Spark Innovations
Science Camp Curriculum

Program Outcomes/Learning Goals

Adapted from the National Science Education Standards (NSES), pp 22-23 and Project 2061's Science for All Americans, pp vi, 3.

The purpose of the Spark Innovations science program is to develop citizens who understand science concepts and science ways of thinking (habits of mind) and provide a learning environment that will foster the development of science knowledge and "habits of mind" for becoming self-regulated life-long learners. Summer Science Camps are exciting week-long educational opportunities designed for students to explore the wonders of science. Camps feature enriched instruction with a hands-on, minds-in approach with the expectation that students will exit the program with either a new or renewed interest in science and technology.

At the end of science camp, students will be able to:

1. Ask, find, and determine answers to questions derived from curiosity about everyday experiences.
2. Describe, explain, and predict natural phenomena, using laws of nature and logical reasoning to connect evidence and assumptions.
3. Read and view, with understanding, information about science in the media and to engage in social conversation about the validity of the conclusions.
4. Identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed.
5. Evaluate the validity and quality of scientific information on the basis of its source and the methods used to generate it.
6. Appreciate the dependency of living things on each other and on the physical environment.
7. Develop a respect for nature that should inform decisions on the uses of technology.
8. Understand that science has a particular way of observing, thinking, experimenting and validating to develop information about the world.
9. Recognize that science is a human endeavor that has profoundly affected the world throughout history.

The Method to the Madness

Demonstrations vs. Experiments

Learn the difference between a demonstration and an experiment.

The first key to doing real science with students is to understand the difference between a science demonstration and a hands-on science experiment. Demonstrations are usually performed by the teacher (follow the recipe and something happens) and are typically used to illustrate a science concept, which is wonderful, but if we want to do true science experiments we have to give students the opportunity to pose their own "what if…?" questions, which inevitably leads to controlling a variable—changing some aspect of the procedure or the materials used to perform the experiment.

A demonstration is interesting, entertaining, many times fun, but if it doesn't ask a question, test anything, or make any comparisons, or lead to someone [aka students] doing those things, then it doesn't offer much chance for exploration or discovery.

Take, for example, the demonstration we've done thousands of times that shows what happens when you drop a roll of Mentos® mints into a bottle of Diet Coke. As most of you know, a huge geyser erupts out of the bottle. Cool, right? But what does that teach students? Nothing [besides the fact that if you drop candy into soda, it explodes.] If, however, you change the number of Mentos you drop into the soda or you change the type of soda, then you and your students can

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make some comparisons between what happened in the original demonstration and in the secondary test and discover some things.

"C^3 It!"

It all boils down to a very simple concept—one named C^3. The 3 C's stand for Change, Create, and Compare and that's what we want for students. If they change something, create a new experiment, and then compare their results then you can be assured that your experiments are not only stupendous, but science as well.

Terms to Remember

Variable

A variable is something that changes in your experiment. There are two types of variables—independent and dependent variables. In a good experiment, only one variable changes at a time. If more than one variable changes, it is impossible to know which variable causes the result that occurs. For example, if you change the number of Mentos mints and the type of soda at the same time, how do you know if the number of mints or the type of soda changed the height of the geyser?

Independent Variable

This is the element of your experiment that you will change to answer your question. For example, if you want to test which type of soda produces the largest Mentos Geyser, your independent variable would be the types of soda you use in your experiment.

Dependent Variable

This is the action that occurs in response to the changing independent variable. For example, if you change the types of soda in your Mentos experiment, the height of your geyser would be your dependent variable.

Control

The control should be the element of the experiment where the independent variable is left unchanged. So, if you are trying to find out if another soda works better than Diet Coke in the Mentos Geyser, you would first measure the height of your geyser using Diet Coke. That height becomes the control element of your experiment to which you compare your other results. You will hear this process referred to as "controlling your variable."

Scientific Method

Every great experiment starts with the Scientific Method

The Scientific Method is just a road map to get you and your students from your question to their answer. We actually use it all the time without realizing what we're doing for everything from getting dressed to making dinner. Follow these steps to make your experiments effective learning experiences.

Question: What are you trying to find out?

When developing questions with students, remind them to nix nothing, if you assume you know the answer, then you don't really have a question.

Hypothesis: What do you predict will happen?

Make an educated guess about what you think the outcome of your experiment will be, based on the research you have gathered and what you know so far.

Procedure: What steps did you take to run your tests?

Perform your experiment. Be sure to think through and write out every step you take as you run your tests. Here's where you test your ideas! You're still gathering information that will help you find your answer. When you experiment, things don't always go as planned. Don't consider this a failure - it's just a part of learning. Don't give up! Be willing to allow for an unexpected variable and accept the possibility that the answer you discover might lead to more questions! It's completely okay to conduct an experiment and arrive at a discovery that is a complete surprise to you. Remember, it's the job of a scientist to wonder, discover, and explore. Keep asking questions and moving forward with your experiment.

Data: What photos, charts, and/or graphs did you include to show your results?

From the very start, write notes, draw pictures, take photos, make recordings, share what you learn with classmates, and test your results so that you know your facts are right. Take detailed notes about the processes and results of your experiment. Document every part of your experiment. Take notes, draw pictures, use your camera, and anything else that will help you keep track of each step of your procedure. You will eventually use that data to make charts and graphs to add to your conclusion.

Observations: What actually happened? Explain your results.

Write down what you discovered from your experiment. These discoveries will lead you to your conclusion.

Conclusion: "So What?" What did you learn? Was your hypothesis correct?

Summarize the results of your experiment and compare the results to your original guess. Was your hypothesis correct or incorrect? Remind students, if you reach a conclusion that is different than you expected, that's okay! Now is the time to start asking more questions... why did my experiment turn out this way? What are some possible explanations for these results?

Discovery vs. Conclusion

Discoveries are very different from conclusions, and it's important to know the difference. For example, dropping Mentos mints into soda creates an eruption. That's a discovery (not a conclusion) and this discovery leads to more questions.

How many Mentos do you need to make a soda geyser shoot up 20 feet? To answer this question, you have to set up a series of experiments where you test what happens when you drop different numbers of Mentos into soda. In this case, the number of Mentos used in each experiment is the only thing that changes - it's the variable - while everything else stays the same. Each test result leads you to make a new discovery. The test using four Mentos makes a ten foot geyser, while five Mentos creates a fifteen foot geyser.

Discoveries are just that—observations with no right or wrong answer. Only after you've made a number of discoveries can you formulate a conclusion. In the case of the Mentos experiment, you

discovered that there was a relationship between the number of Mentos you used and the height of the geyser. So, it's fair to make this conclusion… A soda geyser using ten Mentos mints will shoot up higher than a geyser using only two Mentos mints.

Tips:

You might also consider adding a checklist for the board in the classroom. This checklist helps your students remember all the sections they need to include in their experiment/journals and will help you as the teacher make sure the scientific method has been followed. The display board checklist should include the following:

Question

What are you trying to find out?

Hypothesis

What do you predict will happen?

List of Materials

What supplies did you use in your experiment?

Procedures

What steps did you take to run your tests?

Data

What photos, charts, and/or graphs did you include to show your results?

Observations/Discoveries

What actually happened? Explain your results.

Conclusion

"So What?" What did you learn? Was your hypothesis correct?

Day One: Fluid Behavior: Properties of Air & Water p. 14-42

Core Concepts Covered:

- Temperature effects
- Atmospheric conditions
- Cloud formation
- Air takes up space, exerts pressure
- Atmospheric convection
- Currents and oceanic temperature differences
- Properties of water adhesion/cohesion
- Gravity
- Surface tension
- Hydrophobic/hydrophilic
- Water resources/chemistry & environmental science

Day Two: The Facts of the Matter p. 43-85

Core Concepts Covered:

- Solids, liquids, gases
- Freeze, melt, evaporate
- Physical properties
- Mixtures [making & separating]
- Physical properties of matter
- States of matter
- Physical and chemical changes
- Mixtures
- Density
- Non-Newtonian

Day Three: Energy to Burn p. 86-118

Core Concepts Covered:

- Solar effects
- Potential and kinetic energy
- Momentum
- Conservation of Energy
- Gravity
- Velocity

Day Four: Laws of Attraction p. 119-153

Core Concepts Covered:

- Magnetic Fields
- Magnetic Lines of Force
- Magnetic Poles
- Magnets
- Position
- Friction
- Gravitational Force

Day Five: Forces at Work p. 154-191

Core Concepts Covered:

- The relationship between magnetism and electricity
- Electromagnets
- Newton's Laws
- Energy
- Forces
- Centripetal Force
- Pressure
- Gravity
- Electricity
- Forces acting at a distance
- Conduction
- Insulators
- Simple circuits

Correlating Standards

The following SPIs will be skills and processes that will apply to experiments throughout the week.

Kindergarten

- 7.Inq.1 Use senses and simple tools to make observations of the world of familiar objects using the senses and tools.
- 7.Inq.2 Communicate interest in simple phenomena and plan for simple investigations and ask questions, make logical predictions, plan investigations, and represent data.
- 7.Inq.3 Communicate understanding of simple data using age-appropriate vocabulary to explain the data from an investigation.
- 7.Inq.4 Collect, discuss, and communicate findings from a variety of investigations.
- 7.T/E.1 Explain how simple tools are used to extend the senses, make life easier, and solve everyday problems and recognize that both natural materials and human-made tools have specific characteristics that determine their use.
- 7.T/E.2 Invent designs for simple products and apply engineering design and creative thinking to solve practical problems.
- 7.T/E.3 Use tools to measure materials and construct simple products.

1st Grade

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- 7.T/E.2 Invent designs for simple products and apply engineering design and creative thinking to solve practical problems.
- 7.T/E.3 Use tools to measure materials and construct simple products.
- 7.1.3 Make diagrams to record and communicate observations.

2nd Grade

- 7.Inq.1 Use senses and simple tools to make observations of the world of familiar objects.
- 7.Inq.2 Communicate interest in simple phenomena and plan for simple investigations and ask questions, make logical predictions, plan investigations, and represent data.
- 7.Inq.3 Communicate understanding of simple data using age-appropriate vocabulary to explain the data from an investigation.
- 7.Inq.4 Collect, discuss, and communicate findings from a variety of investigations.
- 7.T/E.1 Explain how simple tools are used to extend the senses, make life easier, and solve everyday problems and recognize that both natural materials and human-made tools have specific characteristics that determine their use.
- 7.T/E.2 Invent designs for simple products and apply engineering design and creative thinking to solve practical problems.

- 7.T/E.3 Use tools to measure materials and construct simple products.

3rd Grade

- 7.Inq.1 Select an investigation that could be used to answer a specific question and explore different scientific phenomena by asking questions, making logical predictions, planning investigations, and recording data.
- 7.Inq.1 Identify specific investigations that could be used to answer a particular question and identify reasons for this choice and select and use appropriate tools and simple equipment to conduct an investigation.
- 7.Inq.2 Identify tools needed to investigate specific questions and select and use appropriate tools and simple equipment to conduct an investigation.
- 7.Inq.3 Maintain a science notebook that includes observations, data, diagrams, and explanations and organize data into appropriate tables, graphs, drawings, or diagrams.
- 7.Inq.4 Analyze and communicate findings from multiple investigations of similar phenomena to reach a conclusion and identify and interpret simple patterns of evidence to communicate the findings of multiple investigations. [Recognize that people may interpret the same results in different ways & compare the results of an investigation with what scientists already accept about this question.]
- 7.T/E.1 Select a tool, technology, or invention that was used to solve a human problem.
- 7.T/E.2 Recognize the connection between a scientific advance and the development of a new tool or technology.
- 7.T/E.1 Explain how different inventions and technologies impact people and other living organisms and describe how tools, technology, and inventions help to answer questions and solve problems.
- 7.T/E.2 Design a tool or a process that addresses an identified problem caused by human activity and apply a creative design strategy to solve a particular problem generated by societal needs and wants. [Recognize that new tools, technology, and inventions are always being developed.]
- 7.T/E.3 Determine criteria to evaluate the effectiveness of a solution to a specified problem [Identify appropriate materials, tools, and machines that can extend or enhance the ability to solve a specified problem.]
- 7.T/E.4 Evaluate an invention that solves a problem and determine ways to improve the design. [Recognize the connection between scientific advances, new knowledge, and the availability of new tools and technologies.]
- SPI 7.T/E.1 Select a tool, technology, or invention that was used to solve a human problem.
- SPI 7.T/E.2 Recognize the connection between a scientific advance and the development of a new tool or technology.

4th Grade

- 7.Inq.1 Identify specific investigations that could be used to answer a particular question and identify reasons for this choice, explore different scientific phenomena by asking questions, making logical predictions, planning investigations, and recording data.
- 7.Inq.1 Select an investigation that could be used to answer a specific question.
- 7.Inq.2 Identify tools needed to investigate specific questions and select and use appropriate tools and simple equipment to conduct the investigation.
- 7.Inq.3 Maintain a science notebook that includes observations, data, diagrams, and explanations and organize data into appropriate tables, graphs, drawings, or diagrams.
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5th Grade

- 7.Inq.1 Identify specific investigations that could be used to answer a particular question and identify reasons for this choice, explore different scientific phenomena by asking questions, making logical predictions, planning investigations, and recording data.
- 7.Inq.1 Select an investigation that could be used to answer a specific question.
- 7.Inq.2 Identify tools needed to investigate specific questions and select and use appropriate tools and simple equipment to conduct the investigation.
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- 7.T/E.4 Evaluate an invention that solves a problem and determine ways to improve the design. [Recognize the connection between scientific advances, new knowledge, and the availability of new tools and technologies.]

6th Grade

- SPI 7.Inq.1 Design a simple experimental procedure with an identified control and appropriate variables.
- SPI 7.Inq.2 Select tools and procedures needed to conduct a moderately complex experiment.
- SPI 7.Inq.3 Interpret and translate data in a table, graph, or diagram.
- SPI 7.Inq.4 Draw a conclusion that establishes a cause and effect relationship supported by evidence.

