, or only partially shade them? Explain your reasoning.

Survey for Estimating Home Energy Costs

In what year was your house built? __________

How many square feet is your home? _________
(Do not count the basement if it is not heated or cooled.)

How many stories tall is your house (above ground)? _____________

What direction does the front of your house face? _____________

What type of foundation does your house have?
- Slab
- Vented crawlspace
- Unvented crawlspace
- Basement (is it heated/cooled?)

How many inches of insulation are there in the attic? _______

Are the walls insulated? ________ Is the floor insulated? ________

Do you have a clothes washer? ________

How many refrigerators and standalone freezers do you have? ________

What kind of water heater, heating, and air conditioning do you have?
(Use the back of the page if needed.)

Viewed from the front, how many windows are there in your house?

front ____ back _____ left _____ right _____

What are your base rates for electricity, natural gas, propane, and fuel oil?

How many occupants of your house are between 0 and 5 years of age? ______

How many occupants of your house are between 6 and 13 years of age? ______

How many occupants of your house are between 14 and 64 years of age? ______

How many occupants of your house are 65 years of age or older? ______

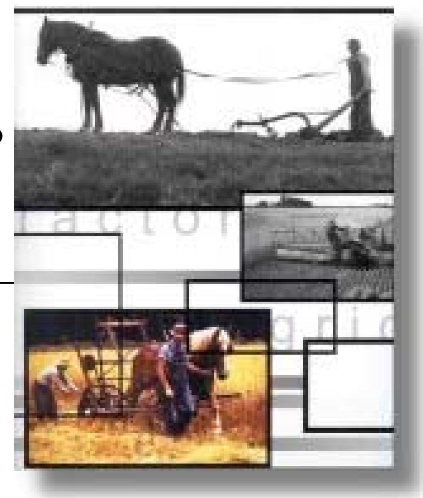
Timeline of Important Events Related to Achievement #3:

???	Discovery that rubbed amber attracts bits of fur.
1745	Leyden jar invented.
1752	Ben Franklin charges Leyden jars from a key attached to a kite flown during a thunderstorm.
1753	Russian physicist electrocuted trying to duplicate Franklin's experiment.
1800	Allesandro Volta creates world's first battery.
1829-1831	Joseph and Faraday discover that electricity can be produced by magnetism.
1860s	Dynamos, devices for generating electricity by moving wire coils in a magnetic field, are developed.
1881	Thomas Edison builds his steam-engine-driven dynamo for the 1881 Paris Electrical Exposition with the goal of providing an electrical distribution system to bring lighting into the home.
1882	Edison begins commercial operation of an electric power plant, in New York City. 26 days later, he begins operation of his first hydroelectric power plant, which uses water to rotate the blades of a turbine. This plant supplies power to two mills and one home.
1903	First electric power plant that uses a steam turbine, in which steam rotates the blades on a wheel, begins operation in Chicago.
1932	Construction begins on Hoover Dam, a giant hydroelectric project.
1933	Tennessee Valley Authority (TVA) is established.
1935	President Franklin Delano Roosevelt orders creation of cooperatives ("co-ops") that bring electricity to millions of rural Americans.
1942	Grand Coulee Dam on the Columbia River is completed.
1942	There are 800 rural electric cooperatives with 350,000 miles of lines.
1958	First US commercial central electric-generating station to use nuclear energy begins operation in Pennsylvania.

ACHIEVEMENT #4:
Agricultural Mechanization

Teacher's Guide

Introduction



One of the great technical challenges of all time was learning to make and power machinery that would ease the burden for farmers. For centuries, farmers worked the fields with horse or ox-drawn plows, hand tools for planting and reaping, or just their hands. From sun up to sun down, it was backbreaking labor with little time for fun. Kids didn't have much time for fun, either.

Early tractors were powered by heavy and cumbersome steam engines – an improvement over animal and human power. The invention of the internal combustion engine marked the beginning of modernization of farms. It was a lighter, more powerful engine – and enabled engineers and inventors to develop all sorts of farm machinery. There was no limit to their creative ideas!

Farmers grew more crops with less hard work. In 1900 it took four farmers to feed 10 people. Today, one farmer can produce enough food to feed 130 people. Early in the century, 75% of the American people were farmers. As mechanization of farms increased, people were free from many of the time-consuming household chores required to feed and care for a large family and hired hands. For centuries, farms were handed down from generation to generation. More people were available to work in professions that advanced technology and modernized the world.

Lesson Focus: innovation and invention

Lesson Synopsis:

Students brainstorm an invention to solve a classroom problem, conduct a survey, and create an invention or innovation to solve a problem identified in the survey.

Related National Science Education Standards:

Content Standard E (Science and Technology):

As a result of activities in grades 5-8, all students should develop Understandings About Science and Technology. Fundamental concepts and principles that underlie this standard include:

- Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations.

Related Benchmarks from Benchmarks for Science Literacy:

Section 3C (Issues in Technology):

By the end of 5th grade, students should know that:

- An invention is likely to lead to other inventions. Once an invention exists, people are likely to think up ways of using it that were never imagined at first.
- Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems.

By the end of 8th grade, students should know that:

- Technology … is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live.

Section 8A (Agriculture):

By the end of 8th grade, students should know that:

- With improved technology, only a small fraction of workers in the United States actually plant and harvest the products that people use.

Section 10J (Harnessing Power):

By the end of 8th grade, students should know that:

- The steam engine was invented to solve the urgent problem of pumping water out of coal mines. As improved by James Watt, it was soon used to move coal, drive manufacturing machinery, and power locomotives, ships, and even the first automobiles.

Section 12D (Communication Skills):

By the end of the 8th grade, students should be able to:

- Locate information in reference books, back issues of newspapers and magazines, compact discs, and computer databases.

Related National Standards for Technological Literacy:

Standard 1: In order to comprehend the scope of technology, students in grades 6-8 should learn that:

- ♦ Technology is closely linked to creativity, which has resulted in innovation.

Standard 6: In order to be realize the impact of society on technology, students in grades 6-8 should learn that:

- ♦ The use of inventions and innovations has led to changes in society and the creation of new needs and wants.

Standard 10: In order to be able to comprehend other problem-solving approaches, students in grades 6-8 should learn that:

- ♦ Invention is a process of turning ideas and imagination into devices and systems. Innovation is the process of modifying an existing product or system to improve it.

Glossary:

invention The process of turning ideas and imagination into devices and systems. The term invention is also used to refer to the products of the processes of invention and innovation.

innovation The process of modifying an existing product or system to improve it.

prototype A trial working model of a design that is built to test design decisions and identify potential problems.

patent A grant issued by the US Government giving inventors the right to exclude all others from making, using, or selling their inventions within the US, its territories, and possessions

trademark A word, name, symbol, design, combination of word and design, or slogan used by a manufacturer or merchant to identify its goods or services and distinguish them from those manufactured or sold by others.

copyright Copyright protection means that permission must be granted by the copyright holder to allow reproduction, distribution, performance, or display of the author's original work. Copyright covers the expression of ideas but not the idea itself.

Important Concepts:

- ♦ Farm mechanization has dramatically decreased the human labor involved in agriculture, resulting in a shift from rural to urban life and providing people with a wider variety of career choices.
- ♦ Innovation in agricultural mechanization has incorporated engineering achievements such as the gasoline engine to improve the usefulness of farm machinery.

Materials for Each Inquiry Team:

- Copies of the Invention Idea Survey Form
- Inventor's Log for each student
- Materials for creating drawings and design prototypes

Safety Precautions: Prior to construction of prototypes, remind students of basic safety rules for the use of construction tools and materials, as appropriate.

Procedure:

Engagement:

If you have not shown the video to the class, you may do so and then proceed with the Exploration activity. If you have already shown the video, you may want to use the activity **"Practicing Inventive Thinking with Your Class"** as an Engagement activity.

"Practicing Inventive Thinking with Your Class"
(Activity 3 from The Inventive Thinking Curriculum Project)

Before your students begin to find their own problems and create unique inventions or innovations to solve them, you can assist them by taking them through some of the steps as a group. Solving a "class" problem and creating a "class" invention will help students learn the process and make it easier for them to work on their own invention projects.

Identifying a Problem:

1. Let the class list problems in their own classroom that need solving. Use a "brainstorming" technique. (Perhaps some of your students never have a pencil ready when it is time to do an assignment, because it is either missing or broken.)

2. Select one problem for the class to solve using the following steps:
    a. Find several problems.
    b. Select one to work on.
    c. Analyze the situation.
    d. Think of many, varied, and unusual ways of solving the problem.

3. List the possible solutions. (Be sure to allow even the silliest possible solution, as creative thinking must have a positive, accepting environment in order to flourish.)

Deciding on a Solution:

1. Select one or more possible solutions to work on. (You may want to divide into groups if the class elects to work on several of the ideas.)

2. Improve and refine the idea(s).

3. Share the class or individual solution(s)/invention(s) for solving the class problem.

Exploration:
Have students use the **"Invention Idea Survey Form"** to survey their class, another class, parents, etc. to obtain a list of problems for potential consideration.

Explanation, and Extension:
Have students read the handout and examine the Timeline to infer the importance of both invention and innovation in agricultural mechanization. As an Engineering Challenge, have them work in groups to select a problem and design and construct an invention/innovation to solve the problem.

Evaluation:
Hold an Invention Convention or Invention Fair for students to display and demonstrate their inventions/innovations.

Ideas for Further Exploration:

1. Have students add events to the timeline or research inventors or inventions listed on the timeline.
2. Have students research the events that influenced particular inventors to invent particular products.
3. Have students explore information on patents, trademarks, and copyrights.
4. Encourage students to participate in the Craftsman/NSTA Young Inventors Awards Program. (See http://www.nsta.org/programs/craftsman.asp for details.)

References:

- **The History of Tractors**, an online exhibit at: http://www.ssbtractor.com/features/index.html
- **The Invention Dimension**, website sponsored by MIT, highlights a different American inventor every week with a biographical sketch covering his or her accomplishments and their impact on society. Online at http://web.mit.edu/invent/
- **The Inventive Thinking Curriculum Project**, a 64-page document produced as an outreach program of the United States Patent and Trademark Office, available online at: http://www.uspto.gov/web/offices/ac/ahrpa/opa/projxl/invthink/invthink.htm

ACHIEVEMENT #4:

Agricultural Mechanization

Student Handout

Invention Idea Survey Form

One of the best ways to collect ideas for developing an innovation or an invention is to take a survey. Try to interview a variety of people of all different ages and occupations. (The more people you talk to, the more ideas you will get.) The following list of questions may help you:

1. What product does not work as well as you would like it to work?

2. What job(s) would you like to see solved?

3. What problem(s) would you like to see solved or made easier?

4. If you could invent something to make your life easier, what would you invent?

5. What is the most annoying problem you experience

at home? ____

at school?____

at work? ____

in an airport? ____

on the road? ____

at the grocery store? ____

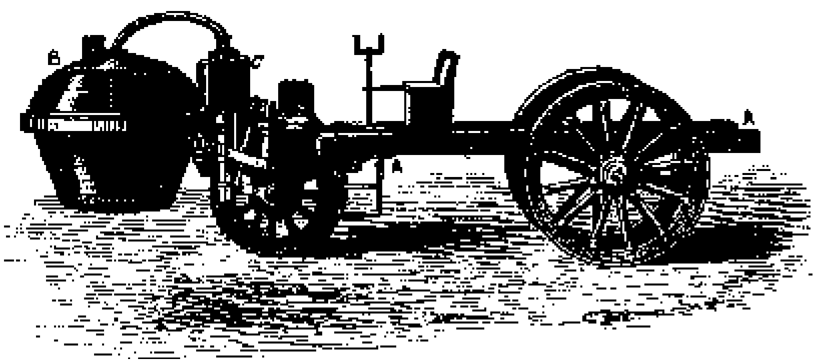
at the bank? ____

at the shopping mall? ____

Who Invented the Tractor?

Between 1900 and 1950, the number of tractors in use on US farms rose from about 500 to over 3 million. This rapid shift from manual labor and animal power has tremendously affected our choices about the jobs we choose and where we live. More than any other farm machine, the tractor deserves the greatest credit for this change.

Carefully review the Timeline on the next page. There you will find the dates of many events in the history of the development of the modern farm tractor. You might think it would be easy to determine who actually invented the tractor, but what exactly do we mean by "tractor" – the gasoline-engine farm tractor? In 1769 a Frenchman named Nicholas Cugnot built a three-wheeled road vehicle powered by a "steam traction engine" and to some people's thinking this was the world's first "tractor" (**and** the first road vehicle). However, Cugnot's Steam Carriage (or Steam Tractor) was driven on roads and used to haul cannons, rather than being used in agriculture.



Cugnot's Steam Tractor (1769)

Invention and Innovation:

Invention refers to the process of turning ideas and imagination into devices and systems, while **innovation** refers to the process of modifying an existing product or system to improve it. (The term invention is also used to refer to the products of the processes of invention and innovation.) Comparing Cugnot's steam tractor to a modern farm tractor, you can see how new innovations over time led to a product that is radically different from the initial one, although still having recognizable similarities.

