Arduino Blink Challenge

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson explores computer programming and the impact of computers on society. Students build and test a program to turn a light on and off using an Arduino board. They connect the hardware, program the code, test their system, adapt it for variations in blinking times, evaluate their results, and share observations with their class.

Lesson Synopsis

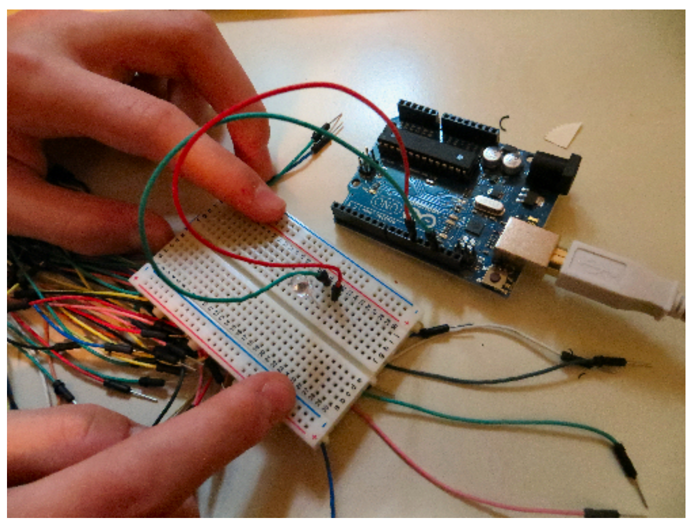
The "Arduino Blink Challenge" lesson explores how computer and software engineers work to solve the challenges of a society, such as providing systems for turning lights on and off automatically. Students work in teams to set up and program an Arduino board to turn a light on and off at a 5 second on and 2 second off interval. Teams build their system, program and test it, reflect on the challenge, and present their experiences to their class.

Age Levels

14-18.

Objectives

- Learn about engineering design and redesign.
- Learn about circuits, computers, and software coding.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.



Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- engineering design
- computer engineering
- software engineering
- teamwork

Lesson Activities

Students explore how engineers have solved societal problems such as applying computing to turn lights on and off. Students work in teams to set up and program an Arduino board to turn a light on and off at a 5 second on and 2 second off interval. Teams build their system, program and test it, reflect on the challenge, and present their experiences to their class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- TryComputing (www.trycomputing.org)
- Arduino (http://arduino.cc/en/)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- Beginning Programming All-In-One Desk Reference For Dummies (ISBN: 978-0470108543)
- Hello World! Computer Programming for Kids and Other Beginners (ISBN: 978-1933988498)
- Arduino Cookbook (ISBN: 978-1449313876)
- Programming Arduino Getting Started with Sketches (ISBN: 978-0071784221)

Optional Writing Activity

- Write an essay or a paragraph that identifies three major products or systems that have been overwhelmingly impacted by computer programming.

Optional Extension Activity

- Require students to make the Arduino blink in the pattern of S-O-S…or have them select three other activities (run a fan, make a stoplight, etc.).

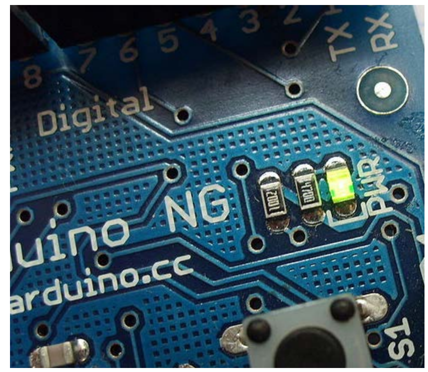
Arduino Blink Challenge

For Teachers:
Teacher Resources

◆ Lesson Goal

The "Arduino Blink Challenge" lesson explores how computer and software engineers work to solve the challenges of a society, such as providing systems for turning lights on and off automatically. Students work in teams to set up and program an Arduino board to turn a light on and off at a 5 second on and 2 second off interval. Teams build their system, program and test it, reflect on the challenge, and present their experiences to their class.

◆ Lesson Objectives

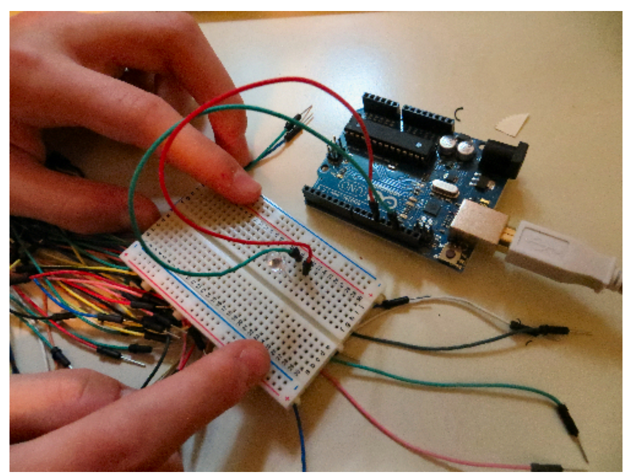


- Learn about engineering design and redesign.
- Learn about circuits, computers, and software coding.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

◆ Materials

- Student Resource Sheets
- Student Worksheets
- Classroom Materials: computer with internet access (for set up); Arduino Board kit (You can purchase individual items or a starter kit that contains an Arduino Uno, a 3' USB Cable, a solderless breadboard, 65 jumper wires, and a breadboard holder for about $38 US via Amazon; items can also be purchased directly from other electronics suppliers and links are available through Arduino at http://arduino.cc/en/)
- Student Team Materials: Arduino board, connectors, optional breadboard, led lights, fan, insulators.

◆ Procedure



1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, consider asking the students how stoplights are timed to change for traffic.
3. Teams of 2 or more students will consider their challenge, and conduct research into how the Arduino operates.
4. Students set up their Arduino, program it and test it until it meets the challenge.
5. Teams reflect on the challenge, and present their experiences to the class.

◆ Time Needed

Two to three 45 minute sessions.

Student/Teacher Resource: Advanced Arduino Applications?

◆ Beyond Flashing Lights

If you have completed the Arduino Blink Challenge, there are many other applications for using an Arduino board that you can try on your own, as a team, in the classroom, or on your own time. You can also find advanced tutorials at http://arduino.cc/en/Tutorial/HomePage to show you how to read a switch, read a potentiometer, use a pushbutton to control an LED, play tones on multiple speakers, make an LED bar graph, send a text string, or even output the values from a barometric pressure sensor as a web page.

The following are some sample ideas so you can see how versatile your new computing skills are!

Control Sensors

Try controlling an external sensor with your Arduino. You can sample air for pollution, identify how bright an area is, set up a flood alarm with a water sensor, or attach a motion detector. Or, consider using the Arduino to control sensors that measure electromagnetic Fields, sample air for humidity levels, take the temperature, identify if a gas is present in the air, or gather data from an anemometer that measures wind speed. You can even attach a bar code scanner (which simulates a keyboard) or a keyboard to the Arduino.

Visual and Audio Applications

Your arduino can be set up to manage a camera system, and control photography settings. This can be done with most equipment, including Nikon, Canon, Sony, Minolta, Olympus and Pentax cameras. You can even attach a bar code scanner (which simulates a keyboard) or a keyboard to the Arduino.

Motors and Robotics

Arduino is a great tool for controlling motors and robotics. Try connecting DC motors or stepper motors. You can control a highly accurate stepper motor using a potentiometer with an Arduino.

◆ Community of Developers

There is a growing commuity of Arduino application developers who share code, ideas, and example. Additional documentation has been created by the Arduino community on the publicly-editable playground wiki at www.arduino.cc/playground.

Arduino Blink Challenge

Student Resource:
What is Arduino?

◆ **Open Source Computing**

Arduino is an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be simple -- such as turning on and off a light -- or very complex. The boards can be assembled by hand or purchased preassembled; the open-source software can be downloaded for free. The Arduino software runs on Windows, Macintosh OSX, and Linux operating systems.

◆ **Computer Programming**

Computer programming (often shortened to programming or coding) is the process of designing, writing, testing, debugging, and maintaining source code of computer programs. The code can be written in many different programming languages. Programming is basically a set of instructions that a computer or other device uses to perform a task -- it might be turning on a light, opening a door, or writing a document.

◆ **Arduino Development Environment**

The Arduino development environment or software contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. Software written using Arduino is called a "sketch." These sketches are written in the text editor. Sketches are saved with the file extension .ino. There are features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino environment including complete error messages and other information. The bottom right hand corner of the window displays the current board and serial port.

Note: Some content and images on this page are derived from Arduino.cc via their Arduino getting started guide (http://arduino.cc/en/Guide/HomePage)

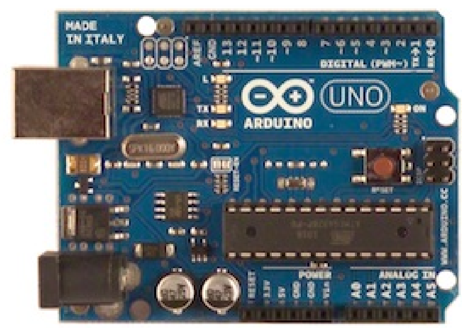
Arduino Blink Challenge

Student Resource:
Arduino Tutorial -- Step by Step - P 1 of 2

This document explains how to connect your Arduino board to the computer and upload your first sketch. This is provided and available online by Arduino at http://arduino.cc/en/Guide/HomePage. These pages apply to the windows environment, but Arduino works on Mac OS X and Linux and the website provides step by step instructions for all operating systems.

1 | Get an Arduino board and USB cable

In this tutorial, we assume you're using an Arduino Uno, Arduino Duemilanove, Nano, or Diecimila. If you have another board, visit http://arduino.cc/en/Guide/HomePage and read the corresponding page for that product in the getting started guide. You also need a standard USB cable (A plug to B plug): the kind you would connect to a USB printer, for example. (For the Arduino Nano, you'll need an A to Mini-B cable instead.) (Note: TryEngineering.org recommends purchasing kits via Amazon or other retailers which are already bundled with breadboards, lights, cable, or other parts you might use down the road as you explore more advanced Arduino challenges.)



2 | Download the Arduino environment

Get the latest version from the download page.
When the download finishes, unzip the downloaded file. Make sure to preserve the folder structure. Double-click the folder to open it. There should be a few files and sub-folders inside.

3 | Connect the board

The Arduino Uno, Mega, Duemilanove and Arduino Nano automatically draw power from either the USB connection to the computer or an external power supply. If you're using an Arduino Diecimila, you'll need to make sure that the board is configured to draw power from the USB connection. The power source is selected with a jumper, a small piece of plastic that fits onto two of the three pins between the USB and power jacks. Check that it's on the two pins closest to the USB port. Connect the Arduino board to your computer using the USB cable. The green power LED (labeled PWR) should go on.

4 | Install the drivers

Installing drivers for the Arduino Uno with Windows7, Vista, or XP:
Plug in your board and wait for Windows to begin its driver installation process. After a few moments, the process will fail, despite its best efforts. Click on the Start Menu, and open up the Control Panel. While in the Control Panel, navigate to System and Security. Next, click on System. Once the System window is up, open the Device Manager.
Look under Ports (COM & LPT). You should see an open port named "Arduino UNO (COMxx)"

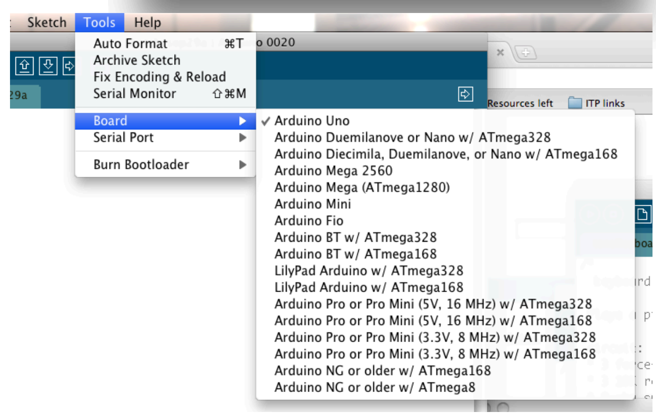
Student Resource:
Arduino Tutorial -- Step by Step - P 2 of 2

4 | Install the drivers (continued)

Right click on the "Arduino UNO (COmxx)" port and choose the "Update Driver Software" option. Next, choose the "Browse my computer for Driver software" option. Finally, navigate to and select the Uno's driver file, named "ArduinoUNO.inf", located in the "Drivers" folder of the Arduino Software download (not the "FTDI USB Drivers" sub-directory). If your software does not allow you to select a specific file, just select the "Drivers" folder and Windows will finish up the driver installation from there. When you connect the board, Windows should initiate the driver installation process (if you haven't used the computer with an Arduino board before).

5 | Launch the Arduino application

Double-click the Arduino application.



6 | Open the blink example

Open the LED blink example sketch: File > Examples > 1.Basics > Blink.

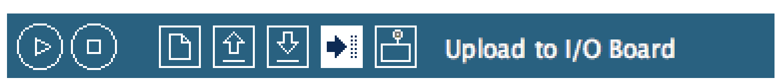
7 | Select your board

You'll need to select the entry in the Tools > Board menu that corresponds to the type of Arduino you are using.

8 | Select your serial port

Select the serial device of the Arduino board from the Tools | Serial Port menu. This is likely to be COM3 or higher (COM1 and COM2 are usually reserved for hardware serial ports). To find out, you can disconnect your Arduino board and re-open the menu; the entry that disappears should be the Arduino board. Reconnect the board and select that serial port.

9 | Upload the program



Now, simply click the "Upload" button in the environment which may look like an arrow pointing to the right. Wait a few seconds - you should see the RX and TX LEDs on the board flashing. If the upload is successful, the message "Done uploading." will appear in the status bar. A few seconds after the upload finishes, you should see the pin 13 (L) LED on the board start to blink (in orange). If it does, congratulations! You've gotten Arduino up-and-running.

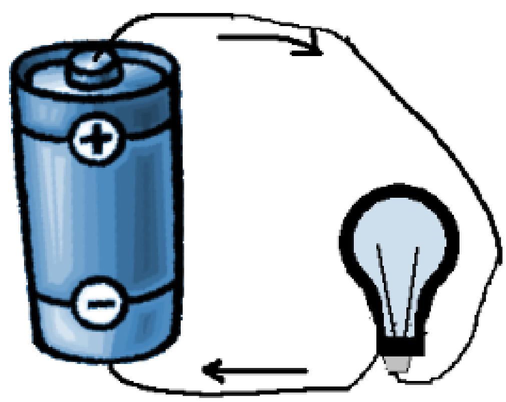
Note: Some content and images on this page are derived from Arduino.cc via their Arduino getting started guide (http://arduino.cc/en/Guide/HomePage)

Student Resource:
Circuit Basics

◆ **Simple Circuit**

A simple circuit consists of three minimum elements that are required to complete a functioning electric circuit: a source of electricity (battery), a path or conductor on which electricity flows (wire) and an electrical resistor (lamp) which is any device that requires electricity to operate. The illustration below shows a simple circuit containing, one battery, two wires, and a bulb. The flow of electricity is caused by excess electrons on the negative end of the battery being attracted to flow toward the positive end, or terminal, of the battery. When the simple circuit is complete, electrons flow from the negative terminal through the wire conductor, then through the bulb (lighting it up), and finally back to the positive terminal - in a continual flow.

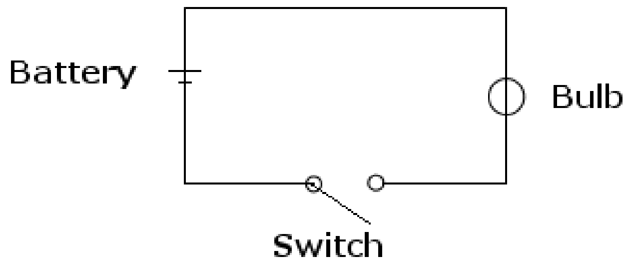
Simple Circuit



◆ **Schematic Diagram of a Simple Circuit**

The following is a schematic diagram of the simple circuit showing the electronic symbols for the battery, switch, and bulb.

Schematic Diagram of a Simple Circuit

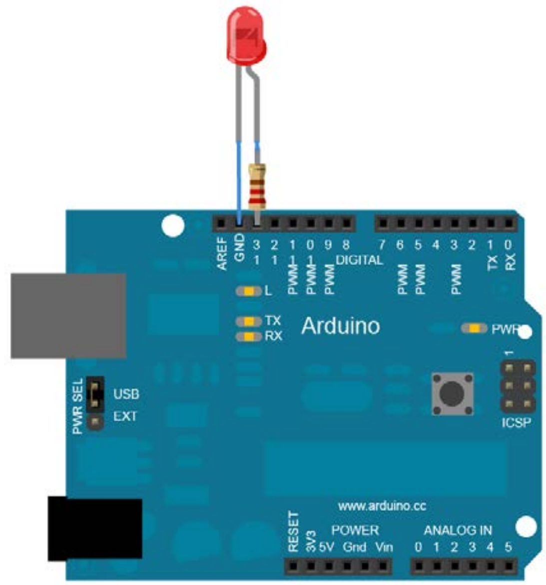


Arduino Blink Challenge

Student Worksheet:

◆ Engineering Teamwork and Planning

You are part of a team of engineers given the challenge of using Arduino to make a light blink on for 5 seconds and off for 2. The instructions and code below will help you see how to program the Arduino to blink for one second on and one second off.

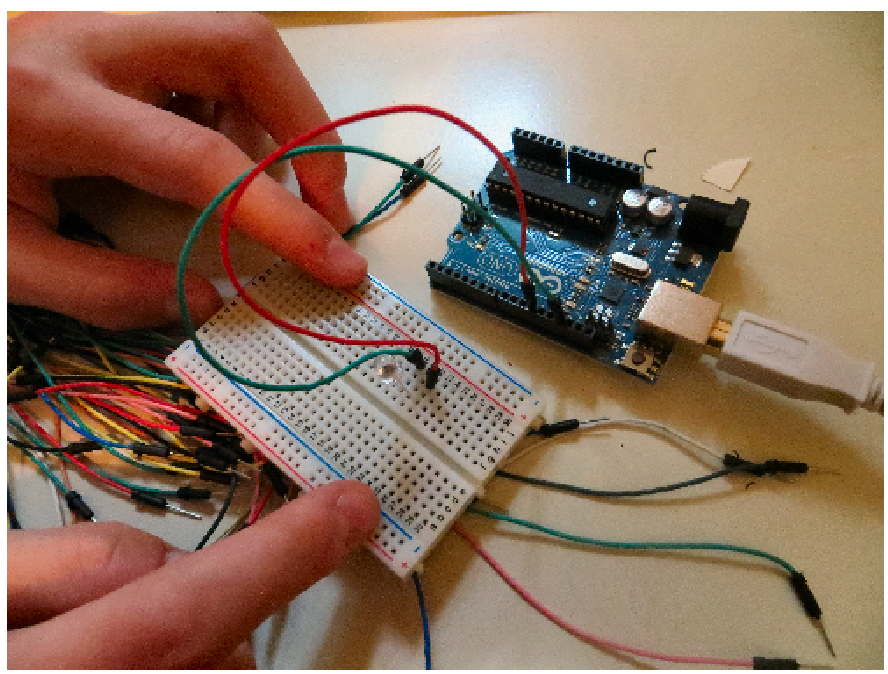


◆ Research Phase

Read the materials provided to you by your teacher. If you have access to the internet ahead of the activity, explore the Arduino website and become familiar with the logic of the programming code.

◆ Building the Circuit

To build the circuit, attach a 220-ohm resistor to pin 13. Then attach the long leg of an LED (the positive leg, called the anode) to the resistor. Attach the short leg (the negative leg, called the cathode) to ground. Then plug your Arduino board into your computer, start the Arduino program, and enter the code below. Note: Most Arduino boards already have an LED attached to pin 13 on the board itself. If you run this example with no hardware attached, you should see that LED blink.

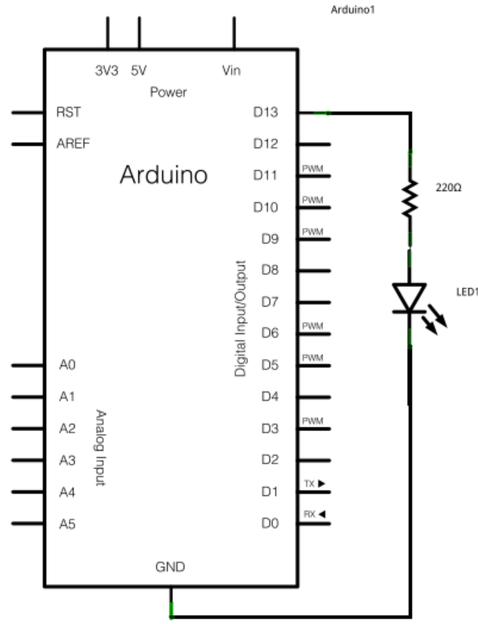


You may also set up your blinking light using a breadboard as in the image above. In this case, you'll use the connectors to link the Arduino to the breadboard and make a complete circuit by having another connector going back to Arduino. You would need to include a separate light on the breadboard too. You can do this lesson either way...with or without the breadboard -- it just depends on what materials you have provided to you and if your team wishes to gain some experience on the breadboard.

Note: Some content and images on this page are derived from Arduino.cc via their Arduino getting started guide (http://arduino.cc/en/Guide/HomePage)

◆ Schematic

The illustration or schematic on the right shows how the circuit for the light works in the Arduino.



◆ Code

In the program below, the first thing you do is to initialize pin 13 as an output pin with the line
`pinMode(13, OUTPUT);`
In the main loop, you turn the LED on with the line:
`digitalWrite(13, HIGH);`
This supplies 5 volts to pin 13. That creates a voltage difference across the pins of the LED, and lights it up. Then you turn it off with the line:
`digitalWrite(13, LOW);`
That takes pin 13 back to 0 volts, and turns the LED off. In between the on and the off, you want enough time for a person to see the change, so the `delay()` commands tell the Arduino to do nothing for 1000 milliseconds, or one second. When you use the `delay()` command, nothing else happens for that amount of time.

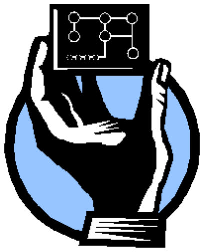
```
/*
Blink
Turns on an LED on for one second, then off for one second,
repeatedly.

This example code is in the public domain.
*/

// Pin 13 has an LED connected on most Arduino boards.
// give it a name:
int led = 13;

// the setup routine runs once when you press reset:
void setup() {
// initialize the digital pin as an output.
pinMode(led, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop() {
digitalWrite(led, HIGH); // turn the LED on (HIGH is the voltage
level)
delay(1000); // wait for a second
digitalWrite(led, LOW); // turn the LED off by making the voltage LOW
delay(1000); // wait for a second
}
```



Student Worksheet:

◆ **Reflection**

Complete the reflection questions below:

1. What challenges did you have, if any, to programming the Arduino to blink on and off at 1 second intervals? How did you resolve any challenges you encountered?

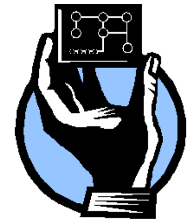
2. Were you able to adjust the code to change the intervals to 5 seconds on and 2 seconds off?

3. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

4. What do you think about the Arduino? Was it a good way for you and your team to explore basic computer programming?

5. How complicated or different do you think code would be to provide instructions to a cell phone to play a particular ringtone?

6. Do you think that stoplights use computer programming to provide a pattern for lights changing at intersections? How do you think stoplights were coordinated prior to computer technology?



For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- Properties and changes of properties in matter
- Transfer of Energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Risks and benefits
- Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor
- History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Interactions of energy and matter

CONTENT STANDARD E: Science and Technology

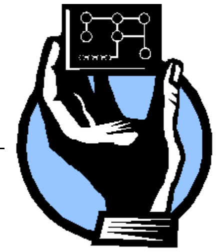
As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local, national, and global challenges



For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor
- Historical perspectives

◆Next Generation Science Standards Grades 3-5 (Ages 8-11)

Energy

Students who demonstrate understanding can:

- 4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆Next Generation Science Standards Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

◆ CSTA K-12 Computer Science Standards Grades 6-9 (ages 11-15)

Computational Thinking:

- 13. Understand the notion of hierarchy and abstraction in computing including high level languages, translation, instruction set, and logic circuits.

Collaboration:

- 1. Apply productivity/multimedia tools and peripherals to group collaboration and support learning throughout the curriculum.
- 3. Collaborate with peers, experts, and others using collaborative practices such as pair programming, working in project teams, and participating in group active learning activities.
- 4. Exhibit dispositions necessary for collaboration: providing useful feedback, integrating feedback, understanding and accepting multiple perspectives, socialization.

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆ CSTA K-12 Computer Science Standards Grades 6-9 (ages 11-15)

Computing Practice & Programming:

- 1. Select appropriate tools and technology resources to accomplish a variety of tasks and solve problems.
- 2. Use a variety of multimedia tools and peripherals to support personal productivity and learning throughout the curriculum.
- 5. Implement problem solutions using a programming language, including: looping behavior, conditional statements, logic, expressions, variables, and functions.
- 8. Demonstrate dispositions amenable to open ended problem solving and programming (e.g., comfort with complexity, persistence, brainstorming, adaptability, patience, propensity to tinker, creativity, accepting challenge).
- 9. Collect and analyze data that is output from multiple runs of a computer program.

Computers & Communications Devices:

- 1. Recognize that computers are devices that execute programs.
- 3. Demonstrate an understanding of the relationship between hardware and software.

◆ CSTA K-12 Computer Science Standards Grades 9-10 (ages 14-16)

Computational Thinking:

- 2. Describe a software development process used to solve software problems (e.g., design, coding, testing, verification).

Collaboration:

- 1. Work in a team to design and develop a software artifact.
- 4. Identify how collaboration influences the design and development of software products.

Computing Practice & Programming:

- 3. Use various debugging and testing methods to ensure program correctness (e.g., test cases, unit testing, white box, black box, integration testing)
- 4. Apply analysis, design, and implementation techniques to solve problems (e.g., use one or more software lifecycle models).
- 8. Explain the program execution process.

Computers & Communications Devices:

- 4. Compare various forms of input and output.

◆ CSTA K-12 Computer Science Standards Grades 10-12 (ages 16-18)

Collaboration:

- 3. Evaluate programs written by others for readability and usability.

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

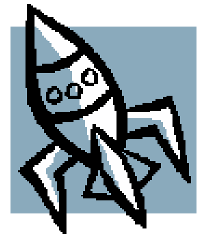
Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 12: Students will develop abilities to use and maintain technological products and systems.
- Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

Blast Off!



Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on aerospace engineering and how space flight has been achieved from an engineering vantage point. Students build and launch a model rocket and consider the forces on a rocket, Newton's Laws, and other principles and challenges of actual space vehicle launch. They design their structure on paper, learn about aerospace engineering, launch their rocket, and share observations with their class. *Note: Teachers and students should be aware that most commercially available rockets generate considerable heat. Great care should be exercised to follow the manufacturer's instructions closely. Supplementary safety instructions are given at the end of this lesson plan.*

Lesson Synopsis

The "Blast Off" lesson explores rocketry, and the principals of space flight. Students work in teams with teacher supervision and construct and launch a rocket from an inexpensive kit. They observe their own achievements and challenges, as well as those of other student teams, complete a reflection sheet, and present their experiences to the class.

Age Levels

14-18.

Objectives

- Learn about aerospace engineering.
- Learn about engineering design and redesign.
- Learn about space flight.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- aerospace engineering
- engineering design
- space flight
- teamwork

Lesson Activities

Students explore how engineers have developed rocketships over the years, and learn about the principals of rocketry. They work in teams to construct and launch a model rocket from a kit under teacher supervision. The students compare their accomplishments and challenges with those of other student teams, complete a reflection sheet, and present to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Timeline of Rocket History (http://history.msfc.nasa.gov/rocketry/)
- NASA Beginners Guide to Rockets (www.grc.nasa.gov/WWW/K-12/rocket/bgmr.html)
- European Space Agency - Space Engineering (www.esa.int/SPECIALS/Space_Engineering)
- Rocketry Planet (www.rocketryplanet.com)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- Rockets and Missiles: The Life Story of a Technology (ISBN: 978-0801887925)
- Rocket and Spacecraft Propulsion: Principles, Practice and New Developments (ISBN: 978-3642088698)
- It's ONLY Rocket Science (ISBN: 978-0387753775)
- "A Pictorial History of Rockets" (www.nasa.gov/pdf/153410main_Rockets_History.pdf)

Optional Writing Activity

- Write an essay or a paragraph describing an example of rockets might be used to help society in peaceful times.

Extension Activity

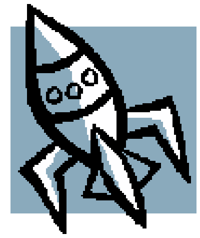
- Have older or more advanced students use an altimeter to measure acceleration as part of this lesson and incorporate g-force discussions.

Safety Notes

- Please read and follow safety recommendations on page 15.
- For younger students TryEngineering.org offers a water pressure rocket lesson, called "Water Rocket Launch"

Blast Off!

For Teachers: Teacher Resources



◆ **Lesson Goal**

The "Blast Off!" lesson focuses on aerospace engineering and how space flight has been achieved from an engineering vantage point. Students build and launch a model rocket and consider the forces on a rocket, Newton's Laws, and other principles and challenges of actual space vehicle launch. They design their structure on paper, learn about aerospace engineering, launch their rocket, and share observations with their class.

◆ **Lesson Objectives**

- Learn about aerospace engineering.
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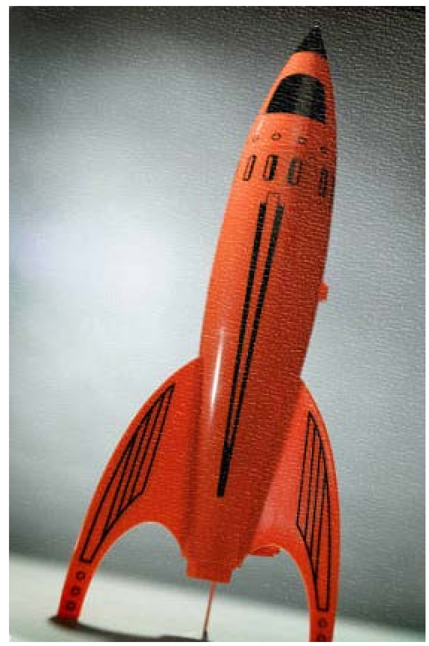


◆ **Materials**

- Student Resource Sheets
- Student Worksheets
- Student Team Materials: paper, pen, pencil; model rocket kit.
- Suggested resources for model rocket kits:
  - Estes (www.estesrockets.com)
  - Model Rockets (www.modelrockets.co.uk)
  - Local or national rocket competitions
- Internet access (optional) to explore www.grc.nasa.gov/WWW/K-12/rocket/ for research and to use online rocket simulator

◆ **Procedure**

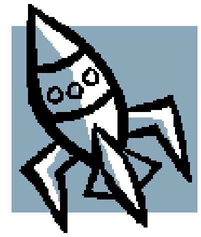
1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, consider asking the students how they think a rocket can fly and how engineers have to consider payload, weather, and the shape and weight of a rocket when developing a new or re-engineered rocket design.
3. Teams of 3-4 students will consider their challenge, read about rocketry, and explore the online rocket simulator (if internet access is available)
4. Teams next build and launch their rocket as a team, and observe the flight patterns of other rockets that are launched.
5. Teams reflect on the experience, and present to the class.

◆ **Safety Note**

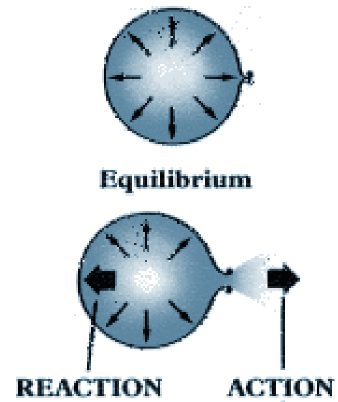
This lesson is intended for older and mature students, under continual supervision of a responsible teacher or teacher team with prior experience with rocket launch kits. Be sure to follow your school's safety guidelines at all times.

◆ **Time Needed**

Two to four 45 minute sessions.



Student Resource: Rocket Principles



A rocket in its simplest form is a chamber enclosing a gas under pressure. A small opening at one end of the chamber allows the gas to escape, and in doing so provides a thrust that propels the rocket in the opposite direction. A good example of this is a balloon. Air inside a balloon is compressed by the balloon's rubber walls. The air pushes back so that the inward and outward pressing forces are balanced. When the nozzle is released, air escapes through it and the balloon is propelled in the opposite direction.

When we think of rockets, we rarely think of balloons. Instead, our attention is drawn to the giant vehicles that carry satellites into orbit and spacecraft to the Moon and planets. Nevertheless, there is a strong similarity between the two. The only significant difference is the way the pressurized gas is produced. With space rockets, the gas is produced by burning propellants that can be solid or liquid in form or a combination of the two.

One of the interesting facts about the historical development of rockets is that while rockets and rocket-powered devices have been in use for more than two thousand years, it has been only in the last three hundred years that rocket experimenters have had a scientific basis for understanding how they work.

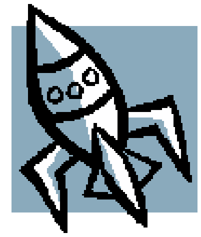
The science of rocketry began with the publishing of a book in 1687 by the English scientist Sir Isaac Newton. His book, entitled Philosophiae Naturalis Principia Mathematica, described physical principles in nature. Today, Newton's work is usually just called the Principia. In the Principia, Newton stated three important scientific principles that govern the motion of all objects, whether on Earth or in space. Knowing these principles, now called Newton's Laws of Motion, rocketeers have been able to construct the modern giant rockets of the 20th century such as the Saturn V and the Space Shuttle.

◆ Newton's Laws of Motion

- Objects at rest will stay at rest and objects in motion will stay in motion in a straight line unless acted upon by an unbalanced force.
- Force is equal to mass times acceleration.
- For every action there is always an opposite and equal reaction.

All three laws are really simple statements of how things move. But with them, precise determinations of rocket performance can be made.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)



Student Resource:
Rocket Principles (Continued)

◆ Newton's First Law

This law of motion is just an obvious statement of fact, but to know what it means, it is necessary to understand the terms rest, motion, and unbalanced force.

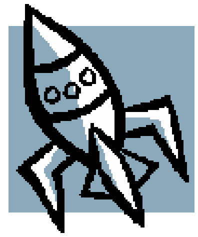
Rest and motion can be thought of as being opposite to each other. Rest is the state of an object when it is not changing position in relation to its surroundings. If you are sitting still in a chair, you can be said to be at rest. This term, however, is relative. Your chair may actually be one of many seats on a speeding airplane. The important thing to remember here is that you are not moving in relation to your immediate surroundings. If rest were defined as a total absence of motion, it would not exist in nature. Even if you were sitting in your chair at home, you would still be moving, because your chair is actually sitting on the surface of a spinning planet that is orbiting a star. The star is moving through a rotating galaxy that is, itself, moving through the universe. While sitting "still," you are, in fact, traveling at a speed of hundreds of kilometers per second.

Motion is also a relative term. All matter in the universe is moving all the time, but in the first law, motion here means changing position in relation to surroundings. A ball is at rest if it is sitting on the ground. The ball is in motion if it is rolling. A rolling ball changes its position in relation to its surroundings. When you are sitting on a chair in an airplane, you are at rest, but if you get up and walk down the aisle, you are in motion. A rocket blasting off the launch pad changes from a state of rest to a state of motion.

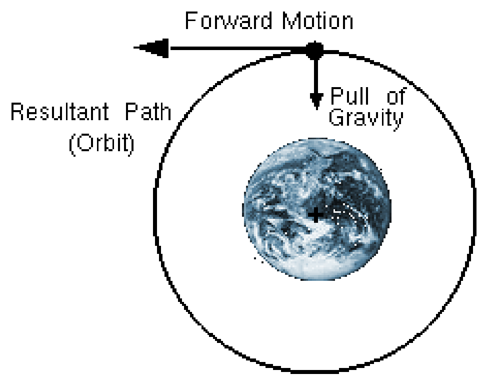
The third term important to understanding this law is unbalanced force. If you hold a ball in your hand and keep it still, the ball is at rest. All the time the ball is held there though, it is being acted upon by forces. The force of gravity is trying to pull the ball downward, while at the same time your hand is pushing against the ball to hold it up. The forces acting on the ball are balanced. Let the ball go, or move your hand upward, and the forces become unbalanced. The ball then changes from a state of rest to a state of motion.