- SPI 7.Inq.5 Identify a faulty interpretation of data that is due to bias or experimental error.
- 7.Inq.1 Design and conduct an open-ended scientific investigation to answer a question that includes a control and appropriate variables.
- 7.Inq.2 Identify tools and techniques needed to gather, organize, analyze, and interpret data collected from a moderately complex scientific investigation.
- 7.Inq.3 Use evidence from a dataset to determine cause and effect relationships that explain a phenomenon.
- 7.Inq.4 Review an experimental design to determine possible sources of bias or error, state alternative explanations, and identify questions for further investigation.
- 7.Inq.5 Design a method to explain the results of an investigation using descriptions, explanations, or models.
- SPI 7.T/E.1 Identify the tools and procedures needed to test the design features of a prototype.
- SPI 7.T/E.2 Evaluate a protocol to determine if the engineering design process was successfully applied.
- SPI 7.T/E.3 Distinguish between the intended benefits and the unintended consequences of a new technology.
- SPI 7.T/E.4 Differentiate between adaptive and assistive engineered products (e.g., food, biofuels, medicines, integrated pest management).
- 7.T/E.1 Use appropriate tools to test for strength, hardness, and flexibility of materials.
- 7.T/E.2 Apply the engineering design process to construct a prototype that meets certain specifications and know that the engineering design process involves an ongoing series of events that incorporate design constraints, model building, testing, evaluating, modifying, and retesting.
- 7.T/E.3 Explore how the unintended consequences of new technologies can impact society.
- 7.T/E.4 Research bioengineering technologies that advance health and contribute to improvements in our daily lives.
- 7.T/E.5 Develop an adaptive design and test its effectiveness.

7th Grade

- SPI 7.Inq.1 Design a simple experimental procedure with an identified control and appropriate variables.
- SPI 7.Inq.2 Select tools and procedures needed to conduct a moderately complex experiment.
- SPI 7.Inq.3 Interpret and translate data in a table, graph, or diagram.
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- 7.T/E.2 Apply the engineering design process to construct a prototype that meets certain specifications.
- 7.T/E.3 Explore how the unintended consequences of new technologies can impact society.
- 7.T/E.4 Research bioengineering technologies that advance health and contribute to improvements in our daily lives.
- 7.T/E.5 Develop an adaptive design and test its effectiveness.

8th Grade

- SPI 7.Inq.1 Design a simple experimental procedure with an identified control and appropriate variables.
- SPI 7.Inq.2 Select tools and procedures needed to conduct a moderately complex experiment.
- SPI 7.Inq.3 Interpret and translate data in a table, graph, or diagram.
- SPI 7.Inq.4 Draw a conclusion that establishes a cause and effect relationship supported by evidence.
- SPI 7.Inq.5 Identify a faulty interpretation of data that is due to bias or experimental error.
- 7.Inq.1 Design and conduct an open-ended scientific investigation to answer a question that includes a control and appropriate variables.
- 7.Inq.2 Identify tools and techniques needed to gather, organize, analyze, and interpret data collected from a moderately complex scientific investigation.
- 7.Inq.3 Use evidence from a dataset to determine cause and effect relationships that explain a phenomenon.
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- 7.T/E.3 Explore how the unintended consequences of new technologies can impact society.
- 7.T/E.4 Research bioengineering technologies that advance health and contribute to improvements in our daily lives.
- 7.T/E.5 Develop an adaptive design and test its effectiveness.

High School

- Inq.1 Develop a testable question for a scientific investigation.
- Inq.2 Develop an experimental design for testing a hypothesis.
- Inq.3 Select appropriate independent, dependent, or controlled variables for an experiment.
- Inq.4 Perform an experiment to test a prediction.
- Inq.5 Gather, organize, and transform data from an experiment.

- Inq.6 Analyze and interpret the results of an experiment.
- Inq.7 Use knowledge and data-interpretation skills to support a conclusion.
- Inq.8 State a conclusion in terms of the relationship between two or more variables.
- Inq.9 Compare the results of an experiment with what is already known about the topic under investigation.
- Inq.10 Suggest alternative explanations for the same observations.
- Inq.11 Analyze experimental results and identify possible sources of bias or experimental error.
- Inq.12 Formulate and revise scientific explanations and models using logic and evidence.
- Inq.13 Develop a logical argument about cause-and-effect relationships in an experiment.
- T/E.1 Select appropriate tools to conduct a scientific inquiry.
- T/E.2 Apply the engineering design process to construct a prototype that meets developmentally appropriate specifications.
- T/E.3 Explore how the unintended consequences of new technologies can impact human and non-human communities.
- T/E.4 Present research on current bioengineering technologies that advance health and contribute to improvements in our daily lives.
- T/E.5 Design a series of multi-view drawings that can be used by other students to construct an adaptive design and test its effectiveness.
- 6.Math.1 Choose, construct, and analyze appropriate graphical representations for a data set.
- 6.Math.4 Select and apply an appropriate method to evaluate the reasonableness of results.

Fluid Behavior: Properties of Air & Water

Experiments

1. Cloud in a Bottle
2. Colorful Convection Currents
3. Traveling Water
4. Anti-Gravity Water
5. Oil Absorbing Polymers & Magic Sand
6. Practical Polymers and helpful Hydrogels/Soil Soakers
7. Balloon in a Bottle
8. Marshmallow Masher
9. Heavy Newspaper
10. CD Hovercraft
11. Potato Pusher/Flying Potatoes

Kindergarten

Key Terms:

- Air
- Change
- Cloud
- Water
- Weather
- Observe
- Temperature
- Tools
- Ocean
- Soil
- Solid/liquid

Key Standards:

- 7.9.1 Observe, identify, and compare the properties of various objects
- 7.9.2 Observe, discuss, and compare characteristics of various solids and liquids.
- 7.11.1 Use a variety of objects to demonstrate different types of movement. (e.g., straight line/zigzag, backwards/forward, side to side, in circles, fast/slow).

1st Grade

Key Terms:

- Property
- Push/pull
- Precipitation
- Weather
- Heat
- Matter
- Classify
- Invent
- Prediction

Key Standards:

- 7.9.1 Classify solids according to their physical properties. ex. according to their size, shape, color, texture, hardness, ability to change shape, magnetic attraction, whether they sink or float, and use.
- 7.9.2 Compare liquids and distinguish between the properties of solids and liquids, ex. according to their color, ability to flow, solubility in water, and use.

- 7.9.3 Investigate and describe the results of mixing different substances and predict the changes that may occur when different materials are mixed, ex. salt and pepper, water and sand, water and oil, and water and salt.
- 7.11.2 Investigate and explain how different surfaces affect the movement of an object or material
- 7.11.1 Use familiar objects to explore how movement can be changed by forces (push/pull).
- HLE 14.1 describe different types of pollution and their environmental affects

2nd Grade

Key Terms:

- Compare/contrast
- Depend
- Dissolve
- Evaporation
- Investigate
- Scientific inquiry
- Similarities/differences
- Scientist
- Reasoning
- Observation

Key Standards:

- 7.9.1 Use tools, ex. hand lenses, measurement devices, and simple arm balances, to observe and gather data about the physical properties of different objects and materials.
- 7.9.4 Explain what happens when a balloon is blown up and recognize that air takes up space.
- HLE 14.1 describe different types of pollution and their environmental affects;
- 2.3.02 Recognize the interaction between human and physical systems around the world.
    - a. Analyze how individuals and populations depend upon land and water resources.
    - d. Understand the rudimentary elements to the hydrologic cycle.

3rd Grade

Key Terms:

- Atmosphere
- Barometer
- Anenometer
- cumulonimbus
- cumulus
- Mixture
- Physical Change
- Stratus

Key Standards:

- 7.8.2 Match cloud types with specific atmospheric conditions.
- 7.9.1 Use physical properties to compare and contrast substances and describe a substance in terms of its physical properties.
- 7.9.2 Identify methods for separating different types of mixtures.

- 7.9.5 Investigate different ways to separate mixtures such as filtration, evaporation, settling, or using a sieve.
- 7.11.1 Identify how the direction of a moving object is changed by an applied force.
- HLE 14.3 evaluate and select environmentally safe products;
- CU 7.5.4 Determine how changes in an environmental variable [ex. clean water] can affect plants and animals of an area.
- 3.3.02 Recognize the interaction between human and physical systems around the world.
    - c. Understand the concept of an ecosystem.
    - e. Understand how technology allows people to adapt the environment to meet their needs.
- 3.6.01 Recognize the impact of individual and group decisions on citizens and communities.
    - b. Examine the relationships and conflict between personal wants and needs and various global concerns, such as use of imported oil, land use, and environmental protection.
    - c. Give examples of economic, social, or political changes that result from individual or group decisions.

4th Grade

Key Terms:

- Condensation
- Physical Change
- Transparent
- Translucent

Key Standards:

- 7.9.1 Use appropriate tools to measure and compare the physical properties of various solids and liquids.
- 7.9.3 Interpret the causes and effects of a physical change in matter.
- 7.8.2 Distinguish between weather and climate.
- 7.11.2 Identify factors that influence the motion of an object.
- 7.7.2 Analyze how different materials are utilized to solve human problems or improve the quality of life.
- HLE 14.1 identify the causes and effects of different types of pollution;
- HLE 14.3 evaluate and select environmentally safe products;

5th Grade

Key Terms:

- Dissipate
- Convection

Key Standards:

- 7.10.2 Use data from an investigation to determine the method by which heat energy is transferred from one object or material to another and describe the differences among conduction and convection.
- 7.12.1 Explain and give examples of how forces act at a distance [and up close].
- 7.2.3 Use information about the impact of human actions or natural disasters on the environment to support a simple hypothesis, make a prediction, or draw a conclusion.
- 5.3.02 Recognize the interaction between human and physical systems around the world.
- 7.12.1 Recognize that the earth attracts objects without touching them.
- 7.12.2 Identify the force that causes objects to fall to the earth.
- 7.12.3 Design and explain an investigation exploring the earth's pull on objects.
- HLE 14.1 identify the causes and effects of different types of pollution;
- HLE 14.3 evaluate and select environmentally safe products;

6th Grade

Key Terms:

- Atmospheric convection
- Cause and effect
- Control
- Criteria
- Energy
- Ocean current
- Protocol
- Prototype
- Tides
- Variable

Key Standards:

- CU 7.8.1 Recognize how convection currents in the atmosphere produce wind.
- SPI 7.8.1 Analyze data to identify events associated with heat convection in the atmosphere.
- 7.8.2 Recognize the connection between the sun's energy and the wind.
- 7.8.3 Describe how temperature differences in the ocean account for currents.
- CU 7.8.3 Design an experiment to demonstrate how ocean currents are associated with the sun's energy.
- HLE 14.1 identify major environmental health concerns that impact human health (e.g. air, water and noise pollution; negative social-emotional environment);
- HLE 14.3 evaluate and critique products and their effects on the environment;

7th Grade

Key Terms:

- Phenomenon
- Impact
- Physical Process
- Diffusion
- Speed
- Momentum

Key Standards:

- CU 7.7.9 Evaluate how human activities affect the condition of the earth's land, water, and atmosphere.

- SPI 7.7.7 Analyze and evaluate the impact of man’s use of earth’s land, water, and atmospheric resources.
- 7.3.08 Understand how human activities impact and modify the physical environment.
    - c. Analyze the environmental consequences of humans changing the physical environment.
- 7.11.4 Recognize how a net force impacts an object’s motion.
- 7.7.9 Evaluate how human activities affect the condition of the earth’s land, water, and atmosphere.

8th Grade

Key Terms:

- Variation
- Human Impact
- Interdependence
- Debate
- gravitation (universal law)

Key Standards:

- 7.12.6 Identify factors that influence the amount of gravitational force between objects.
- 7.12.7 Explain how the motion of objects is affected by gravity.
- 7.12.6 Illustrate how gravity controls the motion of objects…
- 0.2.4 Predict how various types of human activities affect the environment.

High School

Key Terms:

- Atmospheric cycle
- Convection currents
- Pascal’s principle (fluid, pressure)
- Friction
- Gas Laws (Boyles, Charles)
- Bernoulli’s principle
- Resistance

Key Standards:

- 0.6.3 Investigate an environmental issue involving pollution of land, air or water.
- 5.5.6 Describe how convection currents drive movement, ex. plate tectonics.
- 1.1.5 Evaluate and describe phenomena related to Archimedes’ Principle, Pascal’s Principle, and Bernoulli’s Principle.
- 1.1.7 Select [create] the correct vector diagram to illustrate all forces on an object affected by gravity, friction and an applied force.

Cloud in a Bottle

Have you ever wondered how clouds form?

Have you ever wondered how clouds form? Moist air rises in the atmosphere, cools, and water droplets form into clouds. Making your own cloud is a popular experiment in many science books, but it can be a little tricky. Sometimes the results are a little hard to see, but practice always makes perfect.

Materials

- 1-liter clear plastic bottle with cap
- Foot pump with rubber stopper attached
- Water
- Rubbing alcohol
- Safety glasses

* Or, use the Cloud in a Bottle Activity Kit from stevespanglerscience.com

Adult supervision is required!

1. Put on your safety glasses and start by pouring just enough warm water in the bottle to cover the bottom.

2. Swirl the water around and then put the rubber stopper in the bottle.

3. Start by pumping the foot pump five times. You will notice that as you start to pump, the rubber stopper will want to pop right out. Hold it in the bottle tightly, being very careful not to let it fly out of the bottle.

4. After five pumps, pull the stopper out of the bottle. You'll likely see a very faint "poof" of a cloud. There wasn't enough pressure in the bottle to make a good cloud, but now you are starting to get the feel of the foot pump.

5. Repeat the experiment again, but instead of five pumps, pump the foot pump ten times. You'll notice that the more you pump, the harder it is to keep the stopper in the bottle. Just remember to hold it in there tightly. When you are done pumping, pull out the stopper. You should see a slightly more visible cloud this time.

6. Now that you have a good feel for how the experiment works, fill the bottom of the bottle again and pump the foot pump 15-20 times. You want to put about 9 kg (20 lbs) of pressure in the bottle.

7. When you remove the rubber stopper, you should see a good cloud.

Okay, so you've mastered the technique and you're ready for an even better cloud? Make sure you are still wearing your safety glasses. Place just a few drops of rubbing alcohol in the bottom of the 1-liter bottle. Swirl the alcohol around in the bottle, making sure to coat the sides. Then put the rubber stopper in the bottle. Follow steps 3-7 above to make a more visible (and more impressive) cloud.

How does it work?

Even though we don't see them, water molecules are in the air all around us. These airborne water molecules are called water vapor. When the molecules are bouncing around in the atmosphere, they don't normally stick together.

Pumping the bottle forces the molecules to squeeze together or compress. Releasing the pressure allows the air to expand, and in doing so, the temperature of the air becomes cooler. This cooling process allows the molecules to stick together - or condense - more easily, forming tiny droplets. Clouds are nothing more than groups of tiny water droplets!

The reason the rubbing alcohol forms a more visible cloud is because alcohol evaporates more quickly than water. Alcohol molecules have weaker bonds than water molecules, so they let go of each other more easily. Since there are more evaporated alcohol molecules in the bottle, there are also more molecules able to condense. This is why you can see the alcohol cloud more clearly than the water cloud.

Clouds on Earth form when warm air rises and its pressure is reduced. The air expands and cools, and clouds form as the temperature drops below the dew point. Invisible particles in the air in the form of pollution, smoke, dust or even tiny particles of dirt help form a nucleus on which the water molecules can attach.