Student Handout (continued)

Timeline of Important Events Related to Agricultural Mechanization:

1705	Thomas Newcomen develops a steam engine used to pump water from coalmines.
1763	James Watt develops important innovations on the Newcomen engine, allowing the Watt steam engine to be used to operate factory machinery.
1790	George Washington signs a bill establishing the US Patent and Trademark Office.
1831	Cyrus McCormick, at age 22, designs and builds first machine (the horse-drawn reaper) used to harvest (reap) grain, such as oats, barley, and wheat.
1849	First portable steam engine for farming use developed.
1862	Nikolaus Otto develops the internal combustion engine (gasoline engine).
1892	First record of a successful gasoline-engine tractor. Case begins production of the Case farm tractor, powered by a steam traction engine.
1893	Rudolf Diesel patents the principle for the diesel engine.
1904	Benjamin Holt develops his gasoline-powered tractor.
1907	Henry Ford builds his first experimental tractor. Estimates are that only about 600 tractors were in use on US farms at this time.
1911	Case's steam-engine production peaks when the company also produces its first gasoline-powered tractor.
1916	Ford Motor Company begins production of the Fordson tractor.
1925	Benjamin Holt merges with Best Tractor to form Caterpillar Tractor Company.
1948	Frank Zybach invents the center-pivot irrigation machine, revolutionizing irrigation technology.
1949	John and Mack Rust develop the first mechanical cotton picker.
1950	An estimated 3,400,000 tractors in use on US farms.
1956	Rollover bars made available on tractors to reduce fatal injuries.

Engineering Challenge: Invent a Product that Solves a Problem

Selecting a problem and Evaluating Potential Solutions:

Select one of the problems identified in your survey and brainstorm possible solutions in your Inventor's Log. Evaluate the possible solutions by considering the following questions:

1. Is my idea practical?
2. Can it be made easily?
3. Is it as simple as possible?
4. Is it safe?
5. Will it cost too much to make or use?
6. Is my idea really new (an invention) or is it a modification of an existing product (an innovation)?
7. Will it withstand use, or will it break easily?
8. Is my idea similar to something else?
9. Will people really use my invention/innovation? (Survey your classmates or the people in your neighborhood to document the need for and potential usefulness of your idea.)

Producing Your Invention/Innovation:

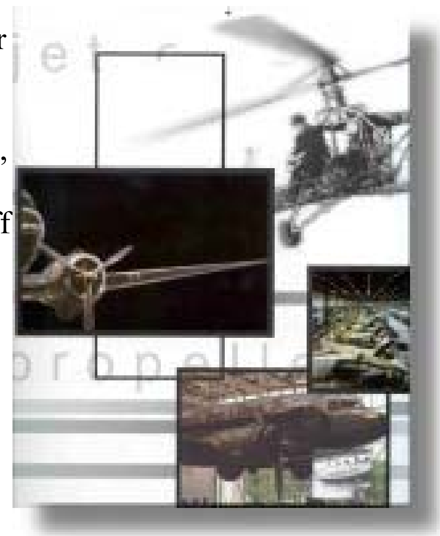
1. Give your invention/innovation a name.
2. List the materials needed to illustrate your invention/innovation and to make a model of it. (You will need paper, pencil, and crayons or markers to draw your invention. You might use cardboard, paper, clay, wood, plastic, yarn, paper clips, etc. to make a model.)
3. List, in order, the steps for completing your invention/innovation.
4. Think of the possible problems that might occur. How would you solve them?
5. Complete a "prototype" (working model) of your invention/innovation. (In some cases, a non-functioning scale model or design drawings may be substituted for a working model. Check with your teacher before proceeding.)

ACHIEVEMENT #5:

The Airplane

Teacher's Guide

Introduction



Flight was a challenge that caused people to try anything to get in the air – and stay there. Early pioneers studied birds – their wing shapes, how they took off and landed. There were many ingenious attempts to achieve the basic elements of flight -- thrust, lift, sustaining momentum, and landing – safely. Finally, traveling by air evolved from gliders to piston engines, and the airplane was no longer seen merely as a show-off attraction at county fares.

Two engineers revolutionized the aviation industry by inventing the jet engine - in England, Sir Frank Whittle, and, across the Channel in Germany, Hans von Ohain. These men discovered a radically different way to propel aircraft. Unprecedented speeds were possible. Increases in engine size and power helped to lower the operating cost per plane. Eventually making travel affordable for all.

At the beginning of the century hardly anyone went to Europe except the wealthy, and if they did it took 7 to 10 days by ship. Now, people travel all over the world in a matter of hours. And soon, we all could be spending summer vacations at space stations – simply because engineers searched for ways to make engines go faster!

Lesson Focus: Solving the Mysteries of Mechanical Flight

Lesson Synopsis: Students demonstrate the Bernoulli Principle, review the influences that affected the Wright Brothers, and make and modify paper airplanes.

Related National Science Education Standards:

Content Standard B (Physical Science):

As a result of their activities in grades 5-8, all students should develop an understanding of Motions and Forces. Fundamental concepts and principles that underlie this standard include:

- ♦ Unbalanced forces will cause changes in the speed or direction of an object's motion.

Related Benchmarks from Benchmarks for Science Literacy:

Section 3C (Issues in Technology):

By the end of 5th grade, students should know that:

- ♦ Once an invention exists, people are likely to think up ways of using it that were never imagined at first.
- ♦ Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems.

By the end of 8th grade, students should know that:

- ♦ Technology … is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live.

Related Standards for Technological Literacy:

Standard 3 (Relationships Among Technologies and Connections Between Technology and Other Fields):

In order to appreciate the relationships among technologies and other fields of study, students in grades 6-8 should learn that:

- ♦ A product, system, or environment developed for one setting may be applied to another setting.
- ♦ Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.

Glossary:

aeronautics The science of flight. Scientists and engineers who study aeronautics learn about how and why airplanes fly.

aerodynamics A field of fluid dynamics that studies how gases, including air, flow and how forces act upon objects moving through air.

Bernoulli's Principle The principle that increasing the velocity of a fluid (including air) decreases its pressure. Explains how wing shape and position is important in generating lift.

drag The air resistance encountered by a moving object. Drag is one of the four forces acting on an airplane, the others being lift, thrust and weight.

lift The lifting force on a flying object (in particular, a wing or an aircraft), due to its motion relative to the surrounding air.

thrust The force acting on a rocket or an airplane, produced by the action of its motor and pulling it forward.

weight The force exerted on mass by gravity.

opposing forces Forces that are pushing or pulling in the opposite direction. For example, lift is perpendicular to the airflow around an aircraft. If the aircraft is flying straight and level, the lift force (which is pulling up) will be opposing the weight force (which is pulling the aircraft toward the earth).

Important Concepts:

- There are four forces that act upon airplanes to influence their flight.
- Innovation involves creativity and may involve applying knowledge from a wide variety of fields.

Materials for Each Inquiry Team for Engagement Activity:

Newspaper
Scissors
Ruler
Copy Paper

Materials for each Engineering Team for Engineering Challenge:

Copy paper
Tape
Scissors
Paper clips
Glue
Ruler
Other types/sizes of paper

Safety Precautions:

Because a pointed paper airplane is a projectile, protective eyewear should be used during testing.

Procedure:

Engagement: Have students follow the directions in the Student Handout to demonstrate the Bernoulli Principle and to create a Ring Wing Glider.

Exploration, Explanation: Have students read the information on the Wright Brothers and explore the Timeline.

Extension: Have students do the Engineering Challenge.

Evaluation: Ask students to draw a sketch of their glider design and mark on the drawing the 4 forces that affect its flight, showing the directions of the forces.

Ideas for Further Exploration:

- Have students build kites and research their historical significance.
- Have students research the biographies of other important figures in the history of aeronautics and aviation.
- Have students research current issues related to the airplane, such as the need for upgrading of the Air Traffic Control System.

References:

- **Exploring Aeronautics**, a CD available for $5 from NASA. For details, see the website at: http://exploringaerospace.arc.nasa.gov/
- **What is Aeronautics?**, background information from NASA, online at: http://quest.arc.nasa.gov/aero/background/
- **757 Glider Kit**, downloadable file at http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Technology/Models/757.Glider.Kit/.index.html
- **Innovation Through Engineering**, downloadable poster and 3 activities, available at: http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Mathematics/Innovation.Through.Engineering/.index.html
- **The Process of Invention** (source of the reading material on the Wright Brothers), downloadable poster with an activity and background information, available at: http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/The.Process.of.Invention/.index.html
- **Aeronautics and Aerospace Teaching Resources**, online at: http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Physical.Science/Aeronautics.and.Aerospace/.index.html
- **NASA Paper Airplane Activity**, online at: http://www.grc.nasa.gov/WWW/K-12/aerosim/LessonHS97/paperairplaneac.html
- **Simple Paper Airplane Design**, the source of the basic design used in the Engineering Challenge, online at: http://edu.larc.nasa.gov/fdprint/a9.html

ACHIEVEMENT #5:

The Airplane

Student Handout

How do Airplanes Fly?
To begin to understand how airplanes are able to fly, try these simple experiments:

Materials for Each Inquiry Team:

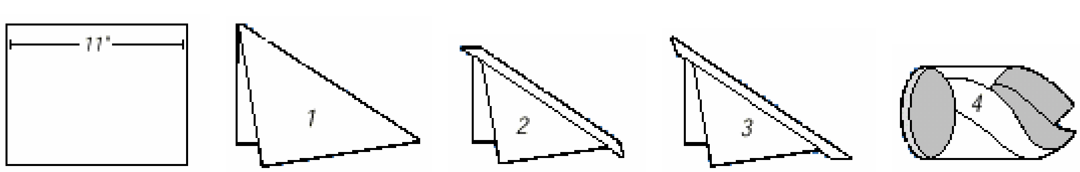
- Newspaper
- Scissors
- Ruler

1. Cut a piece of newspaper about 1 inch wide and 6 inches long. Hold one end against your lower lip and let the other end hang down. Now blow. What happens? Try blowing harder or more softly and note what happens.
2. Cut a sheet of newspaper into 2 pieces about the size of a sheet of notebook paper. Hold the 2 sheets about 2 inches apart. Now blow between them. What happens?

What's going on here? Flowing air has less pressure than still air. This is an extension of what Daniel Bernoulli discovered in studying water flow and is important in aeronautics. Because you blew across the top of your strip of newspaper, the air under the paper was pushing up harder than the air above was pushing down and so the paper moved up. When you blew between the 2 sheets of newspaper, the moving air did not press against the paper as hard as the still air on either side, so the sheets were pushed together by the still air. Aeronautical engineers apply their knowledge of the Bernoulli Principle in the design of aircraft, especially wings.

Make a Simple Ring Wing Glider

1. Fold a sheet of lightweight paper diagonally as shown below in step 1.
2. Make a ½ inch fold along the previously folded edge.
3. Make a second ½ inch fold along that edge.
4. Curl the ends of the paper to make a ring and tuck one end into the fold of the other.
5. Gently grasp the V between the 2 "crown points" and toss the glider lightly forward.



Solving the Mysteries of Flight the Wright Way

Why were the Wright Brothers successful in their engineering of the airplane? As you read some of the following information about the Wright Brothers, look for clues to their success and for experiences that influenced them. Make a list of these as you read.

The Flying Toy

Wilbur (1867-1912) and Orville Wright (1871-1948) were brothers. They lived in Dayton, Ohio, at 7 Hawthorn Street. Their older brothers were Reuchlin and Lorin. Katharine was their younger sister. Their father, Milton, was a bishop in the Church of the United Brethren in Christ. Their mother, Susan, the daughter of a wagon maker, made toys for her children and encouraged their curiosity. One day, Bishop Wright brought home a small toy "helicopter" made of wood with two twisted rubber bands to turn a small propeller. Wilbur and Orville played with it until it broke then made new copies of the toy themselves. They also sold toys to their friends, including handmade kites. The Wright brothers did things together from the time they were small boys.

The Bicycle Business

The Wright brothers went into the printing business together in 1889. Three years later, they opened their first bicycle shop. Initially, they sold and repaired bicycles. They would replace spokes, fix broken chains, and sell accessories. In 1896, they began to build their own brand of bicycles. The Wright brothers' experiences with bicycles aided them in their investigations of flight. They used the technology they learned from their bicycle business in their airplanes: chains, sprockets, spoke wires, ball bearings, and wheel hubs. Their thoughts on balancing and controlling their aircraft were also rooted in their experience as cyclists.

The Search for Control

Orville and Wilbur Wright were convinced of the need to control an aircraft in three axes of motion. An elevator, or horizontal control surface, in front of the wings on their aircraft, enabled the pilot to control climb and descent (pitch axis). The elevator was controlled by a lever in the pilot's left hand. A "wingwarping" system controlled the aircraft in a roll (roll axis). To initiate a roll, the pilot would shift his hips from side to side in a cradle on the lower wing, "twisting" the wings left or right or restoring them to level flight. Orville and Wilbur developed this idea from observing birds in flight. They observed the buzzards keeping their balance by twisting their wings and sometimes curving one wing more than the other. In 1902, the brothers added a vertical rudder to the rear of their machine to control the left and right motion of the nose of the aircraft (yaw axis).

The Kite/Glider Experiments

The Wright brothers began their aeronautical research in 1899. Their first aircraft was a small kite with a five-foot wingspan that was used to test their notions of aircraft control. In 1900, they built their first machine designed to carry a pilot and chose Kitty Hawk, NC, as a suitable testing ground. With its strong steady winds, open areas, and tall sandy dunes, the area was perfect for their experiments. When their 1900 aircraft produced less lift than expected, the Wright brothers flew it as a kite and gathered information that would enable them to design improved machines. They returned to Kitty Hawk in 1901 with a new glider that did not perform as they expected. While they had learned a great deal with their first two machines, they had also encountered new puzzles and dangers.

The Wind Tunnel

To simulate flight conditions, the Wrights tested small model wings in a wind tunnel they had built. The wind tunnel was a box with a fan at one end that blew a steady stream of air over model wings mounted on a special "balance" inside the tunnel. Using this device, the brothers were able to gather information that could be used to design the wings of the gliders and powered aircraft that would carry them into the air. The wind tunnel provided them with information on the most satisfactory wing shape. It also enabled them to calculate the size of wing that would be required to lift them into the air, the performance of their propellers, and the amount of power that their engine would have to produce. They based the design of their next glider on this information.