In rocket flight, forces become balanced and unbalanced all the time. A rocket on the launch pad is balanced. The surface of the pad pushes the rocket up while gravity tries to pull it down. As the engines are ignited, the thrust from the rocket unbalances the forces, and the rocket travels upward. Later, when the rocket runs out of fuel, it slows down, stops at the highest point of its flight, then falls back to Earth.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)



Student Resource: Rocket Principles (Continued)

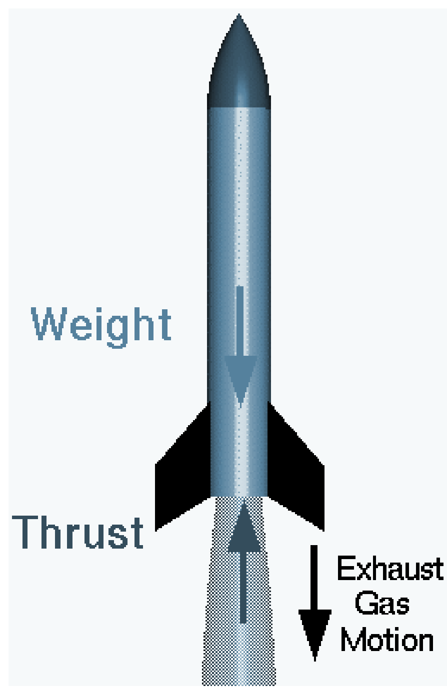


Objects in space also react to forces. A spacecraft moving through the solar system is in constant motion. The spacecraft will travel in a straight line if the forces on it are in balance. This happens only when the spacecraft is very far from any large gravity source such as Earth or the other planets and their moons. If the spacecraft comes near a large body in space, the gravity of that body will unbalance the forces and curve the path of the spacecraft. This happens, in particular, when a satellite is sent by a rocket on a path that is parallel to Earth's surface. If the rocket shoots the spacecraft fast enough, the spacecraft will orbit Earth. As long as another unbalanced force, such as friction with gas molecules in orbit or the firing of a rocket engine in the opposite direction from its movement, does not slow the spacecraft, it will orbit Earth forever.

Now that the three major terms of this first law have been explained, it is possible to restate this law. If an object, such as a rocket, is at rest, it takes an unbalanced force to make it move. If the object is already moving, it takes an unbalanced force, to stop it, change its direction from a straight line path, or alter its speed.

◆ Newton's Third Law

For the time being, we will skip the second law and go directly to the third. This law states that every action has an equal and opposite reaction. If you have ever stepped off a small boat that has not been properly tied to a pier, you will know exactly what this law means.



A rocket can lift off from a launch pad only when it expels gas out of its engine. The rocket pushes on the gas, and the gas in turn pushes on the rocket. The whole process is very similar to riding a skateboard. 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 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. This concept will be better explained in a discussion of the second law.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

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. To enable a rocket to lift off from the launch pad, the action, or thrust, from the engine must be greater than the mass of the rocket. In space, however, even tiny thrusts will cause the rocket to change direction.

One of the most commonly asked questions about rockets is how they can work in space where there is no air for them to push against. The answer to this question comes from the third law. Imagine the skateboard again. On the ground, the only part air plays in the motions of the rider and the skateboard is to slow them down. Moving through the air causes friction, or as scientists call it, drag. The surrounding air impedes the action-reaction. As a result rockets actually work better in space than they do in air. As the exhaust gas leaves the rocket engine it must push away the surrounding air; this uses up some of the energy of the rocket. In space, the exhaust gases can escape freely.

◆ Newton's Second Law

This law of motion is essentially a statement of a mathematical equation. The three parts of the equation are mass (m), acceleration (a), and force (f). Using letters to symbolize each part, the equation can be written as follows:

$f = ma$

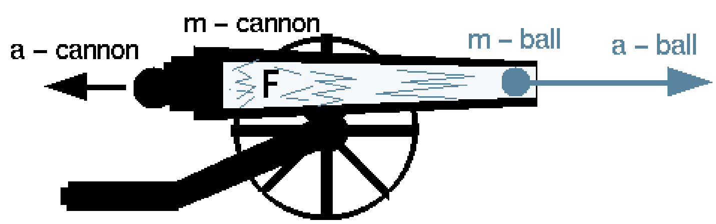
By using simple algebra, we can also write the equation two other ways:

$a = f/m$

$m = f/a$

The first version of the equation is the one most commonly referred to when talking about Newton's second law. It reads: force equals mass times acceleration. To explain this law, we will use an old style cannon as an example.

When the cannon is fired, an explosion propels a cannon ball out the open end of the barrel. It flies a kilometer or two to its target. At the same time the cannon itself is pushed backward a meter or two. This is action and reaction at work (third law). The force acting on the cannon and the ball is the same. What happens to the cannon and the ball is determined by the second law. Look at the two equations below.



$f = m(\text{cannon}) * a(\text{cannon})$

$f = m(\text{ball}) * a(\text{ball})$

The first equation refers to the cannon and the second to the cannon ball. In the first equation, the mass is the cannon itself and the acceleration is the movement of the cannon. In the second equation the mass is the cannon ball and the acceleration is its movement.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource: Rocket Principles (Continued)

The first equation refers to the cannon and the second to the cannon ball. In the first equation, the mass is the cannon itself and the acceleration is the movement of the cannon. In the second equation the mass is the cannon ball and the acceleration is its movement. Because the force (exploding gun powder) is the same for the two equations, the equations can be combined and rewritten below:

$$m(cannon) * a(cannon) = m(ball) * a(ball)$$

In order to keep the two sides of the equations equal, the accelerations vary with mass. In other words, the cannon has a large mass and a small acceleration. The cannon ball has a small mass and a large acceleration.

Let's apply this principle to a rocket. Replace the mass of the cannon ball with the mass of the gases being ejected out of the rocket engine. Replace the mass of the cannon with the mass of the rocket moving in the other direction. Force is the pressure created by the controlled explosion taking place inside the rocket's engines. That pressure accelerates the gas one way and the rocket the other. Some interesting things happen with rockets that don't happen with the cannon and ball in this example. With the cannon and cannon ball, the thrust lasts for just a moment. The thrust for the rocket continues as long as its engines are firing. Furthermore, the mass of the rocket changes during flight. Its mass is the sum of all its parts. Rocket parts include engines, propellant tanks, payload, control system, and propellants. By far, the largest part of the rocket's mass is its propellants. But that amount constantly changes as the engines fire. That means that the rocket's mass gets smaller during flight. In order for the left side of our equation to remain in balance with the right side, acceleration of the rocket has to increase as its mass decreases. That is why a rocket starts off moving slowly and goes faster and faster as it climbs into space.

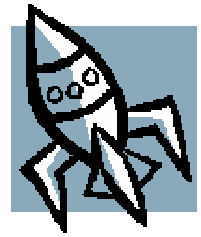
Newton's second law of motion is especially useful when designing efficient rockets. To enable a rocket to climb into low Earth orbit, it is necessary to achieve a speed, in excess of 28,000 km per hour. A speed of over 40,250 km per hour, called escape velocity, enables a rocket to leave Earth and travel out into deep space. Attaining space flight speeds requires the rocket engine to achieve the greatest action force possible in the shortest time. In other words, the engine must burn a large mass of fuel and push the resulting gas out of the engine as rapidly as possible. Newton's second law of motion can be restated in the following way: the greater the mass of rocket fuel burned, and the faster the gas produced can escape the engine, the greater the thrust of the rocket.

◆ Putting Newton's Laws of Motion Together

An unbalanced force must be exerted for a rocket to lift off from a launch pad or for a craft in space to change speed or direction (first law). The amount of thrust (force) produced by a rocket engine will be determined by the mass of rocket fuel that is burned and how fast the gas escapes the rocket (second law). The reaction, or motion, of the rocket is equal to and in the opposite direction of the action, or thrust, from the engine (third law).

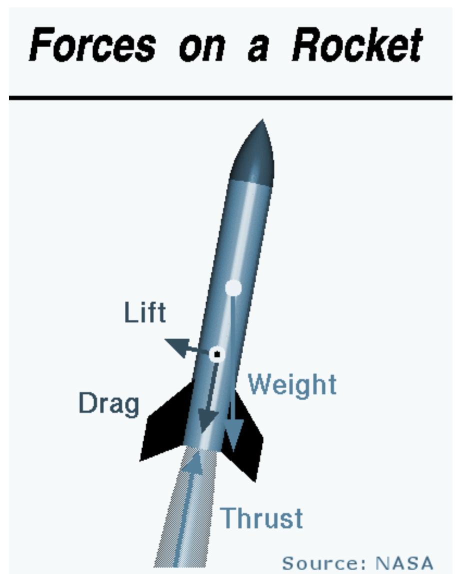
(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Blast Off!



Student Worksheet: How Rockets Fly

In flight, a rocket is subjected to four forces; weight, thrust, and the aerodynamic forces, lift and drag. The magnitude of the weight depends on the mass of all of the parts of the rocket. The weight force is always directed towards the center of the earth and acts through the center of gravity, the yellow dot on the figure. The magnitude of the thrust depends on the mass flow rate through the engine and the velocity and pressure at the exit of the nozzle. The thrust force normally acts along the longitudinal axis of the rocket and therefore acts through the center of gravity. Some full scale rockets can move, or gimbal, their nozzles to produce a force which is not aligned with the center of gravity. The resulting torque about the center of gravity can be used to maneuver the rocket. The magnitude of the aerodynamic forces depends on the shape, size, and velocity of the rocket and on properties of the atmosphere. The aerodynamic forces act through the center of pressure, the black and yellow dot on the figure. Aerodynamic forces are very important for model rockets, but may not be as important for full scale rockets, depending on the mission of the rocket. Full scale boosters usually spend only a short amount of time in the atmosphere.



In flight, the magnitude -- and sometimes the direction -- of the four forces is constantly changing. The response of the rocket depends on the relative magnitude and direction of the forces, much like the motion of the rope in a "tug-of-war" contest. If we add up the forces, being careful to account for the direction, we obtain a net external force on the rocket. The resulting motion of the rocket is described by Newton's laws of motion.

Although the same four forces act on a rocket as on an airplane, there are some important differences in the application of the forces:

- On an airplane, the lift force (the aerodynamic force perpendicular to the flight direction) is used to overcome the weight. On a rocket, thrust is used in opposition to weight. On many rockets, lift is used to stabilize and control the direction of flight.
- On an airplane, most of the aerodynamic forces are generated by the wings and the tail surfaces. For a rocket, the aerodynamic forces are generated by the fins, nose cone, and body tube. For both airplane and rocket, the aerodynamic forces act through the center of pressure (the yellow dot with the black center on the figure) while the weight acts through the center of gravity (the yellow dot on the figure).
- While most airplanes have a high lift to drag ratio, the drag of a rocket is usually much greater than the lift.
- While the magnitude and direction of the forces remain fairly constant for an airplane, the magnitude and direction of the forces acting on a rocket change dramatically during a typical flight.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource: Commercial Spaceflight - News

SpaceShipTwo: The World's First Commercial Spaceship

In 2011, in the skies above Mojave Air and Spaceport CA, SpaceShipTwo, the world's first commercial spaceship, demonstrated its unique reentry 'feather' configuration for the first time. In 2012, Virgin Galactic announced that its vehicle developer, Scaled Composites (Scaled), has been granted an experimental launch permit from the Federal Aviation Administration (FAA) for its suborbital spacecraft, SpaceshipTwo, and the carrier aircraft, WhiteKnightTwo

Already, SpaceShipTwo and WhiteKnightTwo have made significant progress in their flight test program. With 80 test flights completed, WhiteKnightTwo is substantially through its test plan, while the more recently constructed SpaceShipTwo has safely completed sixteen free flights, including three that tested the vehicle's unique "feathering" re-entry system. Additionally, ten test firings of the full scale SpaceShipTwo rocket motor, including full duration burns, have been safely and successfully completed.
With this permit now in hand, Scaled is now authorized to press onward towards rocket-powered test flights. In preparation for those powered flights, SpaceShipTwo will soon return to flight, testing the aerodynamic performance of the spacecraft with the full weight of the rocket motor system on board. Integration of key rocket motor components, already begun during a now-concluding period of downtime for routine maintenance, will continue into the autumn. Scaled expects to begin rocket powered, supersonic flights under the just-issued experimental permit toward the end of the year.
"The Spaceship program is making steady progress, and we are all looking forward to lighting the vehicle's rocket engine in flight for the first time," said Doug Shane, president of Scaled.

Although a handful of experimental launch permits have been granted to other rockets, SpaceShipTwo is the first rocket-powered vehicle that carries humans on board to receive such a permit.

Virgin also announced in 2012 that they will construct a rack system to allow research payloads to fly to space aboard Virgin Galactic's SpaceShipTwo (SS2). With these new racks, SS2 will allow researchers to conduct experiments during several minutes of microgravity using a mounting system also employed on the International Space Station (ISS). Standard racks will support up to 108 cubic feet of usable payload volume. Additionally, experiments can be positioned within the rack system for a view through Virgin Galactic's large, 17-inch-diameter-windows should acquisition of spectral data or imaging be desired

(Source: Virgin Galactic. More details and updates on this effort at www.virgingalactic.com)

Blast Off!

Student Worksheet:

◆ **Engineering Teamwork and Planning**

You are part of a team of engineers given the challenge of building a model rocket from a kit that can rise the highest and straightest compared with other student teams in your class. You'll research ideas online (if you have internet access), learn about rocket design and flight, and work as a team to construct and test your rocket. You'll consider the results of other teams, complete a reflection sheet, and share your experiences with the class.

◆ **Research Phase**

Read the materials provided to you by your teacher. If you have access to the internet, also visit www.grc.nasa.gov/WWW/K-12/rocket/ for additional research and to use the online rocket simulator, RocketModeler III.

◆ **Planning and Design Phase**

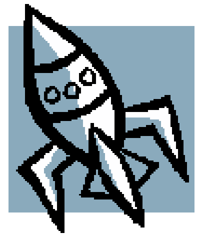
On a separate piece of paper draw a detailed diagram of how your rocket will look when completed and estimate how high you believe your rocket with travel. Is there anything you can do to encourage your rocket to go higher and straighter?

◆ **Build and Launch**

As a team, build your rocket -- but always under the supervision of your teacher! You'll then test the rocket. Be sure to observe how high and how straight the rockets built by other teams go.

◆ **Reflection / Presentation Phase**

Complete the attached student reflection sheet and present your experiences with this activity to the class.



Student Worksheet:

◆ **Reflection**
Complete the reflection questions below:

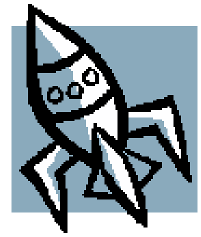
1. How did the height you estimated your rocket would reach compare with the actual estimated height?

2. What do you think might have caused any differences in the height you achieved?

3. Did your rocket launch straight up? If not, why do you think it veered off course?

4. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

5. Did you adjust your model rocket at all? How? Do you think this helped or hindered your results?



◆ **Reflection (continued)**

Complete the reflection questions below:

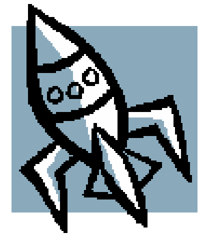
6. How do you think the rocket would have behaved differently if it were launched in a weightless atmosphere?

7. What safety measures do you think engineers consider when launching a real rocket? Consider the location of most launch sites as part of your answer.

8. When engineers are designing a rocket which will carry people in addition to cargo, how do you think the rocket will change in terms of structural design, functionality, and features?

9. Do you think rocket designs will change a great deal over the next ten years? How?

10. What tradeoffs do engineers have to make when considering the space/weight of fuel vs. the weight of cargo?



For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- ✦ Chemical reactions
- ✦ Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor
- ✦ Nature of scientific knowledge
- ✦ Historical perspectives

◆Next Generation Science Standards - Grades 6-8 (Ages 11-14)

Matter and its Interactions

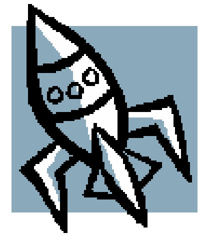
Students who demonstrate understanding can:

- ✦ MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

Engineering Design

Students who demonstrate understanding can:

- ✦ MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- ✦ MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.



For Teachers:
Alignment to Curriculum Frameworks

◆Next Generation Science Standards – Grades 9-12 (Ages 14-18)

- HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.

Technology and Society

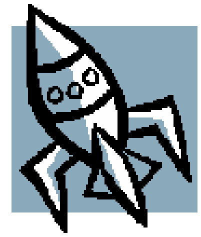
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

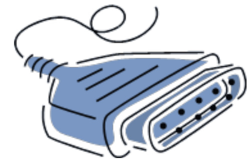
- Standard 11: Students will develop abilities to apply the design process.



For Teachers:
Supplementary Safety Considerations

- Students and the teacher in charge should read and follow the rocket manufacturer's instructions CAREFULLY.
- Teachers who have never supervised a rocket launch may want to team with a teacher who has for their first launch.
- Be sure to follow your school's safety policies.
- Launching can, of course, only be done out of doors.
- Students and others who are not actively involved in launching the rocket should be kept well back. 250 ft is a safe figure.
- All members of the launch team should wear protective eye shields.
- Rockets of the type illustrated are ignited electrically by a pair of wires about 20 ft long. Launch team should stand behind an automobile or other protective barrier. They could even sit inside the car if necessary.
- Note that an alternate to rocket launch kits would be to use a foot pump and launch an air rocket (using an empty soda bottle or other container for the rocket).

The Phone Charger Conundrum



Provided by TryEngineering - www.tryengineering.org

Lesson Focus
Lesson focuses on how technical standards are developed and demonstrates how standards enable products to work together.

Lesson Synopsis
Teams of students will develop models of wireless phone chargers that are compatible with other teams' mobile device designs.

Age Levels
12-18

Objectives
Students will be able to:

- Define what a standard is
- Explain the role of standards in the development of technology
- Develop a standard for a product
- Work in teams to develop a product that complies with a standard

Anticipated Learner Outcomes
As a result of this activity, students should develop an understanding of:

- technical standards
- engineering concepts
- problem solving
- teamwork

Lesson Activities
Student teams learn how engineers work together to develop products that are compatible with other products.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks
See attached curriculum alignment sheet.

Internet Connections

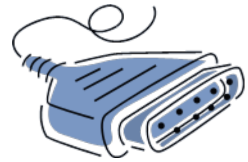
- IEEE Standards Association (http://standards.ieee.org)
- American National Standards Institute (ANSI) (www.standardslearn.org)

Optional Writing Activity

- For younger students: Students can create a marketing sheet that explains all of the features of the phone their team designed.
- For older students: Students can create a product specifications sheet that includes information on elements such as: design, hardware, software and applications, communication, security, sharing and internet, navigation, photography, music and audio, video, environmental friendly features, accessibility etc.

Credits

Developed by the IEEE Standards Education Committee



For Teachers:
Teacher Resources

◆ **Lesson Objectives**

Students will be able to:

- Define what a standard is
- Explain the role of standards in the development of technology
- Develop a standard for a product
- Work in teams to develop a product that complies with a standard

◆ **Materials**

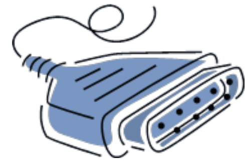
- Plastic forks, writing paper, pencils, cardstock, construction paper, clear tape, glue sticks, scissors, markers, crayons, plastic wrap, aluminum foil, rulers, protractors

◆ **Procedure**

1. Show students two different devices that are not compatible (such as an iPhone and a Blackberry charger). Invite two students to come up in front of the class and try to charge the phone with the charger.
   - Ask students why they think the phone and charger don't work together, and what they think the solution is.
   - Invite students to share other examples of products that need to work together.
2. Review background material on standards as provided in the Student Resource sheets.
3. Divide students into teams of two to three.
4. Share with students that a brand new wireless phone charger known as the PowerFork has recently been developed. They have been selected to help develop the standard that will outline what is required for a phone to be compatible with the PowerFork.
5. Provide each team with a PowerFork (one plastic fork), so they can document its properties (shape, size, appearance etc.). As additional option, as a class you can come to a consensus on modifications to the PowerFork such as breaking off one or more of the tines before documenting its properties.
6. As a class, develop a standard explaining what is required to create a mobile phone that successfully plugs into the PowerFork. (e.g. how many holes does it need, how deep do the holes need to be, what is their diameter, how far apart must they be, are the holes straight or at an angle, are there any concerns regarding temperature since the PowerFork is plastic?)
7. Challenge each team of engineers to design a smart phone prototype out of the materials provided, that will be compatible with the PowerFork phone charger (based on the standard they developed).
8. When students have completed their designs, they can test compatibility with the PowerForks, tweaking as needed.
9. Students can then present their designs and test results to the class.
10. If you wish to evaluate students' designs, you can rate each team's design on a scale of 1-5 using each of the following criteria: original design, compatible design, and creativity

◆ **Time Needed**

- One to two 45 minute sessions



◆ **What is a technical standard?**

A technical standard is a norm or requirement that establishes uniform engineering or technical criteria, methods, process and practices. A standard is usually a formal document that spells out a specific set of requirements for an item, material, component or system.

Standards influence virtually everything, such as computers, phones, communication systems, power and energy, tools, transportation, medical devices, safety, and even toys.

Standards help enable products made by different companies to work together. For example, below is a picture of a wireless router and a laptop computer. You may have one in your home or school. **IEEE Standard 802.11** enables your computer to connect to the wireless router to get online even though both devices are made by different companies.

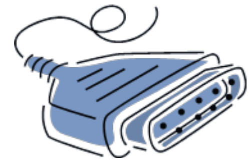
Below is an example of something that is standardized at a national or regional level, but not on a global level. What happens when you travel to a different country and your phone charger doesn't fit into the plug? This is a very good illustration of why technical standards can help make life easier.

For advanced discussion / older students: Standards may be voluntary, where manufacturers can choose to utilize the standard. Standards may be established as procurement guidelines by major buyers, which can provide a significant incentive for manufacturers to adopt the standards. Standards may also be established as regulatory or legal requirements so non-conforming products would be unlawful.

Discussion questions:

- Why might a manufacturer choose not to implement a standard? [answers include: will not work with their device, they feel they have a better idea, and for this example they want to make an increased profit off of a unique design – ideally patent protected so no other supplier can compete with that item.]

- Using the example of the electrical outlets above, why do you think there might be standards at a national or regional level, but not on a global level? One aspect might be that there are trade barriers that protect local markets for appliances.



Student Worksheet:

◆ **Engineering Teamwork and Planning**

A brand new wireless phone charger known as the PowerFork has recently been developed. You are part of a team of engineers that has been selected to help develop a new mobile phone that is compatible with or works with the PowerFork.

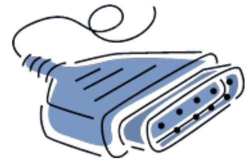
Once you receive your PowerFork, document its properties including (shape, size, length of tines, distance between tines, appearance etc.)

As a class, you will decide what is required to make the mobile phone that you design fit with the PowerFork.

Your phone can be any size, shape or have any features you wish, as long as it fits your PowerFork and everyone else's. Not only does your phone need to be functional, but it also needs to be attractive to users. You will a build your prototype out of the simple materials provided, and then test your design.

◆ **Planning and Design Phase**

Sketch your design ideas below. Include measurements.



Student Worksheet:

◆ Construction Phase

Build your phone and test it to see if it plugs into the PowerFork perfectly. If yes, go to other teams and test whether it fits with their PowerFork.

◆ Presentation and Measurement

Present your mobile phone design and the results of your testing to the class.

◆ Evaluation

Complete the evaluation questions below:

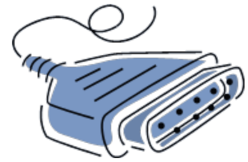
1. How similar was your design to the actual mobile phone you built?

2. Were you able to design a phone that was compatible with the PowerFork? Was it compatible with other teams' PowerForks?

3. Did it work the first time, or did you need to make any modifications? Describe why your team decided to make revisions.

4. What was special or different about your phone, which in your opinion, made it better than others?

5. What is one thing you have learned about standards after participating in this activity?



For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understanding about scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Understanding about science and technology

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in society

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

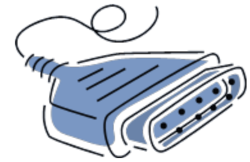
As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology



For Teachers:
Alignment to Curriculum Frameworks

◆Next Generation Science Standards Grades 3-5 (Ages 8-11)

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

◆Next Generation Science Standards Grades 3-5 (Ages 8-11)

Engineering Design

- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆Next Generation Science Standards Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

Design

- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

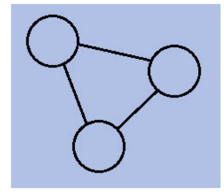
- Standard 11: Students will develop abilities to apply the design process.

The Designed World

- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

TryEngineering

Choose Your Best Way



Provided by TryEngineering.org - www.tryengineering.org

Lesson Focus

Lesson focuses on how mathematic models help to solve real problems and are realized in computers. Students work in teams to build a graph model of their city map while learning how mathematic models work. Student should be encouraged to use this model to solve real problems.

Lesson Synopsis

The “Choose Your Best Way” lesson explores how to build a mathematic model that helps solve real problems and how to realize algorithmic thinking in computers. Students work in teams to build a graph model of their city map. Students then try to solve a real problem based on the model, evaluate their solutions, and present their reflections to the class.

Age Levels

12-18.

Objectives

- Learn about discrete mathematic modeling.
- Learn about graph theory.
- Learn about computer algorithms.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this lesson, students should develop an understanding of:

- mathematic models
- graph theory
- computer algorithmic thinking
- teamwork

Lesson Activities

Students learn how to solve a real problem in computer with the help of discrete mathematic models. They work in teams to build a graph model of their city map while learning how mathematic models work.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheets (attached)
- Student Worksheets (attached)

Internet Connections

- TryComputing (www.trycomputing.org)
- Graph theory tutorials of the University of Tennessee at Martin (http://www.utm.edu/departments/math/graph)

Recommended Reading

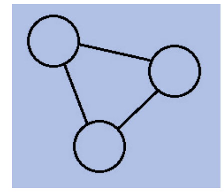
- A Beginner's Guide to Discrete Mathematics (ISBN: 978-0817642692)
- Introductory Graph Theory (ISBN: 978-0486247755)
- Beginning Programming All-In-One Desk Reference For Dummies (ISBN: 978-0470108543)
- Schaum's Outline of Graph Theory (ISBN: 978-0070054899)

Optional Writing Activity

- Explore how the Internet finds the website you want when you tell your browser to go to CNN.com or Google.com. Write an essay or paragraph explaining how this relates to the graph problem described in this unit.

Credits

- This lesson plan was developed by Shuang Liu, an IEEE Student Member from Hannover Germany (Region 8) as part of the IEEE TryComputing.org Lesson Plan Competition.



For Teachers:
Teacher Resources

◆ Lesson Goal

The “Choose Your Best Way” lesson explores how to build a mathematic model that helps solve real problems and how to realize an algorithmic thinking in computers. Students work in teams to build a graph model of their city map. Once they completed teams should try to solve real problems based on the model, evaluate their solutions, and present their reflections to the class.

◆ Lesson Objectives

- Learn about discrete mathematic modeling.
- Learn about graph theory.
- Learn about computer algorithms.
- Learn about teamwork and working in groups.

◆ Materials

- Student Resource Sheets
- Student Worksheets
- One set of materials for each group of students:
  - A city map.
  - Ruler, eraser, pencil, pencil sharpener, marker pen.

◆ Procedure

1. Show students the Student Reference Sheets. These may be read in class, or provided as reading material for the prior night’s homework.
2. Divide students into groups of four or five.
3. To introduce the lesson, discuss with students the use of networks in daily life. For instance road and rail systems, connections via social media and computer networks.
4. Teams will consider their worksheet.
5. Student teams complete an evaluation/reflection sheet and share their experiences with the class.

◆ Time Needed

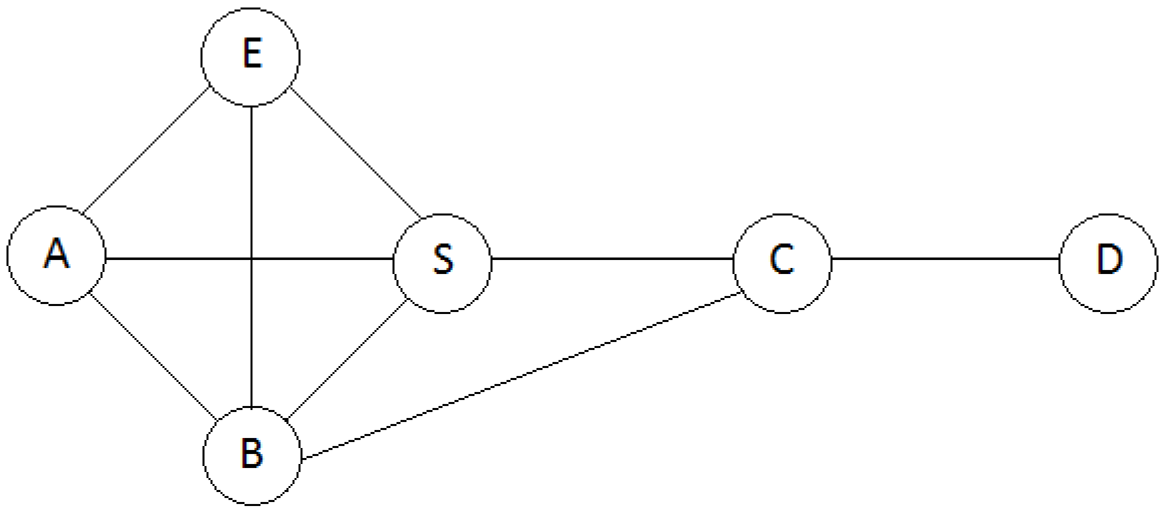
- Two 45 minute sessions.

◆ Advanced Option

The teacher makes a presentation using electronic map software or automotive navigation system to give students a deep impression.

For Teachers:
Sample to the students worksheets

◆ **A Sample Graph Corresponding to a Map**



◆ **The Distance Sheet**

Unit: m

distance	school	A's home	B's home	C's home	D's home	E's home
school	-	200	400	100	-	600
A's home	200	-	300	-	-	500
B's home	400	300	-	400	-	700
C's home	100	-	400	-	200	-
D's home	-	-	-	200	-	-
E's home	600	500	700	-	-	-

For Teachers:
Sample to the students worksheets

◆ **The Results**

First method:
Order: School-C-D-C-B-A-E-School, Total Distance: 2300 meters.
Second method:
Order: School-C-D-C-School-A-E-A-B-A-School, Total Distance: 2600 meters.

Attention: This is the so-called Traveling Salesman Problem. Both of the routes cannot ensure the most optimal solution.

Student Resource:
Discrete Mathematics and Graph Theory

◆ Discrete Mathematics

Discrete mathematics is the study of mathematical structures that can be counted with whole numbers, like your fingers and toes. Such as integers, graphs and statements in logic are the objects studied in discrete mathematics. Discrete mathematics is useful in studying and describing objects and problems in computer sciences.

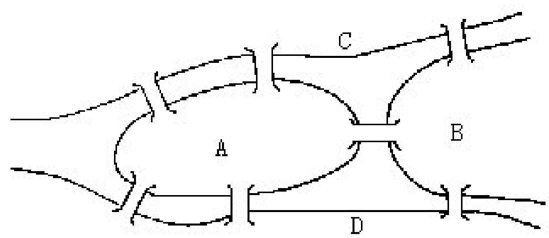
◆ Graph Theory

Graph theory is the study of graphs. A graph refers to a collection of vertices and a collection of edges that connect pairs of vertices. The paper written by Leonhard Euler on the Seven Bridges of Königsberg and published in 1736 is regarded as the first paper in the history of graph theory.

◆ The Seven Bridges of Königsberg

During the eighteenth century, the city of Königsberg in East Prussia (now Kaliningrad, Russia) was divided into four sections by the river Pregel. Seven bridges connected these regions. The challenge was to find a walk through the city that would cross each bridge once and only once. The islands could not be reached by any route other than the bridges. Euler proved that the problem has no solution.

◆ Eulerian Path and Eulerian Circuit



In graph theory, an Eulerian path is a path in a graph which visits every edge exactly at once. Similarly, an Eulerian circuit is an Eulerian path which starts and ends on the same vertex.

◆ Hamiltonian Path and Hamiltonian Circuit

In graph theory, a Hamiltonian path is a path in a graph which visits each vertex exactly at once. A Hamiltonian circuit is a cycle which visits each vertex exactly once and returns to the starting vertex.

Student Worksheet: Search the Shortest Path

◆ **Graph Layout**

Read the city map carefully.

1. Use a marker or pen to circle your school and home of each member in your team in the map. Find the shortest roads between each pair of the places. (If the number of your team is less than four, please choose some typical places instead, such as parks, libraries, etc.)

2. Sketch the corresponding graph below.

3. Fill in the blanks with the words “places” and “roads”.
The edges of this graph represent __________, while the vertexes represent __________.

4. Read the student resource sheets. Then discuss whether your graph contains an Eulerian Path or an Eulerian Circuit.

What about Hamiltonian Path and Hamiltonian Circuit?

Student Worksheet:
Search the Shortest Path

5. In graph theory, if every pair of distinct vertices is connected by a unique edge in a graph, then the graph is called a complete graph.
Is your graph a complete graph, or does your graph contain such a complete graph?

6. Measure the distances between each pair of the places and fill in the data on the following sheet. Please pay attention to the scale of the map. If there is no direct way between any two places, write down "-" instead.

Unit: _______

distance	school	_____'s home	_____'s home	_____'s home	_____'s home	_____'s home
school	-					
_____'s home		-				
_____'s home			-			
_____'s home				-		
_____'s home					-	
_____'s home						-

7. Now, do you think you can remake the graph just using the data in this sheet? If your answer is yes, try to do it. Then you may understand how a graph can be stored in computers. This is one possible solution, of course there are also many other solutions.

◆ Search the Shortest Path

Assume that now you are at school with your friends and you forget to bring your homework. You need to go back home to pick it up and return to school. Since all of you are very good friends, you prefer to be together, that means you need to start from school to everyone's home and finally return to school.

8. Think about how to find the shortest path that covers all of the places and write down your idea. Then try to find the shortest path.

9. Search the path using the following two different methods and calculate the length of the path.

First method:
Start the path from school and mark the school as visited;
The path always goes to the next place that does not be marked as visited and is the nearest neighboring place until all the places are marked as visited;
If there is no further place available, return to the last place;
Then path end at the school.

The order of places: ____
Length of the path: ____

Second method:
Find the shortest distance between any two places and mark the places as visited;
Repeat to find another shortest distance between any two places (at least one of the places should not be marked), until all the places are marked as visited;
Check if any two places can be connected by the paths. If not, find the shortest way to connect them.

The order of places: ____
Length of the path: ____

Student Worksheet:
Review and Evaluation

◆ Review

The paper on the Seven Bridges of Königsberg published in 1736 by Leonhard Euler is regarded as the cornerstone of graph theory. After hundreds of years of development, graph theory is now the fundamental of computer science and is widely used in applications. Many algorithms have been found for problems in different fields, such as electrical networks, coding theory, operations research and computer programming.

◆ Evaluation

Complete the evaluation questions below:

1. Compare the results of both methods. Which result is better?

2. Compare your answer with other groups. Are the answers the same?

3. If the results are not equal to the best solution you have obtained in task 8, which result do you prefer? And which method do you prefer?

4. Assume that you have a map of thousands places. Which method do you think is more efficient?

5. Do you think the methods are appropriate for computers? Why?

6. Which applications do you think your work is significant for?

Choose Your Best Way

Teacher Resource: Alignment to Curriculum Frameworks

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- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆ Principles and Standards for School Mathematics

As a result of activities, all students should develop

Number and Operations Standard

- ✦ Compute fluently and make reasonable estimates

Geometry Standard

- ✦ Specify locations and describe spatial relationships using coordinate geometry and other representational systems
- ✦ Use visualization, spatial reasoning, and geometric modeling to solve problems

Measurement Standard

- ✦ Understand measurable attributes of objects and the units, systems, and processes of measurement
- ✦ Apply appropriate techniques, tools, and formulas to determine measurements.

Problem Solving Standard

- ✦ Apply and adapt a variety of appropriate strategies to solve problems.
- ✦ Solve problems that arise in mathematics and in other contexts.

Representation

- ✦ Use representations to model and interpret physical, social and mathematical phenomena

◆ Common Core State Standards for School Mathematics Grades 2-8 (ages 7-14)

Measurement and data

- Measure and estimate lengths in standard units.