Colorful Convection Currents

Demonstrate convection currents in a very colorful fashion

Convection is one of those words that we often hear used, but we may not completely understand its meaning. Weather forecasters show how convection currents are formed when warm and cold air masses meet in the atmosphere. Convection currents are responsible for warm water currents that occur in oceans. This activity demonstrates convection currents in a very colorful fashion.

Materials (per group)

- Four empty identical bottles (mouth of the bottle should be at least 1 1/2 inches in diameter)
- Access to warm and cold water
- Food coloring (yellow and blue)
- 3 x 5 inch index card or an old playing card

1. Fill two bottles with warm water from the tap and the other two bottles with cold water. Use food coloring or the Fizzers coloring tablets to color the warm water yellow and the cold water blue. Each bottle must be filled to the brim with water.
2. Hot over cold: Place the index card or old playing card over the mouth of one of the warm water bottles. Hold the card in place as you turn the bottle upside down and rest it on top of one of the cold water bottles. The bottles should be positioned so that they are mouth to mouth with the card separating the two liquids. You may want to do this over a sink.

3. Carefully slip the card out from in between the two bottles. Make sure that you are holding onto the top bottle when you remove the card. Observe what happens to the colored liquids in the two bottles.
4. Cold over hot: Repeat steps 2 and 3, but this time place the bottle of cold water on top of the warm water. Observe what happens.

How does it work?

Hot air balloons rise because warm air is lighter than cold air. Similarly, warm water is lighter in weight or less dense than cold water. When the bottle of warm water is placed on top of the cold water, the more dense cold water stays in the bottom bottle and the less dense warm water is confined to the top bottle. However, when the cold water bottle rests on top of the warm water, the less dense warm water rises to the top bottle and the cold water sinks. The movement of water is clearly seen as the yellow and blue food coloring mix, creating a green liquid. Likewise, when the water mixes in the Split Demo Tank, the less dense, cold water stays on the bottom of the tank, and the more dense, warm water moves to the top.

The movement of warm and cold water inside the bottles (or tank) is referred to as the convection current. In our daily life, warm currents can occur in oceans, like the warm Gulf Stream moving up north along the American Eastern Seaboard. Convection currents in the atmosphere are responsible for the formation of thunderstorms as the warm and cold air masses collide.

Although the bottles whose colored liquids mix are more interesting to watch, the other set of warm and cold water bottles helps to illustrate another important phenomenon that occurs in the atmosphere during the winter months. During daylight hours, the sun heats the surface of the earth and the layer of air closest to the earth. This warm air rises and mixes with other atmospheric gases. When the sun goes down, the less dense warm air high up in the atmosphere often blanket s the colder air that rests closer to the surface of the earth. Because the colder air is more dense than the warm air, the colder air is trapped close to the earth and the atmospheric gases do not mix. This is commonly referred to as temperature inversion.

Additional Info

What are the results of temperature inversion? Air pollution is more noticeable during a temperature inversion since pollutants such as car exhaust are trapped in the layer of cold air close to the earth. As a result, state agencies in many parts of the country oxygenate automobile fuels during winter months with additives like MTBE in an attempt to reduce the harmful effects of trapped pollution. This trapped pollution is what causes the "brown cloud" effect. Wind or precipitation can help alleviate the brown cloud effect by stirring up and breaking up the layer of warm air that traps the cold air and pollution down near the surface of the earth.

Traveling Water

Think you can pour water from one cup to another using a string?

Whereas most people normally pour water from one cup to another by... well... pouring water from one cup to another, that is far too simple for us. How about pouring the water from one cup to another using a string and holding the cups apart from each other? Are you up to the challenge? How far can you go? How long of a string can you use?

Materials

- Plastic cups
- White cloth string
- Water
- Scissors
- Tape
- Additional materials to test

1. Using the scissors, cut a length of string roughly two to three feet long.
2. Tape one end of the string to the bottom of one of the cups. Any type of tape will work, just make sure the bottom of the cup is dry when you tape the string down.
3. Fill another cup with water and put the other (not taped) end of the string in the water.
4. Hold the cups with one above the other, but not directly over each other. Hold the cups far enough apart that the string is as close to taut as you can make it. Be careful not to pull the string out of your top cup.
5. Slowly begin pouring the water out of the top cup. Pour the water out of the side of the cup with the string.
6. You'll begin to see the water travel down the string towards the other cup. At first, the water won't make it all the way down, but eventually you'll be able to pour the water straight from your top cup to your bottom cup.

Observations

Have students try performing this experiment a second time, but this time wet the entire string before beginning to pour the water. How does that work in comparison to the dry string?

How does it work?

You have probably heard water referred to as H2O. That means that each molecule of water is made up of two hydrogen atoms and one oxygen atom. Water as you know it, the liquid you drink or the liquid you swim in, consists of thousands upon thousands of water molecules that are held together by molecular bonds. The bonds in this case are called hydrogen bonds and are quite strong. These strong hydrogen bonds make water molecules stick together very well.

While performing this experiment, you are able to see these hydrogen bonds in action. Through a physical property calledcohesion, the action of like molecules sticking together, water molecules are able to stick to other water molecules on their way to the lower cup.

But what about the water that poured out at first? It didn't have any water to stick to. Molecules aren't only able to stick to like molecules (water to water). Molecules of water can stick to other materials, too. This is a property called adhesion. In this case, water molecules are able to stick to the string. The reason you see some water fall off the string is because adhesion is not as strong as cohesion.

Additional Info

Now that students know about cohesion and adhesion, have them try performing this experiment with other materials. Try different liquids like milk or soda and try different "strings" like fishing line or a shoelace. Which liquids have the best cohesion? Which materials have the best adhesion?

Anti-Gravity Water

Amaze your students by making water defy gravity.

Water in rivers, in a glass, or falling from clouds obeys gravity. It's going to fall towards the ground because of the physical pull of the earth. But, what if we told you that you could turn a glass of water completely upside down and the water wouldn't fall to the floor? That's what happens in the Anti-Gravity Water demonstration. It's a simple experiment that dramatically demonstrates the amazing physical properties of water. And make sure you don't throw away that plastic mesh bag from the grocery store used to sell onions and potatoes. You'll amaze your students with this cool experiment that defies gravity and uncovers the mystery of surface tension.

Materials

- Tall glass with a round edge
- A handkerchief
- Plastic mesh bag used for produce at the grocery store
- Wide mouth bottle
- Rubber band
- Index card
- A pitcher of water
- Bowl or sink

1. Drape the handkerchief over the glass, making sure that you push the center of the handkerchief down into the glass.
2. Fill the glass 3/4 full with water by pouring water into the middle of the handkerchief.
3. Slowly pull the handkerchief down the sides of the glass making it taut (stretched tightly across the surface of the glass). Grip the ends of the handkerchief at the bottom of the glass.
4. Place one hand over the mouth of the glass and turn it over with the other hand.
5. Pull the lower hand away from the glass (slowly) and the water should stay in the glass! This just goes to prove that the handkerchief has anti-gravity properties. The thunderous applause will drown out the cries of, "How did you do that?"
6. For the big finish, put your hand over the mouth of the glass and turn the glass right-side up. Remove the handkerchief from the glass and pour the water back into the pitcher. Of course, take your well-deserved bow.

How does it work?

Most people predict that the water will leak through the holes in the handkerchief because the water leaked through the holes as it was poured into the glass. The holes in the handkerchief literally disappeared when the cloth was stretched tightly across the mouth of the glass. This action allowed the water molecules to bond to other water molecules, creating what is called surface tension. The water stays in the glass even though there are tiny holes in the handkerchief because the molecules of water are joined together to form a thin membrane between each opening in the cloth. Be careful not to tip the glass too much because you'll break the surface tension and surprise everyone with a gush of water!

Continue to experiment: What else will surface tension hold?

Variation One" Fill a cup or beaker until it's overflowing with water. Then, place an index card or cardstock paper over the top, pressing down slightly to make sure it's touching the rim of the cup. With your hand securing the card onto the cup, turn the cup upside-down. When you're ready, remove your hand. The card will hold the water in the cup.

Variation Two:

1. Plastic mesh bags come in all shapes and sizes. The mesh bags used to sell small onions or cloves of garlic seem to work well. Cut a piece of mesh from the bag large enough to drape over the mouth of the bottle.
2. Stretch the mesh over the bottle and use a rubber band to secure it in place.
3. Fill the bottle with water by pouring the water through the screen. This proves to your students that the water easily flows through the screen. Fill the bottle almost to the very top.
4. Cover the bottle with an index card. Hold the card in place as you turn the card and the bottle upside down. Slowly remove the card from the opening and the water mysteriously stays in the bottle. Oh, did we mention that you should probably hold the bottle over the bucket? Or you can just hold the bottle over your friend who is holding the bucket.
5. Tip the bottle slightly to the left or right and the water will fall. Shake the bottle and the water will fall. Touch the screen and the water will fall. It might be a good idea to tell your friends about this so they have a chance to run.
6. If you have a very steady hand, try this. While the bottle is turned upside down and the water is defying gravity, gently feed a toothpick through one of the screen holes without breaking the water seal and watch it float to the surface. Okay, this is easier said than done, but be sure to watch the video of Steve Spangler doing this.

How does it work?

If you dip a piece of the screen (the mesh bag) into a glass of water, you notice that the water fills the screen holes. A force called cohesion, which is the attraction of molecules that are the same to each other, causes this effect. The surface tension "membrane" is always trying to contract, which explains why falling droplets of water are spherical or ball shaped. The water stays in the bottle even though the card is removed because the molecules of water are joined together to form a thin membrane between each opening in the screen. Tipping the bottle or touching the screen will break the surface tension and

surprise everyone with a gush of water!

Magic Sand

How can something submerged in water stay dry?

How can something submerged in water stay dry? When ordinary sand gets wet, the result is a clumpy mess. However, "Magic Sand" begins as normal looking sand, until it's coated with a substance that repels water. This special coating keeps the sand dry even after it has been dumped into a container of water. Build castles and other structures under the water, then simply pour the water off when you're finished and the sand is still dry!

Materials

- Magic Sand (available at stevespanglerscience.com)
- Regular sand
- Water
- Cups
- Plastic soda bottle
- Vegetable oil
- Food coloring
- Plastic spoons
- Additional liquids to test

What Makes Magic Sand Magic?

1. Fill a cup 3/4 full with water.
2. Slowly pour Magic Sand in a continuous stream into the water. Look closely at the sand. What is that silver-like coating on the sand?
3. Pour off the water from the sand into a second container. Touch the sand and see what you find. To your amazement, the sand is completely dry! To better understand how Magic Sand works, try this demonstration…
    - Fill a plastic soda bottle (16 oz works well) 3/4 full with water.
    - Fill the remaining portion of the bottle with vegetable oil or mineral oil. Immediately, the students will notice that the oil and water do not mix.
    - Add a few drops of food coloring to the mixture. Notice how the food coloring only colors the water and not the oil… even when the bottle is shaken.

How does it work?

This is a great demonstration to introduce students to the properties of substances that are hydrophobic and hydrophilic.*Hydrophobic* substances do not mix with water. The term “water-fearing” is often used

to describe the word hydrophobic.*Hydrophilic* substances, on the other hand, are “water-loving.” Notice how the drops of food coloring color only the water and not the oil. Since oil is hydrophobic, the oil did not mix with the food coloring or the water. What are other examples of oil and water not mixing? A newly waxed car will make water form beads on its surface. Oil from cars will float on top of puddles. Oil and vinegar salad dressings need to be shaken up before using. So, how does Magic Sand work? The surface of sand grains is made wet by water, which means that water molecules are attracted to sand grains. Remember, this water-loving property of sand is called a hydrophilic property. Magic Sand is regular sand that has been coated with an oil-like substance that is water-hating or hydrophobic.
Additional Info

Regular Sand vs. Magic Sand

For this activity you’ll need a small amount of regular sand and Magic Sand. Fill 2 cups with water. Use a spoon to sprinkle a small amount of regular sand into one of the cups. Notice how the sand immediately sinks. Sprinkle a thin layer of Magic Sand on the surface of the water in the second cup. Why does the Magic Sand float on the surface whereas the regular sand sinks? The surface of the regular sand grains is made wet by water, which means that water molecules are attracted to sand grains. Magic Sand is regular sand that has been coated with an oil-like substance so it is water-hating. The Magic Sand grains like to stay in contact with each other. Also, the surface tension of the water makes the Magic Sand float.

Making Magic Sand Wet

Pour a small amount of Magic Sand in a cup of water. As expected, the Magic Sand stays dry. Try other liquids, does it still stay dry? Add about 12 drops of liquid detergent to the water and use a spoon to stir the mixture. Soap breaks down the oil coating on the sand and lowers its hydrophobic properties. Adding soap removes the “magic” from Magic Sand and causes it to behave like regular sand. The secret is revealed!

Other Uses for Magic Sand

The coating on Magic Sand is like Scotchguard, which is sprayed on fabric to protect it from stains. Another potential use of Magic Sand is to bury junction boxes for electric and telephone wires in the Arctic in order to protect the utilities from the extreme cold temperatures but make it easy to dig up for repairs. Normal earth is frozen so hard because of moisture content and it is difficult to dig. However, Magic Sand remains dry and is easy to dig, regardless of how cold it is.

Magic Sand was originally developed as a way to trap oil spilled from oil tankers near the shore. The idea was that when Magic Sand was sprinkled on floating petroleum, it would mix with the oil and make it heavy enough to sink. This would prevent the oil from contaminating beaches. However, it is not being used for this purpose, perhaps because of the expense of making Magic Sand. This fact will play an important role in the comparison project with Oil Absorbing Polymers.

Oil Spill Absorbing Polymer

Changing the way environmental scientists approach oil spills!

Just imagine if the solution to an oil spill was this simple: Sprinkle a small amount of a non-toxic powder onto the layer of oil and in seconds the powder bonds to the oil, forming a sponge-like material that can be easily removed from the surface of the water. It's more than just a dream... a new form of superabsorbent polymer technology is changing the way environmental scientists approach oil spills and waste management problems. The results are amazing!

Materials:

- Marvel Mystery Oil (473 mL)
- Oil Absorbing Polymer (150 g)*
- Regular Sand
- Containers: ex: 2 Gallon Tupperware style Containers or disposable aluminum 9x13 pans.
- Option: Feathers, fur, cloth

* Enviro-Bond 403 Polymer is a specially formulated chemical designed to clean up crude oil.

Sprinkle a small amount of this polymer onto the layer of oil and in seconds the polymer bonds to the oil, forming a sponge-like material that can be easily removed from the jar of water. This polymer is specially formulated to bond quickly and safely to many types of liquid hydrocarbons including crude oil, diesel fuel, and gasoline. The bonding is so complete that it literally encapsulates the liquid hydrocarbons in just seconds.