Controlling the Aircraft

During the 1901 glider tests, the Wright brothers had discovered that "wingwarping" created unequal drag on the two wings. Key to solving the control problem was the addition of a rudder to the glider design in 1902. They developed a direct linkage between the rudder and warping system. With the success of this system design, the Wrights were ready to move onto a powered aircraft.

The Solution

At Kill Devil Hills, NC, at 10:35 am, the Wright 1903 Flyer took off under its own power with Orville as the pilot. It flew 12 seconds and went a distance of 37 meters. Orville and Wilbur took turns making three more flights that morning. Wilbur was at the controls for the fourth and longest flight, traveling 260 meters in 59 seconds. The Wright 1903 Flyer became the first powered, heaver-than-air machine to achieve controlled, sustained flight with a pilot aboard. Today, this amazing flying invention can be viewed as it is suspended overhead, at the National Air and Space Museum in Washington, DC. (www.nasm.edu/nasm/nasmexh.html)

The Wright 1904 Flyer

Having achieved success in North Carolina, the Wright brothers decided to continue their experiments closer to home. They built and flew their second powered airplane at Huffman Prairie, a pasture eight miles east of Dayton, Ohio. Progress was slow without the strong, steady winds of Kitty Hawk, but the brothers did achieve the first circular flight of an airplane on September 20, 1904. This first complete circle flight lasted only 1 minute 36 seconds and covered 1,244 meters. Stability problems still plagued the Wright brothers' invention. The modifications made during 1904 helped but did not solve the stability problem.

The Wright 1905 Flyer

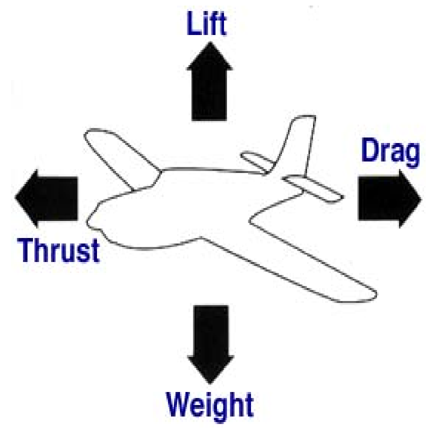
This Flyer was the world's first practical airplane. During more than 40 flights at Huffman Prairie, the machine was repeatedly banked, turned, circled, and flown in figure eights. On two occasions the flight exceeded half an hour. Wilbur and Orville Wright, brilliant self-trained engineers, had overcome complex technical problems that had barred the way to mechanical flight for centuries.

As you look at the Timeline, think about how the Wright Brothers' invention has changed our world!

Timeline of Events:

1738	Daniel Bernoulli publishes a book on "hydrodynamics", in which he presents the results of his study of fluids. These principles are later applied to "aerodynamics".
1889	Lilienthal publishes **The Flight of Birds as a Basis of Aviation**.
1891	Lilienthal builds and flies the first truly successful glider in history. Gradually modifying his design, he makes over 2000 flights in the next five years.
1892	Australian Lawrence Hargrave invents the box kite.
1894	**Progress in Flying Machines** published by Octave Chanute, an American civil engineer. He begins corresponding with the Wright Brothers.
1896	Samuel Pierpont Langley's 30-pound unmanned tandem-wing craft, employing a lightweight steam engine for propulsion, flies 4,200 feet at about 30 mph.
1899	Wilbur Wright notices that buzzards in flight adjust the shape and position of their wings. When he twists a long box used to ship a bicycle tube and observes how its shape changes, he decides to try using control lines to twist the wings on a biplane kite. He discovers that "wing warping" allows him to control the kite's direction.
1901	Langley builds a gasoline-powered version of his tandem-winged model, the first gasoline engine used to propel an aircraft, and launches large unmanned steam-powered models on many successful flights.
1901	Wilbur Wright is invited by Chanute to give a speech, entitled "Some Aeronautical Experiments", to the Western Society of Engineers.
1901	The Wright Brothers build a small wind tunnel and create delicate balances to measure the lift and drag for 200 different miniature wings of different shapes.
1903	Langley nearly drowns after he tries to fly a catapult-launched full-size version of his aircraft.
1903	Eight days after Langley's crash, the Wright Brothers **Flyer** makes the first successful manned and powered flight, after 4 years of testing and over 1000 successful glider flights. Their first flight lasted only 12 seconds, and they traveled only 120 feet.
1914-18	World War I encourages rapid development in aviation.
1920	Donald Douglas starts manufacturing airplanes.
1927	Charles Lindbergh becomes first person to cross the Atlantic solo and nonstop.
1937	Sir Frank Whittle in England and Hans von Ohain in Germany construct the first turbojet propulsion engines.
1947	Air Force established.
1947	First airplane to break the sound barrier (700mph), flown by USAF Capt Charles E Yeager
1970	The DC-10, the first "jumbo jet" from Douglas, makes its first flight.
1994	First computer-designed commercial aircraft, Boeing 777-200.

What Forces Act on an Airplane?



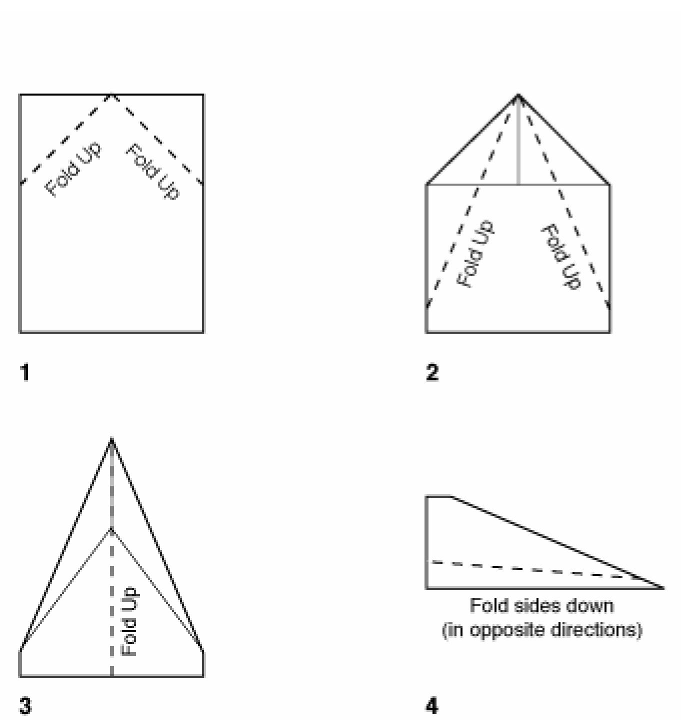
There are 4 forces that act on an airplane, **lift** (an upward push), **weight** (a downward push), **thrust** (a forward push), and **drag** (a backward push). It is the combination of all these forces that determines how the plane moves.

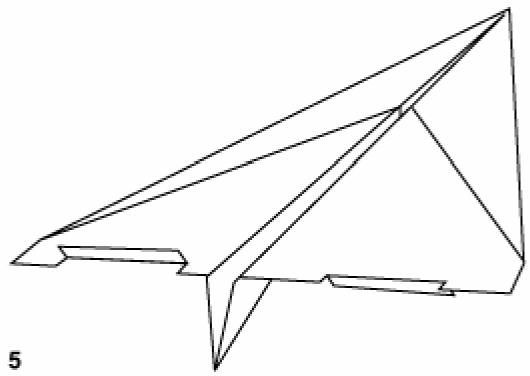
Engineering Challenge:
Making and Improving an Experimental Glider

Materials for each Engineering Team:

Copy paper
Tape
Scissors
Paper clips
Glue
Ruler
Other types/sizes of paper

Folding Instructions for the Basic Glider, using 1 sheet of copy paper:

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Testing Your Glider

Using protective eyewear, test the basic design in terms of how far it flies (distance), how long it flies (time aloft), and how straight it flies.

Modifying Your Glider: Things to Try

1. Change the size of the wings, either by folding differently or by cutting.

2. Add a flap to the back of each wing by making 2 small cuts and then bending the flap up or down. (Be sure the flap on one side matches the one on the other, or see if that matters.) By varying the distance between the cuts and the length of the cuts, you can try different size flaps.

3. Add a flap (rudder) to the tail. Try different rudder sizes and positions.

4. Try using paper clips to add weight to different areas of the body of the plane.

5. Try a larger or smaller **scale** version. (To do this, you will need to cut a piece of paper so that the ratio of its width to its length is 8 1/2 to 11, just as for the copy paper. An easy way to test smaller sizes would be to draw a black line around the edge of the paper and then to photocopy it at a reduced size and cut along the lines.)

6. Try using a different paper type.

7. Make a crease near the end of the wings and bend the tips up or down.

8. Cut off a "point" (on the nose, wings, or tail).

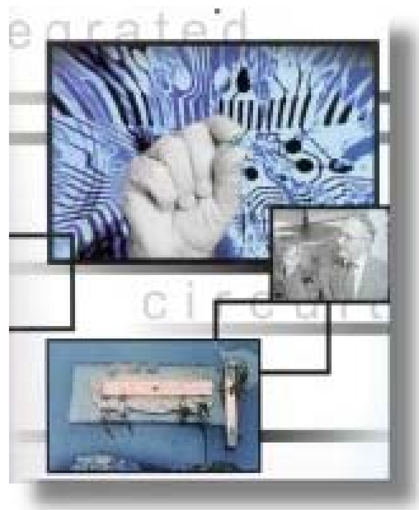
9. Try using a different paper size or shape – square, wider than long, long and narrow, so that the new model is not to scale.

ACHIEVEMENT #6:

Integrated Circuit

Teacher's Guide

Introduction



Integrated circuits are tiny chips with all the instructions needed to run electronic games, video cameras, touch-tone phones, calculators, microwave ovens and much more.
Jack Kilby and Robert Noyce independently invented the integrated circuit. Once people realized how important it would be, engineers had to find a way to mass-produce it. They experimented with different materials – always searching for the best material, and the most economical methods.

Mass production made the microchip affordable. Once, you could only find machines for writing and calculating in an office. You had to go to the library to research a report for school. Now most people can do all of this work from home or school on a computer.

Microchips also made products smaller. Compare this CD Player to the radios of the 30s. This calculator to an old adding machine. This laptop to an early computer which would be the size of room. The smaller things get, the more power they have. All of this from this little chip.

Lesson Focus: Smart Appliances

Lesson Synopsis: Students brainstorm microchip-containing products in their home, review the history of the invention and application of microchips, and design and create an ad for a new smart appliance.

Related National Science Education Standards:

Content Standard E (Science and Technology):

As a result of activities in grades 5-8, all students should develop Abilities of Technological Design, including the ability to

- Identify Appropriate Problems for Technological Design,
- Design a Solution or Product,
- Implement a Proposed Design,
- Evaluate Completed Technological Designs and Products, and
- Communicate the Process of Technological Design.

Related Benchmarks from Benchmarks for Science Literacy:

Section 3C (Issues in Technology):

By the end of 5th grade, students should know that:

- Once an invention exists, people are likely to think up ways of using it that were never imagined at first.
- Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems.

By the end of 8th grade, students should know that:

- Technology … is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live.

Related Standards for Technological Literacy:

Standard 1 (Characteristics and Scope of Technology):

In order to comprehend the scope of technology, students in grades 6-8 should learn that:

- New products and systems can be developed to solve problems or to do things that could not be done without the help of technology.
- The development of technology is a human activity and is the result of individual or collective needs and the ability to be creative.
- Technology is closely linked to creativity, which has resulted in innovation.
- Corporations can often create demand for a product by bringing it onto the market and advertising it.

Glossary:

integrated circuit An electronic circuit of transistors etched onto a small piece of silicon. Commonly referred to as a **microchip**, a **chip**, or a **silicon chip**.

transistors Invented to replace vacuum tubes, can now be etched onto small chips of silicon to create integrated circuits.

microprocessor An integrated circuit that contains thousands, or even millions, of transistors that work together to store and manipulate data so that the microprocessor can perform a wide variety of useful functions.

semiconductor A substance that conducts electricity better than an insulator but not as well as a conductor. Silicon is a semiconductor used to make microchips.

Important Concepts:

- The invention and mass production of integrated circuits has allowed the invention of numerous small, relatively inexpensive, energy efficient electronic devices.
- Appliances containing embedded microchips can react to stimuli, communicate with other such appliances, or connect to the Internet.

Materials for Each Design Team:

- Posterboard
- Markers
- Pens

Safety Precautions: no special precautions are needed

Procedure:

Engagement: Pass out the Student Handout and have them brainstorm all the microchip-containing products in their homes.

Exploration and Explanation: Have students read the handout and explore the Timeline.

Extension: Divide the class into design teams and have each design a new smart appliance. Provide them with materials to create an ad for the product.

Evaluation: Have students give examples of how home appliances that were available before 1958 are different from those available today and relate these differences to the invention of integrated circuits.

Ideas for Further Exploration:

- Have students research the biographies of key figures listed on the Timeline.
- Have students research how microchips are manufactured.

ACHIEVEMENT #6:

Integrated Circuit

Student Handout

How Many Microchips Do You Own?

In 1958, Jack Kilby and Robert Noyce independently invented the integrated circuit, now commonly called the microchip. How many microchips do you have in your home? You may think that you don't have any unless you own a PC, but it is estimated that there are 40-50 microchips in the average American home in addition to the 10 or so in a typical PC!

Microchips are the "brains" of electronic gadgets ranging from smoke detectors to VCRs to garage-door openers to cordless phones. They are even being implanted in dogs as an electronic ID. Brainstorm a list of the microchip-containing products in your home. Don't forget your digital watch, your calculator, or your electronic games.

History of Microchips

In electronic devices, components called **transistors** are connected into circuits. Before the microchip, transistors were no smaller than the eraser on the end of a pencil. The more transistors used, the bigger the size of the completed circuits. This limited how small and how inexpensive electronic products could be.