- ✦ CCSS.Math.Content.2.MD.A.1 Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
- ✦ CCSS.Math.Content.2.MD.A.3 Estimate lengths using units of inches, feet, centimeters, and meters.

◆ Common Core State Standards for Mathematics Grades 9-12 (ages 14-18)

Number and Quantity

- Quantities

- o Reason quantitatively and use units to solve problems
- ✦ CCSS.Math.Content.HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

Teacher Resource:
Alignment to Curriculum Frameworks

◆ **Standards for Technological Literacy – All Ages**

The Nature of Technology

- Standard 2: Students will develop an understanding of the core concepts of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

The Designed World

- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

◆ **CSTA K-12 Computer Science Standards Grades 6-9 (ages 11-15)**

5. 2 Level 2: Computer Science and Community (L2)

- Computational Thinking: (CT)
  3. Define an algorithm as a sequence of instructions that can be processed by a computer.
  7. Represent data in a variety of ways including text, sounds, pictures, and numbers.
  8. Use visual representations of problem states, structures, and data (e.g., graphs, charts, network diagrams, flowcharts).
- Collaboration (CL)
  3. Collaborate with peers, experts, and others using collaborative practices such as pair programming, working in project teams, and participating in group active learning activities.
  4. Exhibit dispositions necessary for collaboration: providing useful feedback, integrating feedback, understanding and accepting multiple perspectives, socialization.

Conveyor Engineering

Provided by TryEngineering - www.tryengineering.org

Lesson Focus
Lesson explores the engineering behind the conveyor belt and considers the impact this invention has had on transportation and the coordinated shipping and delivery of goods. Students work in teams to design and build a conveyor system out of everyday materials that can transport pieces of candy 4 feet (120cm). The conveyor must make a 90 degree turn as it moves along. Student teams design their system, build and test it, evaluate their designs and those of classmates, and share observations with their class.

Lesson Synopsis
The "Conveyor Engineering" lesson explores how engineers work to solve the challenges of a society, such as moving goods and people. Students work in teams to devise a conveyor system using everyday materials that can move pieces of candy 4 feet (120cm) including a 90 degree turn. They sketch their plans, build their system, test it, reflect on the challenge, and present to their class.

Age Levels
8-18.

Objectives
- Learn about engineering design and redesign.
- Learn about manufacturing processes and conveyor systems.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes
As a result of this activity, students should develop an understanding of:
- engineering design
- manufacturing and distribution
- conveyor systems
- teamwork

Lesson Activities
Students explore how engineers have solved societal problems such as moving goods, materials, and people using conveyor systems. Students work in teams to develop a conveyor system out of everyday materials than can move pieces of candy 4 feet (120cm) including a 90 degree turn. They evaluate their results, and the results of other teams, and share their reflections with the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Ford Motor Company History - The Assembly Line (http://fordmotorhistory.com/history/assembly_line.php)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- Conveyors: Application, Selection, and Integration (Industrial Innovation) (ISBN: 978-1439803882)
- Belt conveyors and Belt Elevators (ISBN: 978-1177755047)
- The Invention of the Moving Assembly Line: A Revolution in Manufacturing (ISBN: 978-1604137729)
- From the American System to Mass Production, 1800-1932: The Development of Manufacturing Technology in the United States (ISBN: 978-0801829758)

Optional Writing Activity

- Write an essay or a paragraph about three existing and one imagined application of a conveyor belt system.

Extension Activity

- Have advanced or older students power their conveyor systems with motors or gear systems.

For Teachers:
Teacher Resources

◆ **Lesson Goal**

Lesson explores the engineering behind the conveyor belt and considers the impact this invention has had on transportation and the coordinated shipping and delivery of goods. Students work in teams to design and build a conveyor system out of everyday materials that incorporates a 90 degree turn and transports pieces of candy 4 feet (120cm). Student teams design their system, build and test it, evaluate their designs and those of classmates, and share observations with their class.

◆ **Lesson Objectives**

- Learn about engineering design and redesign.
- Learn about manufacturing processes and conveyor systems.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

◆ **Materials**

- Student Resource Sheets
- Student Worksheets
- Classroom Materials (candy or similar sized items)
- Student Team Materials: tubes (can be paper towel rolls, toilet paper rolls, or pvc piping or other similar materials - or even rows of soda bottles or pencils) rubber bands, ball bearings, balls, fabric sheets, string, gears, handles, paper cups, straws, paper towels, paper clips, tape, soda bottle, glue, string, foil, plastic wrap, pens, pencils, paper, hose or tubes, crayons, other items available in the classroom.

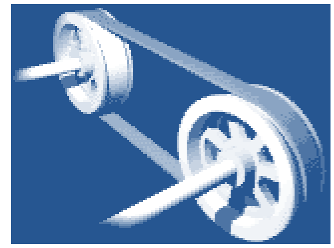
◆ **Procedure**

1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, consider asking the students if they have been to an airport to consider how their luggage was sorted or delivered. Ask them to think about any "moving sidewalks" they have traveled on (airports, malls, other large buildings).
3. Teams of 3-4 students will consider their challenge, and conduct research into how conveyor belt systems operate.
4. Teams then consider available materials and develop a detailed drawing showing their conveyor system including a list of materials they will need to build it.
5. Students build their conveyor system, and test it, and also observe the systems developed and tested by other student teams.
6. Teams reflect on the challenge, and present their experiences to the class.

◆ **Time Needed**

Two to three 45 minute sessions.

Student Resource:
What is a Conveyor Belt?



Conveyor belts can be made out of many different materials, but in its most basic form is a frame with rollers installed that move materials on top. It can be motorized so that the rollers move at a set speed, be manually powered, or move with the force of gravity.

There is also an application called a sandwich belt in which two basic conveyors run in parallel -- one on top of the other, leaving enough space to sandwich a box between. It is used frequently to move items up steep inclines and was developed in 1979 to improve efficience when removing rocks and other materials from mines.

◆ Who uses conveyor systems?

Conveyor systems are commonly used in many industries, including shipping, automotive, agricultural, computer, electronic, food processing, aerospace, pharmaceutical, chemical, bottling and canning, and packaging. Although most materials can be conveyed, some of the most common include food items in boxes, bottles, and cans; automotive components; mining materials and scrap; and grain or animal feed. They are also used to move people and materials (such as boxes and luggage) at airports. A common installation site for conveyor belts are packaging departments and also throughout manufacturing areas. Belts are usually installed at waist height to make it easier for people to oversee the operation and observe materials moving through the system. And...in many countries sushi restaurants are using conveyor belts to route dishes of sushi through customer tables, so they just see what goes by and pick up the plate that looks good!

◆ How does it work?

A conveyor system usually consists of a metal frame with rollers installed at various intervals along the length of the conveyor belt. Usually these are covered with a smooth or rubbery material that covers the rollers and helps materials move along without being stuck between rollers. Some roller systems are straight and some are curved. Some are flat, and some move materials up or down between floors or even into underground mines.

◆ What is mass production?

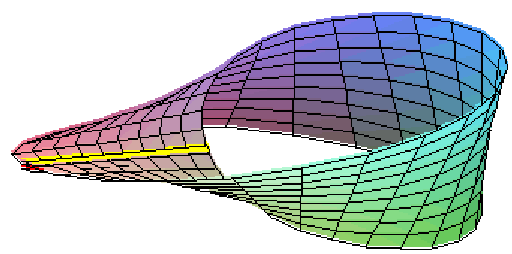
Mass Production involves making many copies of products, very quickly, using assembly line techniques to send partially complete products to workers who each work on an individual step, rather than having a worker work on a whole product from start to finish.

Student Resource: Conveyor Belt History and the Assembly Line

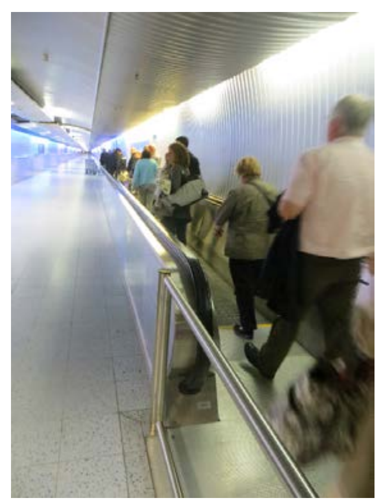
◆ History and Inventors

Primitive conveyor belts have been in use since the 1800s -- initially used in transporting goods to and from mines, which had a great impact on improving the speed with which mined materials could be brought to the surface. In 1913, Henry Ford introduced conveyor-belt assembly lines at Ford Motor Company's Highland Park, Michigan, US factory. The assembly line developed by Ford Motor Company between 1908 and 1915 made assembly lines famous in the following decade through the social ramifications of mass production -- and the conveyor belt was a key component of the system, allowing parts to be moved in from of workers.

In 1957, the B. F. Goodrich Company patented a conveyor belt ultimately called the Turnover Conveyor Belt System. It incorporated a half-twist on the belt called a Möbius Strip (see diagram at right). This design had a big advantage over conventional belts because it exposed all of its surface area to wear and tear and so lasted longer. Now, möbius strip belts are no longer manufactured because untwisted modern belts made from several layers of materials are more durable.



The longest belt conveyor system in the world as of 2012 is 98 km long, connecting the phosphate mines of Bu Craa to the Western Sahara coast. For baggage applications, the longest conveyor system at 92 km is in the Dubai International Airport.



◆ Moving Sidewalks

Another type of conveyor system is the moving sidewalk, which transports people instead of goods or suitcases! The first moving walkway debuted at the World's Columbian Exposition of 1893, in Chicago, IL, US. Now these transport systems are used in airports, malls, and any area where people may be expected to walk long distances. The first moving walkway in an airport was installed in 1958 at Love Field in Dallas, Texas, US. The animated TV series The Jetsons depicts moving walkways everywhere, even in private homes.

Student Worksheet:

◆ **Engineering Teamwork and Planning**

You are part of a team of engineers given the challenge of developing your own conveyor belt out of a range of materials. You will need to convey candy along your belt which has to include a 90 degree turn. You can use any materials you like that are provided to you….and can share or trade materials with other student teams. , There are a few rules: 1. Candy cannot be glued or affixed to the belt surface, 2. Candy cannot fall off.

◆ **Research Phase**

Read the materials provided to you by your teacher. If you have access to the internet, explore examples of conveyor systems and consider how groceries are moved along to the cashier in a market or grocery store.

◆ **Planning and Design Phase**

Draw a diagram of your planned conveyor belt on the back of this page and make a list and quantity of all the materials you think you will need in the box below. You'll need to consider how you will make the conveyor belt move -- you can use your hands to move rollers, gears, or you could use a motor -- just don't touch the cup!

Materials you will need:

◆ **Presentation Phase**
Present your plan and drawing to the class, and consider the plans of other teams. You may wish to fine tune your own design.

◆ **Build it! ...and Redesign if you need to!**
Next build your conveyor belt and test it. You may share unused building materials with other teams, and trade materials too. Be sure to watch what other teams are doing and consider the aspects of different designs that might be an improvement on your team's plan.

◆ **Test it!**
Next, the class will test their conveyor belt systems. Be sure to watch all the tests so you can see the advantages or disadvantages of other systems.

◆ **Reflection**
Complete the reflection questions below:

1. How similar was your original design to the actual conveyor your team built?

2. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.

3. Which conveyor system that another team engineered was the most interesting to you? Why?

4. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

5. If you could have used one additional material (tape, glue, wood sticks, foil -- as examples) which would you choose and why?

Conveyor Engineering

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Properties of objects and materials
- ✦ Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understanding about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Types of resources
- ✦ Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Properties and changes of properties in matter
- ✦ Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Risks and benefits
- ✦ Science and technology in society

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor
- History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Motions and forces
- Conservation of energy and increase in disorder
- Interactions of energy and matter

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Personal and community health
- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Historical perspectives

◆Next Generation Science Standards - (Ages 8-11)

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆Next Generation Science Standards - (Ages 11-14)

Engineering Design

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

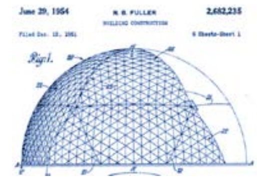
Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- Standard 18: Students will develop an understanding of and be able to select and use transportation technologies.

Design a Dome



Provided by TryEngineering - www.tryengineering.org

Lesson Focus
Lesson focuses on the engineering behind building framing for structures, and explores examples of geodesic domes and other buildings. Students work in teams to design and build a small dome frame out of everyday items that can hold a weight on top without collapsing.

Lesson Synopsis
The "Design a Dome" activity explores construction and engineering design. Students work in teams to design a domed structure out of everyday materials that is strong enough to support 120 grams of coins or candy on top. They will design the frame for their dome on paper, select and gather materials, construct their dome, and test it. They present their domes to the class and complete reflections on the lessons learned.

Age Levels
8-18.

Objectives

- Learn about engineering design and redesign.
- Learn about construction techniques
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes
As a result of this activity, students should develop an understanding of:

- construction
- engineering design
- teamwork

Lesson Activities
Students learn about domes and work in teams to construct their own using everyday materials. They will design the frame for their dome on paper, gather materials, construct their dome, test it, and present their work to the class. They also complete a reflection sheet on the activity.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Buckminster Fuller (www.thirteen.org/cgi-bin/bucky-bin/bucky.cgi)
- Buckminster Fuller Archive at Stamford University (www-sul.stanford.edu/depts/spc/fuller)
- History Channel Statue of Liberty Video (www.history.com/topics/statue-of-liberty/videos#statue-of-liberty-unknown)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

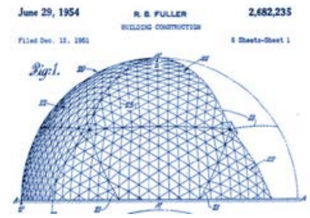
Recommended Reading

- Fuller Houses: R. Buckminster Fuller's Dymaxion Dwellings and Other Domestic Adventures (ISBN: 978-3037781418)
- Ultimate Guide to House Framing (ISBN: 978-1580114431)

Optional Writing Activity

- Write an essay or a paragraph about why sturdy framing is so important to construction. How have the materials used for building framing changed as buildings have become taller and taller?

Design a Dome



For Teachers:
Teacher Resources

◆ **Lesson Goal**
The "Design a Dome" activity explores construction and engineering design. Students work in teams to design a structure with an internal frame and optional exterior decorations that is strong enough to support 120 grams of coins or candy on top. They will design the frame for their dome on paper, select and gather materials, construct their dome, and test it. They present their domes to the class and complete reflections on the lessons learned.

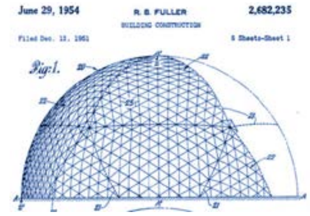
◆ **Lesson Objectives**
- Learn about engineering design and redesign.
- Learn about construction techniques
- Learn about teamwork and problem solving.

◆ **Materials**
- Student Resource Sheets
- Student Worksheets
- Student Team Materials: range of materials including but not limited to cardboard, wooden dowels, tape, foil, construction paper, tissue paper, glue, string, rubber bands, wire, popsicle sticks, paper cups, straws, pipe cleaners, paper clips, screen, fabric.

◆ **Procedure**
1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, discuss the wide range of shapes and sizes of buildings and have the class consider the advantages or disadvantages of different shapes. Discuss the geodesic dome and have the group consider why domes can be a good shape choice for some projects and environments, examples are the South Pole dome and dome design camping tents.
3. If possible, have students consider the structure of a geodesic dome. The resources at www.bfi.org will give some insights into geodesic dome use and history.
4. Teams will consider their challenge and draw a diagram of their planned dome on paper and make a list of the materials they think they will require.
5. Teams next construct their domes with the requested materials list. Teams may request additional materials during the construction process or may trade materials with other student teams.
6. Teams then suspend their dome on the strings provided by the teacher, observe other dome designs, and score their own work.
7. Student teams complete a reflection sheet and share their experiences with the class.

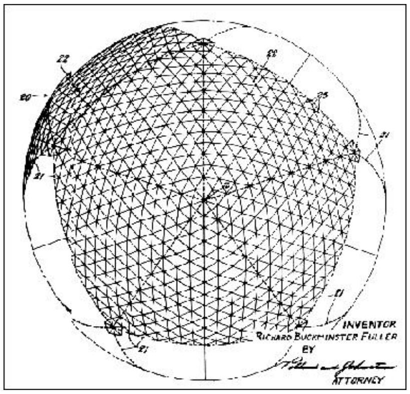
◆ **Time Needed**
One to two 45 minute sessions.

Design a Dome



Student Resource:
Domes and Construction

◆ The Geodesic Dome



Many structures require framing to provide shape and strength before an outer shell is created. A good example is the geodesic dome. A geodesic dome is a spherical or partial-spherical shell structure or lattice shell based on a network of great circles (geodesics) lying on the surface of a sphere. The geodesics intersect to form triangular elements that have local triangular rigidity and also distribute the stress across the entire structure. Walther Bauersfeld was a German engineer, employed by the Zeiss Corporation, who, on a suggestion by the German astronomer Max Wolf, started work on the first projection planetarium during 1912. Bauersfeld completed the first planetarium, known as the Zeiss I model during 1923, which is considered the first geodesic dome derived from the icosahedron, more than 20 years before Buckminster Fuller reinvented and popularized this design. Although Fuller was not the original inventor, he developed the intrinsic mathematics of the dome, thereby allowing popularization of the idea -- for which he received a U.S. patent in 1954. Spaceship Earth at Epcot, Walt Disney World, in Florida, USA is a geodesic sphere.

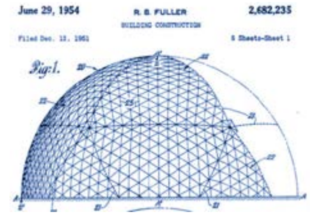
◆ Uses of Domes

Geodesic domes have been used as the basis of many buildings and structures including collapsible camping tents. The National Science Foundation image to the right shows the deconstruction of a geodesic dome which for about three decades sheltered polar researchers and support crews who lived at the bottom of the world. The dome, spanning 164 feet and topping out at about 52 feet high, was dedicated in January 1975. It shielded a collection of buildings that housed scientists and support personnel year-round from wind and snow. The structure far outlived its projected expiration date.

◆ Other Structures with Interesting Framing

Another interesting framing and construction project was the Statue of Liberty in New York, USA. Alexandre Gustave Eiffel (designer of the Eiffel Tower) was commissioned to design the massive iron pylon and secondary skeletal framework which allows the Statue's copper skin to move independently yet stand upright. He produced a 94-ft-high wrought-iron square skeleton that supports a secondary iron frame that carries a system of flat wrought iron bars. The bars support the copper plates that form the statue's exterior skin. It has proved to be an excellent frame structure -- in a 50-mph wind, the monument only moves about 3 inches!

Design a Dome



Student Worksheet:

◆ Engineering Teamwork and Planning

You are part of a team of engineers given the challenge of building a dome to hold 120 grams of coins, candy, or other materials selected by your teacher. You'll have lots of materials to use such as cardboard, wooden dowels, tape, foil, construction paper, tissue paper, glue, string, rubber bands, wire, popsicle sticks, paper cups, straws, pipe cleaners, paper clips, screen, and other readily available materials. Your structure must be at least 14 cm tall measured from the top of the dome to the bottom.

◆ Planning and Design Phase

Think about the different ways you can use the materials provided to construct a dome structure. You may add a skin or shell out of different materials, or have the frame be the full product. On a separate piece of paper, draw a diagram of your planned dome, and in the box below, make a list of the parts you think you might need. You can adjust this later and also add more materials during construction.

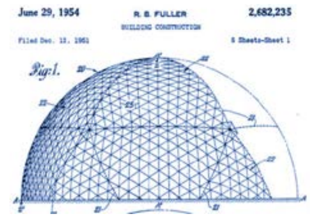
Materials Needed:

◆ Construction Phase

Build your dome and make any adjustments during construction that you like, including asking for additional materials. You can also trade materials with other student teams if they have extra items you would like to incorporate.

◆ Classroom Testing

Your teacher will suspend your dome as well as those made by other teams. You'll receive points based on the following variables.



Student Worksheet (continued):

◆ **Evaluation**

Complete the evaluation questions below:

1. How similar was your original design to the actual dome you built?

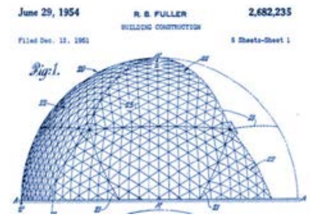
2. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.

3. Which dome that another team made was the most interesting to you? Why?

4. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

5. If you could have used one additional material (tape, glue, wood sticks, foil -- as examples) which would you choose and why?

6. Do you think your dome would have been able to hold 600 grams of weight? Why or why not?



For Teachers:
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- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Properties of objects and materials

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Abilities to distinguish between natural objects and objects made by humans

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Types of resources
- ✦ Changes in environments
- ✦ Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Motions and forces

CONTENT STANDARD E: Science and Technology

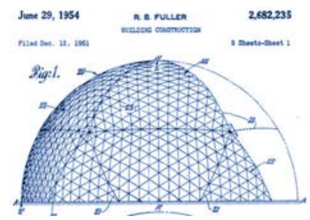
As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in society



For Teachers: Alignment to Curriculum Frameworks (cont.)

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor
- ✦ History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- ✦ Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor
- ✦ Historical perspectives

◆Next Generation Science Standards Grades 2-5 (Ages 7-11)

Matter and its Interactions

Students who demonstrate understanding can:

- ✦ 2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- ✦ 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

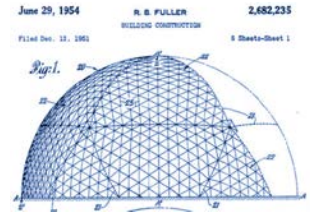
Engineering Design

Students who demonstrate understanding can:

- ✦ 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- ✦ 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- ✦ 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Design a Dome

For Teachers:
Alignment to Curriculum Frameworks (cont.)



◆Next Generation Science Standards Grades 6-8 (Ages 11-14)

Engineering Design

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Standards for Technological Literacy - All Ages

Technology and Society

- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

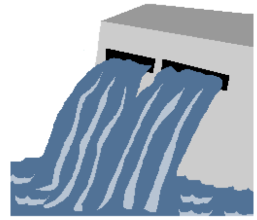
Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.

The Designed World

- Standard 20: Students will develop an understanding of and be able to select and use construction technologies.

Engineer a Dam



Provided by TryEngineering - www.tryengineering.org

Lesson Focus

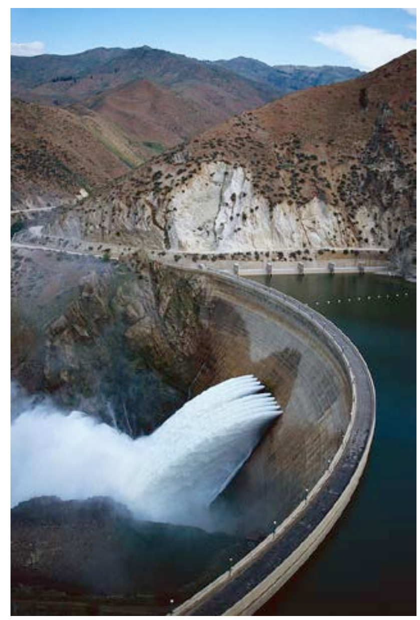
Lesson focuses on the different uses of dams and how they are engineered. Students work in teams to develop a system of damming water in a trough. The system must completely hold back the water and also have a way of executing a controlled release.

Lesson Synopsis

The "Engineer a Dam" activity explores the function and engineering of dams and how they have many uses and solve many problems in the world. Students work in teams to engineer their own dam structure in a classroom water trough that has the ability to release water in a controlled manner, as might be used in irrigation. Students present their plans to the class, execute and test their dams, and reflect on the experience.

Age Levels

8-18.



Objectives

- Learn about dams.
- Learn about engineering design and redesign.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- dams
- structural design and engineering
- engineering design
- teamwork

Lesson Activities

Students explore the multiple uses of dams and how they solve problems. They learn about different types of dams, consider material options, build a dam in a classroom water trough, test it, and share their experiences with the class.

Resources / Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Building Big - All About Dams (www.pbs.org/wgbh/buildingbig/dam)
- GeoGuide: Dams (www.nationalgeographic.com/resources/ngo/education/geoguide/dams/)
- Hydroelectric Power (www.eia.doe.gov/kids/energy.cfm?page=hydropower_home-basics)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- Dams (Library of Congress Visual Sourcebooks) (ISBN: 978-0393731392)
- Hoover Dam: An American Adventure (ISBN: 978-0806122830)
- Hydroelectric Power: Power from Moving Water (ISBN: 978-0778729341)

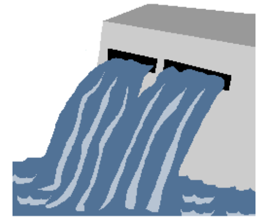
Optional Writing Activity

- Write an essay or a paragraph about how dam construction can impact the environment. What are the ethical considerations an engineering team must consider when constructing a dam or any other structure that has an impact on the environment.

Optional Extension Activity

- Have older or more advanced students should explore how hydroelectricity is generated and consider how they might generate power from the release of water in their classroom dams.

Engineer a Dam



For Teachers:
Teacher Resources

◆ **Lesson Goal**

The "Engineer a Dam" activity explores the function and engineering of dams and how they have many uses and solve many problems in the world. Students work in teams to engineer their own dam structure in a classroom water trough that has the ability to release water in a controlled manner, as might be used in irrigation. Students present their plans to the class, execute and test their dams, and reflect on the experience.

◆ **Lesson Objectives**

- Learn about dams.
- Learn about engineering design and redesign.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

◆ **Materials**

- Student Resource Sheets
- Student Worksheets
- Classroom Materials: water, measuring cup
- Student Team Materials: water trough or long plastic planter, gravel or sand (for "river" base), cardboard, pvc pipes, tape, foil, plastic wrap, cups, straws, paper clips, wooden dowels, cotton balls, plastic sheets, clothes pins, wire, string, screen, fabric, springs, other readily available materials.

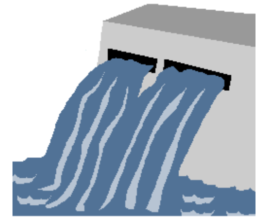
◆ **Procedure**

1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, discuss how engineers solve problems and how a dam can create an energy source as well as redirect water to areas of greater need. Talk about how redirecting or holding back water may impact the environment in a local area. Discuss ethical considerations engineers must consider before building any structure.
3. If possible, have students explore the forces, materials, loads, and shapes lab at the Building Big - All about Dams website and have them consider that they learn before developing their dam design. (www.pbs.org/wgbh/buildingbig/lab/)
4. Teams will consider their challenge and draw a diagram of their planned dam.
5. Teams next construct their dams within their trough -- the base of the trough will have a layer of gravel or small rocks that must not be removed. Teams may request additional materials or parts which surface during the construction process.
6. Teams test their dams with teacher supervision, and must hold back 5 liters of water. Dams must also allow for a controlled release of some of the water. Teams must be able to demonstrate allowing water to flow, then stop, then flow again.
7. Students complete a reflection sheet and share their experiences with the class.

◆ **Time Needed**

Two to three 45 minute sessions.

Engineer a Dam

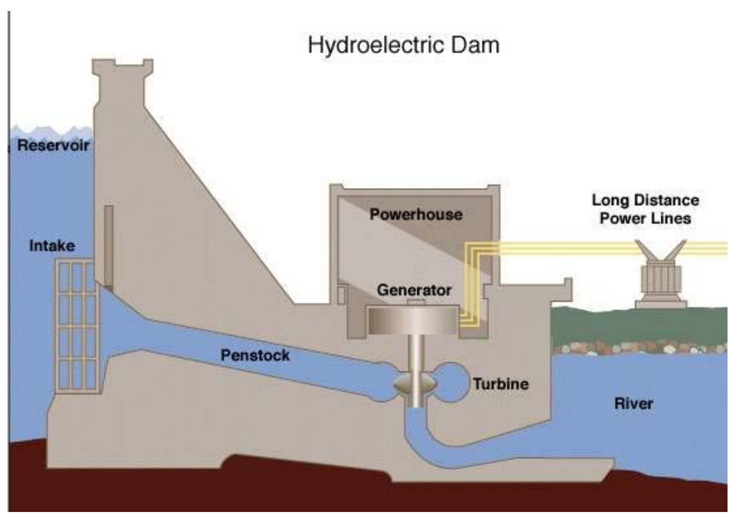


Student Resource: Dams

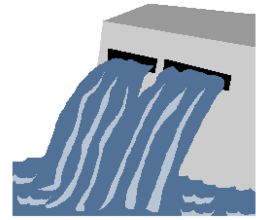
Dams can be formed by people, natural causes, or by animals such as beavers. They serve Dams serve many purposes including storing water to be used later for drinking or irrigation; diverting water from one place to another, such as from a stream to a river; detention to contain sediment or other unwanted materials. Sometimes dams are used to keep water in, and sometimes to keep water out! Some people construct emergency dry dams to keep water out of basements during a heavy rainstorm or flood.

Sometimes when a new dam is created, the people who lived in the surrounding area must be displaced. Millions of people have been displaced to make way for the construction of dams around the world. Of course, many more people have benefited from clean water, crops that have enough water, and the power generated from hydroelectric power plants.

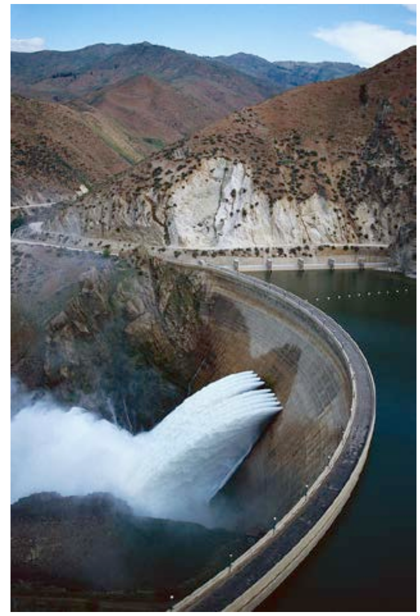
Some dams include "fish ladders" so that fish that migrate can still get to their destination. They are constructed to help fish get up-stream over a dam or a natural barrier so they can reach spawning grounds. You can see an example to the right.



Other dams feed water in a controlled flow to hydroelectric power plants. In a simple sense, the way this works is that a dam is built on a river -- usually one with a drop in elevation so that water released from the dam uses gravity to support the water flow. At the bottom will be a water intake area that leads to a turbine propeller. The propeller moves when the force of the moving water hits it and a shaft from the turbine goes up into the generator, which produces power that is then delivered to homes and businesses via power line. The illustration to the right helps show this system and was developed by the Tennessee Valley Authority. You can read more about hydroelectric power on their website (www.tva.gov/power/hydro.htm).



Student Worksheet: Applying Technology to Solve Problems



◆ Engineering Teamwork and Planning

You are part of a team of engineers given the challenge of building a system to dam up 5 liters of water in a classroom trough. You'll have lots of materials to use such as cardboard, pvc pipes, tape, foil, plastic wrap, cups, straws, paper clips, wooden dowels, cotton balls, plastic sheets, clothes pins, wire, string, screen, fabric, springs, other readily available materials.

You have a base of gravel at the bottom of the trough which simulated the rocky or sandy bottom of a river bed. You'll need to not only stop the water, but develop a system so that you can release a little at a time in a controlled way. You'll need to stop the water, let a little come through, and stop it again.

◆ Research Phase

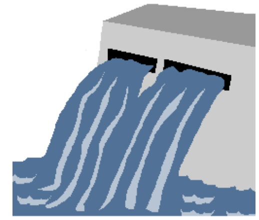
If internet access if available, explore the forces, materials, loads, and shapes lab at the Building Big - All about Dams website and have them consider that they learn before developing their dam design. (www.pbs.org/wgbh/buildingbig/lab)

◆ Planning and Design Phase

Think about the different ways you can use the materials provided to stop the water flow. Also, consider what mechanism you might create that would allow a little water to come through when you want it to. On a separate piece of paper, draw a diagram of your planned dam. In the box below make a list of the parts you think you might need. You can adjust this later and also add more materials during construction.

Material Needed:

Engineer a Dam



Student Worksheet:

◆ **Construction Phase**

Build your dam in your water trough or plastic flower box. You can test it with a little water before the full 5 liters are poured in by your teacher. Make any adjustments during construction that you like, including asking for additional materials you might need. You can also trade materials with other teams if they have extra items you need.

◆ **Classroom Testing**

Your teacher will test each of the dams created in your class. They will look to see if any water escapes through the dam and also if you are able to stop - start - and stop the flow. Be sure to watch as the dams made by other teams are tested so you can evaluate their designs and see what methods worked best. Complete the chart below showing your results -- 30 points is the highest score.

Engineer a Dam Scoring

1. Did your dam hold the water back?

- ☐ 10 points: yes…no water escaped
- ☐ 5 points: some water escaped but less than a liter
- ☐ 0 points: dam did not hold

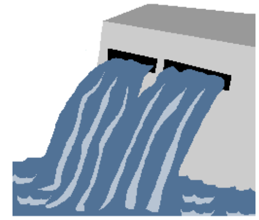
2. Were you able to release water and then stop it again?

- ☐ 10 points: yes
- ☐ 0 points: no

3. Did your team work collaboratively on this project with everyone sharing in the planning and construction?

- ☐ 10 points: yes
- ☐ 0 points: no

Total Score: ____________________



Student Worksheet:

◆ **Evaluation**

Complete the evaluation questions below:

1. How similar was your original design to the actual dam you built?

2. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.

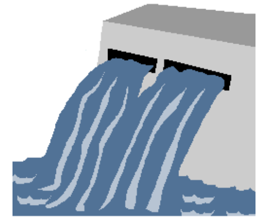
3. If you had a chance to do this project again, what would your team have done differently?

4. Do you think you could have achieved the goal of this lesson using fewer parts or pieces of material than you did?

5. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

6. If you could have used one additional material (tape, glue, wood sticks, foil -- as examples) which would you choose and why?

7. Can you think of any possible negative effects of a new dam on the ecosystem of a region?



For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- Properties of objects and materials
- Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understanding about science and technology
- Abilities to distinguish between natural objects and objects made by humans

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

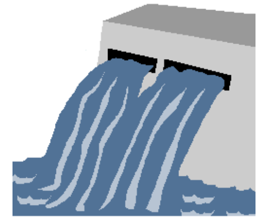
As a result of their activities, all students should develop an understanding of

- Motions and forces
- Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- Abilities of technological design
- Understandings about science and technology



For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Populations, resources, and environments
- ✦ Risks and benefits
- ✦ Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- ✦ Motions and forces
- ✦ Interactions of energy and matter

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

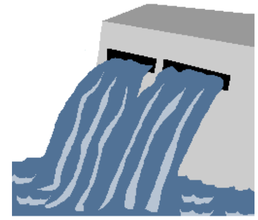
- ✦ Personal and community health
- ✦ Natural resources
- ✦ Environmental quality
- ✦ Natural and human-induced hazards
- ✦ Science and technology in local, national, and global challenges

◆Next Generation Science Standards Grades 2-5 (Ages 8-11)

Engineering Design

Students who demonstrate understanding can:

- ✦ 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- ✦ 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- ✦ 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.



For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆Next Generation Science Standards Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

◆Next Generation Science Standards Grades 9-12 (Ages 14-18)

Engineering Design

Students who demonstrate understanding can:

- HS-ETS1-2.Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 5: Students will develop an understanding of the effects of technology on the environment.

Design

- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.
- Standard 20: Students will develop an understanding of and be able to select and use construction technologies.

Engineered Memory

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on the engineering behind storage devices, and engineering improvements over time. Though exploring the operation of the "floppy" disk, students explore the mechanics underlying operation, and then test the disk under a variety of conditions. Working as a computer engineering group, students then work in teams to evaluate pros and cons of eliminating the floppy disk drive from a new computer under development for use in schools worldwide. They also explore developing punch codes and create punch cards for data storage. They explore the concept of re-engineering and also consider the ethical issues of re-engineering a product.

Lesson Synopsis

The Engineered Memory lesson not only explores how engineers designed the floppy disk and how it has changed over time, but also explores the challenges of computer engineers who must decide what components to include in new systems. Students explore how floppy disks work, test them under a variety of circumstances, then work in teams to determine if they recommend including or excluding the floppy from a new notebook computer designed for schools worldwide. They also explore developing punch codes and create punch cards for data storage. They explore the concept of re-engineering and also consider the ethical issues of re-engineering a product.