How does it work?

The chemical formulation of the polymer is carefully regarded as a trade secret and is under application for patent. However, the inventor agreed to share some limited information about the polymer for educational purposes. The hydrocarbon source (crude oil, diesel fuel, gasoline, etc.) consists of three basic components: paraffinics, naptinics, and the aromatics. The polymer is specifically formulated to bond to these components. The mechanism is three dimensional with cross-link bonding, and the polymer structures are referred to as dieblock, triblock, branched, radial, and liner, according to the manufacturer.

When the polymer comes in contact with a liquid hydrocarbon, the free hydrocarbons bond to the polymer forming a solid mass. The hydrophobic properties of the polymer cause it to float on water, but the density of the polymer is great enough to allow it to sink through the hydrocarbon and maximize the bonding potential. There is no need for mixing since the polymer bonds to the free hydrocarbons automatically.

Enviro-Bond 403 Polymer is also used in treating oily sludge, effectively filtering oil drilling fluids, and stabilizing any other spilled or leaked liquid hydrocarbons that pose a threat to the environment.

Additional Info

Oil is a major source of ground water contamination and ocean pollution. The vast majority of this oil enters the ocean from oil spills on ships that transport petroleum or from manufacturing operations on land. However, oil can also seep into the ocean naturally from cracks in the sea floor. Oil well and oil tanker accidents at sea account for a small portion of ocean oil pollution, yet the lasting effects of these accidental spills can be disastrous.

A personal note from Steve Spangler...

Enviro-Bond 403 Oil Polymer was the invention of a great person in Michigan by the name of Larry Thompson. I first met Larry while researching other kinds of superabsorbent polymers in 1992. I often share the inspirational story of how Larry invented this polymer during my teacher workshops and keynote speeches. Larry was truly passionate about his discoveries and did everything possible to encourage children to better understand the world of chemistry.

Larry Thompson passed away in March of 2004 from a rapid spreading cancer in his liver and pancreas. Up until the last few days of his life, Larry was sending emails and talking with people on the phone about the benefits of his oil absorbing polymers. I recently spoke at the National Honors Society national convention in Florida. After the presentation, a ninth grade girl came up to me and said, "I don't think that I'll ever be as good a scientist as that man who invented the oil polymer, but I can only hope that I make a discovery that helps the world as much as his did.•" I shared this with Larry in our last email correspondence. He will be greatly missed.
-- Steve Spangler

After exploring the properties of oil spill absorbing polymers and Magic Sand, have students design an experiment comparing the effectiveness of Magic Sand vs. Oil Absorbing Polymer on an oil spill. Which helps most in the water? Which helps most on the beaches? Have students conduct an experiment to identify the methods that could be used to mediate (reduce) the effects of an oil spill on waterfowl or animals affected by oil spills by testing on feathers/fur. Does salt affect their effect? What is the most cost effective way to use them? Ex. helicopter delivery system. Students can use containers, regular sand, and water to create their own “beach” and hypothesize the best method for cleaning up oil spills and lessening the effect of environmental disasters on animal and human life..

Balloon in a Bottle

How hard can it be to inflate a balloon in a plastic soda bottle?

Some things look so easy until you try them. Case in point... How hard would it be to inflate a balloon in a plastic soda bottle. Hey, no big deal. Just put the balloon down inside the bottle and puff away. That's until you realize something about the properties of air. Don't worry... Steve Spangler will show you how to be amazing.

Materials

- 1-Liter bottle
- Latex balloons
- Rubber stopper or cork
- Water
- Nail
- Hammer

Slip the balloon inside the neck of the bottle and stretch the mouth of the balloon over the bottle top. Take a deep breath and try to blow up the balloon inside the bottle. Good luck!

Remove the balloon, fill the soda bottle to the brim with water, then seal it with a cap. Ask an adult to punch a small hole with a nail and hammer in the side of the bottle, close to the base. Remove the nail, uncap the bottle, and empty the water out the top.

Place the balloon in the bottle again (Step 1) and try to blow up the balloon. Quite a difference! Blow hard until the balloon fills most of the bottle (a little water left in the bottle helps). Place a finger (or thumb) over the nail hole when you stop blowing. You are too cool! Now, move your finger.

How does it work?

The balloon won't inflate much the first time because the bottle is already filled with air. There's no room for the balloon to expand inside the bottle. However, when you punch a hole in the bottle, the air molecules in the bottle have an exit. They're pushed out as the balloon fills the space inside. As long as you plug the hole, the balloon stays inflated. When you take your thumb off the hole, outside air flows back into the bottle as the balloon collapses. Because of the elasticity of the rubber or latex, the balloon shrinks to its original size as the air rushes out the top of the bottle. By the way, when you filled the bottle with water, you made its walls more rigid and it was easier to push the nail through the flexible plastic. Who'd ever think that flowing, soft water could give that much support?

Try this!
Inflate the balloon in the bottle again and cover the nail hole with your thumb. Pour water into the balloon while keeping your thumb over the hole. Go outside or hold the bottle over a sink before you remove your thumb.

Watch out for that stream of water gushing out of the bottle top! You might decide to hand a full water-balloon-bottle to a friend and just "forget" to tell them about the hole.

Suppose your thumb gets tired while the balloon is inflated. Put a cap tightly on the bottle and remove your thumb. For the air to flow, both holes have to be open.

Ask students, how would more holes or even one large hole change the speed of inflating and deflating the balloon? What would more or bigger holes do to the stream flowing from the water-balloon-bottle? Have them try it out! Balloons and bottles make a great science combo!

Marshmallow Masher

Explore the powerful properties of air.

Students won't believe their eyes as they explore the powerful properties of air when they put marshmallows to the pressure test.

Materials

- Small marshmallows
- Pressurizing pumps (available at stevespanglerscience.com
- Plastic soda bottles (16 oz)

Safety Notes: This demonstration requires adult supervision! Use only plastic soda bottles that are in good condition for this experiment. Wear safety glasses just in case something breaks. Don't get carried away with the pumping. Do not over-pressurize any container using the pressurizing pump. Too much pressure will result in the breakage of the pump. Do not pump more than 40 strokes (pumps) into the 16 oz bottle. Apply only enough pressure to allow you to see the shrinking effects. Never leave a soda bottle in the pressurized state. After observing the effects of compression, always release the pressure.

1. Fill the bottle about half full with marshmallows and screw on the special pressurizing pump.
2. Begin pumping to increase the pressure within the bottle. As you increase the pressure inside the bottle, notice how the marshmallows seem to become wrinkled and shrink. Do not pump more than 40 times!
3. Release the pressure by unscrewing the cap, but don't take your eyes off the marshmallows. Let's just say the rapid decompression is well worth all of the effort of pumping!

How does it work?

The Fizz Keeper is like a miniature bicycle pump that forces molecules of air into the bottle. The increased pressure, in turn, pushes on the marshmallows. Since marshmallows are just puffy pockets of air, the increased pressure compacts the molecules and the marshmallows shrivel up.

Teacher Notes: Use this demonstration to discuss the effects of atmospheric pressure. We sometimes refer to things as being "light as air," but the truth is that the air surrounding our planet weighs a lot and exerts considerable pressure on us. The atmospheric pressure at sea level is 14.7 pounds per square inch of surface area. That's roughly the weight of 2 gallons of milk resting on 1 square inch!

A typical regular-sized marshmallow has a surface area of about 6 square inches. So, the marshmallow has about 88 pounds of atmospheric pressure being exerted upon it (6 square inches x 14.7 pounds per square inch = 88.2 pounds). The marshmallow is really a kind of sugary material that resembles foam rubber. It’s full of tiny bubbles of air. The air pressure inside these tiny bubbles is roughly the same as the air pressure pushing on the marshmallow from the outside, so the pressures are equalized and the marshmallow retains its regular shape.

Additional Info

What do students think would happen if you pulled all of the air out of the bottle instead of pumping extra molecules into the bottle?

Heavy Newspaper

Demonstrate the incredible properties of air and air pressure.

Demonstrate the incredible properties of air and air pressure using a sheet of newspaper, a piece of wood, and some karate-chopping power.

Materials

- Several pieces of pine wood or wood paneling (1" wide x 36" long x 1/4" thick) ex. a yardstick
- Several large sheets of newspaper
- Work gloves
- Table

1. Place the piece of wood on a table and let one end hang over the edge about 4 inches. Ask the spectators, "What will happen if I hit the piece of wood that is hanging over the edge of the table?•" Make sure everyone is out of harm's way as you karate-chop the stick. Of course, the stick goes flying end over end just as expected.

2. Return the stick to the table allowing about 4 inches of the stick to hang over the edge. "Let's use a piece of newspaper to help secure the stick in place."• Show a single sheet of newspaper and fold it in half 3 or 4 times. Place the folded newspaper over the end of the stick that is lying on the table. Again, make sure everyone is standing away from the table as you hit the end of the stick that is hanging over the edge of the table. What happened? Did the newspaper help to hold the stick in place? Of course, the answer is "NO."•

3. Finally, show the spectators a new sheet of newspaper and use it to cover the portion of the stick that is lying on the table. Make sure that the newspaper is flush with the edge of the table. "What do you think will happen now if I hit the stick with the unfolded newspaper covering the stick?"• You might anticipate an answer like, "The newspaper will go flying...or the sheet of newspaper will tear apart.•" Smooth down the newspaper with your hands so that there are no pockets of air under the sheet of paper. Put on your karate-chopping glove to protect your hand. Strike the protruding edge of the stick with your hands with a sudden sharp hit. To everyone's amazement, the stick breaks. Remind the audience that the weight of flat newspaper is exactly the same as the folded newspaper, yet the flat newspaper stayed in place and held the stick in place. That's amazing... but how does it work?

How does it work?

The results of the experiment prove that the newspaper is more difficult to lift when it is spread out over a large area, yet the weight of the folded and flat newspaper remain the same. What other force is exerted on the newspaper that could account for these differences? The answer is as simple as the air we breathe. It is the pressure of the air pushing downward on the newspaper that prevents the paper from rising.

It might be useful to picture a giant column of air resting on top of the newspaper. This column of air is 250 miles (402 km) tall! This column of air above the newspaper pushes down with a force of 14.7 pounds of pressure per square inch (this is at sea level). In other words, each square inch of the newspaper has 14.7 pounds pushing down on it. So, if you know the area of the newspaper, you can calculate the total amount of pressure pushing downward on the paper. Let's say that the newspaper dimensions measure 20 inches by 30 inches. The total area is 20 inches X 30 inches = 600 square inches. If each square inch has a force of 14.7 pounds pushing on it, then 600 square inches X 14.7 pounds per square inch = 8,820 pounds! That's the equivalent weight of two large automobiles. It's no wonder that the newspaper stayed in place at the moment when you hit the stick. Smoothing down the newspaper with your hands prior to hitting the stick is a crucially important step. You want to make certain that there is no air under the newspaper that might help it to lift up when you strike the stick.

Additional Info

As a follow-up activity, have the students calculate the force of the air pressure exerted on the folded sheet of newspaper and compare this number to the force pushing on the flat newspaper. The comparison is startling.

CD Hovercraft

Build a homemade, hovering toy using air pressure

You might think that building your own hovercraft would take a couple of trips to NASA. We quickly realized that it was a little iffy having jet engines and ultra-lightweight material anywhere near students. We had to develop our own design using everyday materials, and that's exactly what we did. Using a CD, a balloon, and a few other household items students can create a working hovercraft, too.

Materials

- Compact disc (CD)
- Sports bottle cap (push/pull closure)
- Card stock or thin cardboard
- Balloon
- Pushpin or thumbtack
- Hot glue gun
- Scissors
- Smooth surface

1. Using a pushpin, have students poke 2 holes near the center of a closed sports bottle cap. Make sure that the tamper-proof ring is removed from the cap and that the holes go all the way through the plastic of the cap.
2. Use the hot glue gun to glue the bottom of the cap to the top of the compact disc. Use as little hot glue as possible, but be sure that there is a perfect airtight seal between the cap and CD. Giving the cap a slight twist when you glue it to the CD can help.
3. Create a collar for the cap by curving or bending a piece of card stock or thin cardboard (2"x6"). Cut two slits, one on each end of the card stock that are 1" from the end. Cut the slits on opposite sides of the collar (think of it as the top and bottom of the collar). Join the slits together to create the collar.
4. Find a clean, smooth surface to place the hovercraft on.
5. Inflate the balloon and twist the opening shut.
6. Pull the open end of the balloon through the collar.
7. Stretch the balloon's opening over the sports bottle cap.
8. Without letting any air out, place the cardboard collar around the base of the balloon and cap.
9. Now let the air out of the balloon.
10. If the hovercraft doesn't slide or spin easily, make sure the CD isn't warped. If it is, you'll need to rebuild your hovercraft. If everything looks normal, try poking larger or more holes in the sports bottle cap.

How does it work?

Hovercrafts work by using air to lift a vehicle off of the ground. The CD Hovercraft is no exception. As the balloon deflates, it is releasing air through the sports bottle cap and beneath the CD. Because of the shape, smoothness, and weight distribution of the CD, the releasing air creates a cushion of air between the CD and the surface. This cushion of air reduces the friction between the CD and surface and allows your hovercraft to move more freely.

Continue to experiment:

Now that students have mastered the basic design, what modifications can be done to direct the direction of the hovercraft?

Launching Potatoes

Nothing's more fun than pushing around a potato.

You just cannot have much more fun than with a potato pusher, a 14 pound sack of spuds, and a big group of kids. Be careful, you might even teach some science along the way! **Please note that this is not a toy, but the demonstration is safe (and very cool!) when performed by and under the supervision of a responsible adult.**

This version of the potato pusher was inspired by the Weird Science team out of Illinois. It's made out of high quality extruded acrylic tubing that will last a long time provided that it is cared for properly. Before delving into the instructions, it's important to take a moment to consider several safety factors:

1. Perform the demonstration outside or in a large room.
2. Warn members of the audience that a projectile potato might be coming their way.
3. Wear safety glasses.
4. Use care when handling the flared end of the tube as the edges may be sharp.

Materials

This experiment write-up pertains specifically to the clear plastic version of the potato pusher sold by Steve Spangler Science.

READ THIS! This science demonstration only uses the power of compressed air to demonstrate Boyle's Law... unlike other versions which use flammable liquids to create an explosion to launch the potato - this is NOT recommended!

1. There are two parts to the potato launcher - the plunger and the tube. Let's start with the plunger. Notice the rubber stopper attached at one end of the rod. Slide the stopper up so that it is approximately 5 inches from the end. This is where you will hold onto the plunger.
2. You'll also notice that both ends of the clear tube have been flared. Use care as the ends of the tube can be sharp or have rough edges.
3. Let's not forget about the potato. Place the potato on a flat surface. Hold the potato securely with one hand while pushing the tube through the potato with the other hand. Pull the tube out of the potato to see your "potato plug".