In 1958, Kilby and Noyce both invented a way to etch transistors onto the surface of a chip of **semiconductor** material. (A semiconductor conducts electricity better than an insulator does, but not as well as a conductor.) Kilby used germanium and Noyce used silicon. The first microchips were made individually. Mass production and the development of precision manufacturing techniques were needed to make the microchip affordable. Soon, microchip-manufacturing plants sprang up in an area of California near the Intel Corporation that became known as the **Silicon Valley**.

Microchips are a great invention, but they can only do what they were designed to do. In 1971, a young (34 years old) scientist at Intel, Ted Hoff, created a chip that was actually a mini-computer. It was only a 1/8" by 1/16" piece of silicon, but it had 2300 transistors etched into it and was more powerful than the first computer ever built. Hoff's invention is now called a **microprocessor**.

Today, nearly 5 billion chips are manufactured in the US each year. Because they are so small, they must be manufactured in special Clean Rooms, where even tiny particles are filtered out of the air, and where workers wear special suits that make them look like astronauts.

Examine the Timeline to discover how quickly and in how many different ways these inventions have had an impact on our lives.

Student Handout (continued)

Timeline of Events Related to Achievement #6:

1934	Electronic hearing aid invented (connected to a unit worn on your belt).
1947	Researchers at Bell Telephone Laboratories invent the transistor.
1954	The transistor radio is introduced and becomes the largest selling item of the time.
1958	Jack Kilby of Texas Instruments and Robert Noyce (who later founds Intel) invent the integrated circuit.
1958	Seymour Cray at Control Data Corp. develops a transistorized computer.
1967	First handheld calculator using an integrated circuit is designed by Jack Kilby and made by Texas Instruments.
1970	The bar code system is created.
1971	Ted Hoff of Intel invents the microprocessor. Beginning of Intel's famous line of 386, 486, and Pentium processors.
1971	First video game and videodisc introduced.
1974	The Altair, first desktop computer designed for personal use, sold as a kit.
1979	Mattel Toy Company receives its 1 millionth chip for electronic games.
1980s	Integrated circuits applied to computers.
1984	Compact disc (CD) player introduced.
1984	First CD-ROM (compact-disc read-only memory) is available.
1995	GE releases its first “smart dishwasher”, which senses dirtiness of dishes.
2000	Sunbeam, General Electric, Maytag announce plans to work with Microsoft to develop “smart appliances”.
2000	GE unveils plans for a “smart microwave” that will read the UPC on a product and set its timing accordingly.
2001	Carrier and IBM create program that allows people to adjust their home air conditioner settings via their cell phone or their computer at work.

Smart Appliances

Although nearly 5 billion microchips are sold each year, only about 2 percent of these end up in computers. The rest are used in other products, including home appliances.
How smart are your home appliances? Do you have a breadmaker that signals you when the bread is done? What about a smoke detector that beeps to remind you when its batteries need to be changed? What about an iron that shuts itself off after several minutes if you forget to?

According to appliance manufacturers, consumers can expect that appliances will be getting smarter and smarter, being designed to react to stimuli, to communicate with each other, and even to connect to the Internet. Carrier already has a program in some places in Europe that allows users to communicate via their cell phones or office computers with their home air conditioning system. Imagine being able to call your air conditioner and tell it to raise or lower the temperature in your home!

What does the future hold in store? What would you like your refrigerator to be able to do? Call a serviceman when it needs repair? Order more eggs and milk when you run low? Offer you recipes downloaded from the Internet? The technology exists to create a refrigerator with any or all of these features.

Design Challenge: Design a New Smart Appliance

Select a home appliance, other than a refrigerator. Imagine all the things you might like for that appliance to be able to do. Create an ad to advertise your newly designed smart appliance and be prepared to share your creation with the rest of the class.

Materials for Each Design Team:

- Posterboard
- Markers
- Pens

ACHIEVEMENT #7:

Air Conditioning and Refrigeration

Teacher's Guide

Introduction

For the first half of the century the average family had to buy food on a daily basis. Many foods spoiled quickly and were available only at certain times during the year. Wealthy people could rent food lockers to store frozen fish and meat, and some could even afford commercial systems in their mansions.

While engineers were working out the problems of making smaller refrigerators that everyone could afford, Fred McKinley Jones was working on a way to refrigerate trucks so that foods that spoiled easily could be shipped safely. In 1939 he solved the problem. ThermoKing revolutionized the transportation of food, and other delicate cargo like flowers, film and pharmaceuticals. It helped the frozen food industry grow and led to the supermarket.

Mr. Jones modified his original design for trains, boats and ships. During WWII he made a portable version so that food and blood could be parachuted behind enemy lines. Thanks to Mr. Jones and other mechanical engineers, we can enjoy many foods year-round, and we can store them right in our own homes. More importantly, we can eat "COOL" foods- especially ice cream.

Another problem early in the century was cooling and drying the air. Much of the South was unlivable, because of heat and humidity. Many people sweltered in the hot summers, and many died of heat exhaustion. Engineers like Willis Haviland Carrier changed all that. After many experiments, Mr. Carrier figured out that chilling air with water to condense it could also dry it. His first air conditioner had the cooling power of 108,000 pounds of ice. That's a lot of ice – think how many soft drinks that would chill. The first machines were used to condition air in factories – to improve the quality of products that didn't do well in heat and humidity. – Soon department stores and movie theaters lured customers in by advertising their air conditioning.

Today, we can live, work and play in any climate. We even build indoor ice skating rinks. It is hard to imagine life without cool, comfortable air. All because inquisitive engineers believed that we could live comfortably even in the hottest climates.

Lesson Focus: Energy Efficiency

Lesson Synopsis: Students attempt to delay the melting of an ice cube by insulating it, consider the importance of purchasing energy efficient products, and design a subdivision where home cooling costs are reduced.

Related Benchmarks from Benchmarks for Science Literacy:

Section 3C (Issues in Technology):

By the end of 5^{th} grade, students should know that:

- Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems.

By the end of 8^{th} grade, students should know that:

- Technology … is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live.

Section 4E (Energy Transformations):

By the end of the 5^{th} grade, students should know that:

- Some materials conduct heat much better than others. Poor conductors can reduce heat (transfer) …

Related Standards for Technological Literacy:

Standard 4 (Cultural, Social, Economic and Political Effects of Technology):

In order to recognize the changes in society caused by the use of technology, students in grades 6-8 should learn that:

- Technology, by itself, is neither good nor bad, but decisions about the use of products and systems can result in desirable or undesirable consequences.

Standard 16 (Energy and Power Technologies):

In order to select, use, and understand energy and power technologies, students in grades 6-8 should learn that:

- Much of the energy used in our environment is not used efficiently.

Standard 20 (Construction Technologies):

In order to select, use, and understand construction technologies, students in grades 6-8 should learn that:

- The selection of designs for structures is based on factors such as building laws and codes, style, convenience, cost, climate, and function.

Glossary:

EnergyGuide labels Yellow labels required by law on certain products to provide consumers with information to allow selection of energy efficient products.

sun controls Features which reduce the amount of sunlight entering south-facing windows in the summer.

freon Chlorine-containing gas used as a refrigerant. When released into the stratosphere, the chlorine destroys ozone.

stratospheric ozone A layer of ozone high in the atmosphere that reduces the amount of UV radiation reaching the Earth's surface. Its depletion over the South Pole creates the Ozone Hole.

Important Concepts:

- Refrigeration and air conditioning account for a major fraction of all home energy costs.
- Home energy costs can be reduced by purchasing energy efficient air conditioners and refrigerators, and by reducing the impact of summer heat on indoor temperatures.
- Choices made in the construction and landscaping of new homes can reduce energy costs.

Materials for Ice Cube Challenge:

Materials for Each Inquiry Team:

- 1 ice cube
- Small disposable cup
- Assigned insulation material

Materials for Entire Class:

- 1 ice cube
- Small disposable cup (for setting up a "control")
- Various insulation materials (newspapers, foam chips, corrugated cardboard, fleece fabric, etc.)

Materials for Subdivision Design:

Materials for Each Team of Consultants:

- Posterboard or sheet of newsprint
- Markers and pens
- Graph Paper
- Ruler

Safety Precautions: No special precautions needed.

Procedure:

Engagement: Have students work in teams on the Ice Cube Challenge. Assign a type of insulating material to each group, with at least 2 groups having the same type.

Exploration, Explanation: Have students read the handout and examine the Timeline.

Extension: Have students do the subdivision-design activity Planning to Reduce Home Cooling Costs.

Evaluation: Student posters and presentations may be evaluated for evidence of comprehension of concepts.

Ideas for Further Exploration:

Have students research R factors and their significance.

Have students research landscaping for energy efficiency and improve their subdivision design based on what they learn.

Have students research the causes and potential consequences of ozone depletion.

References:

The Energy Sourcebook (High School Unit), published in 1990 by TVA (out of print). (The activity **Planning to Reduce Home Cooling Costs** is taken from the activity Energy Efficient Structures.)

Energy Saving Landscaping Ideas for the Department of Energy, online at: http://www.eren.doe.gov/consumerinfo/energy_savers/landscaping.html

ACHIEVEMENT #7:

Air Conditioning and Refrigeration

Student Handout

The Ice Cube Challenge

Before the invention of the electric refrigerator, people had "ice boxes" to refrigerate food and large chunks of ice were regularly delivered to homes to replace the ice as it melted.

Materials for Each Inquiry Team:

- 1 ice cube
- Small disposable cup
- Assigned insulation material

Your challenge is to use the material assigned to you to create a package that will insulate your ice cube so that it melts more slowly than those of the other inquiry teams. After all teams have planned their design, get an ice cube from the teacher. After the ice cube that is placed in an empty cup is totally melted, all teams should unwrap their cubes and compare them.

By comparing the results for teams using your same assigned material and for teams using a different material, what can you conclude about how the type of material and the amount of material affect its insulation capacity?

The Development of Air Conditioning and Refrigeration

Engineers propose solutions relating to human problems, needs, and aspirations. Carl von Linde, a locomotive engineer, invented a machine to compress ammonia in order to cool beer vats in Germany, allowing lager beer to be brewed even in the summer. John Gorrie, a medical doctor, invented a machine to make ice because he wanted to be able to cool the wards in a hospital in Florida. Willis Haviland Carrier invented the first air conditioning system because a printer needed a way to control humidity to keep the paper from changing size as he printed one color on top of another.

As you use the Timelines to trace later events, you will see how quickly both air conditioning and refrigeration have become commonplace in the US.

Student Handout (continued)

Unanticipated Environmental Effects

The early developers of air conditioning and refrigeration technologies could not have foreseen two significant problems resulting from the technologies – the amount of energy they consume and the effects of the refrigerant freon on the Stratospheric Ozone layer. Recent innovations have focused on use of alternative refrigerants and on improving energy efficiency.

Why Buy An Energy Efficient Refrigerator?

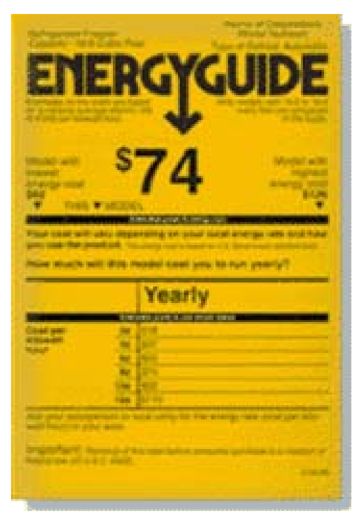
According to the Department of Energy, your refrigerator uses the most electricity of all your kitchen appliances. It can account for as much as 15 percent of a home's total energy usage. (Most of the energy used by a refrigerator is used to pump heat out of the cabinet. A small amount is used to keep the cabinet from sweating, to defrost the refrigerator, and to illuminate the interior.)

The energy bill for a typical new refrigerator, with automatic defrost and top-mounted freezer, will be about $55/year, whereas a typical model sold in 1973 will cost nearly $160/year. If your present refrigerator is more than 15 years old, you'll save money on your electric bills if you replace it with a new, more efficient unit. Although many energy-efficient products may be more expensive to purchase, they will cost less to operate over the lifetime of the appliance. For example, a more expensive model could pay for itself in a little over three years. Over the 15-year lifetime, the more expensive refrigerator might save $750!

Refrigerators made to meet the latest 2001 DOE standards will cut consumers' energy costs by 30 percent compared to the previous (1993) standards, and a family replacing a 1972-vintage model with a product that meets the new standard will see their utility bills drop by over $120 a year. There are super-efficient refrigerators currently on the market that save even more. If every household in the United States had the most efficient refrigerators available, the electricity savings would eliminate the need for more than 20 large power plants.

Using EnergyGuide Labels

Energy Cost Labels are used on refrigerators, refrigerator-freezers, freezers, and other appliances. The large number in the center of the label is the estimated annual cost of the energy needed to use the appliance. This cost is based on a national average electricity rate, which is listed on the upper left under the EnergyGuide headline.



The bar beneath the estimated cost shows the range of operating costs of competing brands and models of similar size and features. The chart at the bottom of the label lets you estimate more closely what your cost to operate the appliance will be based on the price you pay for your energy.

Planning to Reduce Home Cooling Costs

If you are planning to build a new home, there are many ways to cut home cooling costs, including increasing the home's insulation. One important decision is deciding how to orient the house. By having south-facing windows, the sun can help heat the home in winter, but, if we use air-conditioning in summer, the sun can increase energy use and bills unless we provide "sun controls" in the summer. "Sun controls" that might be used include deciduous shade trees, roof overhangs, window blinds and drapes, and thermal insulated windows.