Age Levels

8-18.

Objectives

- Learn about computer engineering.
- Learn about product testing.
- Learn about computing history.
- Learn about meeting the needs of society.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- computer engineering and planning
- computing history
- problem solving
- teamwork

Lesson Activities

Students learn how floppy disks work and explore how they hold up in a variety of situations. Student teams are then challenged with evaluating and deciding whether to include or exclude a floppy disk drive in a new computer designed to be used by schools all over the world. They also develop their own punch card system and make their own punch cards. Student teams present their recommendations to other teams.

Resources/Materials

- Teacher Resource Document (attached)
- Student Worksheets (attached)
- Student Resource Sheet (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Fifty Years of Storage Innovations (www-03.ibm.com/ibm/history/exhibits/storage/storage_fifty.html)
- Wikipedia - Data Storage (http://en.wikipedia.org/wiki/Data_storage_device)
- Columbia University Computing History (www.columbia.edu/acis/history)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Recommended Reading

- Essentials of Mechatronics (ISBN: 047172341X)
- A History of the Personal Computer: The People and the Technology (ISBN: 0968910807)

Optional Writing Activity

- Write an essay or a paragraph about how storage devices have impacted present day life.

For Teachers:
Teacher Resource

◆ Lesson Goal

Lesson focuses on the engineering behind floppy disks and how information storage has changed over time. Students weigh the pros and cons of the floppy disk, and test disks in a variety of situations. Then, working as a computer engineering group, students then work in teams to evaluate pros and cons of eliminating the floppy disk drive from a new, low cost, computer under development for use in schools worldwide. They explore the concept of re-engineering and also consider the ethical issues of re-engineering a product. As an optional activity, student also explore developing punch codes and create punch cards for data storage.

◆ Lesson Objectives

- Learn about computer engineering.
- Learn about product testing.
- Learn about computing history.
- Learn about meeting the needs of society.
- Learn about teamwork and working in groups.

◆ Materials

- Student Resource Sheet
- Student Worksheets
- One set of materials for each group of students:
  - Six floppy disks (assume all will be destroyed), two plastic bags
  - Access to freezer, refrigerator, several strengths of magnets
  - 20 index cards for optional punch card activity

◆ Caution

This lesson shows how standard floppy disks may be vulnerable to cold temperatures and magnets. Placing floppy disks in a computer that are damaged due to magnets and temperature will not harm your computer….but teachers are encouraged to limit testing to these methods. If students add dirt, water, salt, sugar, or other materials into the plastic casing of this disk and then put into a computer it will likely cause damage to your computer. Supervision is required; heating should not be to an extent that it causes a change in the shape of the floppy disk case. Do not put misshapen disks in a computer.

◆ Procedure

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.

2. Divide students into groups of 2-3 student "computer engineers," providing a set of materials per group.

For Teachers:
Teacher Resource (continued)

3. Explain that students must test the limitations of the floppy disk and then work as a team of computer engineers to determine whether or not a floppy disk drive should be included in a new computer system that is under development.

4. Students disassemble one disk to explore the inner workings. Most disks can be taken apart without any tools, though assistance may be needed with younger students.

5. Students then create or copy both a word processing document and a graphic file or photo onto each of the remaining five disks.

6. Student teams then predict on attached student worksheet what will happen to the data on each disk when exposed to extreme cold (freezer), moderate cold (refrigerator), and three strengths of magnets. Disks going into freezer or refrigerator should be put in plastic bags so moisture does not accumulate. Note: you may encourage students to come up with their own tests. If so, you'll need to approve their proposals and consider safety, both to students and to computer hardware.

7. Teams then execute the tests on the disks, and record their results.

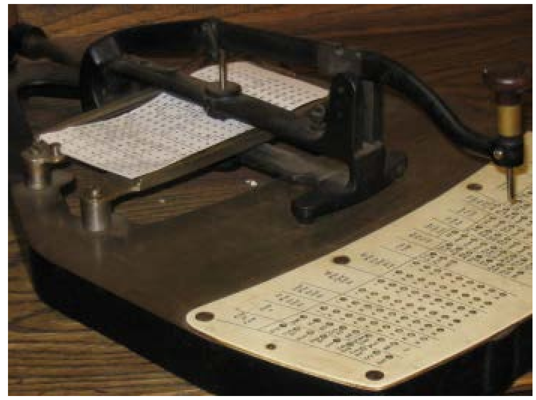
8. Teams then evaluate the floppy disk in order to come to a recommendation as to whether or not a floppy disk drive should be included as a component in a new, low cost, computer system under development for schools worldwide. (student worksheet)

9. Teams present their recommendations to the class.

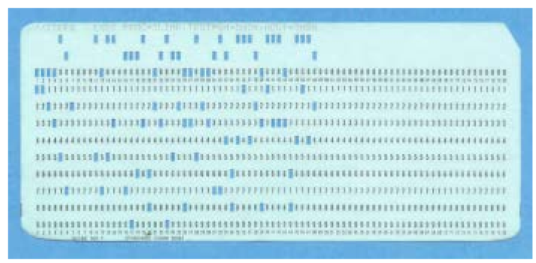
◆ Safety Note
When using floppy discs, be sure to check to make sure the sliding metal panel is not bent or damaged before inserting into computer. A bent panel can cause the disc to be stuck in the computer and can cause damage.

◆ Time Needed
One to two 45 minute sessions (allowing time for freezing and cooling disks). Be sure to leave plenty of time for the engineers to consider the needs of the worldwide users of the product in development.

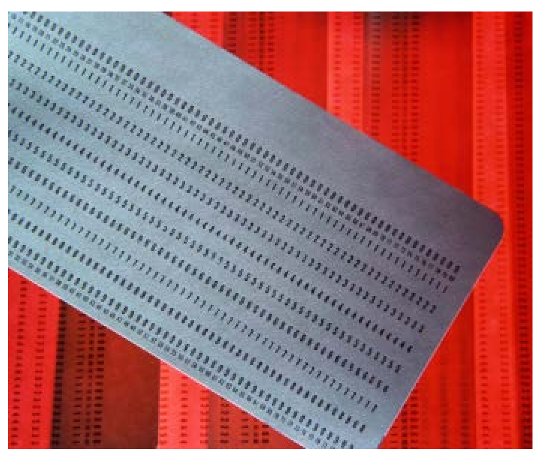
◆ Punch Cards



A punch card or punched card is a piece of stiff paper that contains digital information represented by the presence or absence of holes in predefined positions. Almost an obsolete recording medium, punched cards were widely used throughout the nineteenth century for controlling textile looms and through the twentieth century in unit record machines for input, processing, and data storage. Digital computers used punched cards, later scanned by card readers, as the primary medium for input of both computer programs and data, with offline data entry on key punch machines. Some voting machines have used punch cards. Punched cards were first used around 1725 by Basile Bouchon and Jean-Baptiste Falcon as a more robust form of the perforated paper rolls then in use for controlling textile looms in France.



The early applications of punched cards all used specifically designed card layouts. It wasn't until around 1928 that punched cards and machines were made "general purpose". The rectangular, round, or oval bits of paper punched out are called chad (recently, chads) or chips (in IBM usage). Multi-character data, such as words or large numbers, were stored in adjacent card columns known as fields. A group of cards is called a deck. One upper corner of a card was usually cut so that cards not orientated correctly, or cards with different corner cuts, could be easily identified. This IBM card format, designed in 1928, had rectangular holes, 80 columns with 12 punch locations each, one character to each column.



Originally only numeric information was coded, with 1 or 2 punches per column. Later, codes were introduced for upper-case letters and special characters. For some computer applications, binary formats were used, where each hole represented a single binary digit (or "bit"), every column (or row) was treated as a simple bitfield, and every combination of holes was permitted.

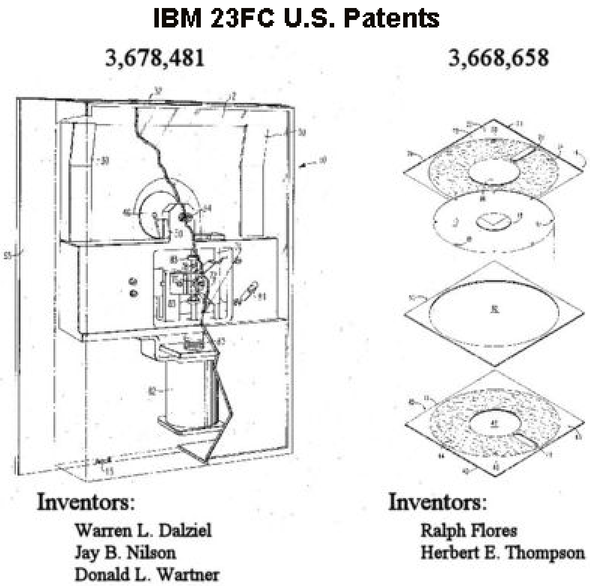
With widespread adoption of data storage on disk or magnetic tape, punch cards have largely become a thing of the past. However, they are still used in voting systems in some countries.

Student Resource: "Floppy Disk" History and Engineering

A "floppy" disk is a data storage device that is composed of a disk of thin, flexible ("floppy") magnetic storage medium encased in a square or rectangular plastic shell. Floppy disks were originally also known as floppies or diskettes -- a name chosen in order to be similar to the word "cassette."

◆ The Beginning

In 1967 IBM gave their San Jose, CA, USA storage development center a new task: develop a simple and inexpensive system for loading microcode into their System/370 mainframes. The 370s were the first IBM machines to use semiconductor memory, and whenever the power was turned off the microcode had to be reloaded ('magnetic core' memory, used in the 370s' predecessors, the System/360 line, did not lose its contents when powered down). Normally this task would be left to various tape drives which almost all 370 systems included, but tapes were large and slow. IBM wanted something faster and more purpose-built that could also be used to send out updates to customers for $5.



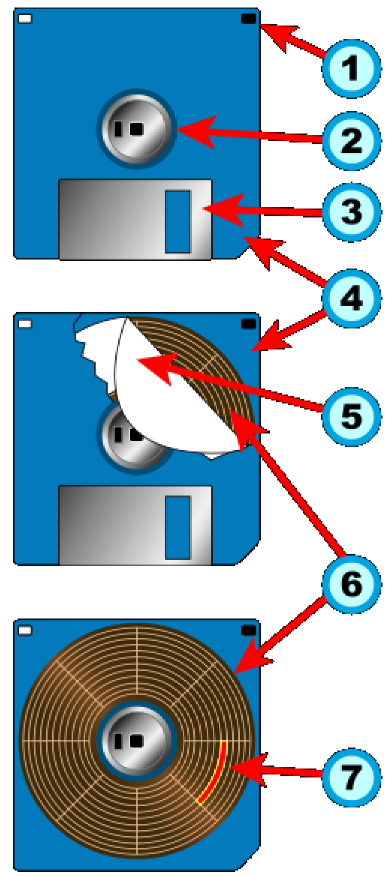
Credit: Drawings from IBM Floppy Disk Drive Patents

Alan Shugart the overall IBM Product Manager assigned this to David Noble who tried a number of solutions to see if he could develop a new-style tape or other media for the purpose, but eventually gave up. Noble's team then invented a read-only, 8-inch (20 cm) floppy they called the "memory disk", holding 80 kilobytes. The original versions were simply the disk itself, but dirt became a serious problem and they enclosed it in a plastic envelope lined with fabric that would pick up the dirt. The new device, developed under the code name Minnow and announced as the 23FD, became a standard part of 370 systems starting in 1969.

Alan Shugart left IBM, moved to Memorex where his team in 1972 shipped the Memorex 650, the first read-write floppy disk drive.

Student Resource:
"Floppy Disk" Operations and Advances

◆ How Do Floppy Disks Work?



Credit: Wikimedia Commons

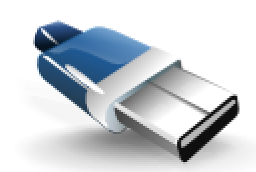
The image to the right shows the basic internal components of a 3½-inch floppy disk:

1. Write-protect tab
2. Hub
3. Shutter
4. Plastic housing
5. Paper ring
6. Magnetic disk
7. Disk sector

Floppy disk drives read or write data to the circular piece of metal-coated plastic that is imbedded in the hard plastic case of the "floppy disk." The plastic is coated with a magnetic material with tracks organized in rings. When being read, the circular plastic spins and the reading heads move to the spot where information is stored almost instantly. When recording, the disk drive will identify blank spots on the disk and record new information where there is space. Electricity and magnetism are the secrets to the process of reading and writing to a floppy disk. In order to record, the electromagnetic head of a disk drive creates a pattern of magnetized and non-magnetized areas on the disk's surface.

By the early 1990s, the increasing size of software meant that many programs were distributed on sets of floppies. Toward the end of the 1990s, software distribution gradually switched to CD-ROM, and higher-density backup formats were introduced. With the arrival of mass Internet access, cheap Ethernet and USB flash drives, the floppy was no longer necessary for data transfer either. For some time, manufacturers were reluctant to remove the floppy drive from their PCs, for backward compatibility. However, manufacturers and retailers have progressively reduced the availability of computers fitted with floppy drives and of the disks themselves. External USB-based floppy disk drives are now available for computers without floppy drives, and they work on any machine that supports USB.

◆ Engineering Improvements to Storage Problems

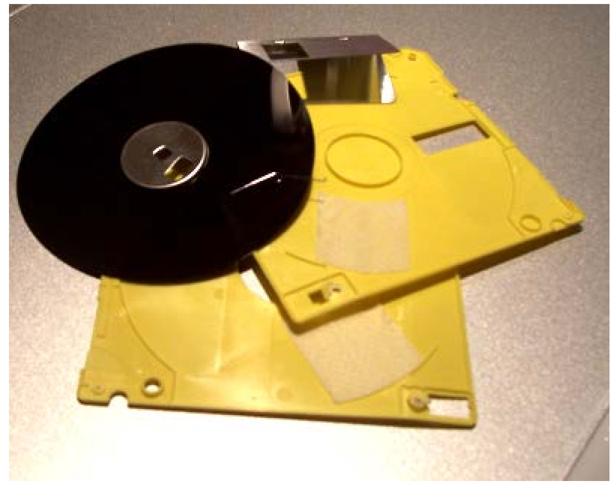


USB flash drives offer lots of advantages over other portable storage devices, particularly the floppy disk. They are more compact, generally faster, hold more data, and are more reliable (due to their lack of moving parts) than floppy disks. A flash drive consists of a small printed circuit board encased in a plastic or metal casing, making the drive sturdy enough to be carried about in a pocket.

Engineered Memory

Student Worksheet:

You are a team of computer engineers meeting to determine whether or not to include a floppy disk drive in a new, low cost computer under development to be distributed to schools all over the world.



◆ Research/Preparation Phase

1. Review the various Student Reference Sheets.

◆ Testing Phase

You have been provided with six floppy disks.

1. Disassemble one disk to explore the inner workings, and compare to the student resource sheet. Most disks can be taken apart without any tools, but ask your teacher for help if you need it!

2. On the remaining five disks, create or copy both a word processing document and a graphic file or photo onto each. Label each, and double check to confirm the files were saved properly on each.

3. As a team, make predictions in the table below about what you think will happen to the data on each disk when exposed to different situations. Note: You may want to come up with your own tests, but be sure to have your teacher approve first.

	Disk 1	Disk 2	Disk 3	Disk 4	Disk 5
Environment Change	**Place disk in freezer overnight**	**Place disk in refrigerator overnight**	**Rub low strength magnet on disk**	**Rub medium strength magnet on disk**	**Rub high strength magnet on disk**
Prediction 1: Will the data be lost? Why?					
Prediction 2: Will the data be changed in any way? How?					
Prediction 3: Will you be able to reformat the disk or use it again?					

Student Worksheet: (continued)

4. Now, execute the tests on the disks, and record your results below.
Note: Put the disks for the freezer or refrigerator in plastic bags to keep out moisture. Be sure to let the disk return to room temperature before inserting into your computer.

	Disk 1	Disk 2	Disk 3	Disk 4	Disk 5
Environment Change	**Place disk in freezer overnight**	**Place disk in refrigerator overnight**	**Rub low strength magnet on disk**	**Rub medium strength magnet on disk**	**Rub high strength magnet on disk**
Result 1: Was the data lost?					
Result 2: Was the data changed in any way? How?					
Result 3: Were you able to reformat the disk or use it again?					

◆ Team Reflection: Why do you think you found these results? Why would certain conditions affect storage devices while others do not?

◆ Team Analysis and Recommendations

Next, your "computer engineering" team must consider what you learned through your testing, and also consider your company's "research, and then come to a recommendation as to whether or not a floppy disk drive should be included as a component in a new, low cost, computer system your company is about to manufacture for schools worldwide. The facts on the next sheet have been provided by your company's marketing research department, some of the mechanical engineers working on the project, and the accounting group which will determine the cost of the new product. Remember that your new computer is to be a low cost solution for schools all over the world, and potential users are children and students in both remote areas and cities, in both affluent and poorer communities.

Student Worksheet: (continued)

◆ Research Report

1. The computer must be useful for students and teachers all over the world.
2. Floppy Disks can cost less than 40 cents each, and hold about 1.44 MB of data.
3. USB Drives cost more than floppy disks; for example a 1GB drive might cost $10.
4. It might cost about $7 to include a floppy disk drive in each computer.
5. The new computer will have 3 USB ports.
6. Two recent research reports are summarized below:

    Magnetic Media Information Services: "In many parts of the world such as Latin America, China, and India, the floppy disk remains a widely-used recording medium, according to Magnetic Media Information Services. For some companies, the production of floppy disks is still a sizable and profitable business. Imation, the world's largest producer, accounts for one-third of the world's total floppy production and claims to produce about two million floppy disks a day, both for itself and for other companies still active in selling diskettes." According to Yaser Shan, marketing manager, Imation Middle East and Africa, "Floppies are a very easy backup. You can easily store data, you can give it anybody and it doesn't need any security. There are many advantages like they are easy to use, cheap, affordable, and the installed base is very huge. Probably if you give data on floppy to somebody, they will definitely have a floppy drive but if you give it on a CD they may or may not have a CDROM. And in the Middle East market, they are still moving to CDs but also use loads and loads of diskettes."

    Japan Recording Media Industries Association: "These days, most PC users seldom if ever use a floppy disk for storage or other purposes. It may surprise the reader that the JRIA believes that demand for diskettes in 2006 will still reach 776 million units. Except for the Japanese market, where the diskette is almost completely forgotten, demand in Europe, North America, and the rest of the world, is expected to be almost equal in 2006, nominally 235 million units for each region. However, by 2009, demand will have declined 56 percent to 336 million diskettes, still distributed almost equally in North America, Europe, and countries in the rest of the world."

◆ Planning as a Team

Make a decision about your computer, and list the three main factors that led to your team decision in the box below. Present your decision to other student teams.

1.

2.

3.

Student Worksheet: Reflection

1. What percentage of the teams in your class decided to incorporate the floppy disk drive in the new computer? Did this surprise you?

2. What did you learn about the re-engineering process through this lesson?

3. What product do you think you'd like to re-engineer? Why? What would you do to change or improve it?

4. What ethical considerations do you think should be discussed when re-engineering a product? What rights or compensation do you think the designer of an original product should retain when a new engineering team re-engineers the original product?

5. Were you surprised that engineers might be working in a team with other engineers (such as mechanical engineers and computer engineers working together)?

Engineered Memory

Student Activity: Punch Card Coding

◆ Planning
Working as a team of 2-3 students develop a coding system using punches on index cards that can communicate a sentence to another team of students. You'll need to develop a code of punching that represents the numbers and letters and punctuation you choose for your sentence. Write out your plans for your punch code in the box below.

◆ Punch!
Next punch your coded sentence onto index cards and provide both your code and your cards to another team to read.

(Hint, make sure to number your cards so that if they get mixed up you can reassemble your deck in the correct order.)

◆ Reflection:

1. Did you find it was easy to come up with a coding system that would efficiently send your message?

2. Was the other team able to read your code?

3. List three drawbacks you can think of to using the punch card system in data processing today:

Engineered Memory

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Properties of objects and materials
- ✦ Light, heat, electricity, and magnetism

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understanding about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in local challenges

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Properties and changes of properties in matter

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Risks and benefits
- ✦ Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Structure and properties of matter
- Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Historical perspectives

◆Next Generation Science Standards – Grades 2-5 (Ages 7-11)

Matter and its Interactions

- 2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.
- 4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

◆Next Generation Science Standards - Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

Engineering Ups and Downs

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on the engineering behind elevators. Teams of students explore principles and requirements of vertical travel, then design and construct a working elevator to service a toy car garage using wheels, pulleys, string, cardboard and other materials.

Lesson Synopsis

The Engineering Ups and Downs lesson explores the engineering and principles behind working elevators. Student teams explore the history of elevators, their design, and develop their own working elevator using wheels, pulleys, string, cardboard and other materials. Student teams design their toy car garage elevator first on paper, then execute their plan, and evaluate the strategies employed all student teams.

Age Levels

11-18.

Objectives

- Learn about engineering design.
- Learn about elevator operations.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- mechanical engineering and design
- problem solving
- teamwork

Lesson Activities

Students learn how elevators meet human needs, explore how they work, and then work in teams to develop a design for their own elevator to service a toy car garage. Teams plan their system, using materials provided, draw their design, build it, troubleshoot as needed, evaluate their own work and that of other students, and then present their observations to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Otis Worldwide (www.otisworldwide.com)
- Online History of Otis Elevators (www.otisworldwide.com/d31-timeline.html)
- The Elevator Museum (www.theelevatormuseum.org)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Recommended Reading

- Up, Down, Across: Elevators, Escalators, and Moving Sidewalks (ISBN: 1858942136)
- Vertical Transportation 3E (ISBN: 0471162914)

Optional Writing Activity

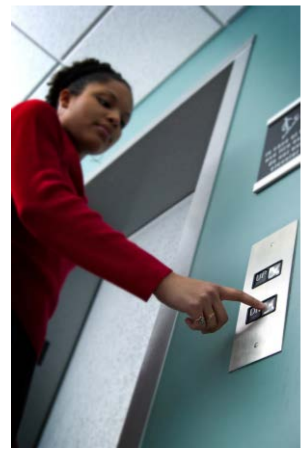
- The invention of elevators has had a huge impact on civil engineering and urban planning. Write an essay or a paragraph about how you think the invention of the elevator has impacted the skyline of the town or city in which you live.

Engineering Ups and Downs

For Teachers: Teacher Resource

◆ Lesson Goal

The Engineering Ups and Downs lesson explores the engineering and principles behind working elevators. Students explore the history of elevators, their design, and develop their own working elevator for a toy car garage using wheels, pulleys, string, cardboard and other materials. Student teams design their elevator first on paper, then execute their plan, and evaluate the strategies employed all student teams.



◆ Lesson Objectives

- Learn about engineering design.
- Learn about elevator operations.
- Learn about teamwork and working in groups.

◆ Materials

- Student Resource Sheet
- Student Worksheets
- One set of materials for each group of students:
  - Glue, string, paperclips, paper, pencils, cardboard, cardboard tubes (such as from paper towel or toilet paper rolls), markers, pulleys or thread spools (3), thin rope, string or fishing line, cardboard box to serve as elevator room (shoe box, large milk carton), small toy cars.

◆ Procedure

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework. Divide students into groups of 2-3 students, providing a set of materials per group.
2. Explain that students are now an "engineering" team that must develop a hand powered elevator to deliver toy cars to a three story parking garage. (you may wish to require a certain weight for each load, or determine that each car is a similar weight). The elevators must be able to securely stop at each floor and lift a toy car of a set weight.
3. Students meet and develop a plan for their elevator system. They agree on materials they will need (out of those you have provided), write or draw their plan, and then present their plan to the class.
4. Student groups next execute their plans. They may need to rethink their plan, add materials, or start over.
5. Each student group evaluates the results, completes an evaluation/reflection worksheet, and presents their findings to the class.

◆ Tips

To speed up the construction process, you may wish to create the three level "garage" first, and then simply have each team move their elevator to the garage for testing. This will eliminate the need for each team to make the garage themselves. Garages can be three shoeboxes taped together, or some other simple structure. Also, if students glue any part of their elevator system, it may require an overnight drying period.

◆ Time Needed

Two to four 45 minute sessions

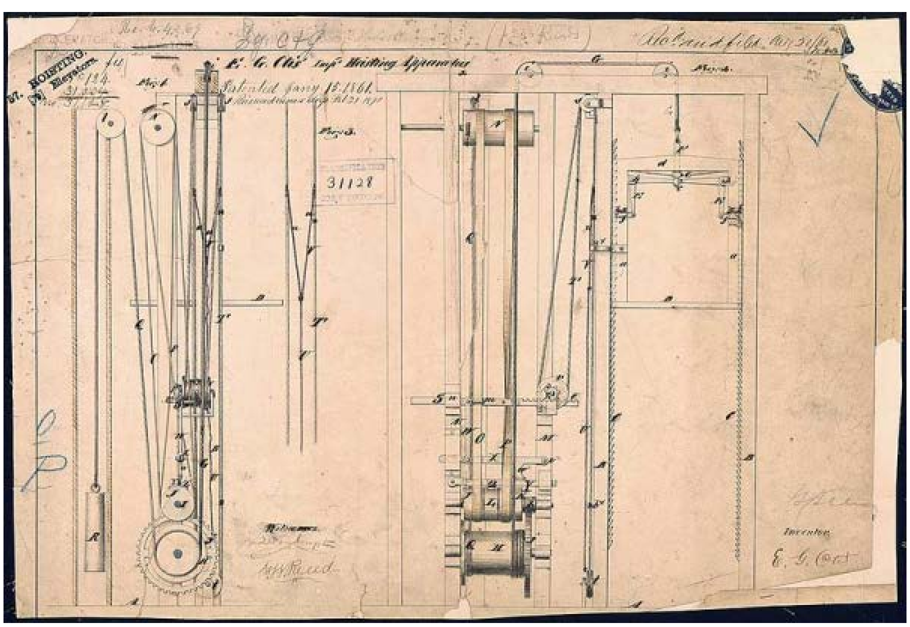
Student Resource:
The History of Elevators

◆ Elevator History

An elevator or lift is a transport device used to move goods or people vertically. The first reference about the elevator is located in the works of the Roman architect Vitruvius, who reported that Archimedes built his first lift or elevator, probably, in 236 B.C. In some literary sources of later historical period lifts were mentioned as cabs, on the hemp rope and powered by hand or by animal's force. In 1853, Elisha Otis introduced the safety elevator, which prevented the fall of the cab if the cable broke. The design of the OTIS safety is somewhat similar to one type still used today. The safety elevator used a special mechanism to lock the elevator car in place should the hoisting ropes fail. Otis made skyscrapers possible by providing safe mechanical transport to upper floors.

◆ Otis and Other Manufacturers

On March 23, 1857 the first Otis elevator was installed at 488 Broadway in New York City. The first elevator shaft preceded the first elevator by four years. Construction for Peter Cooper's Cooper Union building in New York began in 1853. An elevator shaft was included in the design for Cooper Union, because Cooper was utterly confident a safe passenger elevator would soon be invented; the shaft however was circular because Cooper felt it was the most efficient design. Later Otis designed a special elevator for the school. Today the Otis Elevator Company, now a subsidiary of United Technologies Corporation, is the world's largest manufacturer of vertical transport systems, followed by Schindler, Thyssen-Krupp, Kone, and Fujitec. According to United Technologies, Otis elevators carry the equivalent of the world's population every nine days. The following is Elisha Otis's Elevator Patent Drawing, 01/15/1861.



◆ Types of Elevators

In general, there are three means of moving an elevator:

1. Traction elevators: Geared Traction machines are driven by AC or DC electric motors. Geared machines use worm gears to control mechanically movement of elevator cars by "rolling" steel hoist ropes over a drive sheave which is attached to a gearbox driven by a high speed motor. A brake is mounted between the motor and drive sheave (or gearbox) to hold the elevator stationary at a floor. The grooves in the drive sheave are specially designed to prevent the cables from slipping. "Traction" is provided to the ropes by the grip of the grooves in the sheave, thereby the name. As the ropes age and the traction grooves wear, some traction is lost and the ropes must be replaced and the sheave repaired or replaced.

2. Hydraulic elevators: Conventional Hydraulic elevators were first developed by Dover Elevator (now ThyssenKrupp Elevator). They are quite common for low and medium rise buildings (2-10 floors) and use a hydraulically powered plunger to push the elevator upwards. On some, the hydraulic piston (plunger) consists of telescoping concentric tubes, allowing a shallow tube to contain the mechanism below the lowest floor. On others, the piston requires a deeper hole below the bottom landing, usually with a PVC casing (also known as a caisson) for protection

3. Climbing elevator: A climbing elevator is a self-ascending elevator with its own propulsion. The propulsion can be done by an electric or a combustion engine. Climbing elevators are used in guyed masts or towers, in order to make easy access to parts of these constructions, such as flight safety lamps for maintenance.

◆ Did You Know?

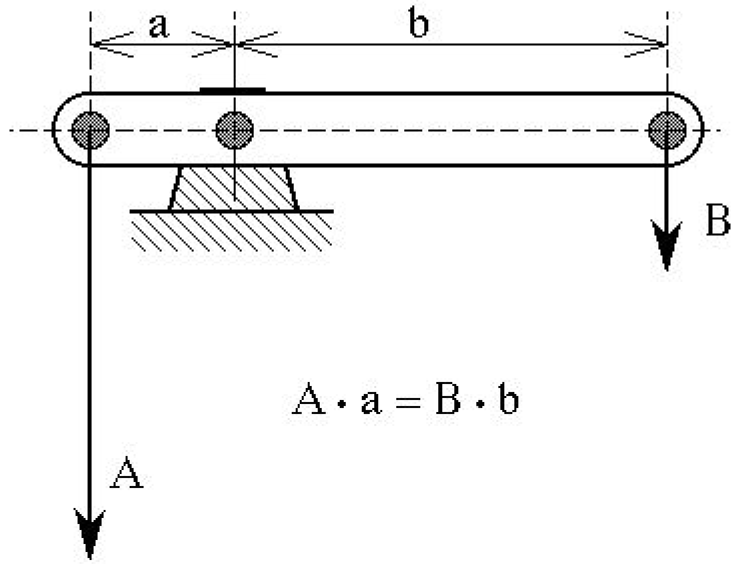
-- The elevator in the new city hall in Hanover, Germany is a technical rarity, and unique in Europe, as the elevator starts straight up but then changes its angle by 15 degrees to follow the contour of the dome of the hall.

-- A small freight elevator is often called a dumbwaiter, often used for the moving of small items such as dishes in a 2-story kitchen or books in a multi-story rack assembly. Dumbwaiters, especially older ones, may also be hand operated using a roped pulley, and they are often found in Victorian-era houses, offices and other establishments when such devices were at their peak.

◆ **What is Mechanical Advantage**

In physics and engineering, mechanical advantage (MA) is the factor by which a mechanism multiplies the force put into it. Following are simple machines where the mechanical advantage is calculated.

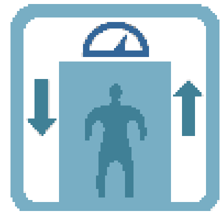
The beam shown is in static equilibrium around the fulcrum. This is due to the moment created by vector force "A" counterclockwise (moment A*a) being in equilibrium with the moment created by vector force "B" clockwise (moment B*b). The relatively low vector force "B" is translated in a relatively high vector force "A". The force is thus increased in the ratio of the forces A : B, which is equal to the ratio of the distances to the fulcrum b : a. This ratio is called the mechanical advantage. This idealized situation does not take into account friction.



Wheel and axle: A wheel is essentially a lever with one arm the distance between the axle and the outer point of the wheel, and the other the radius of the axle. Typically this is a fairly large difference, leading to a proportionately large mechanical advantage. This allows even simple wheels with wooden axles running in wooden blocks to still turn freely, because their friction is overwhelmed by the rotational force of the wheel multiplied by the mechanical advantage.

Pulley: Pulleys change the direction of a tension force on a flexible material, e.g. a rope or cable. In addition, pulleys can be "added together" to create mechanical advantage, by having the flexible material looped over several pulleys in turn. More loops and pulleys increase the mechanical advantage.

Engineering Ups and Downs



Student Worksheet: Build Your Elevator

You are a team of engineers who have been given the challenge of building a small elevator system to deliver cars to a three story toy car garage. Your elevator must be able to securely stop at each floor and lift a toy car of a set weight.

◆ Research/Preparation Phase

1. Review the various Student Reference Sheets.

◆ Planning as a Team

1. Your team has been provided with some "building materials" by your teacher. You have glue, string, paperclips, paper, pencils, cardboard, cardboard tubes (such as from paper towel or toilet paper rolls), markers, pulleys or thread spools (3), thin rope, string or fishing line, cardboard box to serve as elevator room (shoe box, large milk carton), small toy cars and other resources.

2. Start by meeting with your team and devising a plan to build your elevator. Think about how you will incorporate the pulleys and affix materials to the elevator room which could be a small milk carton, pasta box, or other grocery container.

3. Write or draw your plan in the box below, including your projection for the materials you'll require to complete the construction. Present your design to the class, and explain your choice of materials. You may choose to revise your teams' plan after you receive feedback from class.

Materials Needed:

Student Worksheet: Evaluation

◆ Construction Phase

5. Build your elevator!
6. Evaluate your team's results compared to those of other teams, complete the evaluation worksheet, and present your findings to the class.

◆ Use this worksheet to evaluate your team's results in the Engineering Ups and Downs lesson:

1. Did you succeed in creating an elevator that could deliver cars to three stories of the toy car garage? If not, why did it fail?

2. Did you need to request additional or different materials while building your elevator? If so, what happened between the design (drawing) and the actual construction that changed your material needs?

3. Do you think that engineers have to adapt their original plans during the manufacturing process? Why might they?

4. If you had to do it all over again, how would your planned design change? Why?

5. What designs or methods did you see other teams try that you thought worked well?

6. Did you find that there were many designs in your classroom that met the project goal? What does this tell you about engineering plans?

7. Did you find there was an advantage to working in a team for this project? Explain…

8. Do you think that the expectations of riders have impacted the designs of elevators? For example, how has the design been adjusted to accommodate riders with disabilities?

9. What safety considerations do you think engineers must integrate into new elevator designs? For example, many elevators have telephones on board in case of emergencies. What else can you identify?

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Motions and forces
- ✦ Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- ✦ Motions and forces
- ✦ Interactions of energy and matter

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

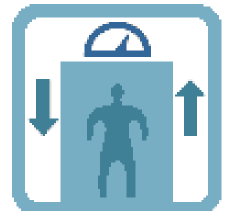
As a result of activities, all students should develop understanding of

- ✦ Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Historical perspectives



For Teachers: Alignment to Curriculum Frameworks (continued)

◆Next Generation Science Standards – Grades 3-5 (Ages 8-11)

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆Next Generation Science Standards – Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 2: Students will develop an understanding of the core concepts of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

◆Standards for Technological Literacy - All Ages

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 5: Students will develop an understanding of the effects of technology on the environment.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- Standard 18: Students will develop an understanding of and be able to select and use transportation technologies.

Program Your Own Game

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on how software engineers design computer games and other software. Student teams work together to develop a simple computer program using free software that is available in multiple languages. Teams evaluate the games developed by other teams and present findings to the class.

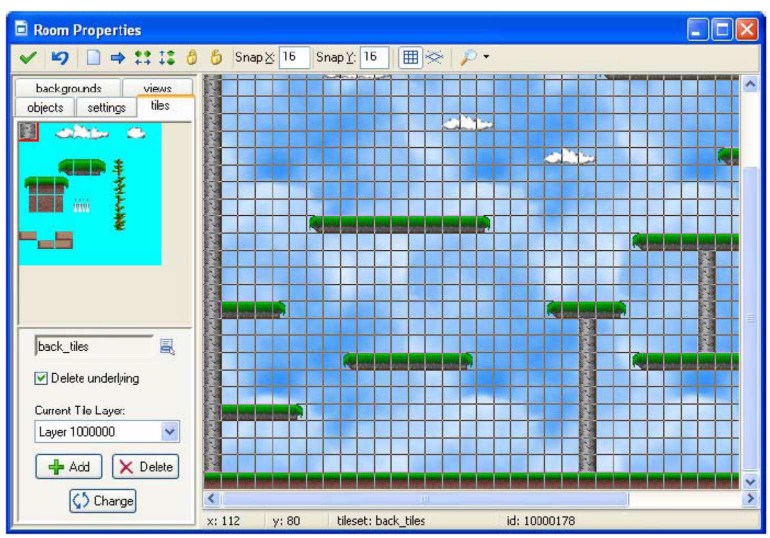
Lesson Synopsis

The Program Your Own Game activity explores the work of software engineers and allows student teams to develop their own computer game using free and simple software. Teams present their game to their class, evaluate other games, and reflect on the engineering experience.