4. Use the plunger (rod) to move the piece of potato to the other end of the tube (actually a few inches from the other end). This is a little tricky until you get the hang of it. Always keep your pushing hand behind the rubber stopper to keep the sharp edge of the tube from hurting your hand.

5. The reason for moving the potato plug is to free up the end to accept another piece of potato. Position the potato securely on a flat surface while pushing the tube into the potato. Now both ends of the potato are plugged!

6. Assuming that you're right handed, hold the clear plastic tube in the middle with your left hand and the plunger in your right hand. The plunger goes into the end where the potato is a few inches from the end of the tube. Push upwards on the bottom piece of potato with the plunger until the top potato piece pops out of the tube. POW! Notice that the rubber stopper keeps the plastic rod from pushing both pieces of potato out of the tube (pretty cool design!) If adjusted properly, the bottom potato should now be positioned a few inches from the top of the tube, and the bottom end of the tube is ready to accept another unsuspecting piece of potato.

7. It takes the average potato-launching-science-enthusiast about 30 launches before feeling completely confident about the mission. Never aim the flying potato at anyone. It's always best to do this demo outside... away from all forms of life. Remember, this is a science demonstration... not a bombing mission. Use caution when demonstrating your newly acquired skill.

8. When you are finished, wash and rinse the tubing with mild soap and water.

How does it work?

The Potato Pusher is an excellent demonstration of the Boyle Law, the Kinetic Theory of Gases, and Newton's Laws of Motion. The potato pusher beautifully illustrates *Boyle's Law* which states that pressure and volume are inversely proportional. In other words, as you decrease the volume of the air trapped in between the two pieces of potato, the pressure exerted by the gas increases. This increase in pressure eventually forces the top end potato to exit the tube with great pizazz!

FAQ: Is this safe for children?

The potato gun requires adult supervision. You are essentially firing 2 inch (5 cm) long potato pieces through the air and whenever anything flies with some velocity, there is always the danger that someone may get hurt.

The Facts of the Matter

Experiments:

Physical/Chemical Changes & Reactions

1. Naked Egg Experiment
2. Magic Crystal Tree-
3. Kid Friendly Elephants Toothpaste
4. Taco Sauce Penny Cleaner
5. Think Ink! - The Clock Reaction
6. The Science of Cleaning Products

Density

7. Straw Stack of Color
8. 9 Layer Density Tower

Three of the States of Matter (Solid, Liquid, Gas)

9. Oobleck & Quicksand: Non-Newtonian Cornstarch Recipe
10. Slime - The Real Recipe vs. White Glue Putty (GAK)
11. Ice Cube Rope
12. Ice cream in a bag

Kindergarten

Key Terms:

- Senses
- Shape
- Size
- Change
- Color
- Tools
- Temperature
- Thermometer
- Observe

Key Standards:

- 7.2.2 Use the senses to investigate and describe an object.
- 7.7.2 Investigate and compare a variety of non-living materials using simple tools.
- 7.9.1 Observe, identify, and compare the properties of various objects such as color, shape, and size.
- 7.9.2 Observe, discuss, and compare characteristics of various solids and liquids.

1st Grade

Key Terms:

- Freezing
- Investigate
- Prediction
- Property
- Mixed
- Classify
- Sequence
- Measure
- Measurement
- Unit
- Graph

Key Standards:

- 7.2.3 Sort and classify a variety of living and non-living materials based on their characteristics and physical properties.
- 7.9.1 Classify solids according to characteristics, ex. size, shape, color, texture, hardness, ability to change shape, magnetic attraction, whether they sink or float, and use, and distinguish between the properties of solids and liquids.
- 7.9.2 Compare liquids according to their color, ability to flow, solubility in water, and use.
- 7.9.3 Investigate and describe the results of mixing different substances, and predict the changes that may occur when different materials are mixed ex. salt and pepper, water and sand, water and oil, and water and salt

2nd Grade

Key Terms:

- Infer
- Investigate
- Observation
- Scientific Inquiry
- Scientist
- Similarities/Differences
- Celsius/Fahrenheit
- Compare/Contrast
- Depend
- Decision
- Transform
- Predicting
- Elapsed time/time interval
- Dissolve

Key Standards:

- 7.9.1 Use tools ex., hand lenses, measurement devices, and simple arm balances, to gather data about the physical properties of different objects.
- 7.9.2 Describe what happens when ice changes from a solid to a liquid [and investigate how temperature changes affect the state of matter.]
- 7.9.3 Describe what happens when water is heated to the point of evaporation [and investigate how temperature changes affect the state of matter].
- 7.12.2 Describe what happens when an object is dropped and record the observations in a science notebook.

3rd Grade

Key Terms:

- Crystallize
- Factor
- Opinion
- Conclusion
- Physical change
- Product
- Liquid Measures
- Mixture
- Tools

Key Standards:

- SPI 7.9.1 Describe a substance in terms of its physical properties.
- SPI 7.9.2 Identify methods for separating different types of mixtures.
- 7.9.1 Use physical properties to compare and contrast substances.
- 7.9.2 Compare and contrast events that demonstrate evaporation, crystallization, and melting.

- 7.9.3 Make predictions and conduct experiments about conditions needed to change the physical properties of particular substances.
- 7.9.4 Classify combinations of materials according to whether they have retained or lost their individual properties.
- 7.9.5 Investigate different ways to separate mixtures such as filtration, evaporation, settling, or using a sieve.

4th Grade

Key Terms:

- Chemical energy
- Chance
- Compare
- Contrast
- Composite
- Accuracy
- Mass
- Relationship
- Opaque
- Transparent
- Translucent
- Physical Change

Key Standards:

- SPI 7.9.1 Choose an appropriate tool for measuring a specific physical property of matter.
- SPI 7.9.2 Determine the mass, volume, and temperature of a substance or object using proper units of measurement.
- SPI 7.9.3 Interpret the causes and effects of a physical change in matter.
- 7.9.1 Use appropriate tools to measure and compare the physical properties of various solids and liquids.
- 7.9.2 Compare the causes and effects of various physical changes in matter.
- SPI 7.11.2 Identify factors that influence the motion of an object.
- SPI 7.10.3 Determine whether a material is transparent, translucent, or opaque.

5th Grade

Key Terms

- Gravity
- Dissipate
- Chemical Properties
- States of Matter
- Data Collection Methods
- Model
- Solution

Key Standards:

- SPI 7.9.1 Distinguish between physical and chemical properties.
- SPI 7.9.2 Describe the differences among freezing, melting, and evaporation.
- SPI 7.9.3 Describe factors that influence the rate at which different types of material freeze, melt, or evaporate.
- 7.9.1 Compare the simple physical and chemical properties of common substances.
- 7.9.2 Investigate how different types of materials freeze, melt, evaporate, or dissipate
- 7.9.3 Use data from a simple investigation to determine how temperature change affects the rate of evaporation and condensation.

- SPI 7.12.2 Identify the force that causes objects to fall to the earth.

6th Grade

Key Terms:

- Cause and effect
- Criteria
- Control
- Protocol
- Variable

Key Standards:

Matter is not addressed at this grade level.

7th Grade

Key Terms:

- Acceleration
- Diffusion
- Phenomenon
- Speed

Key Standards:

Matter is not addressed at this grade level.

8th Grade

Key Terms:

- Chemical Change
- Diffusion
- Density
- Endothermic
- Exothermic
- Gravitation
- Neutral
- Product
- Reactant
- Variation

Key Standards:

- 7.9.1 Identify atoms as the fundamental particles that make up matter.
- 7.9.2 Illustrate the particle arrangement and type of motion associated with different states of matter.
- 7.9.3 Measure or calculate the mass, volume, and temperature of a given substance.
- 7.9.4 Calculate the density of various objects.
- 7.9.6 Differentiate between physical and chemical changes.
- 7.9.7 Describe how the characteristics of a compound are different than the characteristics of their component parts.
- 7.9.8 Determine the types of interactions between substances that result in a chemical change.
- 7.9.11 Use investigations of chemical and physical changes to describe the Law of Conservation of Mass.
- 7.9.12 Differentiate between the reactants and products of a chemical equation.
- SPI 7.9.1 Recognize that all matter consists of atoms.
- SPI 7.9.2 Identify the common outcome of all chemical changes.
- SPI 7.9.6 Compare the particle arrangement and type of particle motion associated with different states of matter.

- SPI 7.9.7 Apply an equation to determine the density of an object based on its mass and volume.
- SPI 7.9.8 Interpret the results of an investigation to determine whether a physical or chemical change has occurred.
- SPI 7.9.10 Identify the reactants and products of a chemical reaction.
- SPI 7.9.11 Recognize that in a chemical reaction the mass of the reactants is equal to the mass of the products (Law of Conservation of Mass).

High School

Key Terms:

- Catalyst
- Colloid
- Solution
- Suspension
- Thermodynamics
- Conduction
- Convection

Key Standards

- 4.2.2 Explain the effect of heat on temperature in terms of the motion of the particles within the substance.
- 1.2.9 Classify properties and changes in matter as physical, chemical, or nuclear.
- 1.2.13 Distinguish among solid, liquid, and gaseous states of a substance, ex. in terms of the relative kinetic energy of its particles.
- SPI 1.2.4 Classify a property of change in matter as physical, chemical, or nuclear.
- 1.Math.3 Apply algebraic properties, formulas, and relationships to perform operations on real-world problems (e.g., solve for density).
- 1.1.23 Explain, in terms of force and/or density, why some objects float and some objects sink.

Naked Egg

Did it come from a naked chicken?

This experiment answers the age-old question, "Which came first, the rubber egg or the rubber chicken?" It's easy to make a rubber egg if you understand the chemistry of removing the eggshell with an acid (vinegar.) What you're left with is a totally embarrassed naked egg and a cool piece of science.

Materials

- Raw eggs
- Graduated cylinder or tall glasses
- Vinegar
- Corn Syrup
- Cardboard
- Patience

1. Place the egg in a graduated cylinder or tall glass and cover the egg with vinegar.
2. Have students develop hypotheses on what is going to happen over the next 2 days.
3. Fill the jar half full of vinegar. Draw two different faces (happy, sad) on opposite sides of each egg. Place the eggs in the jar. Cover the jar with the cardboard.
4. Bubbles will begin to show on the surface of the eggs.
5. After one day, the shells have softened and begun to disappear. Can you still see the faces?
6. If needed, change the vinegar on the second day. Be careful—since the eggshell has been dissolving, the egg membrane may be the only thing holding the egg together. The membrane is not as durable as the

shell. Carefully pour the old vinegar down the drain and cover the egg with fresh vinegar. Place the glass with the vinegar and egg in a safe cool place. Don't disturb the egg but pay close attention to the bubbles forming on the surface of the shell (or what's left of it).

7. After two days, most of the calcium will have dissolved and you can see the thin membranes that are between the shell of each egg and its contents.
8. Remove the eggs from the vinegar and carefully rub any remaining shell off under cold running water.
9. Twenty-four hours later, pour off the vinegar and carefully rinse the egg with water. The egg looks translucent because the outside shell is gone! The only thing that remains is the delicate membrane of the egg. You've successfully made an egg without a shell. Okay, you didn't really make the egg - the chicken made the egg - you just stripped away the chemical that gives the egg its strength.

Continuing the Experiment: Showing Permeability

1. Place one egg in the corn syrup so that the syrup covers it completely. After a few days, you will notice that the egg is much smaller.
   What will happen if we put a "naked" egg into plain water? List hypotheses.
2. Place a second egg in plain water so that it is covered. After a few days, they will notice that this egg is larger. The third egg can be used for a control. They can keep it in a plastic bag to prevent dehydration.

Challenge: You might try reversing the experiment. Note what the egg in the corn syrup looks like after a few days and then put it in the water. Put the egg from the water into the corn syrup. Are you able to reverse the activity?

Hint: In handling during this activity, it is easy to break the membrane of the egg and delay the experiment. Three eggs are suggested so that if one breaks, you still have two to use for the lesson.

Further Hypothesis Questions to Test

Do organic or free-range eggs have an eggshell that is stronger or weaker than generic eggs? Have students conduct their own tests on several different kinds of eggs all at the same time to observe any differences in the time required for the vinegar to dissolve the shell.

Try using concentrated vinegar instead of traditional vinegar. Does it make a difference?

How does it work?

Let's start with the bubbles you saw forming on the shell. The bubbles are carbon dioxide gas. Vinegar is an acid called acetic acid - CH3COOH - and white vinegar from the grocery store is usually about 5% acetic acid and 95% water. Egg shells are made up of calcium carbonate. The vinegar reacts with the calcium carbonate by breaking the chemical into its calcium and carbonate parts (in simplest terms). The calcium part floats around in the solution while the carbonate part reacts to form the carbon dioxide bubbles that you see.

Some of the vinegar will also sneak through, or permeate, the egg's membrane and cause the egg to get a little bigger. This flow of a liquid from one solution through a semi-permeable membrane and into another less concentrated solution is called *osmosis*. That's why the egg is even more delicate if you handle it. If you shake the egg, you can see the yolk sloshing around in the egg white. If the membrane

breaks, the egg's insides will spill out into the vinegar. Yes, you've made a pickled egg! Allowing the egg to react with the carbon dioxide in the air will cause the egg to harden again. Amazing!
Quick Summary: When you submerge an egg in vinegar, the shell dissolves. Vinegar contains acetic acid, which breaks apart the solid calcium carbonate crystals that make up the eggshell into their calcium and carbonate parts. The calcium ions (ions are atoms that are missing electrons) float free, while the carbonate goes to make carbon dioxide—the bubbles that you see.

Naked Egg in Corn Syrup, What Happened?