Materials for Each Team of Consultants:

- Posterboard or sheet of newsprint
- Markers and pens
- Graph Paper
- Ruler

Procedure:

1. Imagine that you are consultants for a real estate developer who wishes to develop a subdivision in which the homes are designed to maximize energy conservation.

2. Draw a simple aerial map showing the compass directions and the meadows and hills where you will construct the "Sunny Acres" Subdivision. Draw in the nearest road that leads into town.

3. Now, plan the access streets that will lead to the main road and mark out the lots on which the contractor will build new homes.

4. Being mindful of the contractor's intention to use heat from the sun to help heat the home in the winter, draw in the placement of the new homes on the map, showing placement of shade trees.

5. Being mindful of the contractor's intention to use heat from the sun to help heat the home in the winter, use graph paper to sketch a simple floor plan showing the walls, doors, and windows of one of the new homes.

6. Indicate special features you would include to prevent unwanted summer sun from entering the windows and to prevent heat loss through the windows during winter.

7. Be prepared to share your team's plan with the rest of the class and to explain why you believe that your plan will allow the contractor to meet his goal.

Student Handout (continued)

Timeline of Events Related to Development of Refrigeration:

1873	Locomotive engineer Carl Von Linde invents a machine to compress ammonia.
1876	An ammonia refrigerator is invented by Linde
1913	First electric refrigerator manufactured.
1914	Clarence Birdseye observes how fish that he catches while ice fishing freeze quickly in the cold air and pioneers the quick freezing of fish.
1925	Clarence Birdseye and Charles Seabrook develop a deep-freezing process for cooked foods that Birdseye patents in 1926.
1929	U.S. electric refrigerator sales top 800,000, and the average price of a refrigerator falls to $292.
1931	GM's Frigidaire division adopts Freon-12 refrigerant gas.
1931	Birds Eye Frosted Foods go on sale across the U.S.
1972	ORNL researchers begin a program of energy research, which later results in more-energy-efficient designs for refrigerators.
1988	Ozone Trends Panel concludes that Antarctic Ozone Hole is caused by Freon.
1996	Carrier produces first air conditioners using a Freon-free refrigerant.
2001	New refrigerator standards go into effect that will increase their required energy efficiency by 30 percent as compared to the 1993 standard.

Timeline of Events Related to Development of Air Conditioning:

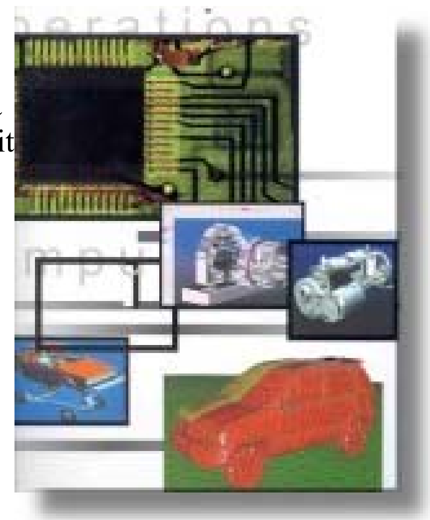
1830s	Dr. John Gorrie experiments with air conditioning at the U.S. Marine Hospital in Apalachicola, Fla., by blowing air over buckets of ice suspended from the ceiling.
1851	Gorrie receives the first patent for an ice-making machine.
1902	Willis Haviland Carrier pioneers modern air conditioning.
1906	Stuart Cramer coins the term "air conditioning."
1920s	Carrier introduces small air-conditioning units for residences.
1924	Hudson Department Store air conditions its "bargain basement".
1930s	Air conditioners are placed in railroad cars transporting food.
1936	United Airlines begins air-conditioning its planes.
1939	First air-conditioned automobile, engineered by Packard.
1960	According to the U.S. Census, 12.4 percent of all U.S. households, and 18.3 percent of Florida households, have some kind of air conditioning.
1965	The Astrodome, the world's first air-conditioned indoor stadium, opens in Houston.
1973	80 percent of cars in the South are equipped with air conditioning.
1980	The census reports a majority of American homes, and 84 percent of Florida homes, have air conditioning.
2006	New standards for efficiency of central air conditioners in new homes go into effect that will increase their required efficiency by 30% as compared to the 1987 standard.

ACHIEVEMENT #8:

CAD/CAM and CAE Technology

Teacher's Guide

Introduction



In 1950 when engineers wanted to use a computer to help them design a product, they had to fill out a form, enter the data on punch cards, submit the data to a computer center and wait for the results. This could take weeks. When they got the information back, it looked like this (shows stack of papers). In 1960, a young MIT graduate student, Ivan Sutherland, wondered if computer graphics could be used to help engineers design products differently. His idea was called Sketchpad, and it was an important first step in changing the way design engineers worked.

Other engineers contributed their ideas, and soon they had a tool that helped engineers see their products on a computer screen for the first time. Instead of building expensive models of products to see if they would work, they could design entire automobiles, airplanes and jet engines in 2 and 3 dimensions – and test their theories on the screen. Products that once took several years to design and manufacture can now be made in just months. This is important to the average family, because it means that products are cheaper and in greater supply. And it all started with one engineer's curiosity and good detective skills.

Lesson Focus: **Computer Aided Engineering**

Lesson Synopsis: Students use the NASA applet **FoilSim** to test various airplane wing designs in a simulated wind tunnel.

Related National Science Education Standards:

Content Standard E (Science and Technology):

As a result of activities in grades 5-8, all students should develop Abilities of Technological Design, including the ability to:

- Identify Appropriate Problems for Technological Design,
- Design a Solution or Product,
- Implement a Proposed Design,
- Evaluate Completed Technological Designs and Products, and
- Communicate the Process of Technological Design.

Related Benchmarks from Benchmarks for Science Literacy:

Section 9B (Symbolic Relationships):

By the end of 8th grade, students should know that:

- Graphs can show a variety of possible relationships between two variables.

Section 11B (Models):

In grades 6-8, **"student use of computers should have progressed beyond word processing to graphing and simulations that compute and display the results of changing factors in the model."**

Glossary:

CAD (Computer Aided Design or Computer Aided Drafting) Use of microcomputer systems to engineer and design complex parts in today's manufacturing environment. Prior to the 1980's, draftsmen used drawing boards, T Squares and a plethora of tools to draw blueprints manually, today, engineering design and drafting work is done on CAD Systems, where highly trained operators construct blueprints, models, and complete engineering designs on personal computers, workstations, and networked computer terminals

CAM (Computer Aided Manufacturing) Use of computers in manufacturing workplaces to model parts being constructed in machining operations and design processes, not only for modeling purposes, but for design and quality assurance purposes as well. CAM systems are used for determining the accuracy of design prior to manufacturing. Models can be checked for diameters, wall thickness, stress analysis, clearances, and many other features determined to be critical before the initial product is ever constructed, thus eliminating unnecessary production cost as well as reducing the time it takes to produce the part.

CAE (Computer Aided Engineering) Use of computers and software to solve engineering problems. CAE is a branch of engineering that involves the use of computer technology to solve complex problems that are too difficult, or impossible, to solve with traditional analytical techniques.

Virtual Reality A way for humans to visualize, manipulate and interact with computers and extremely complex data. The visualization part refers to generating visual, auditory or other sensual outputs to the user of a "world" that exists solely within the computer. This "world" may be a CAD model, a scientific simulation, or a view into a database.

airfoil An object with a special shape that is designed to produce lift efficiently when the object is moved through the air. For example, the cross-section of a wing is an airfoil.

lift A force that is perpendicular to the airflow around an aircraft. In normal, forward flight, the lift force "lifts" the aircraft into the air. Engineers design airplanes so that the lift created by the wings can overcome the force of the weight of the airplane.

camber The curvature of an airplane wing.

angle of attack The angle of a wing to the oncoming airflow. A pilot pulls back on the control stick to increase the angle of attack.

wind tunnel testing A tool of aeronautics that involves placing a model of an aircraft or part of an aircraft into a wind tunnel and using instruments to gather data while air is blown past the model. Wind tunnel testing is used to investigate and accurately describe the effects of airflow on an aircraft or part of an aircraft.

Important Concepts:

- Computers can be used to design and test a variety of products, including aircraft.
- Lift is affected by the angle of attack of the wing and by wing shape, including its thickness and curvature (camber).
- Lift is also affected by air speed.

Materials for Each Inquiry Team:

- Computer, with FoilSim Applet installed
- Inventor's Log
- Copies of FoilSim Tutorial

Safety Precautions: Remind students of rules for computer use, as appropriate.

Procedure:

Engagement:

If you have not shown the video, you may choose to do so now. Explain what the terms CAD, CAM, and CAE stand for and then hand out and discuss the **Timeline** portion of the **Student Handout**.

Exploration and Explanation:

- Download the FoilSim II Applet to each computer your students will be using. (See http://www.lerc.nasa.gov/WWW/K-12/FoilSim/ for details on downloading.)
- Have students follow the **FoilSim Tutorial** to experience using a computer simulation to explore factors that affect lift.

Extension:

Have students test a modified wing design under conditions different than the default conditions.

Evaluation:

Have students print out or sketch a Side-3D view of a wing they tested and write a brief report on how it performed under test conditions.

Ideas for Further Exploration:

- Have students research the use of Computer Aided Engineering in the space program and in the automobile industry.

References:

NASA FoilSim Applet, available for downloading at:
http://www.lerc.nasa.gov/WWW/K-12/FoilSim/

ACHIEVEMENT #8:

CAD/CAM and CAE Technology

Student Handout

Timeline of Events Related to Achievement #8:

1947	first commercial computer (UNIVAC)
1950	Air Force develops a system to display computer-processed radar data.
1960	Boeing coins term “computer graphics”.
1961	Integrated circuits used in computers.
1962	Sketchpad, first 2D CAD program, created by Ivan Sutherland.
1965-1968	Sutherland begins development of Virtual Reality technology.
1968	First commercial CAD system.
1971	General Motors begins using DAC (Design Automated by Computers)
1989	Jaron Lanier coins the term “Virtual Reality”

Computer Aided Engineering (CAE)

Our timeline for this achievement is much shorter than the others! Fifty years ago, mechanical engineering students would have taken a course in Mechanical Engineering, in which they would have learned to use drafting tools to make engineering drawings by hand. With the development of microcomputers, it has become possible to create designs with Computer Aided Drafting (CAD) without having to create drawings by hand.

In 1901, the Wright Brothers built a wind tunnel to test wing designs. The blower fan, driven by an overhead belt, produced a 25 to 35 mph wind for testing the lift of various flat and curved surfaces. Data derived from these tests were vital to the successful design of the Wright 1903 Kitty Hawk airplane. Now, engineers can test wing designs in a simulated wind tunnel.

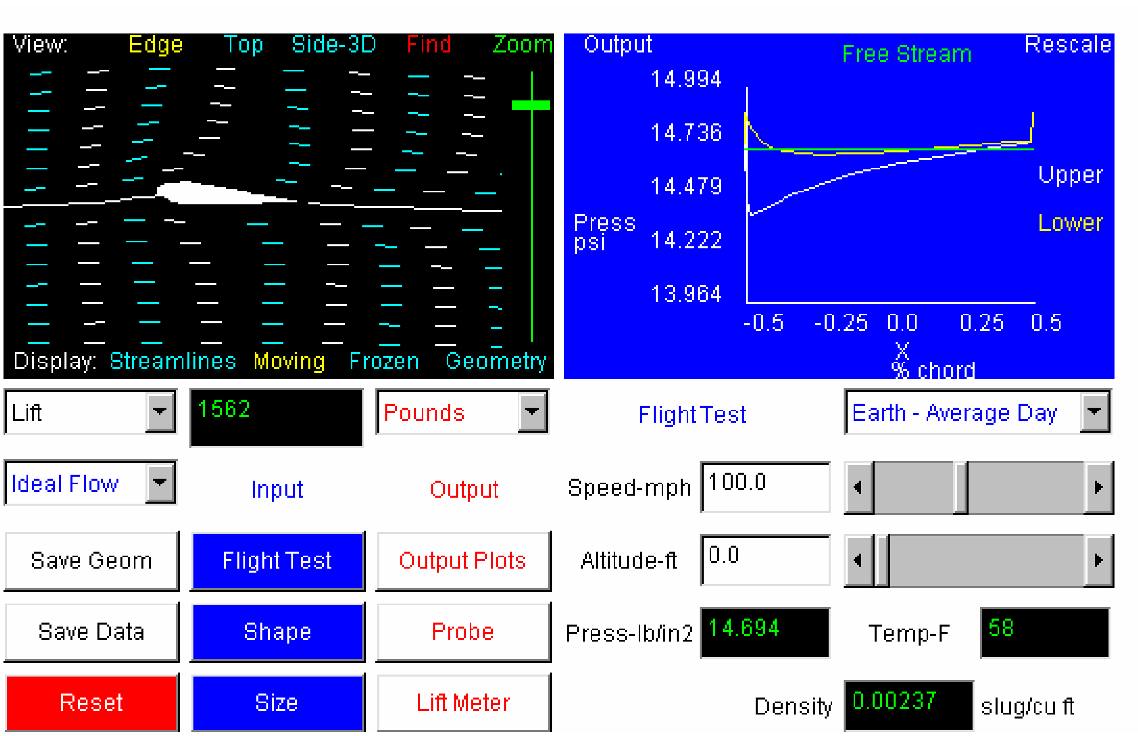
To see what it is like to use a computer to do engineering tasks that formerly required hand drawings and models, we will be using FoilSim, software developed by NASA to simulate the design and of wind tunnel testing of aircraft wings. Although FoilSim is designed primarily as a teaching tool, it was derived from "real-life" engineering software.