Age Levels

11-18 (Note: this lesson can range from very simple programming or program editing for younger students to more advanced programming for older or advanced students.)

Objectives



- Learn how software engineers develop computer games.
- Learn about the process of product re-engineering.
- Learn how engineering teams address problem solving.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- software engineering and programming
- product design and engineering
- problem solving
- teamwork

Lesson Activities

Students learn about basic computer programming and the work of software engineers. Student teams work together to develop a simple computer program using free software that is available in multiple languages. Students execute their own games, and evaluate the games developed by other student teams.

Resources/Materials

- Teacher Resource Documents (attached)
- Game Maker Tutorials (www.yoyogames.com/make/tutorials)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- YoYo Game - Game Maker Software (http://www.yoyogames.com/gamemaker/studio/)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- NCTM Principles and Standards for School Mathematics (http://standards.nctm.org)

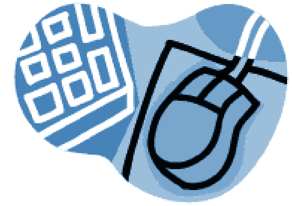
Recommended Reading

- Game Creation For Teens (ISBN: 159863500X)
- Getting Started with Game Maker (ISBN: 1598638823)

Optional Writing Activity

- Write an essay or a paragraph describing the ethical implications of adapting someone else's software programming. The concept of "intellectual property" is an umbrella term for legal entitlements which attach to certain names, written and recorded media, and inventions. Take a stand for or against whether you should provide financial or other credit to the original developer of software that you adapt/change to make new software. Consider that the original software did not sell well, but that your edited version sold very well. As an extension idea, this writing activity could turn into a lively debate of the pros and cons and the concept of intellectual property rights.

Program Your Own Game



For Teachers:
Teacher Resources

◆ **Lesson Goal**

Explore engineering problem solving by working in teams to program a new computer game. Students learn about basic computer programming and the work of software engineers. Student teams work together to develop a simple computer program using free software that is available in multiple languages. Students execute their own games, and evaluate the games developed by other student teams.

◆ **Lesson Objectives**

- Learn how software engineers develop computer games.
- Learn about the process of product re-engineering.
- Learn how engineering teams address problem solving.
- Learn about teamwork and working in groups.

◆ **Materials**

- Student Resource Sheets and Worksheet
- Internet or computer access (free software may be downloaded and installed on windows-based computer without internet access; software is available in multiple languages)

◆ **Procedure**

1. Download and install the free YoYo Games GameMaker software (http://www.yoyogames.com/game_showcases/273/legacy_download) on multiple computers or in a lab so students can work in teams to develop their games. Note that there is a free limited version and a higher level one for a low fee. The free one will work well in the classroom environment for beginners.
2. You may also wish to view the tutorials at www.yoyogames.com/make/tutorials.
3. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework. The pages on "beginning programming" should be reviewed by students in advance of using the software on a computer.
4. Divide students into teams of 2-3 students (you may need to adjust this depending upon how many computer stations you have); provide a set of materials per group.
5. Explain that they are a team of software engineers and they need to develop a new computer game that will be used by students who are aged 6-10.
6. Student teams develop a simple game and share it with the class.
7. Each student group evaluates the games developed by other teams, and completes an evaluation/reflection worksheet.

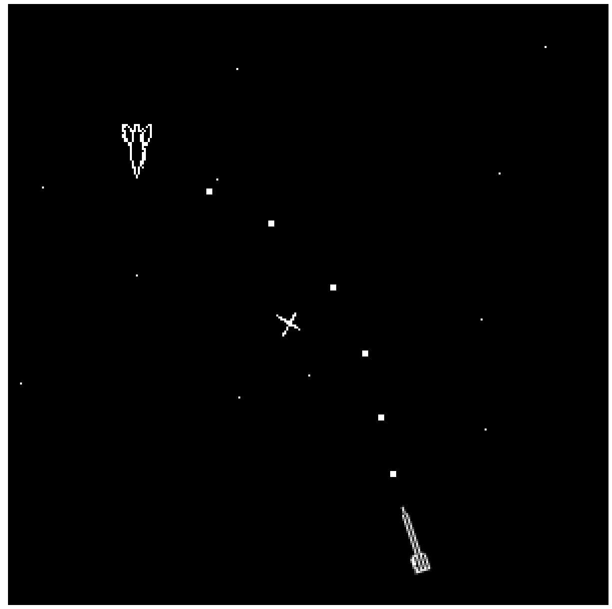
◆ **Tips**

This lesson can be extended to a semester long project, or simplified by instructing students to create or enhance any of the demo games that are provided by the software developer. The "space cleaner" game, for example can be modified within a single class period. If you choose to have students modify a game, have them first explore the existing game, meet as a team to determine what changes they would like to engineer into the game, then have them attempt to execute their plan.

◆ **Time Needed**

One to two 45 minute sessions

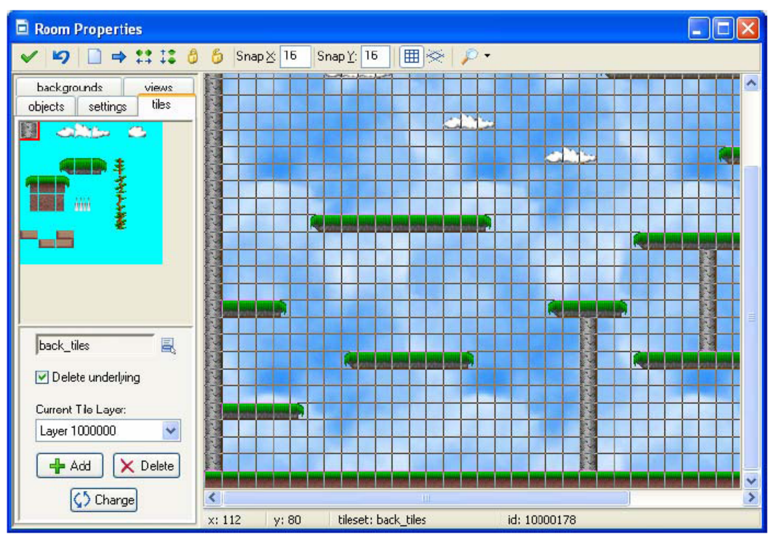
◆ The Start of Computer Gaming



Although personal computers only became popular with the development of the microprocessor, mainframe and minicomputers have been used for computer gaming since at least the 1960s. One of the first computer games was developed in 1961, when MIT students Martin Graetz and Alan Kotok, with MIT employee Stephen Russell, developed Spacewar! on a computer used for statistical calculations. As seen on the right, the game consisted of two player-controlled spaceships maneuvering around a central star, each attempting to destroy the other.

The first generation of PC games consisted of text adventures or interactive fiction, in which the player communicated with the computer by entering commands through a keyboard. By the mid-1970s, games were developed and distributed through hobbyist groups and gaming magazines, such as Creative Computing and later Computer Gaming World. These publications provided game code that could be typed into a computer and played, encouraging readers to submit their own software to competitions.

◆What Software Engineers Do



Software engineers working in applications or systems development analyze users' needs and design, construct, test, and maintain computer applications software or systems. Software engineers can be involved in the design and development of many types of software, including software for operating systems and network distribution, and compilers, which convert programs for execution on a computer. In programming, or coding, software engineers instruct a computer, line by line, how to perform a function. They also solve technical problems that arise. Software engineers must possess strong programming skills, but are more concerned with developing algorithms and analyzing and solving programming problems than with actually writing code.

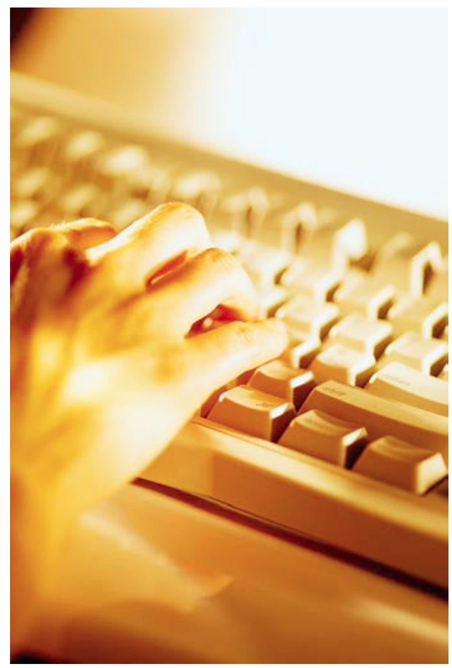
Student Resource
Software Engineering: Algorithms

◆ What is an Algorithm?

In mathematics, computing, linguistics, and related disciplines, an algorithm is a finite list of well-defined instructions for accomplishing some task which, given an initial state, will terminate in a defined end-state. The concept of an algorithm originated as a means of recording procedures for solving mathematical problems such as finding the common divisor of two numbers or multiplying two numbers.

The concept was formalized in 1936 through Alan Turing's Turing machines and Alonzo Church's lambda calculus, which in turn formed the foundation of computer science. A simple example is a flow chart which is basically a logical sequence of steps for solving a problem.

◆ Computer Applications



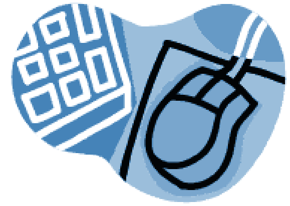
Algorithms are essential to the way computers process information, because a computer program is essentially an algorithm that tells the computer what specific steps to perform (in what specific order) in order to carry out a specified task, such as calculating an invoice, printing report cards, or completing a budget analysis.

Because an algorithm is a precise list of precise steps, the order of computation will almost always be critical to the functioning of the algorithm. Instructions are usually assumed to be listed explicitly, and are described as starting 'from the top' and going 'to the bottom,' -- sometimes also called "flow of control."

Every field of science has its own problems and needs efficient algorithms. Related problems in one field are often studied together.

Some example classes are search algorithms, sorting algorithms, merge algorithms, numerical algorithms, graph algorithms, string algorithms, computational geometric algorithms, combinatorial algorithms, machine learning, cryptography, data compression algorithms and parsing techniques.

Program Your Own Game



Student Worksheet: You are the Engineer!

◆ You are a team of engineers which has to tackle the challenge of developing a new computer game for use by 6 - 10 year old children.

◆ Preparation

1. Review the various Student Reference Sheets.
2. Read the Basic Programming guide that has been provided to you.

◆ Activity Steps

1. As a team, come up with a plan or idea for your game -- also come up with a name for your game. In the box below, write a two sentence description of your new game that might be used in an advertisement:

Game Name:

Description:

2. Work together using the software (http://www.yoyogames.com/gamemaker/studio/) and build your game.

3. Present your game to other teams in your class so they can see how your game works (you'll test out their games as well).

4. Complete the following questions about your game and other games developed in your classroom.

5. As a team, present your findings and reflections to the class.

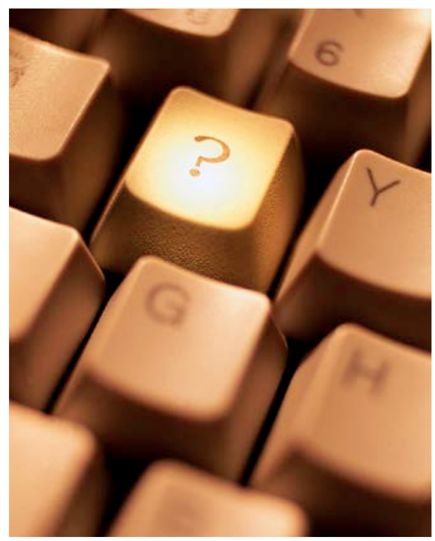
Student Worksheet: You are the Engineer!

◆ Evaluation Questions

1. How did your plan for your game change once you tried to build it using the software provided?

2. How long do you think it would take to develop a new piece of word processing or graphic software? How many people do you think it might take to work on the engineering team to build this type of software? Why?

3. Did you find that it was easier or harder than you thought to program a computer game? Why?

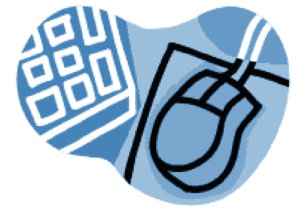


4. What challenges did you face in building your game?

5. What other games developed in your classroom did you like the best? Why? What features appealed to you?

6. Do you think it was easier or harder to have developed this game as part of a team? Do you think you would have been able to create your new design if you had not been working in a team? What are the advantages of teamwork vs. working alone?

7. What did you learn about how engineers solve problems through this lesson?



For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

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- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Historical perspectives

◆Next Generation Science Standards Grades 3-5 (Ages 8-11)

Engineering Design

Students who demonstrate understanding can:

- ✦ 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- ✦ 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- ✦ 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

For Teachers:
Alignment to Curriculum Frameworks (continued)

◆Next Generation Science Standards Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Principles and Standards for School Mathematics

Number and Operations Standard

As a result of activities, all students should develop

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems.
- Compute fluently and make reasonable estimates.

Connections Standard

As a result of activities, all students should develop

- Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.
- Recognize and apply mathematics in contexts outside of mathematics.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 2: Students will develop an understanding of the core concepts of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 12: Students will develop abilities to use and maintain technological products and systems.

The Designed World

- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

For Teachers:
Alignment to Curriculum Frameworks

◆CSTA K-12 Computer Science Standards Grades 6-9 (ages 11-14)

5. 2 Level 2: Computer Science and Community (L2)

- Computational Thinking: (CT)
  6. Describe and analyze a sequence of instructions being followed (e.g., describe a character's behavior in a video game as driven by rules and algorithms).
  7. Represent data in a variety of ways including text, sounds, pictures, and numbers.
  14. Examine connections between elements of mathematics and computer science including binary numbers, logic, sets and functions.
- Collaboration (CL)
  2. Collaboratively design, develop, publish, and present products (e.g., videos, podcasts, websites) using technology resources that demonstrate and communicate curriculum concepts.
  3. Collaborate with peers, experts, and others using collaborative practices such as pair programming, working in project teams, and participating in group active learning activities.
  4. Exhibit dispositions necessary for collaboration: providing useful feedback, integrating feedback, understanding and accepting multiple perspectives, socialization.

◆CSTA K-12 Computer Science Standards Grades 6-9 (ages 11-14)

5. 2 Level 2: Computer Science and Community (L2)

- Computing Practice & Programming (CPP)
  1. Select appropriate tools and technology resources to accomplish a variety of tasks and solve problems.
  3. Design, develop, publish, and present products (e.g., webpages, mobile applications, animations) using technology resources that demonstrate and communicate curriculum concepts.
  5. Implement problem solutions using a programming language, including: looping behavior, conditional statements, logic, expressions, variables, and functions.
- Computers & Communications Devices (CD)
  1. Recognize that computers are devices that execute programs.
  3. Demonstrate an understanding of the relationship between hardware and software.

◆**CSTA K-12 Computer Science Standards Grades 9-10 (ages 14-15)**

5.3 Level 3: Applying Concepts and Creating Real-World Solutions (L3)

- Computational Thinking: (CT)
  2. Describe a software development process used to solve software problems (e.g., design, coding, testing, verification).
  6. Analyze the representation and trade-offs among various forms of digital information.
- Collaboration (CL)
  1. Work in a team to design and develop a software artifact.
  4. Identify how collaboration influences the design and development of software products.
- Computing Practice & Programming (CPP)
  4. Apply analysis, design, and implementation techniques to solve problems (e.g., use one or more software lifecycle models).
  6. Select appropriate file formats for various types and uses of data.

Hand Biometrics Technology

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on engineering applications of biometric technologies for identification or security applications. After exploring hand geometry biometrics, students work in teams of "engineers" to evaluate pros and cons of incorporating a hand recognition biometric technology into a new security system for a museum.

Lesson Synopsis

The Hand Biometrics Technology lesson not only explores how engineers incorporate biometrics technologies into products, but also explores the challenges of engineers who must weigh privacy, security and other issues when designing a system. Students explore different biometrics techniques, find their own hand geometry biometrics, then work in teams of "engineers" to design a high-tech security system for a museum.

Age Levels

8-18.

Objectives

- Learn about biometrics technology.
- Learn about engineering product planning and design.
- Learn about meeting the needs of society.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- biometrics technology
- problem solving
- teamwork

Lesson Activities

Students learn how biometrics technologies have been used worldwide to address security and identification systems. Student teams are then challenged with evaluating and deciding whether a hand geometry-based biometric technology would be the right choice for admitting employees to a museum. Student teams present their recommendations to other teams.

Resources/Materials

- Teacher Resource Document (attached)
- Student Worksheets (attached)
- Student Resource Sheet (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- BBC Interactive Exhibit of Biometric Technology (http://news.bbc.co.uk/2/shared/spl/hi/guides/456900/456993/html/)
- National Biometric Security Project (www.nationalbiometric.org)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Recommended Reading

- Biometric Technologies and Verification Systems (ISBN: 0750679670)
- Handbook of Multibiometrics (International Series on Biometrics) (ISBN: 0387222960)

Optional Writing Activity

- Write an essay or a paragraph about the ethical implications of introducing biometrics into a school setting, such as for allowing student access to a building, or to tracking lunchroom spending patterns.

For Teachers:
Teacher Resource

◆ **Lesson Goal**

Lesson focuses on engineering applications of biometric technologies for identification or security applications. After exploring hand geometry biometrics, students work in teams of "engineers" to evaluate pros and cons of incorporating a hand recognition biometric technology into a new security system for a museum.

◆ **Lesson Objectives**

- Learn about biometrics technology.
- Learn about engineering product planning and design.
- Learn about meeting the needs of society.
- Learn about teamwork and working in groups.

◆ **Materials**

- Student Resource Sheet
- Student Worksheets
    - One set of materials for each group of students: pencils, blank sheets of paper, ruler, copies of all hand geometry codes for the class.

◆ **Procedure**

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
2. Have students work in pairs, so each student determines their own personal hand geometry code, then determines the code of their partner.
3. Divide students into groups of 2-3 students, providing a set of materials per group.
4. Explain that students must work in teams of "engineers" to determine the results of the hand geometry code samples in order to determine if a hand recognition biometrics technology system should be used when developing a security system for a museum.
5. Students complete evaluation and reflection sheets, write out their recommendations, and then present their recommendations to the class.

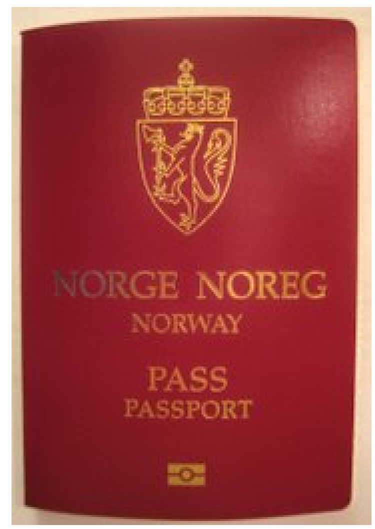
◆ **Time Needed**

One to two 45 minute sessions.

Hand Biometrics Technology

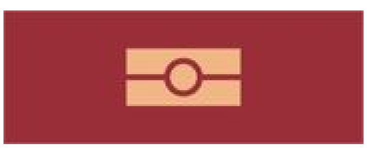
Student Resource: What is Biometrics?

Biometrics (ancient Greek: bios ="life", metron ="measure") is the study of methods for uniquely recognizing humans based upon one or more intrinsic physical or behavioral traits. In information technology, "biometric authentication" refers to technologies that measure and analyze human physical and behavioral characteristics for authentication purposes. Examples of physical (or physiological or biometric) characteristics include fingerprints, eye retinas and irises, facial patterns and hand measurements, while examples of mostly behavioral characteristics include signature, gait and typing patterns.



◆ Sample Applications

1. Since the beginning of the 20th century, Brazilian citizens have used ID cards that incorporate fingerprint-based biometrics.
3. Microsoft has introduced a fingerprint reader that prevents computers from being used by unauthorized people.
2. Some countries have implemented biometric passports that combine paper and electronic identity -- using biometrics to authenticate the citizenship of travelers. The passport's critical information is stored on a tiny RFID computer chip.



The icon to the left is incorporated onto most biometric passports to indicate the technology.

◆ Hand Geometry Biometrics

Hand geometry is a biometric that identifies users by the shape of their hands. Hand geometry readers measure a user's hand along many dimensions and compare those measurements to measurements stored in a file.

Viable hand geometry devices have been manufactured since the early 1980s, making hand geometry the first biometric to find widespread computerized use. It remains popular; common applications include access control and time-and-attendance operations.

Since hand geometry is not thought to be as unique as fingerprints or retinas, fingerprinting and retina scanning remain the preferred technology for high-security applications. Hand geometry is very reliable when combined with other forms of identification, such as identification cards or personal identification numbers. In large populations, hand geometry is not suitable for so-called one-to-many applications, in which a user is identified from his biometric without any other identification.

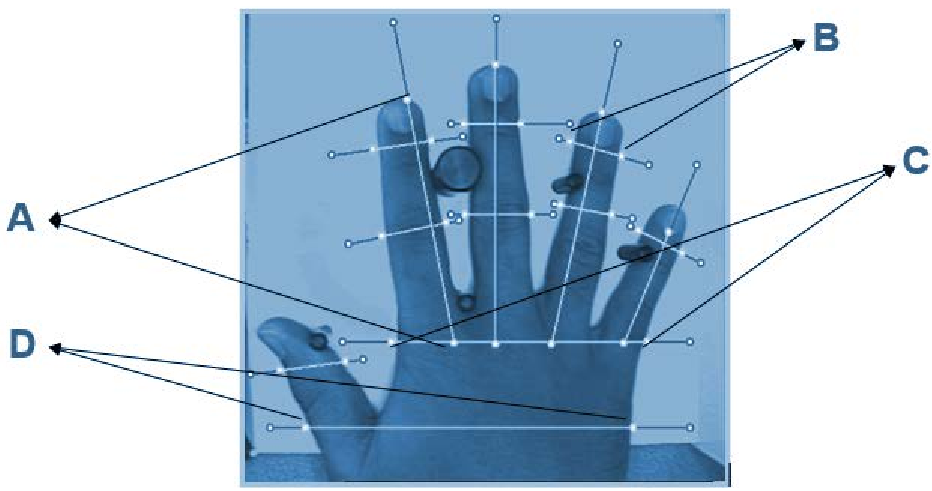
Student Worksheet:
Biometrics and Hand Geometry

◆ Biometrics and Hand Geometry

Biometric templates contain information extracted from biometric traits. The resulting codes can be used for identification in a variety of situations. In this activity, you'll determine your own personal hand geometry code.

Step One:
1. Trace your right hand on a piece of paper, keeping the pencil as close to your skin as possible.
2. Using a ruler, measure the following in centimeters (see diagram below):

A: Distance from index fingertip to bottom knuckle ________cm
B: Width of ring finger, measured across the top knuckle _______cm
C: Width of palm across 4 bottom knuckles ________cm
D: Width of palm from middle knuckle of thumb across hand _______cm



Record the 4 numbers in A, B, C, D order, which is your personal hand geometry code:

____ _____ _____ _____

Step Two:
1. Have someone else in your class trace your right hand, and repeat the measurements above. Record the 4 numbers in A, B, C, D order…are there any differences?

____ _____ _____ _____

(Note: Biometric information on this page is provided by and used with the permission of The National Biometric Security Project (NBSP). Duplication is permitted for educational purposes only.)

Hand Biometrics Technology

Student Worksheet:

You are a team of computer engineers meeting to determine whether personal hand geometry templates or numbers would be unique enough to serve as an element in a new security system for a museum.

◆ Research/Preparation Phase

Each student should determine their own hand geometry template code. A copy of each should be distributed to each team.

◆ Evaluation Phase

As a team, examine the geometry templates you have received. These will represent the codes of staff that need to access the museum during evening hours to check on the security of a group of priceless paintings. Discuss and answer the following questions to help form your plan for incorporating biometrics into the museum's new security system.

1. How similar were the geometry template codes you examined? What did you observe that was most similar? What did your team determine to be different in the group?

2. What problems do you envision an employee might encounter as they placed their hand in the biometric scanning device?

3. Are there any guidelines your engineering team would recommend regarding either capturing the codes from each employee, or in scanning the employee's hand at the entrance to the museum?

4. Do you think that fingerprint scans would be more effective? Why? Why Not?

◆ Presentation

As a team, present the results of your engineering team's evaluations to the rest of your class.

Student Worksheet: Reflection

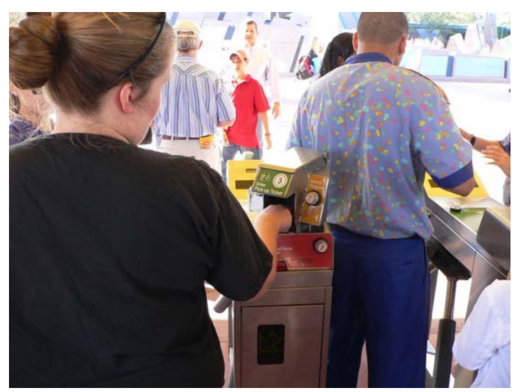
Biometrics can be applied to many situations, such as computer login security, employee recognition, time or attendance record systems, and voter identification. As a team of "engineers" describe three other situations where you think engineers should consider incorporating biometrics technology to solve problems. Please indicate whether any of these situations might warrant at two-level system, where hand biometrics is one of the two levels of verification:

1.

2.

3.

At Walt Disney World, biometric measurements are taken from the fingers of guests to ensure that the person's ticket is used by the same person from day to day. Do you have privacy concerns about this? Why? Why not? If you were part of the engineering team on this project, what would you do to ensure privacy?



For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understanding about scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understanding about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in local challenges

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Risks and benefits
- ✦ Science and technology in society

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

◆**National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Historical perspectives

◆**Next Generation Science Standards Grades 3-5 (Ages 8-11)**

Waves and Their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

- 4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

◆**Next Generation Science Standards Grades 6-8 (Ages 11-14)**

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆**Principles and Standards for School Mathematics**

Number and Operations Standard

As a result of activities, all students should develop

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems.
- Compute fluently and make reasonable estimates.

Connections Standard

As a result of activities, all students should develop

- Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.
- Recognize and apply mathematics in contexts outside of mathematics.

◆ **Common Core State Standards for School Mathematics Grades 2-8 (ages 7-14)**

Measurement and data

- Measure and estimate lengths in standard units.

- CCSS.Math.Content.2.MD.A.1 Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
- CCSS.Math.Content.2.MD.A.3 Estimate lengths using units of inches, feet, centimeters, and meters.

For Teachers:
Alignment to Curriculum Frameworks (continued)

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- Standard 15: Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.
- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

Playing with Parachutes

Provided by TryEngineering - www.tryengineering.org

Lesson Focus
This lesson focuses on parachute design. Teams of students construct parachutes from everyday materials. They then test their parachutes to determine whether they can transport a metal washer to a target on the ground with the slowest possible rate of descent.

Lesson Synopsis
The "Playing with Parachutes" lesson explores how parachutes are used to slow moving objects. Students work in teams of "engineers" to design and build their own parachutes out of everyday items. They test their parachutes, evaluate their results, and present to the class.

Age Levels
8-18

Objectives
During this lesson students will:

- Design and construct a parachute
- Test and refine their designs
- Communicate their design process and results

Anticipated Learner Outcomes
As a result of this lesson, students will have:

- Designed and constructed a parachute
- Tested and refined their designs
- Communicated their design process and results

Lesson Activities
Students work in teams to design and build parachutes out of everyday items. The parachutes need to be able to transport a payload of one metal washer to a target on the ground with the slowest rate of descent. Student teams review their own designs, the designs of other teams, and present their findings to the class.

Resources/Materials
- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks
See attached curriculum alignment sheet.

Internet Connections

- NOVA – Design a Parachute (www.pbs.org/wgbh/nova/mars/parachute.html)
- History of the Parachute (http://inventors.about.com/od/pstartinventions/ss/Parachute.htm)
- TryEngineering (www.tryengineering.org)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Recommended Reading

- The Silken Canopy: History of the Parachute (ISBN: 978-1853108556)
- Sky People : A History of Parachuting (ISBN: 978-1853108693)

Optional Writing Activity

- Research Leonardo DaVinci's conical parachute and compare and contrast it with modern parachute designs.

Playing with Parachutes

For Teachers:
Teacher Resources

◆ Lesson Goal
The goal of this lesson is for students to develop a parachute that can carry a metal washer to a 10 cm diameter target on the ground with the slowest rate of descent. Student teams design their parachutes out of everyday materials and then test their designs. Students then evaluate the effectiveness of their parachutes and those of other teams, and present their findings to the class.

◆ Lesson Objectives
During this lesson, students will:

- Design and construct a parachute
- Test and refine their designs
- Communicate their design process and results

◆ Materials
- Student Resource Sheets
- Student Worksheets
- Meterstick
- Small ladder (for teacher use only)
- One set of materials for each group of students:
  - roll of string
  - plastic trash bag
  - plastic shopping bag
  - several sheets of copy paper
  - coffee filters
  - newspaper
  - aluminum foil
  - scissors
  - masking tape
  - metal washer (3cm diameter)
  - ruler

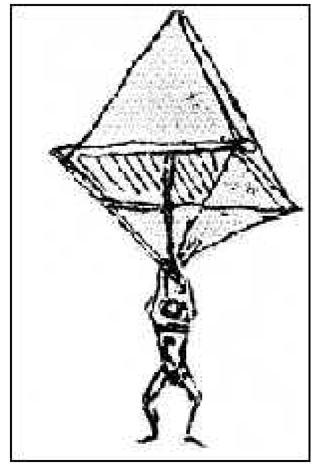
◆ Procedure
1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
2. Divide students into groups of 2-3 students, providing a set of materials per group.
3. Explain that students must develop their own working parachute from everyday items that can carry one metal washer to the ground from a height of 2 M. The parachute has to hit a target 10 cm in diameter with the slowest rate of descent. The parachute that can hit the target with the slowest descent rate is the winner.
4. Students meet and develop a plan for their parachute. They agree on materials they will need, write or draw their plan, and then present their plan to the class.
5. Student teams may trade unlimited materials with other teams to develop their ideal parts list.
6. Student groups next execute their plans. They may need to rethink their plan, request other materials, trade with other teams, or start over.
7. Next….teams will test their parachutes. **Drop height should be measured from the bottom edge of the washer.** The teacher should serve as the dropper. The target can be made on the ground with tape or string, or a paper plate can be used.
8. Teams then complete an evaluation/reflection worksheet, and present their findings to the class.

◆ Time Needed
- Two to three 45 minute class periods

Student Resource:

◆ History of Parachutes

Parachutes are devices used to slow the movement of objects. Parachutes are typically used to slow the movement of falling objects but they can also be used to slow down horizontally moving objects such as racecars. The word parachute is believed to be of French origin combing the words para, (a French word with Greek roots) chute meaning to shield against falling. The modern parachute has evolved over several centuries. It is believed that Chinese acrobats used parachutes in their acts as early as the 1300's. Leonardo DaVinci sketched designs for a pyramid shaped parachute in the mid 15th century. The first time a parachute was actually attempted by a human was in the mid 16th century by Faust Vrancic, a Croatian Inventor. He called his invention Homo Volans or the Flying man. He actually tested out his parachute in 1617 by jumping off a tower in Venice. Andrew Garnerin was the first person on record to use a parachute that did not possess a rigid frame. He used his parachute to jump out of hot air balloons from a height of 8000 feet! He was also the first person to include a vent in the canopy to reduce instability. The parachutes we are more familiar with today didn't begin to take shape until the 18th century.



DaVinci's Sketch
Source: http://news.bbc.co.uk/1/hi/sci/tech/808246.stm

◆ Parts of a parachute

The upper portion of the parachute is known as the canopy. Historically, canopies were made of silk but now they are usually made out of nylon fabric. Sometimes the canopy has a hole or vent in the center to release pressure. When a parachute is housed in a container such as a backpack, it may consist of main canopy and another smaller canopy known as a pilot chute. The pilot chute comes out of the container first and serves to pull open the main canopy. A set of lines connects the canopy to the backpack. The lines are gathered through metal or canvas links attached to thick straps known as risers. The risers are then connected to a harness if the parachute is going to be used by a person.

Student Resource (continued):

◆ Types of Parachutes

There are many different types of parachutes. Here are some of the more common parachute designs.


Round parachute

Round parachute
The parachute most people are familiar with is the round parachute. The round parachute is characterized by a circular canopy.

Square parachute
The square or cruciform parachute possesses a squarish shaped canopy. Square parachutes are beneficial because they reduce jostling of the user and have a slower rate of descent; reducing injuries.


Ram-air parachute

Ram-air parachute
Most of the parachutes which are intended for use by people that we see today are ram-air parachutes. The design of ram type parachutes gives the person using it a great deal more control. The canopy in a ram type parachute is made up of 2 layers of material which are sewn together to form air filled cells.

Ribbon and ring parachute
Ribbon and ring parachutes are intended to be used at supersonic speeds. The canopy has a hole in the center which is designed to release pressure. Sometimes the ring is cut into ribbons so more pressure can be released and so the canopy doesn't explode. These types of parachutes are used when a great deal of strength is required.

Here are a few key science concepts to keep in mind when you are designing and testing your parachutes.

◆ Law of Falling Bodies

Galileo Galilei (1564-1642) was an Italian astronomer and physicist. Galileo conducted much research on motion and developed what is known as the Law of Falling Bodies. This law states that all objects regardless of their mass fall at the same speed, and that their speed increases uniformly as they fall. Galileo's calculations however, did not take into consideration air resistance. Drag, or the force that opposes the motion of an object plays a significant role in the motion of a falling parachute.

◆ Newton's Laws of Motion

Sir Isaac Newton (1642 – 1727) was a brilliant mathematician, astronomer and physicist who is considered to be one of the most influential figures in human history. Newton studied a wide variety of phenomena during his lifetime, one of which included the motion of objects and systems. Based on his observations he formulated Three Laws of Motion which were presented in his masterwork Philosophiæ Naturalis Principia Mathematica in 1686.

Newton's First Law – An object at rest will remain at rest and an object in motion will remain in motion at a constant speed unless acted on by an unbalanced force (such as friction or gravity). This is also known as the law of inertia.

Newton's Second Law – An object's acceleration is directly proportional to the net force acting on it and inversely proportional to its mass. The direction of the acceleration is in the direction of the applied net force. Newton's Second Law can be expressed as: F = ma

Newton's Third Law – For every action there is an equal and opposite reaction.

◆ Gravity

Newton's work on developing the Laws of motion led him to formulate the Law of Universal Gravitation. The law states that two bodies attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

We can use the following equation to calculate the force of gravity with which an object is attracted to the Earth: $F_G = mg$

m = mass of the object
g = the acceleration of gravity 9.8 m / s2

Student Worksheet:
Design a parachute

You are a team of engineers who have been given the challenge to design a parachute out of everyday items. Your challenge is to design a parachute that can carry one metal washer to the ground from a height of 2M and hit a 10 cm target with the slowest possible rate of descent. The parachute that can hit the target with the slowest descent rate is the winner.

◆ Planning Stage

Meet as a team and discuss the problem you need to solve. Then develop and agree on a design for your parachute. You'll need to determine what materials you want to use.

Draw your design in the box below, and be sure to indicate the description and number of parts you plan to use. Present your design to the class.

You may choose to revise your teams' plan after you receive feedback from class.

Design:
Materials Needed:

Student Worksheet (continued):

◆ Construction Phase
Build your parachute. During construction you may decide you need additional materials or that your design needs to change. This is ok – just make a new sketch and revise your materials list.

◆ Testing Phase
Each team will test their parachute. You'll need to time your test to make sure your can support the washer and achieve the slowest rate of descent.

Parachute Testing Data				
	Drop Height (m)	**Drop Time (s)**	**Velocity (m/s)**	**Distance Landed from Target**
Test 1				
Test 2				
Test 3				
Test 4				
Average				

◆ Evaluation Phase
Evaluate your teams' results, complete the evaluation worksheet, and present your findings to the class.

Use this worksheet to evaluate your team's results in the Playing with Parachutes Lesson:

1. Did you succeed in creating a parachute that could hit the target? If so, what was your slowest rate of descent? If not, why did it fail?

2. Did you decide to revise your original design or request additional materials while in the construction phase? Why?

Student Worksheet (continued):

3. Did you negotiate any material trades with other teams? How did that process work for you?

4. If you could have had access to materials that were different than those provided, what would your team have requested? Why?