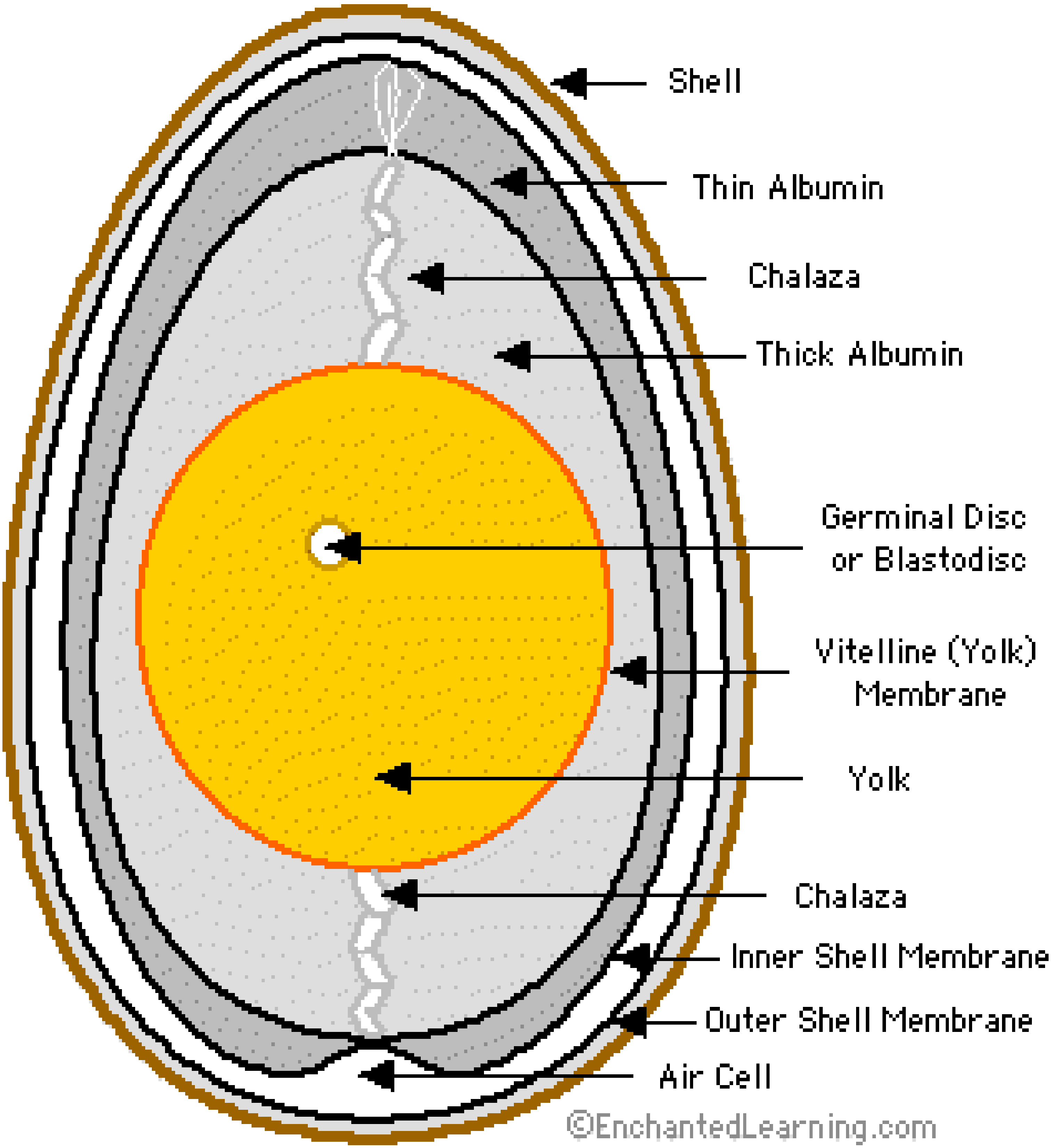
The liquid inside the egg is not as concentrated as the sugar water corn syrup. Chemically, the liquid wants to go where there is a high concentration of matter and equalize the concentration. After two days, you will have only a membrane around an egg yolk because the water from the egg white has moved out of the egg.

Naked Egg in Water, What Happened?

The liquid inside the egg is more concentrated than the plain water in the container. The water goes into the egg to equalize the concentration. After two days, you will have an egg that is nearly the size of a tennis ball.

Egg Definitions

- Air Cell - an empty space located at the large end of the egg; it is between the inner and outer shell membranes.
- Chalaza - a spiral, rope-like strand that anchors the yolk in the thick egg white. There are two chalazae anchoring each yolk; one on the top and one on the bottom. (The plural of chalaza is chalazae.)
- Germinal Disc or Blastodisc - a small, circular, white spot (2-3 mm across) on the surface of the yolk; it is where the sperm enters the egg. The nucleus of the egg is in the blastodisc.
- Inner Shell Membrane - the thin membrane located between the outer shell membrane and the albumin.
- Outer Shell Membrane - the thin membrane located just inside the shell.
- Shell - the hard, protective coating of the egg. It is semi-permeable; it lets gas exchange occur, but keeps other substances from entering the egg. The shell is made of calcium carbonate.
- Thick Albumin - the stringy part of the egg white (albumin) located nearest the yolk.
- Thin Albumin - the watery part of the egg white (albumin) located farthest from the yolk.
- Vitelline (yolk) Membrane - the membrane that surrounds the yolk.
- Yolk - the yellow, inner part of the egg where the embryo will form. The yolk contains the food that will nourish the embryo as it grows.


Shell
Thin Albumin
Chalaza
Thick Albumin
Germinal Disc
or Blastodisc
Vitelline (Yolk)
Membrane
Yolk
Chalaza
Inner Shell Membrane
Outer Shell Membrane
Air Cell
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Magic Crystal Tree

Create a magically colorful, snow-covered tree

Impress your students by creating a colorful Christmas tree out of salt crystals, cardboard, and a few other household items. Within a day, you'll have a colorful snow-covered tree that seemed to magically sprout from nothing!

Materials

- Mrs. Stewart's Bluing (check your local grocer's cleaning section or order online)
- Table salt
- Household ammonia
- Thin cardboard (like the type from the back of a notepad, not corrugated)
- Pen or pencil
- Scissors
- Bowl
- Water
- Measuring spoon
- Food coloring
- Adult supervision

1. Trace two Christmas tree shapes onto the cardboard and cut them out.
2. Cut a slot down the middle of one tree shape. Start at the top and stop in the middle of the shape.
3. In the other tree shape, cut another slot down the middle. On this shape, start at the bottom and cut to the middle.
4. Slide the two slots together, creating a three-dimensional tree shape that can stand by itself.
5. Add drops of food coloring to the edges of the cardboard and let the food coloring soak into the cardboard.
6. Using the bowl, mix these ingredients together:
    - 1 tablespoon of water
    - 1 tablespoon salt
    - 1 tablespoon bluing
    - 1/2 tablespoon of household ammonia

7. Stand your tree in the middle of the bowl containing your magic solution and be patient. Over the next 10 to 12 hours, your Magic Crystal Tree will grow and grow and grow! Pretty soon, you'll have a colorful snow-covered tree that grew by pure magic.

How does it work?

You probably have us figured out... that Magic Crystal Tree isn't magic at all! You're right, but do you know the science behind the crystalline growth of the cardboard tree?

The main principle at work here is *capillary action*. Capillary action is the same process that enables plants and trees to take water and nutrients from the soil up through their stems or trunks and into their leaves, branches, flowers, and fruit. The cardboard tree uses the same process to draw the magic solution up through its entire shape until the cardboard has soaked itself in the solution.

After the magic solution has been drawn throughout the tree by capillary action, the solution begins to evaporate. The evaporation process is accelerated by the ammonia, which evaporates more quickly than water. As the magic solution evaporates off of the tree, the crystals are left behind on the branches of the tree.

The magic crystals that are left behind are a combination of the Mrs. Stewart's Bluing and the table salt. The bluing is a *colloid*, with many tiny particles suspending themselves within the water. It's just like when you shake up a snow globe, except the particles of bluing are much smaller than the snow. These tiny suspended particles aid the dissolved salt in crystalizing as the magic solution evaporates.

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Extending the Experiment: It should work with any shape, but it's best as long as the material is porous...this experiment has been tried on materials such as, bricks, charcoal briquettes, and toilet paper tubes.

Elephant's Toothpaste

This is a kid-friendly version of the popular Elephant's Toothpaste experiment. A child with a great adult helper can safely do it on his or her own and the results are wonderful.

Materials

- 16 oz. empty plastic soda bottles (preferably with a narrow neck such as those made by Coca-Cola)
- 1/2 cup 20-volume hydrogen peroxide (20-volume is 6% solution, purchased from a beauty supply store) or drugstore hydrogen peroxide (3%) which results in a less dramatic eruption than the higher-strength stuff, but it does work.
- Squirt of Dawn dish detergent
- 3-4 drops of food coloring
- 1 teaspoon yeast dissolved in ~2 tablespoons very warm water
- Funnel
- Foil cake pan with 2-inch sides
- Lab goggles
- Lab smock

1. At each student's place: cake pan, plastic bottle, Dawn in small cup, food coloring, funnel, goggles and smock, 1/2 cup peroxide, dissolved yeast mixture.
2. Stand up bottle in the center of the cake pan. Put funnel in opening. Add 3-4 drops of food coloring to the peroxide and pour the peroxide through the funnel into the bottle. Show a water molecule diagram and a peroxide molecule diagram, pointing to the extra oxygen that will be set free.
3. Add the Dawn detergent to the peroxide in the bottle.
4. Pour the yeast mixture into the bottle and quickly remove the funnel.
5. The students can touch the bottle to feel any changes that take place.

Variation: Instead of supplying 20 funnels, have the students measure the yeast in little paper cups (the kind meant to hold candy party favors), using popsicle sticks to stir. The kids will then be able to pour the contents of the little cup right into the bottle by pinching the edge of the cup to form a spout.

Observations

The reaction creates foam that shoots up out of the bottle and pools in the pan. After a minute or so, it begins to come out in a moving stream that looks like toothpaste being squeezed our of a tube. The students can play with the foam as it is just soap and water with oxygen bubbles. The bottle will feel warm to the touch as this is an exothermic reaction.

How does it work?

Talk about the addition of the yeast as a catalyst which makes the peroxide molecule release the oxygen atom faster.

Taco Sauce Penny Cleaner

It's one of those things you hear about but wonder if it's true. Can you use taco sauce to clean the tarnish off of a penny? Believe it or not, taco sauce does a great job of cleaning pennies, but how does it work? Which ingredients in the taco sauce really do the cleaning? Have students tackle these questions as part of your science project and they may make a surprising discovery.

Materials

- Dirty pennies (try to collect tarnished pennies that all look the same)
- Other materials to clean (tarnished silver, other coins, etc)
- Taco sauce (mild sauce from Taco Bell works well, but bring several kinds)
- Vinegar
- Tomato paste
- Lemon Juice
- Salt
- Water
- Small plates
- Masking tape or sticky note

The tarnish on pennies is actually not tarnish at all. It is simply a reaction between the copper in the penny and the oxygen in the air. When the two elements react with one another, they form copper oxide. To get rid of this dull and often greenish substance we need to dissolve it. And reveal the shiny copper that is there underneath. So, how are we going to do it?

1. Let's start by proving that taco sauce does a good job of cleaning pennies. Place several tarnished pennies on a plate and cover them with taco sauce. Use your fingers to smear the taco sauce all over the surface of the pennies. Remember to wash your hands... and don't lick your fingers (pennies are really dirty and some taco sauces are really spicy!).
2. Allow the taco sauce to sit on the pennies for at least two minutes.
3. Rinse the pennies in the sink and look at the difference between the top side of the pennies that touched the taco sauce and the bottom side. It's no myth... taco sauce does the trick.

So, which ingredients are responsible for the cleaning power of taco sauce? Let's find out...

1. Have students place two or three equally tarnished pennies on each of four plates. Use masking tape or a sticky note to mark each plate with the ingredient they are testing (vinegar, tomato paste, salt, and water).
2. Cover the pennies with the various ingredients and allow them to sit for at least two minutes.

3. Rinse the pennies from each test plate with water. Which ingredient cleaned the pennies the best?

Ask the students, did any of them work? Much to your surprise, none of the ingredients did a good job of cleaning the dirty pennies. In fact, the results are terrible. Ask the students, where did we go wrong? Tell the students: Even if an experiment doesn't work, it's a learning experience. Thomas Jefferson made over 200 light bulbs before he got one that worked. He didn't consider himself a failure, he just figured out 200 ways not to make a light bulb. We have found several ways not to clean a penny. Now, let's form another hypothesis to possibly help us actually get it clean.

Since one ingredient at a time didn't work, what should we try next? *(Have students share their ideas and test them.)* Maybe two or more of the ingredients work together to react against the dirt and copper oxide on the penny? Lets set up our second test using various combinations of tomato paste, vinegar and salt.

Place two or three equally tarnished pennies on each of three plates. Make three signs that say "Tomato Paste + Vinegar", "Salt + Vinegar", and "Tomato Paste + Salt".

1. Cover the pennies with each of the mixtures and give the ingredients at least two minutes to react.
2. Rinse the pennies under water and write down your observations.

Observations

The Taco Sauce Penny Cleaner is a great example of a Science Fair project. First, you ask a question - does taco sauce really clean pennies? You find that it does and then you ask another question - What is it in the taco sauce that causes it to clean pennies? You run multiple tests and isolate one variable at a time to see if the vinegar, the tomato paste, the salt, or the water is the real cleaning agent for the pennies. Guess what... nothing cleans the penny. Now what do you do? You ask another question - Could a combination of ingredients cause the cleaning action? Again, you isolate the variables to eventually reach the conclusion that the combination of the vinegar and salt cleans the pennies. The Taco Sauce Penny Cleaner experiment clearly shows scientific inquiry in motion.

How does it work?

The clear winner is the mixture of vinegar and salt. Neither vinegar nor salt by themselves cleaned the pennies, but when they were mixed together something happened. The chemistry behind the reaction is somewhat complicated but very interesting. Dr. Laurence D. Rosenhein from the Department of Chemistry at Indiana State University published an article in the Journal of Chemical Education in 2001 about this very reaction. According to Dr. Rosenhein, salt (sodium chloride) plays a very important role in making a copper chloride complex. Salt breaks down into sodium ions and chloride ions and it is the chloride ions that form a surprising complex with the copper ions (specifically the Cu^{+1}). By themselves, the salt and weak acid do very little in the way of removing the coating of copper oxide on the penny, but together these ingredients make a great cleaning agent. Now you know the cleaning power of taco sauce!

What about other weak acids? Will they work as well?

Try lemon juice and/or lemon juice and salt. Do they clean as wells was the taco sauce?

Science Fair Connection:

The Taco Sauce Penny Cleaner is a great example to show students how they can build a science fair project. First, ask a question - does taco sauce really clean pennies? Test out the question, find that it does and then ask another question - What is it in the taco sauce that causes it to clean pennies? Run multiple tests and isolate one variable at a time to see if the vinegar, the tomato paste, the salt, or the water is the real cleaning agent for the pennies. Guess what... nothing cleans the penny. Now what should be done? YAsk another question - Could a combination of ingredients cause the cleaning action? Again, isolate the variables to eventually reach the conclusion that the combination of the vinegar and salt cleans the pennies.

For variations, try one of these possibilities:

- Compare the cleaning power of taco sauce, lemon juice, and other acidic substances on tarnished pennies. Which is most effective and why?
- Test the cleaning power of taco sauce on different tarnished metals, using pennies as your control and the other metals as your variables.

The Taco Sauce Penny Cleaner experiment clearly shows scientific inquiry in motion and meets all of the requirements of a great science fair project.