Using FoilSim to Explore Factors that Affect Lift of an Airplane Wing

I. An Introduction to FoilSim

With this software you can investigate how an aircraft wing produces **lift**, by changing the values of different factors that may affect lift. If the resulting lift value is a positive number, then the wing is being pushed up. If the lift value is a negative number, then the wing is being pushed down. If the value is zero, then the wing is neither being pushed up nor being pushed down.

Basic Screen Layout:



The program screen is divided into three main parts:

View Window

At the top of the screen are two **graphics windows**. The window on the left is the **View Window**, in which you can display a simulation of the flow of air around the wing you design.

Control Panel

Under the **View Window** is the **Control Panel**. There are 3 **choice boxes**, which allow you to select Lift vs. Coefficient of Lift, Pounds vs. Newtons, and Ideal Flow vs. Stall Model, with Lift, Pounds, and Ideal Flow being the settings when you first open FoilSim.

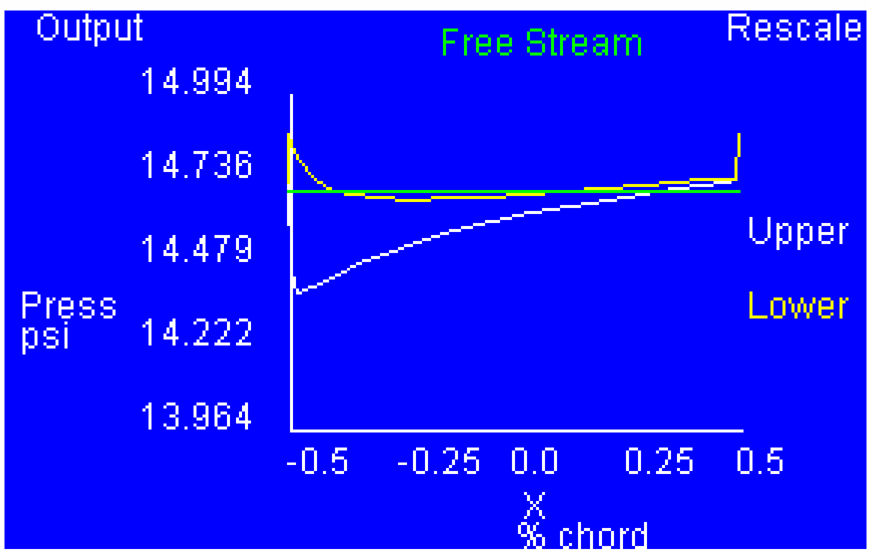
Notice that the **Control Panel** also contains 9 **choice buttons**. The three **blue** choice buttons under the heading **Input** allow you to change the **Flight Test** conditions, the **Shape** of the wing, and the **Size** of the wing.

Output Window

The **graphics window** on the right is the **Output Window**, in which you can display a **Plot** of the flow variables, a **Probe** panel you can use to investigate the pressure and and velocity in the flow field, or a **Lift Meter**.

The Plot Display:

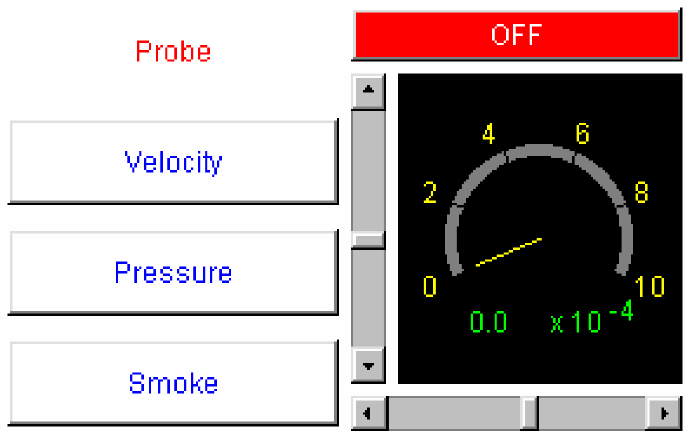
When you first start **FoilSim**, a **Plot** showing the pressure at points along the upper and lower sides of the wing is automatically displayed in the **Output Window**:



FoilSim allows a total of 12 different graphs to be displayed. To select which graph you wish to view, first press the white **Output Plots** button. When the **Select Plot** window opens in the **Output Window**, select and press one of the white buttons.

The Probe Display:

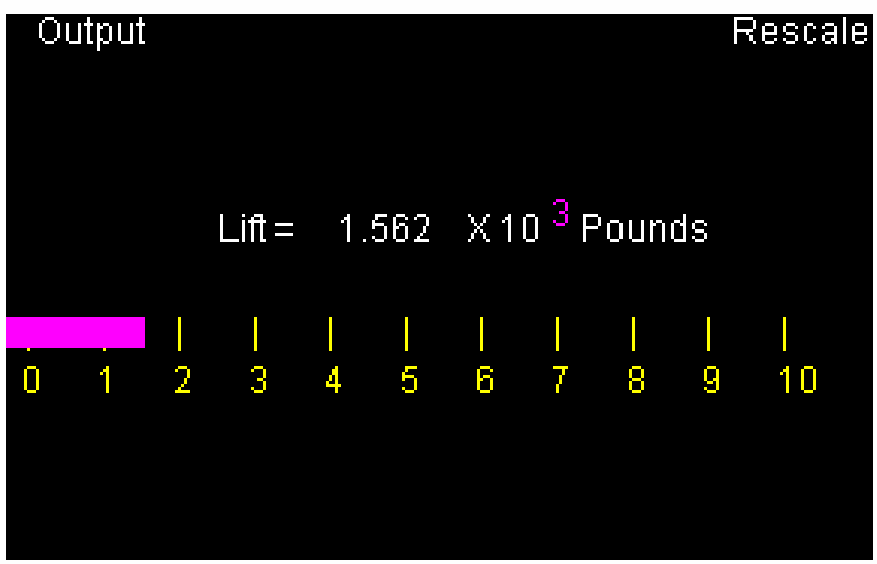
To display the **Probe**, press the white **Probe** button. A **Probe Panel** will appear in the **Output Window**:



You can change the location of the probe, seen as a magenta ball in the **View Window**, by using the two **sliders** to the left and below the **gauge**. The value of the pressure or the velocity at the location of the probe tip (magenta ball) is displayed on the gauge, or a green trail of "smoke" is swept downstream from the probe location. You can turn the probe off by pressing the red **OFF** button located above the gauge.

The Lift Meter:

To display the **Lift Meter**, press the white **Lift Meter** button and the **Lift Meter** will appear in the **Output Window**:

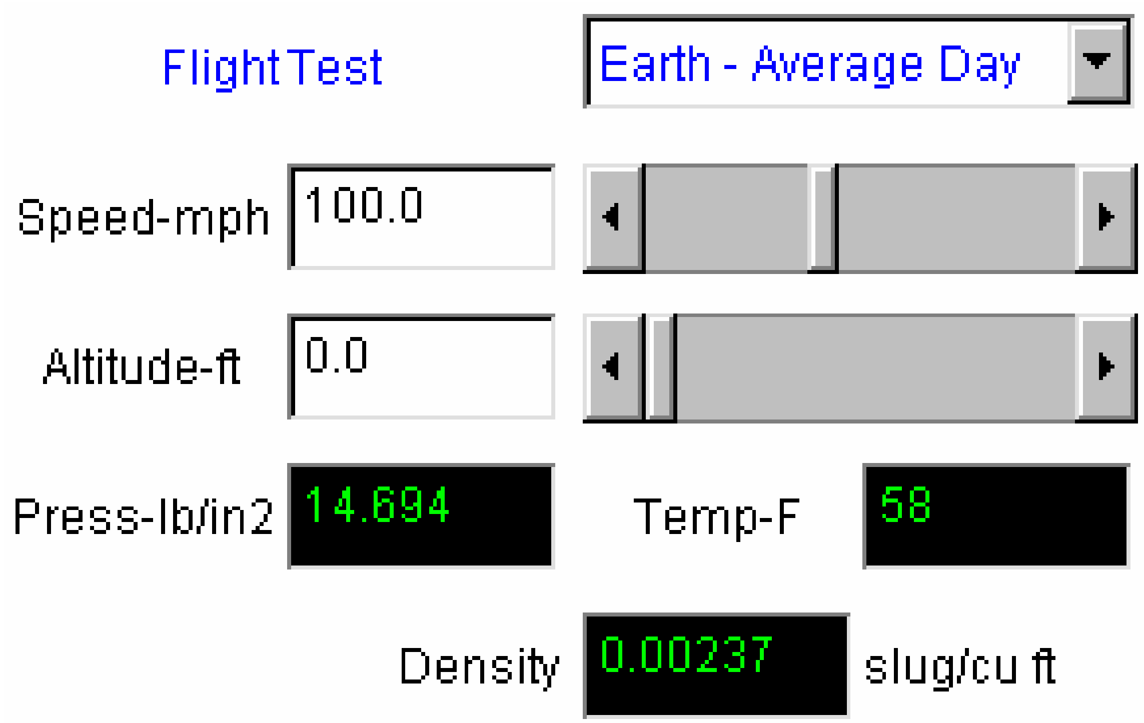


Input Panel

To the right of the **Control Panel** is the **Input Panel**, which changes when you click on one of the three blue buttons, to allow you to change the variables.

Flight Test Input Panel:

When you first start **FoilSim**, the **Input Panel** for the **Flight Test** conditions is displayed:



Note that **FoilSim** begins with a speed of 100 miles per hour and an altitude of zero feet above sea level. The testing temperature is given in degrees Fahrenheit and the pressure is given in pounds per square inch.

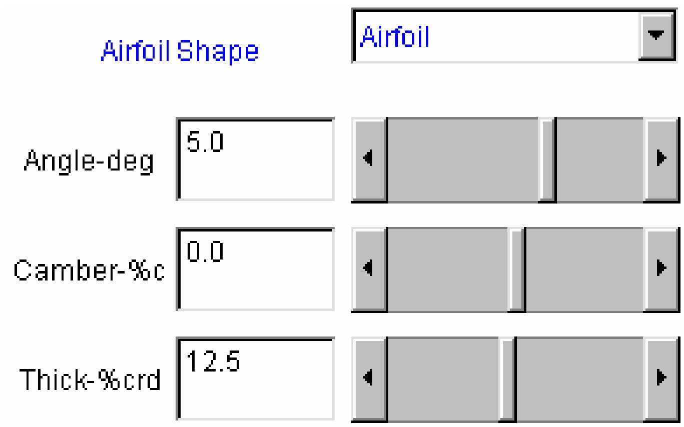
You can vary the speed or the altitude by typing a value into the text window and pressing the **Enter** key on your keyboard or by moving the sliders.

You can test your wing either **on the Earth** (default choice), **on Mars**, or **in water** by making your choice in the **menu box** at the upper right. (You can also choose to specify your own values of temperature and pressure for air, or to specify your own fluid by providing a value of the fluid density.)

Student Handout (continued)

Shape Input Panel:

When you press the blue **Shape** button, the **Shape Input Panel** will appear to the right of the **Control Panel**:

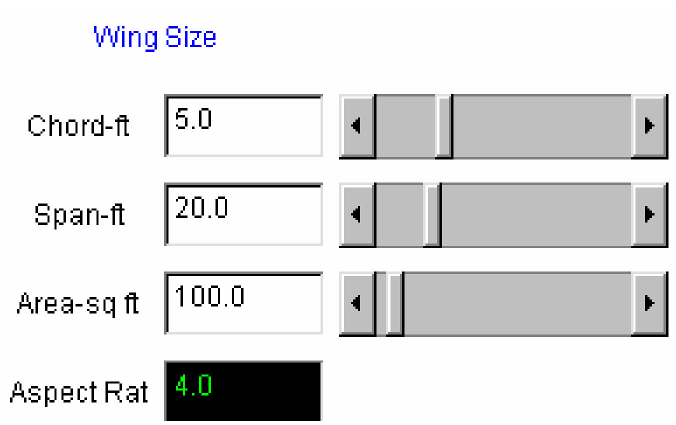


In the menu window, you can select a classic **airfoil** shape, an **ellipse**, or a flat "**plate**". (You can also choose to investigate the lift created by a rotating cylinder, or a spinning ball, but for these problems you must specify the spin rate and radius.)

You can change the **angle of attack** (the angle of a wing to the oncoming airflow), the **camber** (wing curvature), or the thickness of the wing either by entering a value in the text box and pressing the **Enter** key on your keyboard or by using the sliders.

Size Input Panel:

To change the size of the wing, press the white **Size** button and the **Size Input Panel** will be displayed to the right of the **Control Panel**:



Data Window

Under the **Control Panel** is a large text window in which output from the program can be displayed. You can display the airfoil geometry and surface flow data by pushing the **Save Geom** button on the **Control Panel**. You can display the test conditions and calculated lift by pushing the **Save Data** button on the **Control Panel**. (You can use the browser Print command to print out the screen and the data.)

II. Exploring Lift

1. Start the **FoilSim** applet by double clicking on the **FoilSim** icon.

2. In the **Control Panel**, under **Output**, press **Probe** to display the **Probe Panel**.

3. Press the red **Reset** button to reset all values to the basic starting conditions for the test.

4. Under **Input**, press **Flight Test** and record the starting test conditions:

Speed ____________________ Altitude _________________________

5. Press **Shape** and record the starting test conditions:

Angle ___________________ Camber ___________________________

6. Record the current Lift reading: ______________________

6. In the **View Window**, click on **Side-3D**.

A. How does Angle of Attack affect lift?

As you move the slider next to **Angle** to the right or left, observe the **View Window** and describe any changes you see:

Now, as you move the slider back and forth again, note how the lift reading changes. Can you describe a pattern?

B. How does Camber (wing curvature) affect lift?

Press the red **Reset** button and then reselect **Side-3D** to go back to your starting conditions.