5. Do you think that engineers have to adapt their original plans during the construction of systems or products? Why might they?

6. If you had to do it all over again, how would your planned design change? Why?

7. What designs or methods did you see other teams try that you thought worked well?

Student Worksheet (continued):

8. Do you think you would have been able to complete this project easier if you were working alone? Explain…

9. What kind of changes do you think you would need to make to your design if you needed to transport a heavier payload? Try it!

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:
- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop
- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of
- ✦ Properties of objects and materials
- ✦ Position and motion of objects

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of
- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop
- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of
- ✦ Motions and forces

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of
- ✦ Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of
- ✦ History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop
- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of
- ✦ Motions and forces

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of
- ✦ Science and technology in local, national, and global challenges

For Teachers:
Alignment to Curriculum Frameworks (continued)

◆**National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of Historical perspectives

◆**Next Generation Science Standards Grades 2-5 (Ages 7-11)**

Matter and its Interactions

Students who demonstrate understanding can:

- 2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

Energy

Students who demonstrate understanding can:

- 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆**Next Generation Science Standards Grades 6-8 (Ages 11-14)**

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆**Principles and Standards for School Mathematics (ages 11 - 14)**

Measurement Standard

-Apply appropriate techniques, tools, and formulas to determine measurements.

- solve simple problems involving rates and derived measurements for such attributes as velocity and density.

◆Principles and Standards for School Mathematics (ages 14 - 18)

Measurement Standard

- Apply appropriate techniques, tools, and formulas to determine measurements.
  - ✦ analyze precision, accuracy, and approximate error in measurement situations.

◆ Common Core State Standards for School Mathematics Grades 2-8 (ages 7-14)

Measurement and data

- Measure and estimate lengths in standard units.
  - ✦ CCSS.Math.Content.2.MD.A.1 Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
  - ✦ CCSS.Math.Content.2.MD.A.3 Estimate lengths using units of inches, feet, centimeters, and meters.

◆Standards for Technological Literacy - All Ages

Design

- ✦ Standard 8: Students will develop an understanding of the attributes of design.
- ✦ Standard 9: Students will develop an understanding of engineering design.
- ✦ Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Rubber Band Racers

Provided by TryEngineering - www.tryengineering.org

Lesson Focus
The focus of this lesson is on rubber band powered car design. Teams of students construct rubber band powered cars from everyday materials. Students must design their cars to travel a distance of at least 3 meters within a 1 meter wide track.

Lesson Synopsis
The "Rubber Band Racers" lesson explores the design of rubber band powered cars. Students work in teams of "engineers" to design and build their own rubber band cars out of everyday items. They test their rubber band cars, evaluate their results, and present to the class.

Age Levels
8-18

Objectives
During this lesson, students will:
- Design and construct a rubber band car
- Measure distance and calculate speed
- Test and refine their designs
- Communicate their design process and results

Anticipated Learner Outcomes
As a result of this lesson, students will have:
- Designed and constructed a rubber band car
- Measured distance and calculated speed
- Tested and refined their designs
- Communicated their design process and results

Lesson Activities
In "Rubber Band Racers" lesson students explore rubber band car design. Students work in teams of "engineers" to design and build their own rubber band car out of everyday items. They test their rubber band cars, evaluate their results, and present to the class.

Resources/Materials
- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- International Federation of Automotive Engineering Societies: What do Automotive Engineers Do? (www.fisita.com/jobs/careers/do)
- TryEngineering (www.tryengineering.org)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Recommended Reading

- The New Way Things Work (ISBN: 978-0395938478)
- Masters of Car Design (ISBN: 978-8854403376)

Optional Writing Activity

- Write a paragraph or essay explaining what automotive engineers must take into consideration when designing safe vehicles today.

For Teachers:
Teacher Resources

◆ Lesson Goal
Students design rubber band cars out of simple materials. They then test their cars to determine if they can travel a distance of at least 3 meters within a 1 meter wide track. The car that can travel within the track for the greatest distance is the winner.

◆ Lesson Objectives
During this lesson, students will:
- Design and construct a rubber band car
- Measure distance and calculate speed
- Test and refine their designs
- Communicate their design process and results

◆ Materials
One set of materials for each group of students:
- 16 in. x 16 in. piece of corrugated cardboard (or a cereal box/smaller piece of cardboard) and 4: CDs, paper plates, or plastic coffee, yogurt, or takeout lids)
- 4 rubber bands
- 3 unsharpened pencils
- 4 metal paperclips
- package thumb tack
- scissors
- masking tape
- meterstick
- stopwatch

◆ Procedure
1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
2. Divide students into groups of 3-4 students, providing a set of materials per group.
3. Explain that students must develop a car powered by rubber bands from everyday items, and that the rubber band car must be able to travel a distance of at least 3 meters within a 1 meter wide track. Rubber bands cannot be used to slingshot the cars. The car that can travel within the track for the greatest distance is the winner.
4. Students meet and develop a plan for their rubber band car. They agree on materials they will need, write or draw their plan, and then present their plan to the class.
5. Student teams may trade unlimited materials with other teams to develop their ideal parts list.
6. Student groups next execute their plans. They may need to rethink their plan, request other materials, trade with other teams, or start over.
7. Next….teams will test their rubber band car. Students can create the 1 meter wide "track" using masking tape on the floor.
8. Teams then complete an evaluation/reflection worksheet, and present their findings to the class.

◆ Time Needed
- Two to three 45 minute class periods

Student Resource: Automobiles and Automotive Engineering

◆ Brief History of the Automobile

The development of the automobile as we know it today has been an evolution over the past several hundred years. Both Leonardo da Vinci and Isaac Newton sketched ideas for vehicles during their lifetimes. The first steam-powered automobile was developed in the late 18th century by Nicolas Cugnot. Robert Anderson of Scotland developed the first electric vehicle sometime in the 1830s. In 1876 Nicolaus Otto developed the first effective gasoline motor engine which paved the way for the first gasoline powered vehicles. The first successful gasoline-powered vehicles were developed by Karl Benz and Gottleib Daimler in 1885. Some of the first mass-producers of gasoline powered automobiles included Rene Panhard and Emile Levassor and Peugeot in France; and Charles and Frank Duryea, Eli Olds and Henry Ford in the United States.

◆ Modern Automobiles

Even today, automobiles are constantly evolving. Today you can find automobiles in a wide array of colors, shapes and sizes. The vehicles of today possess innovative design features such as GPS, IPod Interfaces, rear video cameras and the ability to parallel park on their own!
In some markets, the size and efficiency of automobiles has become a priority. One of the smallest cars on the market, the smart car Fortwo, was introduced in 1998 by Nicholas Hayek the inventor of Swatch watches. The smart car is roughly 8 feet long 5 feet high and 5 feet wide making it ideal for crowded cities. The smart car Fortwo gets a reported 46.3 mpg in the city, and 68.9 mpg for highway driving.

Some of the greatest innovations in automotive engineering are occurring in the way cars are powered. The supply, cost, and environmental impact of fossil fuels are motivating many automakers to offer vehicles that use green technology or run on alternative energies. Hybrid cars use two systems of power including a gasoline powered engine and an electric motor. Some hybrid models need to be plugged in to recharge power and can even generate electricity. Electric cars run on electric battery powered motors. Some cars are designed to run on alternative fuels such as ethanol or biodiesel. Hydrogen powered cars and cars that run on hydrogen fuels are currently in development. Cars that run on compressed air are also being investigated by automakers around the world.

◆ Automotive Engineering

Automotive engineers design the vehicles that we use for life, work, and play. They are involved in aspects of engineering design ranging from the initial design concept all the way to production. They design, test and refine vehicles for safety, style, comfort, handling, practicality, and customer needs. The work of automotive engineers falls into three basic categories: design, development and production. The work of some engineers involves designing the basic part or systems of an automobile, such as brakes or engines. Research and development engineers devise solutions to various engineering challenges. Production engineers design the processes that will be used to manufacture the automobile.

Here are a few science concepts that will be helpful to keep in mind when designing and testing your rubber band car.

◆ Energy

Energy is the ability to do work. All forms of energy fall into two basic categories: potential energy and kinetic energy. Potential energy is mechanical energy which is due to a body's position. It is also known as stored energy. A car at rest has potential energy. Kinetic energy is mechanical energy that is due to a body's motion. For a car to move, potential energy must be transformed into kinetic energy.

◆ Newton's Laws of Motion

Sir Isaac Newton (1642 – 1727) was a brilliant mathematician, astronomer and physicist who is considered to be one of the most influential figures in human history. Newton studied a wide variety of phenomena during his lifetime, one of which included the motion of objects and systems. Based on his observations he formulated Three Laws of Motion which were presented in his masterwork Philosophiæ Naturalis Principia Mathematica in 1686.

Newton's First Law – An object at rest will remain at rest and an object in motion will remain in motion at a constant speed unless acted on by an unbalanced force (such as friction or gravity). This is also known as the law of inertia.

Newton's Second Law – An object's acceleration is directly proportional to the net force acting on it and inversely proportional to its mass. The direction of the acceleration is in the direction of the applied net force. Newton's Second Law can be expressed as: $F = ma$

Newton's Third Law – For every action there is an equal and opposite reaction.

Student Worksheet:
Design a Rubber Band Racer

You are a team of engineers who have been given the challenge to design your own rubber band car out of everyday items. The rubber band car needs to be able to travel a distance of at least 3 meters within a 1 meter wide track. The car that can travel the farthest distance within the track is the winner.

◆ Planning Stage

Meet as a team and discuss the problem you need to solve. Then develop and agree on a design for your rubber band car. You'll need to determine what materials you want to use.

Draw your design in the box below, and be sure to indicate the description and number of parts you plan to use. Present your design to the class.

You may choose to revise your teams' plan after you receive feedback from class.

Design:

Materials Needed:

Student Worksheet (continued):

◆ Construction Phase

Build your rubber band car. During construction you may decide you need additional materials or that your design needs to change. This is ok – just make a new sketch and revise your materials list.

◆ Testing Phase

Each team will test their rubber band car. Your rubber band car must travel 3 meters within a 1 meter wide track. Calculate your car's speed (distance traveled per unit of time; S = d/t). Be sure to watch the tests of the other teams and observe how their different designs worked.

Rubber Band Car Data			
	Distance Traveled within Track (m)	**Time Traveled within Track (s)**	**Speed (m/s)**
Test 1			
Test 2			
Test 3			
Average			

◆ Evaluation Phase

Evaluate your teams' results, complete the evaluation worksheet, and present your findings to the class.

Use this worksheet to evaluate your team's results in the Rubber Band Racer Lesson:

1. Did you succeed in creating a rubber band car that traveled 3 meters within the track? If so, how far did it travel? If not, why did it fail?

Student Worksheet (continued):

2. Did you negotiate any material trades with other teams? How did that process work for you?

3. What is the average speed your car achieved?

4. Did you decide to revise your original design or request additional materials while in the construction phase? Why?

5. If you could have had access to materials that were different than those provided, what would your team have requested? Why?

6. Do you think that engineers have to adapt their original plans during the construction of systems or products? Why might they?

7. If you had to do it all over again, how would your planned design change? Why?

8. What designs or methods did you see other teams try that you thought worked well?

9. Do you think you would have been able to complete this project easier if you were working alone? Explain…

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Properties of objects and materials

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Motions and forces
- ✦ Transfer of energy

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Risks and benefits
- ✦ Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- ✦ Motions and forces

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in local, national, and global challenges

For Teachers:
Alignment to Curriculum Frameworks (continued)

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Historical perspectives

◆Next Generation Science Standards Grades 3-5 (Ages 8-11)

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Energy

Students who demonstrate understanding can:

- 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆Next Generation Science Standards Grades 6-8 (Ages 11-14)

Energy

Students who demonstrate understanding can:

- MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

For Teachers: Alignment to Curriculum Frameworks (continued)

◆Principles and Standards for School Mathematics (ages 11 - 14)

Measurement Standard

-Apply appropriate techniques, tools, and formulas to determine measurements.

- solve simple problems involving rates and derived measurements for such attributes as velocity and density.

◆Principles and Standards for School Mathematics (ages 14 - 18)

Measurement Standard

- Apply appropriate techniques, tools, and formulas to determine measurements.

- analyze precision, accuracy, and approximate error in measurement situations.

◆ Common Core State Standards for School Mathematics Grades 2-8 (ages 7-14)

Measurement and data

- Measure and estimate lengths in standard units.

- CCSS.Math.Content.2.MD.A.1 Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
- CCSS.Math.Content.2.MD.A.3 Estimate lengths using units of inches, feet, centimeters, and meters.

Expressions & Equations

- Represent and analyze quantitative relationships between dependent and independent variables.

- CCSS.Math.Content.6.EE.C.9 Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. For example, in a problem involving motion at constant speed, list and graph ordered pairs of distances and times, and write the equation $d = 65t$ to represent the relationship between distance and time.

◆Standards for Technological Literacy - All Ages

Technology and Society

- Standard 5: Students will develop an understanding of the effects of technology on the environment.
- Standard 7: Students will develop an understanding of the influence of technology on history.

For Teachers:
Alignment to Curriculum Frameworks (continued)

◆Standards for Technological Literacy - All Ages

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

The Designed World

- Standard 18: Students will develop an understanding of and be able to select and use transportation technologies.

Series and Parallel Circuits

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Demonstrate and discuss simple circuits and the differences between parallel and serial circuit design and functions. Note: This lesson plan is designed for classroom use only, with supervision by a teacher familiar with electrical and electronic concepts.

Lesson Synopsis

The Series and Parallel Circuits activity encourages students to test two different circuit designs through the use of low voltage light bulbs. Students work in teams to predict the difference between the two circuit designs, and then build examples of the two different circuits using wires, bulbs, and batteries. After testing several predictions about each circuit type, the groups will compare results and discuss findings.

Age Levels

8-14.

Objectives

- Learn that different circuit designs result in different electrical behaviors.
- Learn about current flow and the operational differences between series and parallel circuits.
- Learn to predict outcomes and draw conclusions.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- parallel and series circuits
- circuits and current flow
- making and testing predictions
- teamwork

Lesson Activities

Students perform experiments using two different types of circuit arrangements: series and parallel circuits. Students compare a set up of series and parallel bulbs, make predictions about how the circuit will function, record results, and discuss the circuits as a group.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Worksheet (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- National Institute of Standards and Technology (NIST) (www.nist.gov) Information about measurements and measurement uncertainty.
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Recommended Reading

- DK Eyewitness Series: Electricity (ISBN: 0751361321)
- Make Cool Gadgets for Your Room by Amy Pinchuk and Teco Rodriques (ISBN: 1894379128)
- My World of Science: Conductors and Insulators by Angela Royston (Heinemann Educational Books, ISBN: 0431137269)

Optional Writing Activity

- Write an essay (or paragraph depending on age) describing how replacing one light on a holiday string of bulbs with a "blinking" light would cause all the lights in the string to also blink? Is this an example of a parallel or series circuit? Why?

Series and Parallel Circuits

For Teachers:
Teacher Resources

◆ Materials

- Student Resource Sheets
- Student Worksheet
- Notebooks
- Pencils
- Two set-ups for each group of students, each consisting of:
  - 6 pieces of bell wire (6" each) with ends stripped
  - Battery holder
  - Socket
  - Three or more 1.5 volt bulbs
  - Size D batteries

◆ Procedure

1. Review the definitions of series and parallel circuits with the class. Use Student Reference Sheets for background information. These may also be distributed as homework reading on the night prior to the activity.
2. Divide students into small groups of 3-4 students and distribute Student Worksheet and two set-ups (see materials above) to each group.
3. Ask the groups to examine the schematic of a series circuit on the Student Worksheet and draw their own plan for a parallel circuit in the space provided.
4. Have each student group make a series and parallel circuit using batteries, wires, and bulbs.
5. Once the circuits are complete, ask student groups to make predictions as to how the circuits will function if a light bulb is removed. Also discuss whether the bulbs might burn brighter in one set up than another. Students should record their predictions on the Student Worksheet.
6. Have each student group test their predictions using their circuits, and compare their results to their predictions.
7. Bring the student groups together to discuss their findings.

◆ Time Needed
45 Minutes

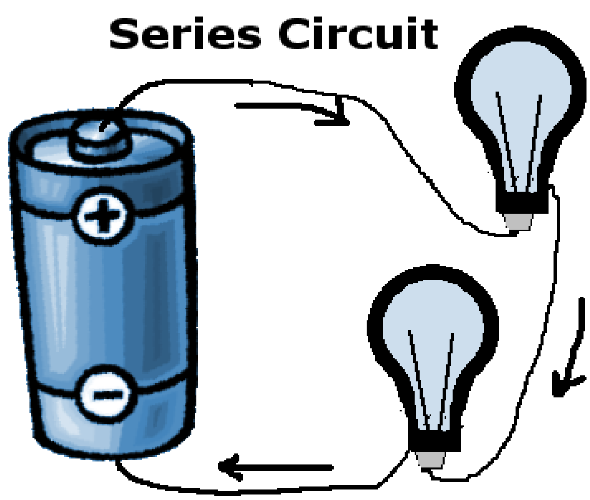
◆ Tips

- Teachers may want to set up the series circuit before class and ask students to create the parallel circuit to save time.
- Teachers should consider distributing the student resource sheets as reading material/homework for the night before the activity will be conducted in class.
- Encourage students to compare all the circuits built by different student groups.

Student Resource:
What is a Simple Circuit?

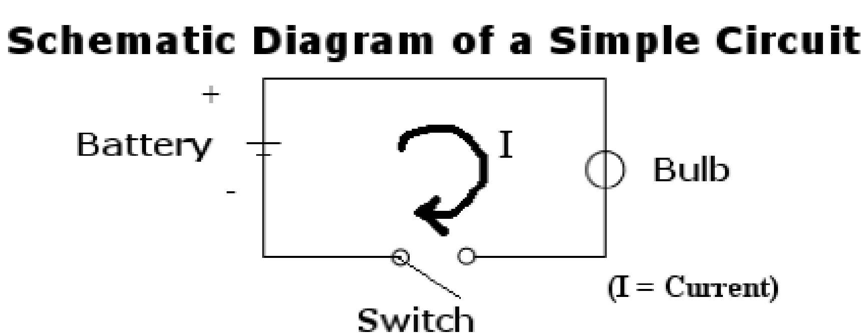
◆ **Simple Circuit**

A simple circuit consists of three elements: a source of electricity (battery), a path or conductor on which electricity flows (wire) and an electrical resistor (lamp) which is any device that requires electricity to operate. The illustration below shows a simple circuit containing a battery, two wires, and a low voltage light bulb. The flow of electricity is caused by excess electrons on the negative end of the battery flowing toward the positive end, or terminal, of the battery. When the circuit is complete, electrons flow from the negative terminal through the wire conductor, then through the bulb (lighting it up), and finally back to the positive terminal - in a continual flow.



◆ **Schematic Diagram of a Simple Circuit**

The following is a schematic diagram of the simple circuit showing the electronic symbols for the battery, switch, and bulb.

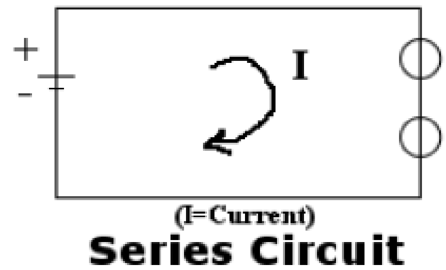


Series and Parallel Circuits

Student Resource:
What are Series and Parallel Circuits?

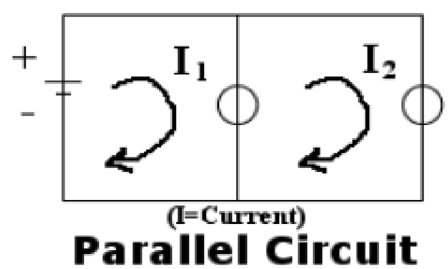
Series and parallel describes two different types of circuit arrangements. Each arrangement provides a different way for electricity to flow throughout a circuit.

◆ Series Circuits



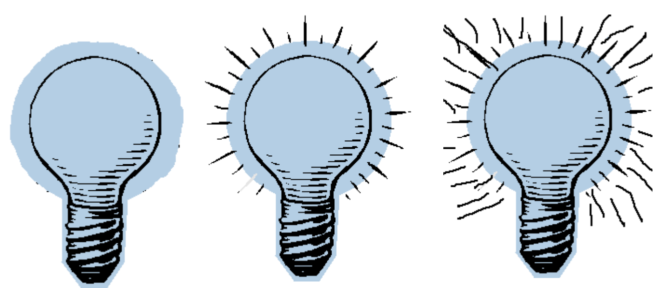
In a series circuit, electricity has only one path on which to travel. In the example to the right, two bulbs are powered by a battery in a series circuit design. Electricity flows from the battery to each bulb, one at a time, in the order they are wired to the circuit. In this case, because the electricity can only flow in one path, if one of the bulbs blew out, the other bulb would not be able to light up because the flow of electric current would have been interrupted. In the same way, if one bulb was unscrewed, the current flow to both bulbs would be interrupted.

◆ Parallel Circuits



In a parallel circuit, electricity has more than one path on which to travel. In the example to the right, two bulbs are powered by a battery in a parallel circuit design. In this case, because the electricity can flow in more than one path, if one of the bulbs blew out, the other bulb would still be able to light up because the flow of electricity to the broken bulb would not stop the flow of electricity to the good bulb. In the same way, if one bulb were unscrewed, it would not prevent the other bulb from lighting up.

◆ What About Resistance?

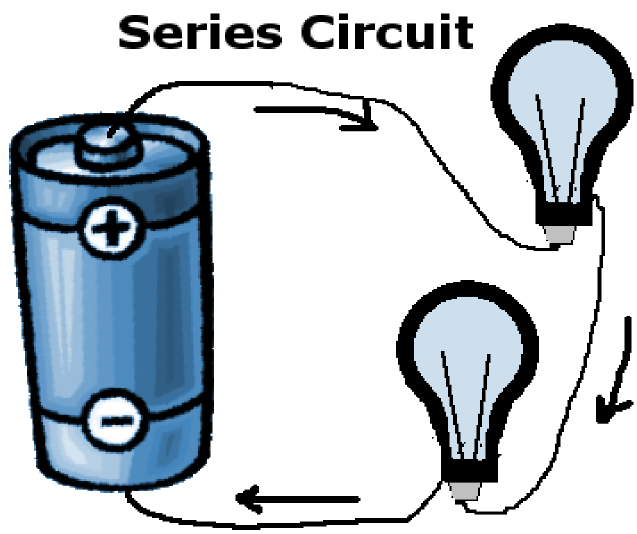


The flow of electricity depends on how much resistance is in the circuit. In our examples, the bulbs provide resistance. In a series circuit, the resistance in the circuit equals the total resistance of all the bulbs. The more bulbs in the circuit, the dimmer they will light. In a parallel circuit, there are multiple paths through which current can flow, so the resistance of the overall circuit is lower than it would be if only one path was available. The lower resistance means that the current will be higher and the bulbs will burn brighter compared to the same number of bulbs arranged in a series circuit.

Student Worksheet:

◆ **Instructions**

You are the engineer! You need to design a system where one switch can turn on multiple lights! An example might be a string of holiday lights. Now, construct both a series circuit and a parallel circuit using the batteries, wires, and bulbs provided to you. Your series circuit will look something like the drawing below:



Draw your own diagram below that illustrates how your Parallel Circuit will look:

Student Worksheet (continued):

◆ Group Predictions

After you have constructed both a series and parallel bulb circuit, make some predictions on the following as a group:

1. Do you think holiday lights are an example of parallel or series bulbs in a circuit? Explain why:

2. Do you think the bulbs in the parallel circuit or the series circuit will burn brighter? Explain why:

3. If you remove a bulb in your parallel circuit, with the other bulb(s) still light? Explain why:

4. If you remove a bulb in your series circuit, with the other bulb(s) still light? Explain why:

◆ Test and Results

Now test your predictions for questions 2, 3 and 4 above. Then respond to the questions below:

1. Were your predictions about the brightness of the bulbs accurate? If not, what happened that was different from what your group expected?

2. Were your predications about what happened if a bulb was removed from the parallel and serial circuits accurate? If not, what happened that was different from what your group expected?

Series and Parallel Circuits

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Light, heat, electricity, and magnetism

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Understanding about science and technology

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Understandings about science and technology

◆Next Generation Science Standards Grades 3-5 (Ages 8-11)

Energy

Students who demonstrate understanding can:

- ✦ 4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

◆Standards for Technological Literacy - All Ages

Design

- ✦ Standard 8: Students will develop an understanding of the attributes of design.
- ✦ Standard 9: Students will develop an understanding of engineering design.
- ✦ Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Fun with Speedboats!

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

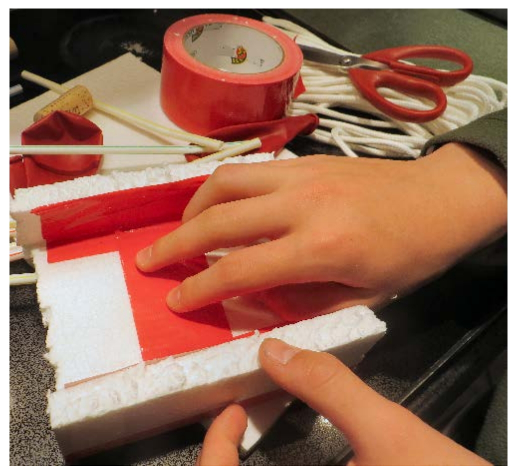
Lesson focuses on how engineers and ship designers have developed boats with a goal of breaking a water speed record. Students work in teams to develop a boat out of everyday materials that will prove to be the fastest in the classroom covering a distance of 5 ft or 150 cm along a classroom trough. Students design, build, and test their speedboats; evaluate their designs and those of classmates; and share observations with their class.

Lesson Synopsis

The Fun with Speedboats lesson explores how boats are engineered to achieve speed. Student teams consider and develop a design, build their speedboat out of everyday items, and test their boat against those developed by other student "engineering" teams. They reflect on the challenge and present their findings to the group.

Age Levels

11-18.



Objectives

- Learn about engineering design.
- Learn about ship design and engineering.
- Learn about world records.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- naval engineering and marine architecture
- engineering testing
- problem solving
- teamwork

Lesson Activities

Student teams learn how engineers have competed in a race for water speed and then design their own speedboat out of everyday items, considering the fastest and most stable propulsion system they can create. They design their speedboat first on paper, build their boat, test and time it against those of other student teams, reflect on the challenge, and present to their class.

Resources/Materials

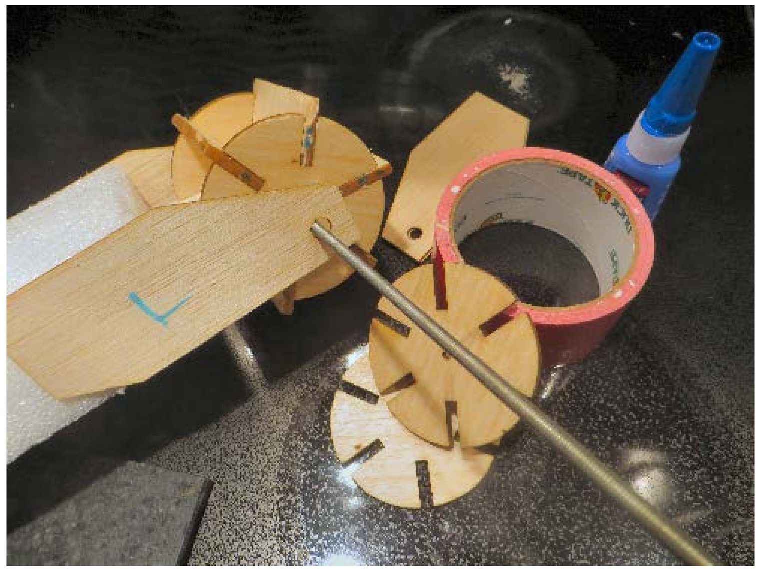
- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Guinness World Records (www.guinnessworldrecords.com)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)



Recommended Reading

- Extreme Machines (ISBN: 978-0789454171)
- Cutwater: Speedboats and Launches from the Golden Days of Boating (ISBN: 978-1879301047)
- Boatbuilding: A Complete Handbook of Wooden Boat Construction (ISBN: 978-0393035544)

Optional Writing Activity

- Write a paragraph or essay describing how engineering has impacted the attainable speed of another transportation vehicle such as a train, car, or spaceship.

Extension Idea

- Require student boats to carry a load (candy, a golf ball) -- and add this variable half way through the challenge so students will have to adapt their designs.

Fun with Speedboats!

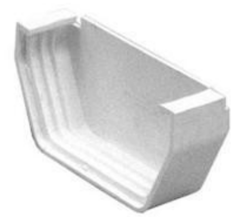
For Teachers:
Teacher Resource

◆ **Lesson Goal**

The Fun with Speedboats lesson explores how boats are engineered to achieve speed. Student teams consider and develop a design, build their speedboat out of everyday items, and test their boat against those developed by other student "engineering" teams. They reflect on the challenge and present their findings to the group.

◆ **Lesson Objectives**

- Learn about engineering design.
- Learn about ship design and engineering.
- Learn about world records.
- Learn about teamwork and working in groups.



◆ **Materials**

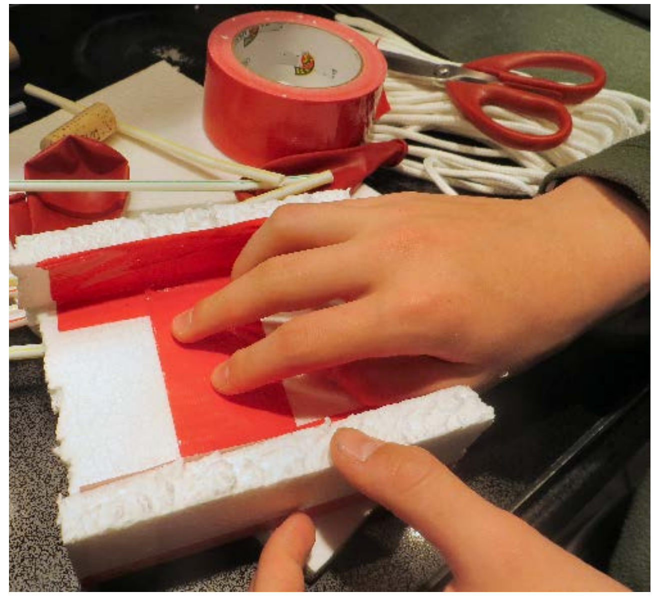
- Student Resource Sheet
- Student Worksheets
- Classroom Materials: water, towels, canal (long waterproof container such as a planter, or gutter section with end pieces attached), stopwatch or other speed measuring device. Gutters are usually sold in 4" or 125 mm x 7 foot/2.2 metre length sections -- with end caps this works well and allows for a water depth of about 3" or 90 mm. Whatever size trough you select will have to be provided to students so their boats fit.
- Student Materials: rubber bands, measuring tape, cardboard, fasteners, blocks or sheets of Styrofoam, duct tape, toothpicks, paper, foil, glue, pencils, straws, gears, paper cups, wax, balloons, string, springs, cork, motors, etc. -- or students can gather their own parts outside of class.

◆ **Procedure**

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework. Divide students into groups of 2-3 students, providing a set of materials per group. Give each team a name or number that will appear on their speed boat for easy identification.
2. Explain that students are now an "engineering" team that must develop a boat that can fit into the testing trough and prove to be the fastest in the class. (Note: be sure to measure the trough you are using and guide students to design their boats so that they are a narrower than the width of the trough. Boats also cannot be longer than 10 inches or 25 cm). The boat must remain in the water at all times during testing….and also has to be built from scratch, although younger students may use plastic boat toys though if building is too difficult.
3. Students meet and develop a plan for their speed boat which they will sketch on paper, including a list of parts.

For Teachers:
Teacher Resource

◆ **Procedure (continued)**



4. Student teams next present their plans to the class and review all the speedboat designs of other teams.
5. Next, students build their speedboat. They have an opportunity to view the boats built by other teams and make a prediction of the speed at which their own boat and the other team boats each will travel.
6. Teams test their boats -- each team can test their boat three times…and take the best speed.
   Note: The teacher should set up the waterway; only one is needed for all testing. Add water to a trough or sealed gutter section and tape the starting line and finish line. Teachers should time the tests for fair reporting. Students record the results of each test, noting distance spanned and stability.
7. Each student group compares their speed predictions with actual results, completes an evaluation/reflection worksheet, and presents their findings to the class.

◆ **Time Needed**

Two to four 45 minute sessions

◆ **Extension Ideas**

Advanced or older students could be challenged with developing a computerized sensor for measuring the time it takes for a boat to cross the "finish line."

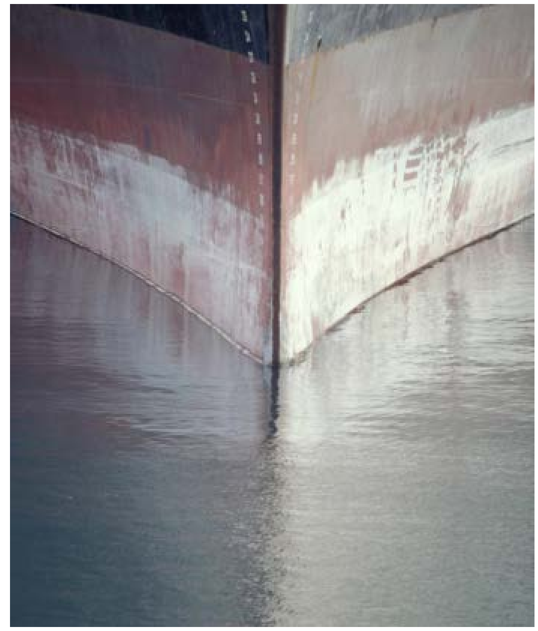
◆ **Tips**

- Testing could be conducted outside to reduce water issues in a classroom setting.

Student Resource: Naval Architecture and Marine Engineering

◆ What do Marine Engineers and Naval Architects Do?

Marine engineers and naval architects are involved in the design, construction, and maintenance of ships, boats, and related equipment. They design and supervise the construction of everything from aircraft carriers to submarines, and from speedboats to tankers. Naval architects work on the basic design of ships, including hull form and stability. Marine engineers work on the propulsion, steering, and other systems of ships. Marine engineers and naval architects apply knowledge from a range of fields to the entire design and production process of all water vehicles.



◆ Type of Vessels

There are a wide range of vessels that are designed and tested by marine engineers and naval architects including:

- Merchant Ships - oil/gas tankers, cargo ships, bulk carrier, container ships
- Passenger/vehicle ferries, cruise ships
- Warships - frigates, destroyers, aircraft carriers, amphibious ships, etc.
- Submarines and underwater vehicles
- Icebreakers
- Offshore drilling platforms, semi-submersibles
- High Speed Craft - hovercraft, multi-hull ships, hydrofoil craft, etc.
- Workboats - fishing boat, platform supply vessel, tug boat, pilot vessels, rescue craft, etc.
- Yachts, power boats, and other recreational craft.

◆ How Important is Testing?

Scientists and engineers use testing systems to evaluate the performance of equipment of all types before construction. Testing can take a variety of forms including wind tunnels, computer simulation, model making, and prototype fabrication.

Fun with Speedboats!

Student Resource: How Fast is Fast?

◆ What is a Speed Boat?
A full size motorboat (or speedboat) is a boat which is powered by an engine. In this lesson, you'll be building a boat that is much smaller and can be propelled using lots of different methods! Some motorboats are fitted with inboard engines, others have an outboard motor installed on the back of the boat that contains an internal combustion engine, a gearbox and the propeller in one unit.

◆ What is a World Record?
A world record (or world best) is usually the best global performance ever recorded and verified in a specific skill or sport. The book Guinness World Records collates and publishes notable records of all types, from first and best to worst human achievements, to extremes in the natural world and beyond. A number of high-profile records are broken on a regular basis, such as the record for the oldest person in the world. At the moment, with the most Guinness World Records is Mr Ashrita Furman, who holds the records for, among many others, long-distance pogo-stick jumping, most glasses balanced on the chin, and most hop-scotch games in 24 hours.

◆ World Water Speed Record
The official world water speed record is 275.97 knots (511.11 km./h, or 317.58 mph) by Ken Warby in the unlimited-class jet-powered hydroplane Spirit of Australia on Blowering Dam Lake, New South Wales, Australia, on 8 October 1978. Warby's record still stands today, and there have only been two official attempts to break it -- both ending in the death of the challengers. It is a good lesson that going fast isn't necessarily safe!