Classic Iodine Clock Reaction

A beaker of water magically turns into ink... or so you think.

Two clear liquids are mixed together and the audience is told to watch closely... "Don't take your eyes off the liquid or you'll miss it!" Then, in a flash, the water changes to ink (or so they think!). Clock reactions like this never fail to capture the student's attention, and the Iodine Clock Reaction is one of the most startling chemical demonstrations you'll ever see. "How did that happen?" is almost always the reaction, and when students ask "How?", they're ready to learn.

Materials:

The kit from stevespanglerscience.com includes enough materials to do the Think Ink demonstration 30 times.

- 2 Mega Test Tubes and Rack
- Timing Mixture
- Trigger Powder
- Starch pellets
- Recycling Powder
- 3 White measuring scoops
- 2 Stirring rods
- 1 Pair of safety glasses

How does it work and what does it teach?

The Think Ink! experiment helps teach the following chemical concepts...
Rate of reaction as a function of temperature
Rate of reaction as a function of reactant concentration.
Two clear liquids are mixed together and the audience is told to watch closely... "Don't take your eyes off the liquid or you'll miss it!" Then, in a flash, the clear water changes to ink (or so they think!). Think Ink! illustrates the amazing chemistry behind the classic clock reaction where molecules meet up and change over time to create this startling reaction. Unlike the classic iodine clock reaction from your high school chemistry class, the Think Ink! formula uses a kitchen chemistry approach to achieve even better results.
This reaction is referred to as the Landolt Clock Reaction. There are three steps in the process that cause this amazing reaction. When you prepare the Solutions A, B, and C, the chemicals begin to mix and form new chemical compounds. This is a very slow reaction, so you don't see any outward changes. When you begin to pour the solutions together a much faster reaction occurs, which leads to the third reaction which is instant. Suddenly, and immeasurably quickly, the clear liquids turn into a jet black iodine-starch

complex. These reactions happen at different intervals because different chemicals react at different speeds.

Additional Info

Discussion of the Chemistry...

The sudden change from a colorless solution to the blue-black solution is the result of four sequential reactions. First, the bisulfite ions (HSO_3^-) reduce some of the iodate ions (IO_3^-) to form iodide ions (I^-). Next, the iodide ions (I^-) are oxidized by the remaining iodate ions (IO_3^-) to form triiodide ions (I_3^-). The solution now consists of triiodide ions (I_3^-) and soluble starch. In the third reaction, the triiodide ions (I_3^-) get reduced by the bisulfite ions (HSO_3^-) to become iodide ions (I^-). That continues until all of the bisulfite has been consumed. Finally, the triiodide ions and starch combine to form the dark blue-black starch complex that looks like ink.

The Science of Cleaning Products

Ever wondered if those cleaning products on the infomercials really work? Do stains really disappear like magic? The makers of OxiClean show how stains literally vanish when the "power of oxygen" is used to safely remove the most stubborn of stains. So, what is the secret behind those little white crystals?

Materials

- OxiClean® powder
- Warm water
- Mixing bowl
- White washcloths
- Stain makers - grape juice, colored drinks, condiments, soy sauce
- Bottled Iodine or the liquid iodine solution from your Landolt Clock/Think Ink Experiment. The following features iodine from your previous reaction as the stain.

The OxiClean® science demonstration presented by Steve Spangler on television (9News) was a version that Steve originally created for the product manufacturers in 1997 as part of a program called the Science of Clean. In Steve's version, the two colorless liquids were mixed together and after a few seconds, the colorless liquid turned jet black! Steve accomplished this by using the classic Landolt Clock Reaction, like the experiment just previous to this one, to produce an iodine solution. Iodine was selected as the stain since it shows up well on television and produces a very visual stain on the washcloth.

We're going to do the same, with your Landolt Clock Reaction.

It's important to remember that this science demonstration was developed specifically to show the amazing oxidation power of OxiClean® (the active ingredient in OxiClean is sodium percarbonate). Sodium percarbonate (C2H6Na4O12) is a great detergent and bleaching agent based on the chemistry of hydrogen peroxide bound with sodium carbonate molecules. Hydrogen peroxide is a strong oxidizing substance which will "bleach" the stains away.

Sodium percarbonate is excellent for cleaning and removing organic stains such as coffee, tea, wine, fruit juices, foods, sauces, grass and blood from fabrics and common surfaces made out of porcelain, ceramics, wood and many more. As a cleaning product, OxiClean® is favorable because it's environmentally safe, biodegradable, and leaves no harmful by-products.

Continuing the Experiment and the Science Fair Connection:

Testing the cleaning powers of OxiClean and other stain treatments makes a great science fair project. It is simple to do, requires few materials, and provides information that might be very useful for parents and teachers who attend the science fair! Below you'll see some questions that you might want to consider for extending the experiment, but we're confident that students will also come up with some other great questions to explore when they let their imagination run wild!

- Stain ten white washcloths with common materials found around the house such as coffee, tea, soy sauce, grape juice, cranberry juice, soda, wine... you name it... and test the bleaching power of OxiClean on each cloth.
- Isolate a particular stain such as coffee and test the cleaning power of several different products that all claim to use the bleaching power of oxygen!

- Select a stain such as cranberry juice to stain five different carpet samples (found at your local carpet store). Test the stain removing action of OxiClean (or any other product) on those five carpet samples. Is there a type of carpet where the stain is permanent?
- Select one stain, such as grape juice, and test to see if the temperature of the water affects the cleaning action of a selected product.
- Set up a science experiment to test the manufacturer's claims. Does a TIDE® cleaning stick really do a good job of removing ink stains? Does OxiClean® remove red wine stains from a carpet?

Teach students that the key to any good science experiment or science fair project is to select *one* variable to test and to make certain that everything else stays the same. Changing the type of stain *and* the temperature of the water may produce false results since two variables were changed at the same time. You have no way of knowing if the type of stain or the temperature of the water caused the result. Remember, only *change* one thing at a time, *create* a new test, and then *compare* your results--we like to call this process "**C^3**." If they go through this process and document your results, they should be able to make some conclusions and have a great experiment, and future science fair project!

Straw Stack of Colors

Messy and fun!

Who would have thought that playing with your food as a kid would lead to a cool science experiment as an adult? Best of all, it will keep the kids occupied for hours. The challenge starts with four different cups of colored water and a clear straw. When you mix red and blue liquid together, you get purple… right? Not so fast. How about a layer of blue liquid sitting on top of the red? Add two more colors and you have four layered liquids in one straw. The secret is density… and a steady hand. Have a competition and the kids might just catch the method faster than you! [Which they'll love!]

Materials

- Pitcher
- clear, plastic cups (12-16 ounces)
- Salt
- 1-qt or 1-L measuring cup
- Measuring spoons
- Food coloring
- Clear, plastic straws (ex. from fast food restaurants)

Demonstration Preparation:

1. Fill four of the plastic cups 3/4 full with water
2. Use food coloring to color each cup a different color – blue, red, green and yellow. You'll want the colors to be fairly dark, so add 15-20 drop of food coloring to each cup.
3. Add 1 tablespoon of salt to the blue water and stir.
4. Add 2 tablespoons of salt to the red water and stir.
5. Add 3 tablespoons of salt to the green water and stir.
6. Add 4 tablespoons of salt to the yellow water, and you guessed it, stir the water. Not all of the salt will dissolve immediately… and that's okay. Over time the salt will completely dissolve, but you don't have to wait for that to happen to get started.
7. This last step in preparing the solutions is very important… Add a little water to each cup so that the water level is the same in all four cups.
8. Let's practice the straw-dropper technique using plain water in the fifth cup. Place one end of the straw into the water – about an inch – and place your index finger over the other end of the straw. Pull the straw out of the water and notice how the water stays in the straw. If you release your finger, the water will fall out of the straw. Remember doing this as a kid with your drink? Hey, maybe you're still a kid and you're an expert! Make sure you can do this well before moving onto the next step.

9. It’s time to layer some liquids. Place the empty straw into the blue water (about an inch below the surface). Seal the other end of the straw with your index finger and remove the straw. There should be about an inch of blue water in the straw. Keep your finger firmly pressed against the top so the blue water doesn’t fall out.
10. Without releasing your finger, lower the straw into the red liquid about an inch lower than the blue liquid in the straw. Slowly release your finger from the top of the straw and the red liquid will push the blue layer up to the level of the water in the blue cup. Press your finger firmly on top of the straw and remove the straw. Look… you have two layers! Don’t get so excited that you release your finger from the top of the straw – you’ll have to start all over again! Also, be sure to hold the straw straight up and down (vertically) because tilting the straw will cause the liquids to mix and you’ll have to start again.
11. Lower the straw with the two colored layers into the green saltwater solution about an inch lower than the red solution in the straw. Slowly release pressure with your finger and the green solution will push the red and blue layers up about an inch. Seal the top of the straw with your index finger and move onto the yellow solution.
12. Lower the straw into the yellow solution (the suspense is killing you… it feels like your finger is going to fall off… but you continue!). Lower the straw about an inch below the top of the green layer and release your finger. The yellow liquid will push the top layers up. Put your index finger over the top of the straw one last time and remove the straw from the water. To everyone’s amazement, you have four layers of colored water in your straw!
13. All good things must come to an end. When it feels like your index finger is going to fall off, release the pressure and your masterpiece will fall into the fifth cup. The crowd yells, “Do it again!” and you can’t resist the temptation.

Experiment Preparation: Students can participate in this preparation for their groups

Make a very concentrated solution of saltwater in the pitcher by mixing 3 cups of warm water with 1 cup of table salt. Stir the mixture well, then let it sit for 2 hr. You will need a helper for one step in the following procedure.

1. Students may notice that some of the salt in the pitcher has not dissolved, but has settled to the bottom. When salt dissolves in water, it takes up spaces in between water molecules, and there is a limit to the available space. The water in the pitcher has absorbed as much salt as it can, and the remainder has settled to the bottom. The liquid at the top of the pitcher is the most concentrated saltwater solution possible at this temperature. It is called a saturated solution.

Pour off 2 cups of the clear liquid from the top of the pitcher into the measuring cup. This will be your most concentrated solution. By adding water to it, you/the students will make a series of progressively more dilute solutions.

2. Line up five glasses on the table [per group]. Turn the glasses upside down, and on the bottom of each one, put a small piece of masking tape. Number the glasses 1 to 5 on the tape, and turn them right side up again. Keep them in numbered order.
3. Pour 1 cup of the salt solution from the measuring cup into the first glass.
4. Add 1 cup of warm tap water to the solution remaining in the measuring cup and stir.

Pour 1 cup of this more-dilute solution into the next glass, and again add 1 cup of tap water to the solution remaining in the measuring cup.
6. Repeat step 5 until each group has five salt solutions in the five water glasses, each one more dilute than the last.
7. Have someone else, or the teacher may do this for each group, mix up the order of the glasses, so the students do not know which colors are in which solutions and add about 4 drops of food coloring to each of the glasses to make each solution a different color. Ex: Use red, green, blue, yellow, and purple (two red drops and two blue drops).
8. Using a clear-plastic drinking straw, have students try to “stack” two colors so that they will stay in the straw without mixing. For this to work, the least-dense solution must be at the top of the “stack” and the densest solution at the bottom. The stacking is done by dipping the straw about a 1⁄2 cm into one of the solutions, putting your finger over the top, withdrawing the straw, inserting the straw into a different color solution, and then repeating the process, going a bit deeper with each color.
Have students create data table in their journals and/or create one on the board. Students may work in groups or this may be a whole class activity. Have students keep testing pairs of colors and keep track of which one is less dense. Each open box on the table represents a pair of colored solutions: one in the horizontal list above the boxes and the other in the vertical column to the left of the boxes. For example, the box in the upper-right-hand corner of the "stacked" solution table is for the green and blue pair; the box directly below that is for the green and red pair; the one below that is for the green and purple pair; and so on. In the box for the pair of solutions you are testing, write the color of the solution that was less dense—that is, the color on top of the pair if the colors did not mix, or the one on the bottom of the pair if the colors did mix. Dispose of liquids in the spare glass. Remind them to be careful not to mix the original solutions.

DATA TABLE 1

Color	Blue	Red	Purple	Yellow	Green
Blue					
Red					
Purple					
Yellow					
Green					

When they have filled in all the spaces on data table 1 by testing pairs, look over their findings, and list on data table 2 the solutions in order of density by color, from least dense to most dense.

DATA TABLE 2		
Density	Color	Number
Least dense		
↓		
Most dense		

To check that they have listed them correctly, have students "stack" all five colors in their straw, beginning with the least dense and ending with the most dense. If they have listed them correctly, the colors will stay in five separate bands in the straw.

12. Now they have ranked their solutions by color in order of density. Do they think there is a relationship between the density and the concentration of a solution?

Discuss with students the definition of density and the process they used to dilute or concentrate each solution from the previous one. Next to the list of colors in the spaces provided on their second data table have students, write the numbers that they think correspond to the concentrations of the colored saltwater solutions they have listed according to density. Assign number 1 to the solution they think is the most concentrated and number 5 to the least concentrated. Then check the numbers written on the tape under the glasses to see if they were correct.

How does it work?

There's really no trick to layering liquids as long as you understand the concept of density. In simplest terms, density is the quantity of something per unit measure (assuming that everything is at the same temperature and pressure). Or in other words, the amount of stuff put into the same amount of space. For example, you added 1 tablespoon of salt to the blue water, but you added 4 tablespoons of salt to the same amount of yellow water. So, the yellow solution has a greater density of salt than the blue water. The density of the yellow solution is greater than the green solution, which is greater than the red, which is greater than the blue. By increasing the amount of salt in each cup of water (and keeping the volume or the amount of water in each cup the same), each liquid had a different density. The solution with the highest density (yellow) (the most "stuff" in the same amount of space) stayed at the bottom of the straw while the solution with the least amount of salt (and the lowest density) remained at the top.

In the same kind of cup (the same area) a cup of oil would be more dense than a cup of rubbing alcohol. Why? Because more oil molecules are stuffed into the same amount of space than the alcohol molecules, so it's more dense. Ex. A classroom that has 45 students and another classroom that is the same size has 10 students. Which classroom is more "dense?"

Extensions

- Can students add more layers? How would they do it? Would they make those layers more or less dense than the ones they already have? How? What colors could they use to show the order of their density? A solution is a mixture of a solid dissolved in a liquid. A concentrated solution has more of the solid mixed into the liquid than a dilute solution.
- What happens when they turn the straw upside down? Why does what happens happen?

Density Tower - Magic with Science

Can you layer nine liquids and seven objects in a vase?

With this trick, you'll put a new spin on the famous Density Column demonstration. First, you'll teach students how to make layers of liquid sit on top of each other. This density demonstration looks cool enough on its own, but what if students could make different objects float in the middle of those layered liquids? You'll impress yourself and your students with what you can do with your Density Tower.