As you move the slider next to **Camber** to the right or left, observe the **View Window** and describe any changes you see:

Now, as you move the slider back and forth again, note how the lift reading changes. Can you describe a pattern?

C. How does Thickness affect lift?

Press the red **Reset** button and then reselect **Side-3D** to go back to your starting conditions.

As you move the slider next to **Thickness** to the right or left, observe the **View Window** and describe any changes you see:

Now, as you move the slider back and forth again, note how the lift reading changes. Can you describe a pattern?

D. Using the Probe to Measure Air Pressure

1. Press the red **Reset** button.

2. Now you see in the **View Window** a cross section of our basic starting wing design.

3. Click on the blue **Probe** button and then on the white **Pressure** button to activate the pressure probe. Use the probe to measure the air pressure above the front of the wing and below the front of the wing:

Pressure above the wing ____________ Pressure below the wing ______________

4. By manipulating wing angle, curvature, and/or thickness, change the wing so that the lift is zero, or close to zero.

5. Record what combination of values you used:

Angle ________ Camber ________ Thickness ___________ Lift ______

6. Measure and record the pressure readings as before:

Pressure above the wing ____________ Pressure below the wing ______________

7. By manipulating wing angle, curvature, and thickness, change the wing so that the lift is negative.

8. Record what combination of values you used:

Angle ________ Camber ________ Thickness ___________ Lift ______

9. Measure and record the pressure readings as before.

Pressure above the wing ____________ Pressure below the wing ______________

10. Compare your data with that of other students. What conclusions can you draw about the relationship between lift and air pressure above and below the wing?

E. Viewing Graphs

Under **Output**, press the **Output Plots** button.

In the **Select Plot** window, press the **Angle** button. Based on the shape of the plot, describe in words **the relationship between Lift and Angle of Attack**, under the current test conditions:

Press **Output Plots** again and this time press the **Camber** button. Based on the shape of the plot, describe in words **the relationship between Lift and Camber**, under the current test conditions:

Press **Output Plots** again and this time press the **Thickness** button. Based on the shape of the plot, describe in words **the relationship between Lift and Thickness**, under the current test conditions:

F. Testing Your Own Designs

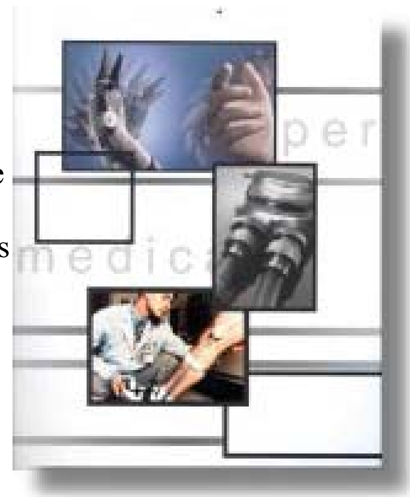
Now that you know how **FoilSim** works, you can create your own wing design and test it under different test conditions. Use the **Save Data** command to display the design data and test conditions in the **Data Window**. Record your design data, your test conditions, and your test results in an **Inventor's Log**.

ACHIEVEMENT #9:

Bioengineering

Teacher's Guide

Introduction



In Bioengineering, engineering knowledge combines with scientific discovery. The result is a better, healthier quality of life for all of us.

The human body is the world's most complex machine. It is an intricate network of mechanics linked to a central super computer. Bioengineers have solved some of the body's greatest mysteries. Like good detectives they study, research and use state of the art materials to create artificial hearts and limbs. Working with new arms, hands, or legs, people can live normal lives, including all kinds of sports, from basketball to snowboarding.

When microchips were first developed, engineers wondered how many ways they could use them to help people. Soon they became the brains in the sensors of crib alarm systems, and the eyes and ears of intensive care units. They have made hearing aids nearly invisible. Engineers use computers to design and manufacture artificial limbs and joints that fit better – which means that injured and disabled people are more comfortable and have greater mobility.

Doctors have asked engineers to help them design machines that will diagnose diseases and other health problems -- and machines that will help them perform surgery and provide cures. By paying close attention to the clues in science, engineers have extended the average life span by 30 years.

Lesson Focus: Ergonomics

Lesson Synopsis: Students perform an ergonomic analysis of their use of computer workstations in the school and compare the traction of various types of shoes on different surfaces using spring scales. They also evaluate the design of school computer workstations.

Related National Science Education Standards:

Content Standard E (Science and Technology):

As a result of activities in grades 5-8, all students should develop Abilities of Technological Design, including the ability to Evaluate Completed Technological Designs and Products. As a result of activities in grades 5-8, all students should develop:

- Understandings About Science and Technology.

Fundamental concepts and principles that underlie this standard include:

- Scientists propose explanations for questions about the natural world, and Engineers propose solutions relating to human problems, needs, and aspirations.
- Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials, other constraints limit choices in the design, for example, human safety.

Related Benchmarks from Benchmarks for Science Literacy:

Section 3A (Technology and Science):

By the end of 8^{th} grade, students should know that:

- Engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems, but they usually have to take human values and limitations into account as well.

Section 3C (Issues in Technology):

By the end of 5^{th} grade, students should know that:

- Once an invention exists, people are likely to think up ways of using it that were never imagined at first.
- Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems.

By the end of 8^{th} grade, students should know that:

- Technology … is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live.

Section 12C (Manipulation and Observation):

By the end of 8^{th} grade, students should be able to:

- Read analog and digital meters on instruments used to make direct measurements… and choose appropriate units fro reporting various magnitudes.

Related Standards for Technological Literacy:

Standard 9 (Engineering Design):

In order to comprehend engineering design, students in grades 6-8 should learn that:

- Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.

Glossary:

bioengineering A term that is used in several different ways:

1. The use of engineering principles of analysis and design to solve problems in medicine and biology. This broad use of the term includes both **biotechnology** (see definition 2) and **biomedical engineering**.
2. The use of recombinant DNA or other specific molecular gene transfer or exchange techniques to add desirable traits to plants, animals, or other organisms, or to enhance biological processes. (Also referred to as **biotechnology** and genetic engineering.)
3. A method of construction using living plants, or plants in combination with dead or inorganic materials. The practice brings together biological, ecological, and engineering concepts to produce living, functioning systems to prevent erosion, to control sedimentation, and/or to provide habitat.

biomedical engineering Application of engineering to solve problems in medicine and biology, including cell and tissue engineering and the development of artificial organs. As broadly used, it includes **biomechanical engineering** (see definition below).

biomechanical engineering Basic and applied studies on biomechanics, development of mechanical prostheses for medical and dental use, and development of mechanical equipment for medical and dental use.

ergonomic design The application of knowledge about human abilities, human limitations, and human characteristics to the design of products, tools, machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use.

newton (N) The newton is the SI unit of force. One newton is the force required to give a mass of 1 kilogram an acceleration of 1 meter per second per second. It is named after the English mathematician and physicist Sir Isaac Newton (1642-1727). **Spring scales are often marked in grams (actually "grams of force"), force should be recorded in newtons. To convert from grams to newtons, multiply by 0.0098.**

traction Resistance to lateral movement between two surfaces that are in contact with one another. Slipperiness is the result of too little traction.

Important Concepts:

- Bioengineering is the application of engineering to the solution of problems in biology and medicine.
- The field of ergonomics applies knowledge about human abilities, human limitations, and human characteristics to the design of products, tools, machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use.

Materials for Each Inquiry Team:

- Shoes with different types of soles
- Variety of test surfaces
- 2000 g (2.5 lb) Pull-type spring scale (available from educational supply companies)

Materials of the Entire Class to Share:

- Zippered plastic bags
- Sand or aquarium rocks

Safety Precautions: Remind students, as appropriate, of basic rules for the use of tools and the conducting of inquiry.

Procedure:

Engagement:

If you have not already shown the video, you may wish to do so at this time. Have students brainstorm definitions of the term bioengineering.

Exploration:

Have students do the activity **"How Slip Resistant are Your Shoes?"** Have students place a weighted bag of sand or gravel in each shoe so that the total weight is between 1 and 2 pounds (500-1000g).

Explanation and Extension:

Have students read and discuss the handout and timeline and evaluate the design of the school's computer workstations.

Evaluation:

Have students examine the definitions they created at the beginning of the lesson and modify them based on what they have learned.

Ideas for Further Exploration:

- Have students continue their use of Pull Meters to explore the effectiveness of shoe treads and tire treads in increasing traction.
- Have students use the Pull Meters to explore the effectiveness of lubricants and special materials in reducing friction.
- Have students research the issue of whether student backpacks are ergonomically suitable for use as book bags.

References:

- **12 Tips for an Ergonomic Computer Workstation**, available online at: http://ergo.human.cornell.edu/dea651/dea6512k/ergo12tips.html

ACHIEVEMENT #9:

Bioengineering

Student Handout

How Slip-Resistant are Your Shoes?

Slips and falls are a common cause of injury, accounting for about 20% of injuries. To reduce the chances of slips, building planners may incorporate special slip-resistant surfaces in hallways and on walkways. In some workplaces where slippery surfaces cannot always be avoided, workers may be encouraged to wear slip-resistant shoes. I 1953, the Department of Commerce proposed the a surface can be called "slip resistant" if it takes at least a force of 0.5 pounds to begin to drag a 1-pound weight across the surface. The US Patent Office has issued over 50 patents for slip-resistance testing devices since 1985. One of the simplest testing devices is called a Horizontal Pull-Meter and consists of a 50-pound block attached to a scale that can read forces up to 80 pounds.

The design of shoe soles considers the amount of traction the wearer is likely to need under typical wear conditions. Let's use a simple version of the Pull-Meter to compare how different shoes perform on different surfaces. Since we will be using shoes instead of a 50-pound block, we will use a smaller scale and record our measurements in ounces or grams, instead of in pounds.

Materials for Each Inquiry Team:

- Shoes with different types of soles
- 2000 g (2.5 lb) Pull-type spring scale
- Variety of test surfaces

Materials of the Entire Class to Share:

- Zippered plastic bags
- Sand or aquarium rocks

Procedure:

1. Use the plastic bags and sand to add weight to each shoe until all the shoes you are testing weigh the same amount using the large spring scale. Record that weight in ounces or in grams.
2. To test a shoe, place it on a surface, attach the scale and gently begin to pull parallel to the surface.
3. Record the force required to just begin to move the shoe across the surface, using the same unit used for weighing the shoe.
4. As time allows, explore different surfaces.

What is Bioengineering and what does it have to do with slip resistance?

Since "bio" refers to "life", **bioengineering** can be broadly defined as the application of engineering to the solution of problems in biology and medicine. What kinds of products are the result of bioengineering?

The video and the timeline on the next page emphasize that part of bioengineering that is concerned with developing medical testing equipment or artificial organs and joints, and cell and tissue engineering. This is sometimes called **biomedical engineering**.

The broad field of bioengineering also includes **genetic engineering** (also called biotechnology). Genetic engineering has led to the transfer of genes between species, creating plants and animals with new characteristics and allowing the mass production of useful proteins.

Finally, bioengineering can be defined to include **ergonomic** engineering, which is "the application of knowledge about human abilities, human limitations, and human characteristics to the design of products, tools, machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use." So, using the broadest definition, someone trying to develop slip-resistant shoes or slip-resistant floor surfaces would be a **bioengineer**, along with people who develop artificial limbs, medical equipment, and much more.

Many of the achievements in bioengineering are the consequence of creative people being able to think of new ways to apply technology originally developed for another application.

An Ergonomic Analysis of Computer Workstations

The principles of ergonomics are being applied to the design of safe work environments.
In factories, machinery is being redesigned to increase worker safety and productivity.

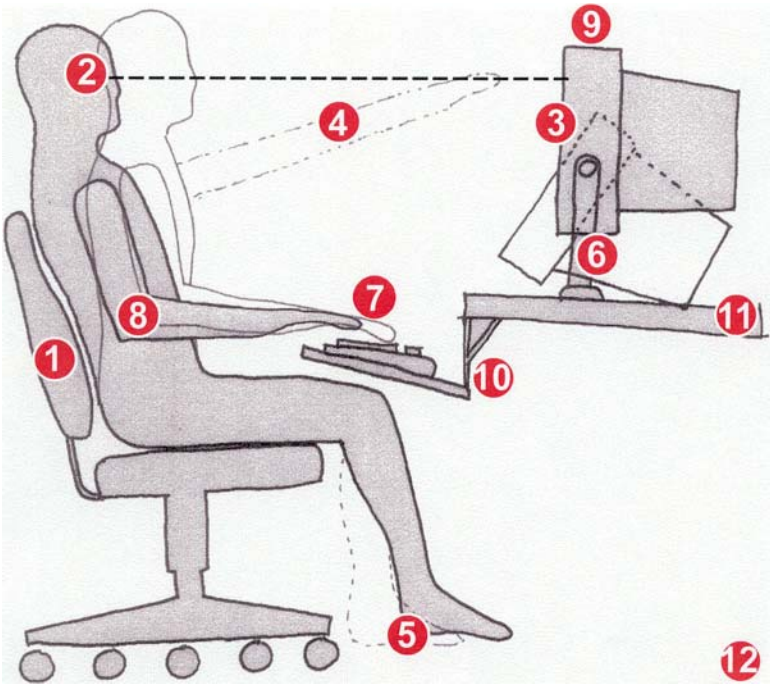
In many businesses today, workers primarily work at a computer, often for long periods of time. Some of these workers develop back strain, eyestrain, and sometimes even more serious problems such as carpel tunnel syndrome, a condition that may require surgery. To reduce the frequency of these health problems, design engineers are designing computer monitors, workstations, and desk chairs based on knowledge of how the human body works.

The handout **10 Tips for an Ergonomic Computer Workstation** is based on ergonomics research and can be used to either set up or evaluate computer workstations. Use it to evaluate the workstations in your school and to make recommendations for improvement.