The Spirit of Australia was powered by a Westinghouse J34 jet engine. The engine was developed by the Westinghouse Electric Company in the late 1940s and was used for jet fighters and other aircraft. The Spirit of Australia is displayed permanently at the Australian National Maritime Museum.

Warby was fascinated with the idea of breaking the world speed record from a young age. As a child he built his own models and powercraft to race on water, setting the scene for his eventual world record attempts. With most of his engineering experience learnt on the job, he designed a wooden 3-point hydroplane which, at record breaking speeds, would make little contact with the water.

(Image Source: Australian National Maritime Museum Press Release - www.anmm.gov.au)

Fun with Speedboats!

Student Worksheet: Design and Testing

You are a team of engineers who have been given the challenge of developing a boat that can travel down a small canal faster than boats designed by other student "engineering" teams. There are a few rules:

1. Your boat must touch the water at all times during its journey.
2. Boats cannot be longer than 10 inches or 25 cm.
3. Boats also cannot be wider than 3 inches or 90 mm -- but check with your teacher as the width of the canal he/she is preparing may have a different width requirement.
4. You must make your boat from scratch (no premade plastic boats allowed, unless your teacher approves).
5. The method you develop for propelling your boat has to be part of the boat, so you cannot for example toss a ball at it to make it go.

◆ Research/Preparation Phase

1. Review the various Student Reference Sheets.

◆ Planning as a Team

Meet as a team and develop a drawing on the other side of this paper showing the design of your speed boat. Be sure to list all the items you think you will need to build it in the box below.

Parts List:

Fun with Speedboats!

Student Worksheet:
Hull Engineering and Testing (continued)

◆ Construction Phase

1. Build your boat using your planned materials…you may find you need to add materials or change the design during this phase. It is ok to trade materials with other teams, or request additional materials from the teacher. In some situations, your team may build your boat outside of school and gather materials as needed outside the classroom.

◆ Competitive Analysis Phase

1. Take a good look at all the speedboats created by other "engineering" teams in your classroom. Notice the differences, and as a team, make predictions of the best speed you think your boat and the competition with achieve during testing. Later, you'll use this sheet to mark down the actual results after testing.

Your team's prediction	Team:	Team:	Team:	Team:	Team:	Team:
Speed (Test 1)						
Speed (Test 2)						
Speed (Test 3)						

convert to miles per hour or km per hour

◆ Speed Race Testing

1. Observe as your team and other teams test their prototypes in your classroom waterway. Record your team's results in the box below, including points and observations.

Actual Results	Team:	Team:	Team:	Team:	Team:	Team:
Speed (Test 1)						
Speed (Test 2)						
Speed (Test 3)						

Fun with Speedboats!

Student Worksheet: Evaluation

◆ Reflection

1. How did your speed boat perform compared to other teams in your classroom?

2. What do you think was the pivotal aspect of the design of the boat that helped it go the fastest?

3. If you had to do it all over again, how would your planned design change? Why?

4. Do you think that engineers often adapt their original plans during the manufacturing process? Why might they?

5. Did you find that there were many designs in your classroom that were very different and yet also very fast? What does this tell you about engineering plans?

6. Explain how working as team impacted (positively or negatively) your team performance on this project.

7. If you could have added a material to your boat that was unavailable, what would that have been? Why?

Fun with Speedboats!

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry
As a result of activities, all students should develop
- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of their activities, all students should develop an understanding of
- ✦ Motions and forces
- ✦ Transfer of energy

CONTENT STANDARD E: Science and Technology
As a result of activities in grades 5-8, all students should develop
- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives
As a result of activities, all students should develop understanding of
- ✦ Science and technology in society

CONTENT STANDARD G: History and Nature of Science
As a result of activities, all students should develop understanding of
- ✦ Science as a human endeavor

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry
As a result of activities, all students should develop
- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of their activities, all students should develop understanding of
- ✦ Motions and forces
- ✦ Interactions of energy and matter

CONTENT STANDARD E: Science and Technology
As a result of activities, all students should develop
- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives
As a result of activities, all students should develop understanding of
- ✦ Science and technology in local, national, and global challenges

For Teachers:
Alignment to Curriculum Frameworks (continued)

◆**National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor

◆**Next Generation Science Standards Grades 3-5 (Ages 8-11)**

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Energy

Students who demonstrate understanding can:

- 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

Students who demonstrate understanding can:

- 4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆**Next Generation Science Standards Grades 6-8 (Ages 11-14)**

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

For Teachers: Alignment to Curriculum Frameworks (continued)

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 2: Students will develop an understanding of the core concepts of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.

The Designed World

- Standard 18: Students will develop an understanding of and be able to select and use transportation technologies.

TryEngineering

Spring Scale Engineering

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on the engineering behind building a spring scale and its use as a measuring device. Students work in teams to design, build, and test their own spring scale that can measure the weight of an apple using everyday items. They compare their designs with those of other student teams and reflect on the experience.

Lesson Synopsis

The "Spring Scale Engineering" activity explores how spring scales work and how they are used for non-exact weight measurement. Students work in teams to develop their own working spring scale out of ordinary items. They test their scale, present their designs to the class, compare their designs with those of other student teams, and reflect on the experience.

Age Levels

8-18.

Objectives

- Learn about scales and measuring devices.
- Learn about engineering design and redesign.
- Learn about construction techniques
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- construction
- engineering design
- teamwork

Lesson Activities

Students learn spring scales and develop their own functional spring scale out of everyday items. They present and then test their scales, and compare their designs with those of other teams. They also complete a reflection sheet on the activity.

Resource and Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Hooke's Law Demo (http://webphysics.davidson.edu/applets/animator4/demo_hook.html)
- Hooke's Law (http://asms.k12.ar.us/classes/physics/general/kenneth/hooke.htm)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- The Story of Measurement (ISBN: 978-0500513675)
- A Measure of Everything: An Illustrated Guide to the Science of Measurement (ISBN: 978-1554070893)
- A Measure of All Things: The Story of Man and Measurement (ISBN: 0312370261)

Optional Writing Activity

- Write an essay or a paragraph explaining examples of where precise measurement is important and where imprecise measurement is acceptable?

Optional Extension Ideas

- Advanced students could graph their spring scale results and calculate the force in Newtons based on the data gathered in the testing phase. The Hooke's Law demo page may be of use to students participating in the extension. See http://webphysics.davidson.edu/applets/animator4/demo_hook.html.

Spring Scale Engineering

For Teachers:
Teacher Resources

◆ **Lesson Goal**

The "Spring Scale Engineering" activity explores how spring scales work and how they are used for non-exact weight measurement. Students work in teams to develop their own working spring scale out of ordinary items. They test their scale, present their designs to the class, compare their designs with those of other student teams, and reflect on the experience.

◆ **Lesson Objectives**

- Learn about scales and measuring devices.
- Learn about engineering design and redesign.
- Learn about construction techniques
- Learn about teamwork and problem solving.

◆ **Materials**

- Student Resource Sheets
- Student Worksheets
- Classroom Materials: a set of identical items to be weighed. Can be a golf ball, a tennis ball, a cup of matching coins, or weights from a classroom weight set.
- Student Team Materials: a spring (can be as simple as a slinky, or a spring ordered from a scientific supply company) and a range of materials including but not limited to cardboard, wooden dowels, tape, foil, construction paper, glue, markers, string, rubber bands, wire, popsicle sticks, paper cups, straws, pipe cleaners, paper clips, screen, small plastic or PVC piping.

◆ **Procedure**

1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, discuss with students examples of situations when measuring or weighing something doesn't need to be extremely accurate. Mention a farmer's market where goods are sold in bulk and rounding up or throwing in an extra apple may be commonplace, compared to the precise measurements required for medicine disbursement.
3. Teams will consider their challenge and draw a diagram of their planned spring scale on paper and make a list of the materials they think they will require.
4. Teams next construct their spring scales with a requested materials list. Teams may request additional materials during the construction process or may trade materials with other teams.
5. Teachers then test each spring scale with the same item, to determine how close the scale came to an accurate weight measurement. The goal is for the student scales to be accurate within 10% of the actual weight.
6. Students compare their designs with other teams and complete a reflection sheet.

◆ **Time Needed**

One to two 45 minute sessions.

Student Resource: Spring Scales

◆ What is a Spring Scale?

A spring scale measures weight by the distance a spring deflects under a load. The first spring balance in Britain was made around 1770 by Richard Salter of West Bromwich. He and his nephews John & George founded the firm of George Salter & Company which is manufacturing scales and balances, and in 1838 patented the spring balance.

Very simply, a spring scale is a spring fixed at one end for stability and with a hook or something to hold the weight of an object (such as an apple) at the other. A measuring system will determine how far the spring stretches under the weight of the item. It is not designed for perfect accuracy, but rather to give a weight that does not require perfect accuracy. It works by Hooke's Law, which states that the force needed to extend a spring is proportional to the distance that spring is extended from its rest position. So, markings on a spring scale are equally spaced.

Most spring scales are marked "Not Legal for Trade" in large letters because the accuracy is really an approximation. Also, the spring in a spring scale can permanently stretch with repeated use and so will become even less accurate over time.

A scale that you might find in a fruit market or the vegetable section of a grocery store is a good example of a spring scale. It does not give you a very precise measurement but rather a ball park estimate so the purchaser can see if they have selected roughly a pound of apples for example. Likely at the register there is a more accurate scale for charging customers an accurate fee. But, at a farmers market, a charge may be based on the spring scale's estimate.

◆ Scale Calibration and Hooke's Law

All scales must be calibrated or marked so that when a weight is added the scale will display the weight of the object. Hooke's law of elasticity is used to calibrate scales. It says that the extension of a spring (how much it expands when a weight pulls it down) is in direct proportion with the weight added to it as long as this load does not exceed the elastic limit. The elastic limit is the point at which the spring is so stretched out that it cannot stretch any more. Actually, Hooke's law applies to any material that expands when a weight is added and then goes back to its original size after a weight is removed. Rubber bands and some plastics work this way, as do many springs. Hooke's law is named after the 17th century British physicist Robert Hooke. He first stated this law in 1676 as a Latin anagram, whose solution he published in 1678 as Ut tensio, sic vis, meaning, "As the extension, so the force."

Student Worksheet:

◆ **Engineering Teamwork and Planning**

You are part of a team of engineers given the challenge of building a spring scale to measure the weight of some items your teacher will provide you. In addition to a spring, you'll have lots of materials to use such as cardboard, wooden dowels, tape, foil, construction paper, glue, markers, string, rubber bands, wire, popsicle sticks, paper cups, straws, pipe cleaners, paper clips, screen, pvc piping, and other readily available materials.

◆ **Planning and Design Phase**

You may structure your scale any way you like, but must have a way of calibrating the scale so it will show a weight to you for whatever items you have to weigh. You'll want your scale to measure the weight of the items provided within 10% of the actual weight. You may want to test your scale with a range of items to make sure your scale works before classroom testing. In the box below, draw a diagram of your planned scale, and include a list of the parts you think you might need. You can adjust this later and also add more materials during construction.

Materials List:

Student Worksheet:

◆ Construction Phase

Build your scale and be sure to test it with several different items. You'll want to see if your scale can distinguish between one golf ball and two, or one onion and two for example. Make any adjustments during construction that you like, including asking for additional materials you might need. You can also trade materials with other student teams if they have extra items you need.

◆ Classroom Testing

Test your scale by weighing several different items at least two times each and record your results in the box below. This will help you to test your scale

For each item, record the mass of the item, the starting position of the spring based on your scale before you add the item to be weighted, and the ending position of the spring (after it is stretched).

Item you weighed	Mass (grams)	Starting Position (cm)	Stretched Position (cm)	Stretch (cm)
Onion				
Ball				

◆ Evaluation

Complete the evaluation questions below:

1. Was your scale able to measure the items provided by your teacher within 10% of the actual weight? If not, how close was your scale and how did it compare with the results of other teams?

2. How similar was your original design to the actual scale you built?

3. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.

4. Which scale in your class came the closest to the actual weight of the items provided by your teacher? Was there something about the design of that scale or materials used that caused it to work the best? Explain…

5. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

6. If you could have used one additional material (tape, glue, wood sticks, foil -- as examples) which would you choose and why?

7. Do you think your scale would have been able to measure a weight of 600 grams? Why or why not?

8. What real world applications can you think of for a scale that is reasonably accurate but not absolutely accurate?

9. Do you think that real engineers redesign their systems and products over and over during planning and manufacturing? Why or why not?

Spring Scale Engineering

For Teachers:
Alignment to Curriculum Frameworks

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- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Properties of objects and materials
- ✦ Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understanding about science and technology
- ✦ Abilities to distinguish between natural objects and objects made by humans

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Properties and changes of properties in matter
- ✦ Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in society

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆**National Science Education Standards Grades 5-8 (ages 10-14)**

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Nature of science
- History of science

◆**National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Historical perspectives

◆**Next Generation Science Standards Grades 3-5 (Ages 8-11)**

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆Next Generation Science Standards Grades 6-8 (Ages 11-14)

Motion and Stability: Forces and Interactions

- MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Principles and Standards for School Mathematics (ages 6 - 18)

Number and Operations Standard

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems
- Compute fluently and make reasonable estimates

Measurement Standard

- Understand measurable attributes of objects and the units, systems, and processes of measurement
- Apply appropriate techniques, tools, and formulas to determine measurements

Representation

- Create and use representations to organize, record, and communicate mathematical ideas
- Use representations to model and interpret physical, social, and mathematical phenomena

◆Common Core State Standards for School Mathematics Grades 2-8 (ages 7-14)

Measurement and Data

- Measure and estimate lengths in standard units.
  - CCSS.Math.Content.2.MD.A.1 Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
  - CCSS.Math.Content.2.MD.A.3 Estimate lengths using units of inches, feet, centimeters, and meters.
- Solve problems involving measurement and estimation.
  - CCSS.Math.Content.3.MD.A.2 Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l).[1] Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem.[2]

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆**Standards for Technological Literacy - All Ages**

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.

The Designed World

- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.

Tall Tower Challenge

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

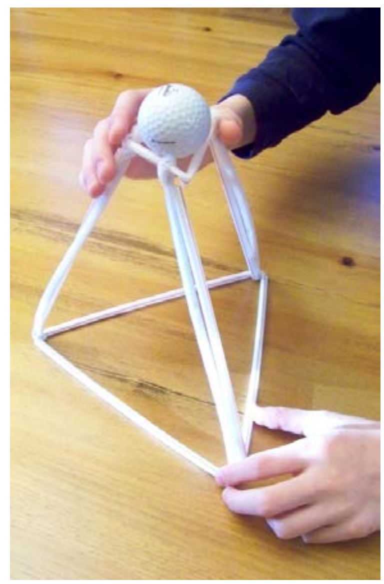
Lesson focuses on the growth of tall buildings and their structures. Students work in teams to develop the tallest tower they can build with limited materials that can support the weight of a golf ball for two minutes. They develop a design on paper, build their tower, present and test their tower to the class, evaluate their results and those of their teammates, and complete reflection sheets.

Lesson Synopsis

The "Tall Tower Challenge" activity explores the design of tall structures such as sky scrapers and telecommunication towers. Students work in teams to engineer the tallest tower they can build using just straws, pipe cleaners, and paperclips. The tower must be strong enough to support the weight of a golf ball for two minutes.

Age Levels

8-18.



Objectives

- Learn about structural engineering.
- Learn about engineering design and redesign.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- structural design and engineering
- engineering design
- teamwork

Lesson Activities

Students explore the tallest buildings in the world and how they were designed and constructed. They then work in teams to develop the tallest tower they can to support the weight of a golf ball for 2 minutes. They are provided with 50 straws, 50 pipe cleaners, and 25 paperclips. They develop a plan on paper, build the tower, test it, and compare their results with those of their classmates.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Burj Khalifa Tower Design and Construction (www.burjkhalifa.ae/language/en-us/the-tower.aspx)
- CN Tower (www.cntower.ca)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- How Tall Is Tall?: Comparing Buildings (ISBN: 978-1432939557)
- Reinforced Concrete Design of Tall Buildings (ISBN: 978-1439804803)
- Construction Technology For Tall Buildings (ISBN: 978-9812818614)

Optional Writing Activity

- Write an essay or a paragraph about how engineering advances led to the explosive growth of vertical buildings at the turn of the 20th century.

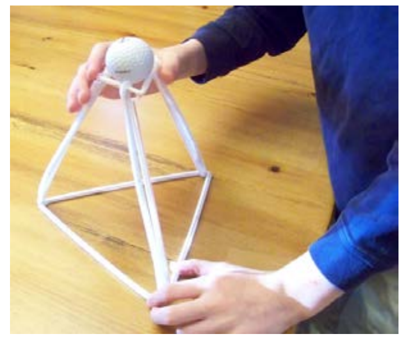
For Teachers: Teacher Resources

◆ **Lesson Goal**

Lesson focuses on the growth of tall buildings and their structures. Students work in teams to develop the tallest tower they can build with limited materials that can support the weight of a golf ball for two minutes. The golf ball must be supported near the top of the tower, with the bottom of the ball no more than 20% below the upper height of the tower. They develop a design on paper, build their tower, present and test their tower to the class, evaluate their results and those of their teammates, and complete reflection sheets.

◆ **Lesson Objectives**

- Learn about structural engineering.
- Learn about engineering design and redesign.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.



◆ **Materials**

- Student Resource Sheets
- Student Worksheets
- Set of materials for each team: 1 golf ball, 50 plastic straws, 50 pipe cleaners, 25 metal paperclips.

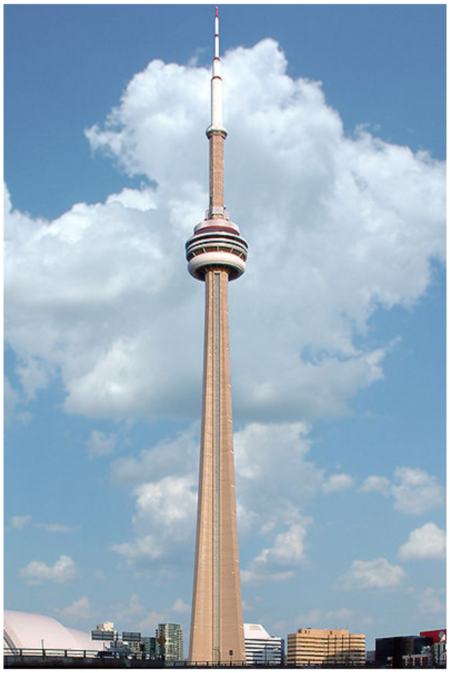
◆ **Procedure**

1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, discuss with students the increase in the height of buildings over the last century. Perhaps consider what the highest building in your community might be, and compare that with some of the tallest buildings in the world.
3. If possible, have students explore the design and manufacturing resources on the Burj Khalifa Tower Design and Construction website and have them consider the shape of the tallest structures. (www.burjkhalifa.ae/language/en-us/the-tower.aspx)
4. Teams will consider their challenge and draw a diagram of their planned tower on paper.
5. Teams next construct their towers, and test them within their team.
6. All teams then present their towers to the class and demonstrate the ability of the tower to hold the golf ball.
7. All towers are measured to determine the tallest tower.
8. Student teams complete a reflection sheet and share their experiences with the class.
9. Note: This lesson can be completed with a full grade of students instead of one classroom so students compete against all others in the school.

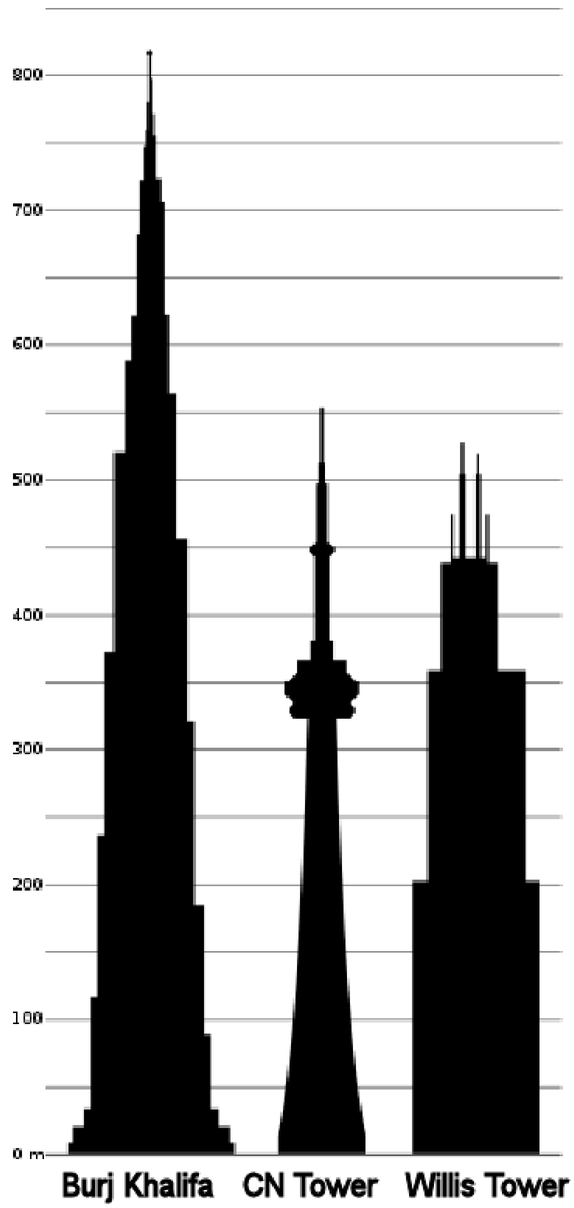
◆ **Time Needed**

One to two 45 minute sessions.

Student Resource:
Tall Structures



The CN Tower (picture to the left), located in Toronto, Ontario, Canada, is a communications and observation tower standing 553.3 metres tall. It was recognized as the tallest free-standing structure on land in the world for 31 years until it was recently surpassed in height by the Burj Khalifa in Dubai in the United Arab Emirates. the Burj Khalifa was built in 2009 and is 828 meters high. The third tallest is the Willis Tower (formerly known as Sears Tower) in Chicago, Illinois, U.S.A., which stands at 527 m (1,729.0 ft) when measured to its pinnacle, The tallest wooden structure is the Gliwice Radio Tower in Poland, which stands at 118 meters high and was built in 1935. The chart to the right shows the height comparison between the Burj Khalifa, the CN Tower, and the Willis Tower.



In January 2010, the world's highest outdoor observation deck located in Burj Khalifa, has opened to the public. Hundreds of people, mostly families, queued up for tickets to Level 124 of Burj Khalifa – and the chance of being among the first to experience its stunning views across the city. The view is said to be similar to what you might see from an airplane. The ascent to the 124th floor is by a double-deck elevator, each deck carrying up to 14 people and travelling at 10 meters per second. In less than a minute, the elevator reaches the observation deck, the world's only public observatory at this height with an outdoor terrace. High windows circle the entire viewing platform, and visitors can scan the horizon and the distant streets below through computerized viewfinders, which also have pre-programmed day and nighttime vistas of the city and surrounding region.

Student Worksheet:
Applying Technology to Solve Problems

◆ **Engineering Teamwork and Planning**

You are part of a team of engineers given the challenge of building the tallest tower you can build using only 50 straws, 50 pipe cleaners, and 25 paperclips.

You do not need to use all the materials, but your tower must support the weight of a golf ball for two minutes. The golf ball must be supported near the top of the tower, with the bottom of the ball no more than 20% below the upper height of the tower.

◆ **Planning and Design Phase**

Think about the different ways you can bend or change the shape of straws, pipe cleaners, and paper clips. You may cut these items, but cannot use tape or other materials to connect them together. In the box below, draw your plan for the tower.

Student Worksheet:

◆ Construction Phase

Build your tower and test it to see if it can support the golf ball. Then, answer the questions below:

1. How similar was your design to the actual tower you built.

2. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.

3. Did you use all the parts provided to you? Were any of the parts used only to increase the height of the tower?

◆ Presentation and Measurement

Present your tower to the class and have your teacher measure the height of the tower. Bear in mind that the golf ball must be supported near the top of the tower, with the bottom of the ball no more than 20% below the upper height of the tower. If the bottom of the ball is more than 20% below the top, your tower will be disqualified. Complete the box below for your tower:

Overall height of the bottom of the ball on/in tower	Distance from bottom of golf ball to top of tower	Percentage of tower supporting golf ball.

Student Worksheet (continued):

◆ **Evaluation**
Complete the evaluation questions below:

1. Describe the shape or construction of the tower that was the tallest and won the challenge? How was this tower different from yours, if yours did not win?

2. If you had a chance to do this project again, what would your team have done differently?

3. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

4. If you could have used one additional material (tape, glue, wood sticks, foil -- as examples) which would you choose and why?

5. Do you think that once a building is designed and approved for construction that many aspects are changed during the building process? Why or why not?

6. How long do you think it will take before a building is constructed that surpasses the height of the Burj Khalifa? Where do you think it will be built? Why?

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Properties of objects and materials

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understanding about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Characteristics and changes in populations
- ✦ Changes in environments
- ✦ Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Populations, resources, and environments
- ✦ Risks and benefits
- ✦ Science and technology in society

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆**National Science Education Standards Grades 5-8 (ages 10-14)**

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- History of science

◆**National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Personal and community health
- Population growth
- Environmental quality
- Science and technology in local, national, and global challenges

◆**Next Generation Science Standards Grades 2-5 (Ages 7-11)**

Matter and its Interactions

Students who demonstrate understanding can:

- 2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

Motion and Stability: Forces and Interactions

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆Next Generation Science Standards Grades 6-8 (Ages 11-14)
Engineering Design

Students who demonstrate understanding can:

- ✦ MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

◆Next Generation Science Standards Grades 6-8 (Ages 11-14)
Engineering Design

- ✦ MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Standards for Technological Literacy - All Ages
The Nature of Technology

- ✦ Standard 1: Students will develop an understanding of the characteristics and scope of technology.

Technology and Society

- ✦ Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- ✦ Standard 5: Students will develop an understanding of the effects of technology on the environment.
- ✦ Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- ✦ Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- ✦ Standard 8: Students will develop an understanding of the attributes of design.
- ✦ Standard 9: Students will develop an understanding of engineering design.
- ✦ Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- ✦ Standard 11: Students will develop abilities to apply the design process.

The Designed World

- ✦ Standard 20: Students will develop an understanding of and be able to select and use construction technologies.

Water Rocket Launch

Provided by TryEngineering - www.tryengineering.org

Lesson Focus
Lesson focuses on aerospace engineering and how space flight has been achieved from an engineering vantage point. Student teams build and launch a rocket made out of a soda bottle and powered with an air pump and consider the forces on a rocket, Newton's Laws, and other principles and challenges of actual space vehicle launch. Teams design their structure on paper, learn about aerospace engineering, launch their rocket, and share observations with their class.

Lesson Synopsis
The "Water Rocket Launch" lesson explores rocketry and the principals of space flight. Students work in teams with teacher supervision and construct and launch a rocket from a soda bottle and everyday materials that is powered by an air pump. They observe their own achievements and challenges, as well as those of other student teams, complete a reflection sheet, and present their experiences to the class.

Age Levels
8-18

Objectives

- Learn about aerospace engineering.
- Learn about engineering design and redesign.
- Learn about space flight.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes
As a result of this activity, students should develop an understanding of:

- aerospace engineering
- engineering design
- space flight
- teamwork

Lesson Activities
Students explore how engineers have developed rockets over the years, and learn about the principals of rocketry. They work in teams to construct and launch a rocket made from a soda bottle that launches with an air pump under teacher supervision. The students compare their accomplishments and challenges with those of other student teams, complete a reflection sheet, and present to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Timeline of Rocket History (http://history.msfc.nasa.gov/rocketry/)
- NASA Beginners Guide to Rockets (www.grc.nasa.gov/WWW/K-12/rocket/bgmr.html)
- European Space Agency - Space Engineering (www.esa.int/SPECIALS/Space_Engineering)
- Rocketry Planet (www.rocketryplanet.com)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- Rockets and Missiles: The Life Story of a Technology (ISBN: 978-0801887925)
- Rocket and Spacecraft Propulsion: Principles, Practice and New Developments (ISBN: 978-3642088698)
- It's ONLY Rocket Science (ISBN: 978-0387753775)
- "A Pictorial History of Rockets" (www.nasa.gov/pdf/153410main_Rockets_History.pdf)
- Soda-Pop Rockets: 20 Sensational Rockets to Make from Plastic Bottles (ISBN: 978-1556529603)

Optional Writing Activity

- Write an essay or a paragraph describing an example of rockets might be used to help society in peaceful times.

Safety Notes

- This is an outside activity.
- This exercise should only be done under the supervision of a qualified teacher.
- Safety glasses should be worn at all times.
- Since a quantity of water will be sprayed over the floor, it is suggested that old clothes or rain coats be worn by the test crew.
- Observing students should stand safely back from launch site.

Related Lesson

- TryEngineering.org offers a lesson incorporating traditional rockets called "Blast Off"

Water Rocket Launch

For Teachers:
Teacher Resources

◆ **Lesson Goal**

The "Water Rocket Launch" lesson explores rocketry and the principals of space flight. Students work in teams with teacher supervision and construct and launch a rocket from a soda bottle and everyday materials that is powered by an air pump. They observe their own achievements and challenges, as well as those of other student teams, complete a reflection sheet, and present their experiences to the class.

◆ **Lesson Objectives**

- Learn about aerospace engineering.
- Learn about engineering design and redesign.
- Learn about space flight.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

◆ **Materials**

- Student Resource Sheets
- Student Worksheets
- Student Team Materials (if building from everyday items: empty soda bottle, cork, paper, pen, pencil; plastic tubing, bicycle tire valve, cardboard, glue, tape, rubber bands, foil, decoration materials.)
- Kit option: Water bottle rocket kits may be purchased inexpensively (via Amazon.com, Antigravity Research at http://antigravityresearch.com, or through most teacher supply stores globally and might be better for younger students, or where there may be issues in drilling a hole through the required cork.
- Classroom Materials: water source, drill (if not using a kit), bicycle tire pump, system/tools for measuring how high the rockets fly.
- Internet access (optional) to explore www.grc.nasa.gov/WWW/K-12/rocket/ for research and to use online rocket simulator

◆ **Procedure**

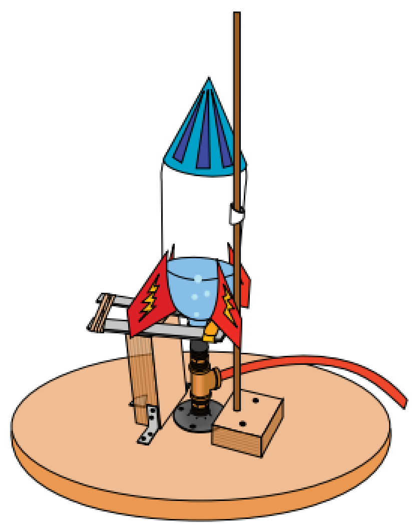
1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, consider asking the students how they think a rocket can fly and how engineers have to consider payload, weather, and the shape and weight of a rocket when developing a new or re-engineered rocket design.
3. Teams of 3-4 students will consider their challenge, read about rocketry, and explore the online rocket simulator (if internet access is available)
4. Teams next build and launch their rocket as a team, and observe the flight patterns of other rockets that are launched.
5. For an optional challenge, require students to launch a payload with their rocket. They'll have to develop a design, add a way to hold an item such as a hardboiled egg or tennis ball on their rocket, and evaluate which design worked best.
6. Teams reflect on the experience, and present to the class.

For Teachers:
Teacher Resources (continued)

◆ **Detailed Assembly and Launch Instructions**

If not using a kit, the procedure is as follows:

- Empty and clean a large plastic soda or water bottle.
- You will need to make the rocket stand up on its own upside down (cap down)…so either guide students to make "tail fins" out of cardboard that can support the weight of a bottle that is 1/4 filled with tap/still water, or make a stand for the class out of wood that will keep the rocket upright during launch. Lengths of wooden dowel held together with duct tape would suffice. For younger students, it is best to have a "launch pad" prepared by the teacher -- this will help ensure that rockets go up and not sideways.
- If you intend to do this lesson multiple times, or want to add another layer of consistency in results, consider building a launching stand for your school. A good plan is at www.nasa.gov/pdf/153405main_Rockets_Water_Rocket_Launcher.pdf. There are many options for building a launcher. Another idea is to set up a joint project with a high school class. The high schools students can design and build the launcher, and the younger students can build the rockets.



- For older students, or to provide additional challenge, after the initial launch, tell student teams that their rockets must now carry a payload (hardboiled egg, tennis ball, packs of sugar).
- Students may decorate their rockets, or, for an extra challenge, require student teams to develop a way to adapt the rocket to carry a payload. This can be done mid-way through testing the rockets to add a twist to the experience.
- Set up a connection from the bottle to a bicycle air pump.
  - You'll need to gather corks which will need to be drilled in order to insert a small plastic tube. Some "corks" are actually made from plastic now, and would be easier to drill evenly. Another alternative is to obtain one of the soft rubber plugs used as temporary stoppers in partially emptied wine bottles. (The type which can be pushed into the neck of the bottle and the air then pumped OUT with a small pump). In essence, the objective here is to somehow obtain a plug which can be tightly squeezed into the neck of the plastic bottle so that it is virtually air-tight.

For Teachers:
Teacher Resources (continued)

◆ **Detailed Assembly and Launch Instructions (continued)**

- o Next obtain a small valve of the type which is used to pump up a football. Carefully drill a hole down the length of the cork. The drill used should be smaller than the diameter of the air valve, to ensure it is a really tight fit in the cork.
- o For extra safety use a plastic tube (hardware store) to add some space between the bicycle pump and the rocket --- you'll need to have two valves to make this connection work. (Note: many kits come with an extension tube for safety.)

✦ Blast Off! Fill the bottle ¼ full with tap/still water and place it in a vertical position in its launchpad. Connect a bicycle pump to the air valve and start pumping GENTLY. Eventually, the pressure of air in the bottle should be sufficient to expel the cork from the bottle. The water in the bottle will then significantly slow down the outgoing flow of air thus giving time for the rocket to rise to a reasonable height. The actual height will partly depend on the weight of water in the bottle and the tightness of fit of the cork in the neck of the bottle. You can try using more or less water to adjust height of the rocket. Make sure you launch in an open area and keep student back from the launching rocket. You may get wet so ponchos or towels are recommended!

◆ **Safety Notes**

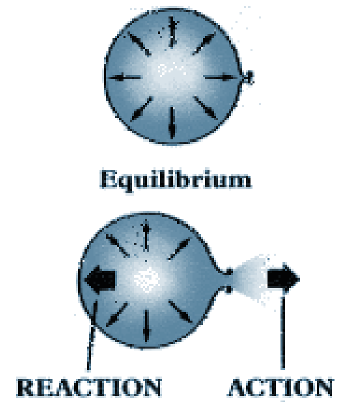
- This outdoor lesson is intended for students who are under the continual supervision of a responsible teacher or teacher team with prior experience with rocket launch kits.
- Be sure to follow your school's safety guidelines at all times.
- Observing students should stay back from launch pad.
- Extend the tube from the bicycle pump to the rocket as far as possible.
- Never stand over a rocket when it is launching.

◆ **Time Needed**

Two to four 45 minute sessions.

Student Resource: Rocket Principles

A rocket in its simplest form is a chamber enclosing a gas under pressure. A small opening at one end of the chamber allows the gas to escape, and in doing so provides a thrust that propels the rocket in the opposite direction. A good example of this is a balloon. Air inside a balloon is compressed by the balloon's rubber walls. The air pushes back so that the inward and outward pressing forces are balanced. When the nozzle is released, air escapes through it and the balloon is propelled in the opposite direction.



When we think of rockets, we rarely think of balloons. Instead, our attention is drawn to the giant vehicles that carry satellites into orbit and spacecraft to the Moon and planets. Nevertheless, there is a strong similarity between the two. The only significant difference is the way the pressurized gas is produced. With space rockets, the gas is produced by burning propellants that can be solid or liquid in form or a combination of the two.

One of the interesting facts about the historical development of rockets is that while rockets and rocket-powered devices have been in use for more than two thousand years, it has been only in the last three hundred years that rocket experimenters have had a scientific basis for understanding how they work.

The science of rocketry began with the publishing of a book in 1687 by the English scientist Sir Isaac Newton. His book, entitled Philosophiae Naturalis Principia Mathematica, described physical principles in nature. Today, Newton's work is usually just called the Principia. In the Principia, Newton stated three important scientific principles that govern the motion of all objects, whether on Earth or in space. Knowing these principles, now called Newton's Laws of Motion, rocketeers have been able to construct the modern giant rockets of the 20th century such as the Saturn V and the Space Shuttle.

◆ Newton's Laws of Motion

- Objects at rest will stay at rest and objects in motion will stay in motion in a straight line unless acted upon by an unbalanced force.
- Force is equal to mass times acceleration.
- For every action there is always an opposite and equal reaction.

All three laws are really simple statements of how things move. But with them, precise determinations of rocket performance can be made.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

◆ Newton's First Law

This law of motion is just an obvious statement of fact, but to know what it means, it is necessary to understand the terms rest, motion, and unbalanced force.

Rest and motion can be thought of as being opposite to each other. Rest is the state of an object when it is not changing position in relation to its surroundings. If you are sitting still in a chair, you can be said to be at rest. This term, however, is relative. Your chair may actually be one of many seats on a speeding airplane. The important thing to remember here is that you are not moving in relation to your immediate surroundings. If rest were defined as a total absence of motion, it would not exist in nature. Even if you were sitting in your chair at home, you would still be moving, because your chair is actually sitting on the surface of a spinning planet that is orbiting a star. The star is moving through a rotating galaxy that is, itself, moving through the universe. While sitting "still," you are, in fact, traveling at a speed of hundreds of kilometers per second.

Motion is also a relative term. All matter in the universe is moving all the time, but in the first law, motion here means changing position in relation to surroundings. A ball is at rest if it is sitting on the ground. The ball is in motion if it is rolling. A rolling ball changes its position in relation to its surroundings. When you are sitting on a chair in an airplane, you are at rest, but if you get up and walk down the aisle, you are in motion. A rocket blasting off the launch pad changes from a state of rest to a state of motion.

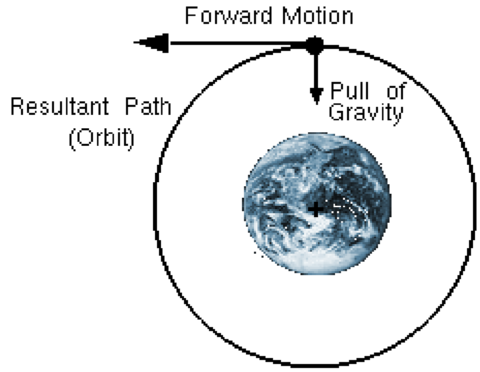
The third term important to understanding this law is unbalanced force. If you hold a ball in your hand and keep it still, the ball is at rest. All the time the ball is held there though, it is being acted upon by forces. The force of gravity is trying to pull the ball downward, while at the same time your hand is pushing against the ball to hold it up. The forces acting on the ball are balanced. Let the ball go, or move your hand upward, and the forces become unbalanced. The ball then changes from a state of rest to a state of motion.

In rocket flight, forces become balanced and unbalanced all the time. A rocket on the launch pad is balanced. The surface of the pad pushes the rocket up while gravity tries to pull it down. As the engines are ignited, the thrust from the rocket unbalances the forces, and the rocket travels upward. Later, when the rocket runs out of fuel, it slows down, stops at the highest point of its flight, then falls back to Earth.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource: Rocket Principles (Continued)

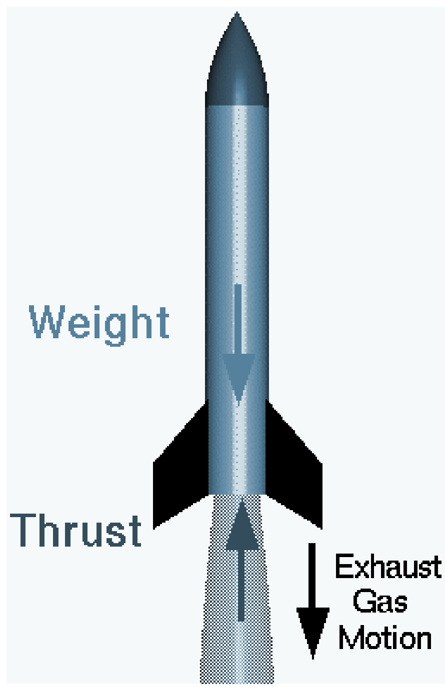
Objects in space also react to forces. A spacecraft moving through the solar system is in constant motion. The spacecraft will travel in a straight line if the forces on it are in balance. This happens only when the spacecraft is very far from any large gravity source such as Earth or the other planets and their moons. If the spacecraft comes near a large body in space, the gravity of that body will unbalance the forces and curve the path of the spacecraft. This happens, in particular, when a satellite is sent by a rocket on a path that is parallel to Earth's surface. If the rocket shoots the spacecraft fast enough, the spacecraft will orbit Earth. As long as another unbalanced force, such as friction with gas molecules in orbit or the firing of a rocket engine in the opposite direction from its movement, does not slow the spacecraft, it will orbit Earth forever.



Now that the three major terms of this first law have been explained, it is possible to restate this law. If an object, such as a rocket, is at rest, it takes an unbalanced force to make it move. If the object is already moving, it takes an unbalanced force, to stop it, change its direction from a straight line path, or alter its speed.

◆ Newton's Third Law

For the time being, we will skip the second law and go directly to the third. This law states that every action has an equal and opposite reaction. If you have ever stepped off a small boat that has not been properly tied to a pier, you will know exactly what this law means.



A rocket can lift off from a launch pad only when it expels gas out of its engine. The rocket pushes on the gas, and the gas in turn pushes on the rocket. The whole process is very similar to riding a skateboard. 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 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. This concept will be better explained in a discussion of the second law.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource:
Rocket Principles (Continued)

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. To enable a rocket to lift off from the launch pad, the action, or thrust, from the engine must be greater than the mass of the rocket. In space, however, even tiny thrusts will cause the rocket to change direction.

One of the most commonly asked questions about rockets is how they can work in space where there is no air for them to push against. The answer to this question comes from the third law. Imagine the skateboard again. On the ground, the only part air plays in the motions of the rider and the skateboard is to slow them down. Moving through the air causes friction, or drag. The surrounding air impedes the action-reaction. As a result rockets actually work better in space than they do in air. As the exhaust gas leaves the rocket engine it must push away the surrounding air; this uses up some of the energy of the rocket. In space, the exhaust gases can escape freely.

◆ Newton's Second Law

This law of motion is essentially a statement of a mathematical equation. The three parts of the equation are mass (m), acceleration (a), and force (f). Using letters to symbolize each part, the equation can be written as follows:

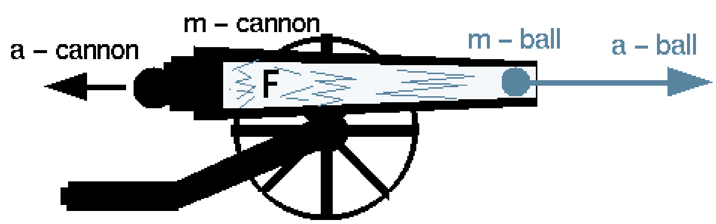
$$f = ma$$

By using simple algebra, we can also write the equation two other ways:

$$a = f/m$$

$$m = f/a$$

The first version of the equation is the one most commonly referred to when talking about Newton's second law. It reads: force equals mass times acceleration. To explain this law, we will use an old style cannon as an example.



When the cannon is fired, an explosion propels a cannon ball out the open end of the barrel. It flies a kilometer or two to its target. At the same time the cannon itself is pushed backward a meter or two. This is action and reaction at work (third law). The force acting on the cannon and the ball is the same. What happens to the cannon and the ball is determined by the second law. Look at the two equations below.

$$f = m(cannon) * a(cannon)$$

$$f = m(ball) * a(ball)$$

The first equation refers to the cannon and the second to the cannon ball. In the first equation, the mass is the cannon itself and the acceleration is the movement of the cannon. In the second equation the mass is the cannon ball and the acceleration is its movement.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource: Rocket Principles (Continued)

The first equation refers to the cannon and the second to the cannon ball. In the first equation, the mass is the cannon itself and the acceleration is the movement of the cannon. In the second equation the mass is the cannon ball and the acceleration is its movement. Because the force (exploding gun powder) is the same for the two equations, the equations can be combined and rewritten below:

$$m(\text{cannon}) * a(\text{cannon}) = m(\text{ball}) * a(\text{ball})$$

In order to keep the two sides of the equations equal, the accelerations vary with mass. In other words, the cannon has a large mass and a small acceleration. The cannon ball has a small mass and a large acceleration.

Let's apply this principle to a rocket. Replace the mass of the cannon ball with the mass of the gases being ejected out of the rocket engine. Replace the mass of the cannon with the mass of the rocket moving in the other direction. Force is the pressure created by the controlled explosion taking place inside the rocket's engines. That pressure accelerates the gas one way and the rocket the other. Some interesting things happen with rockets that don't happen with the cannon and ball in this example. With the cannon and cannon ball, the thrust lasts for just a moment. The thrust for the rocket continues as long as its engines are firing. Furthermore, the mass of the rocket changes during flight. Its mass is the sum of all its parts. Rocket parts include engines, propellant tanks, payload, control system, and propellants. By far, the largest part of the rocket's mass is its propellants. But that amount constantly changes as the engines fire. That means that the rocket's mass gets smaller during flight. In order for the left side of our equation to remain in balance with the right side, acceleration of the rocket has to increase as its mass decreases. That is why a rocket starts off moving slowly and goes faster and faster as it climbs into space.

Newton's second law of motion is especially useful when designing efficient rockets. To enable a rocket to climb into low Earth orbit, it is necessary to achieve a speed, in excess of 28,000 km per hour. A speed of over 40,250 km per hour, called escape velocity, enables a rocket to leave Earth and travel out into deep space. Attaining space flight speeds requires the rocket engine to achieve the greatest action force possible in the shortest time. In other words, the engine must burn a large mass of fuel and push the resulting gas out of the engine as rapidly as possible. Newton's second law of motion can be restated in the following way: the greater the mass of rocket fuel burned, and the faster the gas produced can escape the engine, the greater the thrust of the rocket.

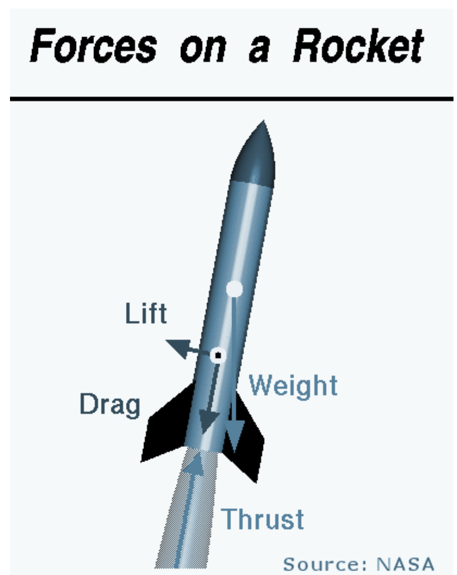
◆ Putting Newton's Laws of Motion Together

An unbalanced force must be exerted for a rocket to lift off from a launch pad or for a craft in space to change speed or direction (first law). The amount of thrust (force) produced by a rocket engine will be determined by the mass of rocket fuel that is burned and how fast the gas escapes the rocket (second law). The reaction, or motion, of the rocket is equal to and in the opposite direction of the action, or thrust, from the engine (third law).

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Worksheet:
How Rockets Fly

In flight, a rocket is subjected to four forces; weight, thrust, and the aerodynamic forces, lift and drag. The magnitude of the weight depends on the mass of all of the parts of the rocket. The weight force is always directed towards the center of the earth and acts through the center of gravity, the yellow dot on the figure. The magnitude of the thrust depends on the mass flow rate through the engine and the velocity and pressure at the exit of the nozzle. The thrust force normally acts along the longitudinal axis of the rocket and therefore acts through the center of gravity. Some full scale rockets can move, or gimbal, their nozzles to produce a force which is not aligned with the center of gravity. The resulting torque about the center of gravity can be used to maneuver the rocket. The magnitude of the aerodynamic forces depends on the shape, size, and velocity of the rocket and on properties of the atmosphere. The aerodynamic forces act through the center of pressure, the black and yellow dot on the figure. Aerodynamic forces are very important for model rockets, but may not be as important for full scale rockets, depending on the mission of the rocket. Full scale boosters usually spend only a short amount of time in the atmosphere.



In flight, the magnitude -- and sometimes the direction -- of the four forces is constantly changing. The response of the rocket depends on the relative magnitude and direction of the forces, much like the motion of the rope in a "tug-of-war" contest. If we add up the forces, being careful to account for the direction, we obtain a net external force on the rocket. The resulting motion of the rocket is described by Newton's laws of motion.

Although the same four forces act on a rocket as on an airplane, there are some important differences in the application of the forces:

- On an airplane, the lift force (the aerodynamic force perpendicular to the flight direction) is used to overcome the weight. On a rocket, thrust is used in opposition to weight. On many rockets, lift is used to stabilize and control the direction of flight.
- On an airplane, most of the aerodynamic forces are generated by the wings and the tail surfaces. For a rocket, the aerodynamic forces are generated by the fins, nose cone, and body tube. For both airplane and rocket, the aerodynamic forces act through the center of pressure (the yellow dot with the black center on the figure) while the weight acts through the center of gravity (the yellow dot on the figure).
- While most airplanes have a high lift to drag ratio, the drag of a rocket is usually much greater than the lift.
- While the magnitude and direction of the forces remain fairly constant for an airplane, the magnitude and direction of the forces acting on a rocket change dramatically during a typical flight.

(Source: NASA - Visit www.grc.nasa.gov/WWW/K-12/rocket for more details on rocketry.)

Student Resource:
Commercial Spaceflight - News

SpaceShipTwo: The World's First Commercial Spaceship

In 2011, in the skies above Mojave Air and Spaceport CA, SpaceShipTwo, the world's first commercial spaceship, demonstrated its unique reentry 'feather' configuration for the first time. In 2012, Virgin Galactic announced that its vehicle developer, Scaled Composites (Scaled), has been granted an experimental launch permit from the Federal Aviation Administration (FAA) for its suborbital spacecraft, SpaceshipTwo, and the carrier aircraft, WhiteKnightTwo

Already, SpaceShipTwo and WhiteKnightTwo have made significant progress in their flight test program. With 80 test flights completed, WhiteKnightTwo is substantially through its test plan, while the more recently constructed SpaceShipTwo has safely completed sixteen free flights, including three that tested the vehicle's unique "feathering" re-entry system. Additionally, ten test firings of the full scale SpaceShipTwo rocket motor, including full duration burns, have been safely and successfully completed.
With this permit now in hand, Scaled is now authorized to press onward towards rocket-powered test flights. In preparation for those powered flights, SpaceShipTwo will soon return to flight, testing the aerodynamic performance of the spacecraft with the full weight of the rocket motor system on board. Integration of key rocket motor components, already begun during a now-concluding period of downtime for routine maintenance, will continue into the autumn. Scaled expects to begin rocket powered, supersonic flights under the just-issued experimental permit toward the end of the year.
"The Spaceship program is making steady progress, and we are all looking forward to lighting the vehicle's rocket engine in flight for the first time," said Doug Shane, president of Scaled.

Although a handful of experimental launch permits have been granted to other rockets, SpaceShipTwo is the first rocket-powered vehicle that carries humans on board to receive such a permit.

Virgin also announced in 2012 that they will construct a rack system to allow research payloads to fly to space aboard Virgin Galactic's SpaceShipTwo (SS2). With these new racks, SS2 will allow researchers to conduct experiments during several minutes of microgravity using a mounting system also employed on the International Space Station (ISS). Standard racks will support up to 108 cubic feet of usable payload volume. Additionally, experiments can be positioned within the rack system for a view through Virgin Galactic's large, 17-inch-diameter-windows should acquisition of spectral data or imaging be desired

(Source: Virgin Galactic. More details and updates on this effort at www.virgingalactic.com)

Student Worksheet:

◆ Engineering Teamwork and Planning

You are part of a team of engineers given the challenge of building a model rocket using a soda or water bottle that will be attached to a bicycle air pump which will be the source of propulsion or energy. You can either make your rocket from everyday materials or use a kit that is provided to you. Either way, your goal is to have your rocket shoot up the highest and the straightest within your class. You'll research ideas online (if you have internet access), learn about rocket design and flight, and work as a team to construct and test your rocket. You'll consider the results of other teams, complete a reflection sheet, and share your experiences with the class.

◆ Research Phase

Read the materials provided to you by your teacher. If you have access to the internet, also visit www.grc.nasa.gov/WWW/K-12/rocket/ for additional research and to use the online rocket simulator, RocketModeler III.

◆ Planning and Design Phase

On a separate piece of paper draw a detailed diagram of how your rocket will look when completed and estimate how high you believe your rocket with travel. You'll need to design a base to hold your rocket before launch. Include a list of materials you will need and consider the weight you are adding to your base bottle.

If you have been given the challenge of adding a payload to your rocket, you'll need to design a way to have the bottle hold the item(s) you are launching into space. Payloads cannot be held inside the bottle.

◆ Build and Launch

As a team, build your rocket -- but always under the supervision of your teacher! You'll then test the rocket. Be sure to observe how high and how straight the rockets built by other teams go.

◆ Estimate Results

As a team, estimate how high your rocket will fly in the box below:

◆ Reflection/Presentation Phase

Complete the attached student reflection sheet and present your experiences with this activity to the class.

◆ **Reflection**

Complete the reflection questions below:

1. How did the height you estimated your rocket would reach compare with the actual estimated height?

2. What do you think might have caused any differences in the height you achieved?

3. Did your rocket launch straight up? If not, why do you think it veered off course?

4. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

5. Did you adjust your model rocket at all? How? Do you think this helped or hindered your results?

◆ **Reflection (continued)**

Complete the reflection questions below:

6. How do you think the rocket would have behaved differently if it were launched in a weightless atmosphere?

7. What safety measures do you think engineers consider when launching a real rocket? Consider the location of most launch sites as part of your answer.

8. When engineers are designing a rocket which will carry people in addition to cargo, how do you think the rocket will change in terms of structural design, functionality, and features?

9. Do you think rocket designs will change a great deal over the next ten years? How?

10. What tradeoffs do engineers have to make when considering the space/weight of fuel vs. the weight of cargo?

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry
- ✦ Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Properties of objects and materials
- ✦ Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understanding about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Properties and changes of properties in matter
- ✦ Motions and forces
- ✦ Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Risks and benefits
- ✦ Science and technology in society

For Teachers:

◆**National Science Education Standards Grades 5-8 (ages 10-14)**

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor
- History of science

◆**National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Chemical reactions
- Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

◆**Next Generation Science Standards Grades 3-5 (Ages 8-11)**

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Energy

Students who demonstrate understanding can:

- 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

◆**Next Generation Science Standards Grades 3-5 (Ages 8-11)**

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

For Teachers:

◆Next Generation Science Standards Grades 3-5 (Ages 8-11)

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆Next Generation Science Standards - Grades 6-8 (Ages 11-14)

Motion and Stability: Forces and Interactions

- MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.

Technology and Society

- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.

Working with Wind Energy

Provided by TryEngineering - www.tryengineering.org
Click here to provide feedback on this lesson.

Lesson Focus

Lesson focuses on how wind energy can be generated on both a large and small scale. Student teams design and build a working windmill out of everyday products and learn about anemometer and site testing. Student windmills must be able to sustain the wind generated by a fan or hairdryer at medium speed at 2 feet and rotate, lifting a small object upward. Students evaluate the effectiveness of their windmill and those of other teams, and present their findings to the class.

Lesson Synopsis

The "Working with Wind Energy" activity explores the growing use of wind energy to generate or augment energy in businesses and homes worldwide. Students work in teams of "engineers" to design and build their own windmill out of everyday items which they select and purchase with a budget. They test their windmill, evaluate their results, and present reflections to the class.

Age Levels

8-18.

Objectives

- Learn about wind energy and wind turbines.
- Learn about engineering design.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- wind energy
- interaction of technology and societal issues
- engineering design
- teamwork

Lesson Activities

Students explore the impact of how technology can positively impact the world by learning about wind energy and equipment used for both site testing and the conversion of wind to energy. Students explore the technology behind wind energy, find out about site studies, and work in teams to develop a windmill out of everyday items. They test their windmill, evaluate their own designs and those of other students, and present their findings to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- National Renewable Energy Laboratory - Wind Research (www.nrel.gov/wind)
- Wind Powering America (www.windpoweringamerica.gov)
- European Wind Energy Association (www.ewea.org)
- Danish Wind Industry Association (www.windpower.org)
- Global Wind Energy Council (www.gwec.net)
- Global Wind Day (www.globalwindday.org)
- National Science Education Standards (www.nsta.org/standards)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- Wind Power: Renewable Energy for Home, Farm, and Business (ISBN: 1931498148)
- Wind Energy Basics: A Guide to Small and Micro Wind Systems (ISBN: 1890132071)
- The Homeowner's Guide to Renewable Energy (ISBN: 086571536X)

Optional Writing Activity

- Write an essay about whether a wind farm -- even if it would provide energy to the local area -- would be a good idea to put in the center of your hometown. What about on the Thames River in London or just off of a resort beach area?

Working with Wind Energy

For Teachers:
Teacher Resources

◆ **Lesson Goal**

Students explore the impact of how technology can positively impact the world by learning about wind energy and equipment used for both site testing and the conversion of wind to energy. Students explore the technology behind wind energy, find out about site studies, and work in teams to develop a windmill out of everyday items. They test their windmill, evaluate their own designs and those of other students, and present findings to the class.

◆ **Lesson Objectives**

- Learn about wind energy and wind turbines.
- Learn about engineering design.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

◆ **Materials**

- Student Resource Sheets
- Student Worksheets
- Hairdryer or Fan; small object for each team to lift (suggestions: toy car, yoghurt cup filled with a few coins, tea bag, battery, pencil)
- One set of materials for each group of students: wooden stick, wooden spoons, small wooden (balsa) pieces, bendable wire, string, paperclips, rubber bands, toothpicks, aluminum foil, tape, dowels, glue, paper, cardboard, plastic wrap, or other materials you have available.

◆ **Procedure**

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
2. Divide students into groups of 2-3 students, providing a set of materials per group.
3. Explain that students must develop their own working windmill from everyday items, and that the windmill must be able to withstand a medium speed fan for one minute while winding a string to lift a small object such as a tea bag. (Note: as an extra challenge, test the windmill's ability to lift heavier objects such as coins or washers.)
4. Students will be given a "budget" from which they will need to purchase materials you provide. Assign a cost for each item that will result in the average team being able to purchase at least 30 material parts.
5. Students meet and develop a plan for their windmill. They agree on materials they will need, write or draw their plan, and then present their plan to the class.
6. Student groups next execute their plans. Student teams may request exchange materials or order more materials from the teacher, or may also trade unlimited materials with other teams to develop their ideal parts list. They will need to determine the "cost" of their design, however, which will be factored in to determine the most efficient classroom design.
7. Next….teams will test their windmills with the fan or hairdryer set up. (Note: you may wish to make the fan available during the building phase so they can test their windmill during the building phase prior to the classroom test.)
8. Teams then complete an evaluation worksheet, and present findings to the class.

◆ **Time Needed**

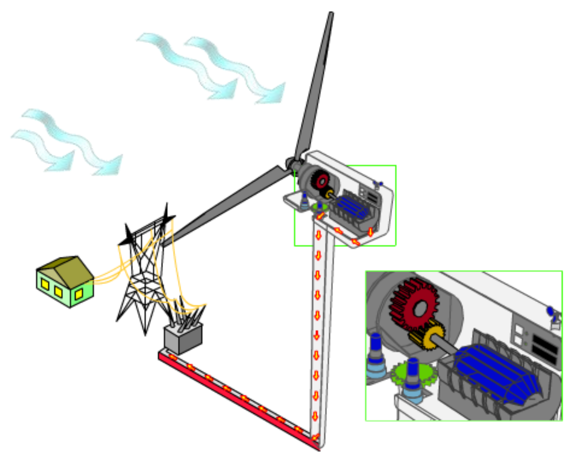
Two to three 45 minute sessions.

Student Resource:
What is Wind Energy?

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetation. Humans use this wind flow, or motion energy, for many purposes: sailing, flying a kite, and even generating electricity. The term "wind energy" describes the process by which the wind is used to generate mechanical energy or electricity. Wind turbines convert the kinetic energy in the wind into mechanical energy. Mechanical energy can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical energy into electricity.

◆ How Wind Turbines Work

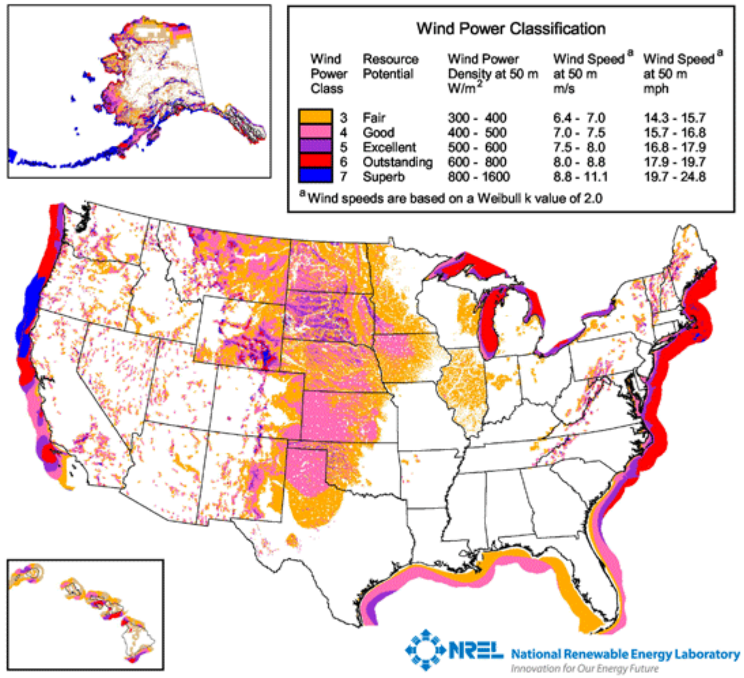
A wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity. Wind turbines, like windmills, are usually mounted on a tower to capture the most energy. Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. Wind turbines are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more above ground, they can take advantage of faster and less turbulent wind. A blade acts much like an airplane wing. When the wind blows, a pocket of low-pressure air forms on the downwind side of the blade. The low-pressure air pocket then pulls the blade toward it, causing the rotor to turn. This is called lift. The force of the lift is actually much stronger than the wind's force against the front side of the blade, which is called drag. The combination of lift and drag causes the rotor to spin like a propeller, and the turning shaft spins a generator to make electricity. Wind turbines can be used to produce electricity for a single home or building, or they can be connected to an electricity grid (see illustration to the right) for more widespread electricity distribution.



Wind speed and the height of the blades both contribute to the amount of energy generated. An interactive game from the Danish Wind Industry Association (www.windpower.org/composite-106.htm) lets you explore this concept in a game.

Source: Some of the information or images on this page are provided by the U.S. Department of Energy, the National Oceanic and Atmospheric Administration, or the National Renewable Energy Laboratory.

Student Resource: Site Testing for Wind Energy



Not all locations are suitable for wind energy development. They need to be evaluated to determine if the cost associated with installing a wind turbine will likely be balanced by the value of energy generated over time.

One of the first steps to developing a wind energy project is to assess the area's wind resources and estimate the available energy. To help the wind industry identify the areas best suited for development, the U.S. Wind Energy Program works with the National Renewable Energy Laboratory (NREL) and other organizations to measure, characterize, and map wind resources 50 meters (m) to 100 m above ground. At the local level, towns and contractors will work with homeowners to determine the cost and likely financial benefits of wind turbine installation. Often the first step is to temporarily install an anemometer to test the wind at a farm or home over several months or even a year.

◆ Using Anemometers to Test Wind Potential

An anemometer is a device that is used for measuring wind speed. Many countries and organizations offer anemometer loan programs, so a company or individual can evaluate the wind at their site to determine if enough wind energy would be generated at their location. For these test sites, an anemometer might collect wind-speed data in 10-minute intervals over a long period of time.

◆ Global Wind Day!

There's even a "Global Wind Day" on June 15 of each year to raise awareness of wind energy worldwide. Thousands of public events are organized simultaneously around the world. More information is at www.globalwindday.org.

Source: Some of the information or images on this page are provided by the U.S. Department of Energy and the National Renewable Energy Laboratory.

Student Resource: Blade Options

◆ Blade Design

Blades come in many shapes and sizes, and there is continuing research into which design is best. It turns out that the optimal design really depends on the application, or where and how the blade will be used. Designers look at the "tip speed ratio" that determines efficiency. This is the ratio between the speed of the wind and the speed the blade tip. High efficiency 3-blade-turbines have tip speed/wind speed ratios of between 6 and 7.

◆ How Many Blades?

Most wind turbines use either two or three blades. Research indicates that as more blades are added there is a increase in aerodynamic efficiency, but this efficiency decreases dramatically with each added blade. For example, increasing the number of blades from one to two can yield a six percent increase in aerodynamic efficiency, but increasing the blade count from two to three yields only an extra three percent in efficiency. And, of course, there are cost implications too. Each additional blade in a design will increase the cost of the end product, so engineers have to factor in both the increased efficiency and the increased cost of manufacturing to determine a design that will be the best for an application. Aesthetics is also a consideration. A small, two or three blade design might be best for a residential area, where a homeowner just wants to pull from the wind enough energy to power their own home, and would prefer a quieter option. A giant 12 blade design would not look very nice atop their home and would perhaps generate more energy than they need, and likely more noise too! To the right you can see how NASA tested a one-bladed rotor configuration. (Photo by NASA Glenn Research Center)

◆ Materials

Early windmills were made of wood with canvas sails. These deteriorated over time and required care – but they represented the materials readily available! More recently, older mechanical turbine blades were made out of heavy steel…but now many are made using fiberglass and other synthetic materials that offer strength at lower weights. And, lower weight building materials can result in larger blades to catch more wind in applications where size and space are less of an issue. Manufacturers also use epoxy-based composites which may offer manufacturing advantages over other materials because the process has less impact on the environment and can result in a smoother surface finish. Carbon fibers have also been identified as a cost-effective method to further reduce weight and increase stiffness. Smaller blades can be made from light metals such as aluminum.

Engineers will be working in this field for years to come to determine the optimal shape, weight, and materials to generate energy most efficiently!

Student Resource: Blade Innovation and Testing

◆ Which Shape is Best?

Turbine blades are made in many different shapes – and sometimes it is the application that determines which shape is best. For example, a wind turbine blade design that researchers at Sandia National Laboratories developed in partnership with Knight & Carver of San Diego, CA promises to be more efficient than current designs. It should significantly reduce the cost-of-energy (COE) of wind turbines at low-wind-speed sites. Named "STAR" for Sweep Twist Adaptive Rotor, the blade (see prototype to the right) has a gently curved tip, termed "sweep," which unlike the vast majority of blades in current use, is specially designed for low-wind-speed regions like the Midwest of the United States. The sites targeted by this effort have annual average wind speeds of 5.8 meters per second, measured at 10-meter height. Such sites are abundant in the U.S. and would increase by 20-fold the available land area that can be economically developed for wind energy. Sized at 27.1 meters long, it is almost three meters longer than the blades it will replace — and, instead of a traditional linear shape, the blade features a curvature toward the trailing edge, which allows the blade to respond to turbulent gusts in a manner that lowers fatigue loads on the blade. It is made of fiberglass and epoxy resin.

◆ Research and Testing

Before starting production of a new blade model, a prototype is tried out in a test bed (see image right courtesy of blade manufacturer LM Glasfiber. The blade is subjected to a strain corresponding to 20 years of operation during the testing process. LM Glasfiber is a good example of a "component" manufacturer – this is a business that does not manufacture an entire product, but focuses on a specific component – in this case turbine blades. LM Glasfiber has produced a total of more than 120,000 wind turbine blades since 1978. This amounts to more than one in three of all the blades in operation today, worldwide. One of the company's goals is to develop new technology that makes wind turbines more efficient and extends the service life of both the turbines and the blades. The company points out that "developing new types of blades is based on concrete decisions regarding design, materials and processes. Any adjustment to one parameter also impacts the others." This means that if they test a new shape, they may need to change a material as well.

Student Worksheet:
Design Your Own Windmill

You are working as a team of engineers who have been given the challenge to design a windmill out of everyday items. Your windmill will need to be able to withstand wind from a fan for at least one minute while winding a string or wire to lift a light object such as a teabag. You are working on a budget and will have to "purchase" materials from your teacher to create your design. You may return materials, exchange materials with other teams, but will need to determine the "cost" of your windmill – the least expensive design that meets the challenge will be considered the most efficient design! Your windmill may be vertical (pointing upward from a table) or horizontal (pointing off the edge of a table).

◆ Planning Stage

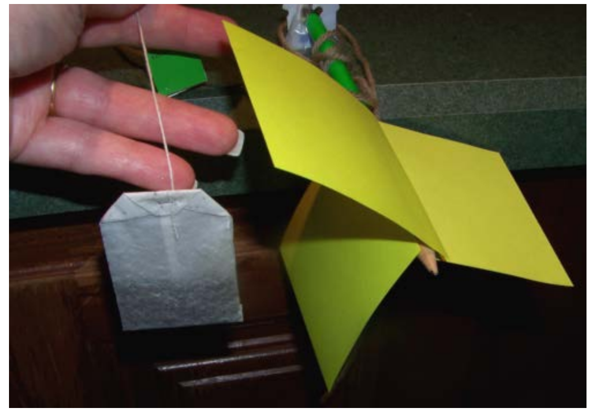
Meet as a team and discuss the problem you need to solve. Then develop and agree on a design for your windmill. You'll need to determine what materials you want to use -- keep in mind that your design must be strong enough to withstand wind from a fan or hairdryer and the base cannot move so it will have to be secured to a table or shelf. Draw your design in the box below, and be sure to indicate the description and number of parts you plan to use. Present your design to the class. You may choose to revise your teams' plan after you receive feedback from class.

Materials Needed and Budget:

Student Worksheet (continued):

◆ Construction Phase

Build your windmill. During construction you may decide you need additional materials or that your design needs to change. This is ok -- just make a new sketch and revise your materials list and budget.



◆ Testing Phase

Each team will test their windmill using a classroom fan or hairdryer -- each windmill will be tested using the same wind speed -- medium -- at a distance of three feet. You'll need to make sure your windmill can operate for a minute at this speed while winding a light object up with a string. Be sure to watch the tests of the other teams and observe how their different designs worked.

◆ Evaluation Phase

Evaluate your teams' results, complete the evaluation worksheet, and present your findings to the class.

Use this worksheet to evaluate your team's results in the "Working with Wind Energy" lesson:

1. Did you succeed in creating a windmill that operated for a minute that could lift an object? If not, why did it fail?

2. Did you decide to revise your original design or request additional materials while in the construction phase? Why?

3. Did you negotiate any material trades with other teams? How did that process work for you?

4. If you could have had access to materials that were different than those provided, what would your team have requested? Why?

Student Worksheet (continued):

5. Do you think that engineers have to adapt their original plans during the construction of systems or products? Why might they?

6. If you had to do it all over again, how would your planned design change? Why?

7. How did the most "efficient" design (the one with the lowest cost or budget) differ from your own?

8. Do you think you would have been able to complete this project easier if you were working alone? Explain…

9. What drawbacks does a wind turbine have as a reliable source of energy? What technologies exist that might compensate for these drawbacks?

10. What advantages does the windmill have as a renewable source of energy?

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Motions and forces
- ✦ Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Science and technology in society

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry
As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of their activities, all students should develop understanding of
- Motions and forces
- Interactions of energy and matter

CONTENT STANDARD E: Science and Technology
As a result of activities, all students should develop
- Abilities of technological design

CONTENT STANDARD F: Science in Personal and Social Perspectives
As a result of activities, all students should develop understanding of
- Natural resources
- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science
As a result of activities, all students should develop understanding of
- Historical perspectives

◆Next Generation Science Standards Grades 3-5 (Ages 8-11)

Motion and Stability: Forces and Interactions
Students who demonstrate understanding can:
- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Energy
- 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.
- 4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

Earth and Human Activity
Students who demonstrate understanding can:
- 4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

Engineering Design
Students who demonstrate understanding can:
- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆Next Generation Science Standards Grades 6-8 (Ages 11-14)

Energy

Students who demonstrate understanding can:

- MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Next Generation Science Standards Grades 9-12 (Ages 14-18)

Energy

Students who demonstrate understanding can:

- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Engineering Design

Students who demonstrate understanding can:

- HS-ETS1-2.Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 2: Students will develop an understanding of the core concepts of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 5: Students will develop an understanding of the effects of technology on the environment.

Design

- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆**Standards for Technological Literacy - All Ages**

The Designed World

- Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.
- Standard 20: Students will develop an understanding of and be able to select and use construction technologies.