Timeline of Important Events Related to Achievement #9:

1895	Roentgen takes an X-ray of his wife's hand.
1903	Dutch physiologist develops the electrocardiograph.
1932	Heart defibrillator developed.
1942	First metallic hip replacement.
1945	Artificial kidney machine developed.
1950s	Development of artificial heart valves.
1950s	Industrial ergonomics, design of industrial machinery to consider human efficiency, health, and safety, emerges as a field of study.
1953	First successful application of a heart-lung machine.
1954	First human kidney transplant.
1956	Plastic contact lenses developed.
1957	First externally worn, battery-powered pacemaker developed.
1960	First totally implanted pacemaker.
1973	CAT scan developed, based on technology developed to computer-enhance pictures of the moon for the Apollo program.
1974	Paper on "Traction in Football Shoes Under Dynamic Loading" presented at the 27th Annual Conference of Engineering in Medicine and Biology.
1982	First permanent artificial heart, designed by Robert Jarvik, implanted.
1985	Soft bifocal contact lenses developed.
1985	Development of implantable ventricular defibrillator.
1998	First human use of a Ventricular Assist Device, based on NASA aerospace engine pump design.
1999	Artificial hand that enables the user to have finger control developed.

10 Tips for an Ergonomic Computer Workstation:



1. Use a good adjustable chair and sit back.

Your upper and lower back should be well supported by the chair.

2. Have the top of monitor 2-3" above your eyes.

Your eyes should be in line with a point on the screen that is 2 to 3 inches below the top of the monitor. If the monitor is above or below this height, your neck will be raised or lowered and the result may be neck pain.

3. There should be no glare on the screen.

4. Sit at arm's length.

The monitor should be at a comfortable distance for viewing, which is usually around arm's length (sit back, raise your arm, and your fingers should touch the screen).

5. Keep your feet on the floor or on a footrest.

Chair height should be set so that the chair seat does not compress the back of the knees.

6. Use a document holder.

7. Keep wrists flat and straight (level with forearms). (See also number 10)

8. Keep arms and elbows close to body.

9. Center the monitor and keyboard in front of you.

10. Use a "negative tilt" downward sloping keyboard tray.

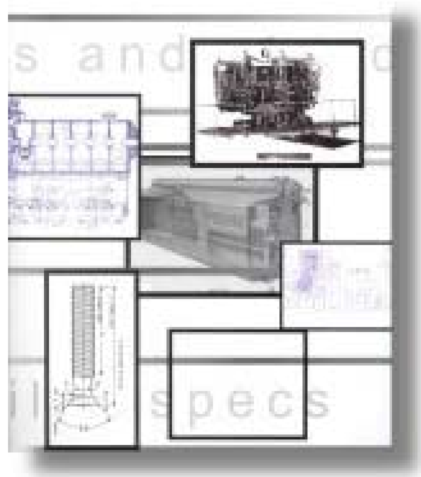
Desktop keyboards and those placed on conventional keyboard trays (those that slope up) do not fully allow the elbows and wrists to remain in a neutral posture (elbows close to the body and wrists level with the forearms).

ACHIEVEMENT #10:

Codes and Standards

Teacher's Guide

Introduction



In 1900 most people never traveled more than 30 miles from home. If they traveled by rail, chances are they had to keep changing trains, because the size of the tracks was different in every state. That's because there were no measurements or rules followed by everybody. There were no standards. Life before standards was often inconvenient, and even dangerous.

In 1904, a terrible fire was raging through Baltimore. Fire engines were racing from all over town to help. They even came from as far away as New York. But when they got there they were shocked to discover that the couplings were all different – and they couldn't connect their hoses to the fire hydrants. The fire brigades were useless, and within 30 hours more than 1500 buildings burned to the ground.

Later, engineers got together and wrote a standard so that this would never happen again. All the fire hydrants and all the fire hose couplings all over the country had to be the same size. It didn't take long before engineers and others deduced that more standards were needed in many industries. Today, in the United States alone, there are about 50,000 voluntary standards that make products safe and life orderly. That's why all electrical plugs will fit in any outlet, and why a bicycle chain you buy in Massachusetts will fit a bike you buy in Texas.

Take a look at the hot water heater in your house -- you will see the ASME code symbol stamped on it. This means that you never have to worry about your water heater exploding --which happened quite often at the beginning of the century.

Lesson Focus: codes and standards, metrology

Lesson Synopsis: Students evaluate the reliability of the cubit as an early unit of measure, use calipers and other measuring tools to measure circumferences and diameters, and create a paper tower that meets a specified set of standards.

Related National Science Education Standards:

Content Standard E (Science and Technology):

As a result of activities in grades 5-8, all students should develop Abilities of Technological Design, including the ability to

- Design a Solution or Product, to
- Implement a Proposed Design, and to
- Evaluate Completed Technological Designs and Products.

As a result of activities in grades 5-8, all students should develop Understandings About Science and Technology. Fundamental concepts and principles that underlie this standard include:

- Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials, other constraints limit choices in the design, for example, human safety.

Related Benchmarks from Benchmarks for Science Literacy:

Section 3A (Technology and Science):

By the end of 8th grade, students should know that:

- Engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems, but they usually have to take human values and limitations into account as well.

Section 3B (Design and Systems):

By the end of 8th grade, students should know that:

- Design usually involves taking constraints into account. Some constraints are unavoidable … Other constraints … limit choices.

Section 3C (Issues in Technology):

By the end of 5th grade, students should know that:

- Scientific laws, engineering principles, properties of materials, and construction techniques must be taken into account in designing engineering solutions to problems.

Section 9D (Uncertainty):

By the end of 8th grade, students should know that:

- The mean, median, and mode tell different things about the middle of a data set.

Section 12B (Computation and Estimation):

By the end of the 8th grade, students should be able to:

- Find the mean and median of a set of data.

Related National Standards for Technological Literacy:

In order to comprehend the core concepts of technology, students in grades 6-8 should learn that:

- Trade-off is a decision process recognizing the need for careful compromises among competing factors.

In order to comprehend the attributes of design, students in grades 6-8 should learn that:

- Requirements for a design are made up of criteria and constraints.

Glossary:

standard A set of technical definitions and guidelines designed to serve as "how to" instructions for voluntary use by designers and manufacturers. Standards may relate to performance (what the product is supposed to do) or to design (composition of the product and how the product is to be made).

code A standard that has been adopted by one or more governmental bodies and has the force of law.

metrology The branch of science that deals with quantifying the measures of physical quantities.

Important Concepts:

- Standards for product design and/or performance may promote product quality, safety, and/or interchangeability of components.
- The standardization of measurement in the industrial world allows countries to produce and consume goods and services in the world economy.

Materials for Each Inquiry Team:

Materials for Engagement Activity:

- Meter stick
- Hand calculator
- Graph paper or graphing software

Materials for Exploration Activity:

- Variety of manufactured circular objects
- String
- Paper
- Metric ruler
- Calipers or mechanical compass

Materials for Engineering Challenge:

- 2 sheets of newspaper
- 10 inches of cellophane tape
- Scissors

Teacher's Guide (Continued)

Safety Precautions: Remind students of safety rules for use of laboratory equipment, as appropriate.

Procedure:

Engagement:

If you have not shown the video to the class, you may do so and then proceed with the Exploration activity. If you have already shown the video, you may want to use the activity "How Long is a Cubit?" as an Engagement activity.

Exploration:

Have students do the activity "From Cubits to Calipers: How Can We Measure Length?".

Explanation, and Extension:

Have students do the activity "Why are Standards Important?", including the Engineering Challenge, "Paper Towers".

Evaluation:

Have students brainstorm and evaluate a potential set of standards for classroom furniture. (They should consider safety, durability, comfort, etc.)

Ideas for Further Exploration:

1. Have students research the history of various units of measure.
2. Have students research local building and fire codes. (Contact the municipal building inspector and fire marshal.)
3. Have students research the functions of organizations such as the American National Standards Institute (ANSI) and the National Institute of Standards and Technology (NIST).
4. Have students revise their paper tower design and test their revised design.
5. Use the online applet at http://phy.ntnu.edu.tw/~hwang/ruler/vernier.html to have students practice measuring with Vernier calipers.

References:

Paper Towers, exercise available online at: http://www.zoology.duke.edu/cibl/exercises/paper_towers.htm

Introduction to ASME Codes and Standards, available online at: http://www.asme.org/codes/

NIST Virtual Museum Exhibit on the history of standardization of weights and measures in the US, online at http://museum.nist.gov/exhibits/ex1/index.html

NIST in Your House, an online exhibit showing NIST's unseen role in setting standards for a variety of household products, online at http://www.nist.gov/public_affairs/nhouse

NIST at 100: Foundations for Progress, links to information on the history of the National Bureau of Standards (now called the National Institute of Standards and Technology), online at http://www.100.nist.gov/

ACHIEVEMENT #10:

Codes and Standards

Student Handout

"How Long is a Cubit?"

Overview:

One of the earliest recorded units of length is the **cubit**, first used in ancient Egypt. Defined as the length of the forearm from the elbow to the tips of the fingers, this was the unit of length used to measure and position the blocks used to construct the Great Pyramid of Giza.

Materials for Each Inquiry Team:

- Meter stick
- Hand calculator
- Graph paper or graphing software

Procedure:

1. Working in pairs, use a meter stick to measure each partner's arm length from the elbow to the tips of the fingers. Do this by resting your elbow on your desktop and placing the meter stick next to your forearm.
2. Record each "personal cubit" in mm and tabulate the data for the class.

   Length of a cubit according to my arm = __________
3. Find the range, mean, median, and mode for the class data:

Range = _________ to ___________ Mean = _____________

Median = ______________ Mode = _____________

4. Create a histogram from the class data. (If graphing software is available, use it.)
5. Switch partners and measure each other's arms again. Do the two measurements agree exactly? If not, how do you account for the difference?
6. Since the length of a cubit varies according to whose arm is used and perhaps even from one use to the next, suggest a way that the Egyptians could have ensured that all the stones used in one construction project were about the same size?

ACHIEVEMENT #10:

Codes and Standards

Student Handout

"From Cubits to Calipers: How Can We Measure Length?"

Overview

Can you imagine not being able to buy an accurate ruler, yardstick, or tape measure? What if you had to make your own by using someone else's ruler to mark a stick or a length of ribbon? What if **no** rulers were available? The discovery of "cubit sticks" and blocks of black granite or marble cut to a standard length at Egyptian archeological sites is the earliest evidence of efforts to "standardize" a unit of measure initially related to body proportions.

Materials for Each Inquiry Team:

- Variety of manufactured circular objects
- String
- Paper
- Metric ruler
- Calipers or mechanical compass

Procedure:

Goal: To use the tools available to measure as accurately as possible the circumference and diameter of each of the circular objects provided to you.

1. Use different tools to measure the same object. (Be creative.)

2. If your measurements of the same object are different, decide which is probably the most accurate and why.

3. Be prepared to report your "most accurate" measurements and to explain how you obtained each measurement.

ACHIEVEMENT #10:

Codes and Standards

Student Handout

"Why Are Standards Important?"

The Development of Standards and Codes

In modern usage, a **standard** is a set of technical definitions and guidelines designed to serve as "how to" instructions for voluntary use by designers and manufacturers. Standards promote quality, safety, and/or interchangeability. Standards may relate to performance (what the product is supposed to do) or to design (composition of the product and how the product is to be made). A **code** is a standard that has been adopted by one or more governmental bodies and has the force of law.

As you examine the **Timeline** for this engineering achievement, you will see some of the events that created a need for standards and some of the ways that standards have contributed to product quality, safety, mass-production, and convenience. Can you see why having standardized units of measure and more-precise measuring tools has been important to our being able to develop and apply product standards?

Engineering Challenge:

Meeting Standards for Building a Paper Tower:

Your challenge is to use only 2 sheets of newspaper and 10 inches of cellophane tape to build the tallest tower that can withstand a strong wind, in this case a strong breath from one arm's length away. You may fold, cut, or tear your paper any way you want to. The tape may only be used to attach paper to paper (not to attach the tower to the floor). Your instructor will inform you of the time limit for construction.

Drawing Conclusions:

Having observed the outcomes of the "wind tests," what advice would you give to future students who attempt this engineering challenge?

Timeline of Important Events Related to Achievement 10:

3000 BC In ancient Egypt, the "cubit" is defined as the length of the arm from the elbow to the fingertips.

2000 BC The cubit is redefined as the length of a designated block of marble or black granite.

1120 AD The "ell" is defined as the length of King Henry I's arm from the tip of his nose to the tips of his fingers.

1689 Boston requires bricks to all be 9X4X4 inches to allow rapid rebuilding after a devastating fire.

1780 Eli Whitney (the Father of Standardization) uses standardized musket parts to mass-produce 10,000 muskets for the US government.

1799 A platinum bar designated as 1 meter long and a platinum bar designated as having a mass of 1 kilogram are deposited in Paris as standards for length and mass in the Metric System.

1880 The American Society of Mechanical Engineers (ASME) is founded.

1883 An ASME committee on standards and gauges is created**.**

1884 The first code of practice for boiler testing is published by ASME.

1886 Track gauges for US railroads are standardized.

1901 National Bureau of Standards established (now called the National Institute of Standards and Technology (NIST)

1904 A fire in Baltimore destroys 1500 buildings in 30 hours and points out the need for inter-compatibility of hydrants and fire hose couplings.

1905 A boiler explosion in Brockton Shoe Factory in Massachusetts levels the factory and results in 58 deaths and 117 injuries.

1915 The ASME Boiler and Pressure Vessel Code is published.

1927 A national code for colors for traffic signals is established.

1960 The name International System of Units (SI) is given to our current system of metric units.