Materials

- Tall, narrow, clear container (500 mL [2 cup] or 1000 mL [4 cup] graduated cylinders are perfect or large glass flower vases)
- Cups (at least 9)
- 50-100 mL (1.5-3.5 oz or 3-7 Tblsp) lamp oil
- 50-100 mL rubbing alcohol
- 50-100 mL vegetable oil
- 50-100 mL tap water
- 50-100 mL dish soap
- 50-100 mL milk
- 50-100 mL maple syrup
- 50-100 mL corn syrup
- 50-100 mL honey
- Ping pong ball
- Soda bottle cap
- Plastic bead
- Grape tomato
- Board game die
- Popcorn kernel
- Metal nut or bolt

Note: To add a colorful effect to the liquids, try mixing in a different color of food coloring to each layer. It will make your density column look pretty sweet and will help you identify the individual liquids.

1. Measure out equal amounts of each liquid into the cups.
2. Use food coloring to color the water (green) and the rubbing alcohol (blue).
3. Start your column by pouring the honey, then the corn syrup, then the maple syrup into the

cylinder. Pour each liquid SLOWLY into the container, one at a time. It is very important to pour the liquids slowly and into the center of the cylinder. Make sure that the liquids do not touch the sides of the cylinder while you are pouring. It’s okay if the liquids mix a little as you are pouring. The layers will always even themselves out because of the varying densities.
   - Honey
   - Corn syrup
   - Maple syrup
4. Now, have students use the turkey baster to layer the rest of the liquids in the vase in the middle. Have students go SLOW and be careful. Make sure you pour the liquids in the following order:
   - Milk
   - Dish soap
5. Next, starting with the water (green), have students use the turkey baster to pour the liquids down the side of the vase, along the wall
   - Water
   - Vegetable oil
   - Rubbing alcohol
   - Lamp oil
6. After letting the liquid layers settle, you'll notice that they remain in the order you poured them into the cylinder and that they are clearly distinguishable from each other. What scientific principle do you think contributes to the column's layers?
7. Make a chart that shows the order of each layer.
8. Take the various small objects and drop them into the column. Drop them in the following order:
   - Metal nut or bolt
   - Popcorn kernel
   - Board game die
   - Grape tomato
   - Plastic bead
   - Soda cap [they will have to help the soda cap fill with liquid using a stick or skewer]
   - Ping pong ball
9. Each of the objects will sink through or float on a different layer of the density column. What makes some objects sink deeper into the column while some hardly sink at all?

Observations

When all the liquids and small objects have been added to your density tower, you will have what appears to be a magic column. All of the liquids will be clearly distinguishable from each other and each of the objects will have settled at different levels within the liquids. Construct a chart to show the order that the liquids are in and the position of each object.

Why do you think these two phenomena happen? What scientific principle is this illustrating?

How does it work?

The same amount of two different liquids will have different weights because they have different masses. The liquids that weigh more (have a higher density) will sink below the liquids that weigh less (have a lower density). Surface tension plays a role as well.

To test this, you might want to set up a scale and measure each of the liquids that you poured into your column. Make sure that you measure the weights of equal portions of each liquid. You should find that the weights of the liquids correspond to each different layer of liquid. For example, the honey will weigh more than the Karo syrup. By weighing these liquids, you will find that density and weight while not the same thing, are closely related.

Density is basically how much "stuff" is smashed into a particular area... or a comparison between an object's mass and volume. Remember the all-important equation: Density = Mass divided by Volume. Based on this equation, if the weight (or mass) of something increases but the volume stays the same, the density has to go up. Likewise, if the mass decreases but the volume stays the same, the density has to go down. Lighter liquids (like water or rubbing alcohol) are less dense than heavy liquids (like honey or Karo syrup) and so float on top of the more dense layers.

The same goes for the small objects that you dropped into your density column. The metal bolt is more dense than any of the liquids in the column and therefore sinks directly to the bottom. Less dense objects will float on individual layers of the column, however. For instance, the plastic bead is more dense than the vegetable oil and everything above it but less dense than the water and everything below it. This makes the bead settle on the top of the water.

Additional Info

In the materials, we had you grab a bunch of miscellaneous tiny objects. This is the perfect opportunity to get in some scientific exploration! Use what you learned from dropping the bead, soda bottle cap, tomato, and die into the container to figure out which items are more and less dense than water. Which items have more density than vegetable oil? What items are less dense than honey?

Note: Avoid pouring lamp oils, and other flammables and contaminates down the sewer drain or septic system. Students of all ages should have a basic awareness of the concept of hazardous materials (HAZMAT), and best practices for disposal. There are many types of "lamp oil". If yours is made from petroleum then it should be disposed of just like used motor oil. If it is made from natural organic sources (olive oil, vegetable oil, etc.) it can be disposed of by simply throwing it into the trash. There is no harm to the environment.

Oobleck & Quicksand: Non-Newtonian Cornstarch Recipe

Make your own ooey, gooey goo using cornstarch and water.

Anyone who has ever watched a classic western movie knows about the dangers of quicksand. You know… that gooey stuff that grabs a hold of its victim and swallows them alive? So, what is quicksand and how does it really work? In this experiment, you'll use ordinary cornstarch to model the behavior of real quicksand. Oobleck is a classic science experiment that's perfect for entertaining both kids and adults, though you may want to take it outside. If you haven't seen it in action it's very fascinating stuff and before too long you'll have your hands covered with it, happily making a mess that can be washed away with water, especially if you take it outside!

Oobleck is a non-newtonian fluid. That is, it acts like a liquid when being poured, but like a solid when a force is acting on it. You can grab it and then it will ooze out of your hands. Make enough Oobleck and you can even walk on it!

Oobleck gets its name from the Dr. Seuss book *Bartholomew and the Oobleck* where a gooey green substance, Oobleck, fell from the sky and wreaked havoc in the kingdom. Here the Oobleck will be made in a bowl and will likely make a mess, but only because you can get carried away playing with it.

Make your own ooey, gooey glop that is guaranteed to produce a room full of ooohs & ahhhs! Using only cornstarch and water, this amazing mixture behaves like a solid and a liquid at the same time. By the end of the activity, you will have your hands on, in, and all over this wonderful solid-liquid-like mess.

Materials

- boxes of cornstarch (16 oz)
- Large mixing bowls
- Cookie sheet, square cake pan, or something similar
- Pitcher of water
- Spoon
- Gallon size zipper-lock bag
- Newspaper or a plastic drip cloth to cover the floor
- Water
- Cooked Spaghetti Noodles

1. The goal is for students to get a consistency where the Oobleck reaches a state that is the liquid and yet solid.
2. Pour approximately 1/4 of the box of cornstarch into the mixing bowl and slowly add about 1/2 cup of water. Stir. Sometimes it is easier to mix the cornstarch and water with your bare hands--of course, this only adds to the fun.
3. Continue adding cornstarch and water in small amounts until you get a mixture that has the consistency of honey. It may take a little work to get the consistency just right, but you will eventually end up mixing one box of cornstarch with roughly 1 to 2 cups of water. Notice that the mixture gets thicker or more viscous as you add more cornstarch.
4. Sometimes they will need more cornstarch. If so, have them keep adding more than the initial 1.5 cups. If they add too much, just add some water back into it. They will have to play with it to see what feels appropriately weird.

Tell students:

5. Pour the mixture onto the cookie sheet or cake pan., or keep it in the bowl Notice its unusual consistency when you pour it into the pan. Stir it around with your finger, first slowly and then as fast as you can.
6. Skim your finger across the top of the glop. What do you notice?
7. Sink your entire hand into the glop and try to grab the fluid and pull it up.
8. Try to roll the fluid between your palms to make a ball.
9. You can even hold your hand flat over the top of the pan and slap the liquid glop as hard as you can. Most students will run for cover as you get ready to slap the liquid, fearing that it will splash everywhere. Fear not, all of the glop stays in the pan...hopefully. If your mixture inadvertently splatters everywhere, you will know to add more cornstarch.
10. As your students play with the glop, ask them to speculate as to why the liquid behaves in this manner. What causes it to feel like something solid when you squeeze it, yet flow like syrup as it drips off your finger?
11. When you are finished, Wash hands with water. Add plenty of extra water to the mixture before pouring it down the drain. Wipe up any dried cornstarch with a dry cloth before cleaning up any remaining residue with a damp sponge. If keeping it, pour the glop into a large zipper-lock plastic bag for later use.

How does glop act like a solid sometimes and a liquid at other times?

Cornstarch molecules are long and stringy, like spaghetti. A bowl of spaghetti noodles acts just like this substance - punch it and your fist is stopped, but push your fist into it slowly and the noodles have time to move out of the way and your fist penetrates the surface. If the long molecules slide past each other easily, then the substance acts like a liquid because the molecules flow. Even very young children seem to understand this example and it gives them a peek into the idea that the shape of molecules has something to do with the way they behave.

Glop is an example of what is called a Non-Newtonian fluid - a fluid that defies Isaac Newton's law of viscosity. All fluids have a property known as viscosity. It is the measurable thickness or resistance to flow in a fluid. Honey and ketchup are liquids that have a high resistance to flow. When I think of viscosity, I always remember the television commercial of the child who is patiently waiting for the ketchup to flow out of the bottle and onto the hamburger bun. Be thankful that the viscosity of ketchup is greater than that of water the next time you are sitting across the table from somebody who is pounding on the bottom of the ketchup bottle.

Other, more familiar substances change states (from solids to liquids to gases) when we change the temperature, such as freezing water into ice or boiling it away into steam. But this simple mixture shows how changes in pressure, instead of temperature, can change the properties of some materials.
The cornstarch and water mixture acts like a solid sometimes and a liquid at other times. Applying pressure to the mixture increases its viscosity (thickness). A quick tap on the surface of Oobleck will make it feel hard, because it forces the cornstarch particles together. But dip your hand slowly into the mix, and see what happens—your fingers slide in as easily as through water. Moving slowly gives the cornstarch particles time to move out of the way.

Oobleck and other pressure-dependent substances (such as Silly Putty and quicksand) are not liquids such as water or oil.This concoction is an example of a suspension - a mixture of two substances, one of which is finely divided and dispersed in the other. In the case of the cornstarch quicksand, it's a solid dispersed in a liquid.

When you punch the cornstarch quicksand, you force the long starch molecules closer together. The impact of this force traps the water between the starch chains to form a semi-rigid structure. When the pressure is released, the cornstarch flows again.

Newton stated that the viscosity of a fluid can be changed only by altering the fluid's temperature. For example, motor oil or honey flows more easily when you warm it up and becomes very thick when it gets cold. So, a Non-Newtonian fluid has the same dependence on temperature, but its viscosity can also be changed by applying pressure, thus it is non-Newtonian. When you squeeze a handful of glop, its viscosity increases so it acts like a solid for a split second. When you release pressure, the glop behaves just like a liquid.

Ironically, the cornstarch will not stay mixed with the water indefinitely. Over time, the grains of cornstarch will separate from the water and form a solid clump at the bottom of the plastic storage bag. It is for this reason that you must not pour this mixture down the drain. It will clog the pipes and stop up the drain. Pour the mixture into a zipper-lock bag and dispose of it in the garbage.

What is Quicksand?

Quicksand is nothing more than a soupy mixture of sand and water, where the sand is literally floating on water. Scientifically speaking, quicksand is actually a substance that behaves like a solid and a liquid at the same time. This is the interesting sensation you experienced with the cornstarch and water mixture. Quicksand is just solid ground that has been liquefied by too much water, and the term "quick" refers to how easily the sand shifts when in this solid-liquid state.

Quicksand is created when water floods or saturates an area of loose sand and the sand begins to move around. Think of quicksand as a soupy mixture of sand and water that is constantly being stirred. When the water in the sandy soil cannot escape, it creates a liquid-like soil that can no longer support any weight. If an excessive amount of water flows through the sand, it forces the sand particles apart. This separation of particles causes the ground to loosen, and any weight on the sand will begin to sink through it.

The quicksand phenomenon can be caused by something like flowing underground water rising to the surface or even an earthquake causing the sand to be agitated. You are likely to find quicksand around riverbanks, lake shorelines, marshes, beaches, near underground springs or any place where an uprising of water over saturates and agitates the sand.

The next time you are standing barefoot on the beach, think about the properties of quicksand. Normally, the grains of wet sand are compressed together tightly and this firm ground easily supports your weight. The friction between grains of wet sand is strong enough to make it easy to build sand castles. However, when the sand on the beach is flooded with an excess amount of water, the agitated sand particles begin to move, separate, and quickly wash away right out from under your feet!

This activity is a great example of how to use a model to study something that most of us will never see in person. While the cornstarch and water mixture is not real quicksand, its behavior is strikingly similar. The use of these kinds of models are an important part of a scientist's research into the areas of the unknown.

Additional Info: Escaping from Quicksand

According to The Worst-Case Scenario Survival Handbook, escaping from quicksand is easier than you might think. Stepping into quicksand is like stepping in a pond of goo. Your weight causes you to sink. A person's natural instinct is to thrash around in an attempt to get out. In fact, this is the worst thing you could do because you only succeed in forcing yourself down farther in the quicksand pit. The best thing to do is to move slowly to bring yourself to the surface, lie back, and try to float on your back. According to the experts, you'll be able to use your arms to slowly paddle to safety.

GAK - Elmer's Glue Borax Recipe vs. PVA Slime

Using the Scientific Method, can students produce a new non-newtonian fluid?

Is it a solid? Is it a liquid? Just what is this slimy, stringy, rubbery stuff? This variation on slime will probably remind you of a similar substance found in many toy stores. This is the most popular version of "slime" among teachers because it's so easy to make and serves as a great visual tool for introducing students to changes in state and non-Newtonian fluids.

Materials

- Elmer's Glue® (8 oz bottle of Elmer's Glue-All)
- Borax (a powdered soap found in the grocery store)
- Clear PVA (polyvinyl alcohol available at stevespanglerscience.com)
- Large mixing bowl
- Plastic cups (8 oz size works well)
- Measuring Spoons
- Stir sticks
- Measuring cup
- Food coloring (the spice of life)
- Water
- Paper towel (hey, you've got to clean up!)
- Zipper-lock bags
- Two sealable jars per group
- Water

Instruct Students:

The unique physical and chemical properties of a non-Newtonian substance or mixture can be changed by the amount of each different ingredient used to make them. Sometimes the amount of one ingredient compared to the amount of another ingredient can make a big difference. This is called a ratio, and a ratio can be useful to know how much of each ingredient to add to your mixture so you will end up with a mixture that has desirable properties. Chemical properties are qualities that can be observed during a chemical reaction, like when vinegar reacts with baking soda. Physical properties are qualities that can be observed during physical change in the absence of a chemical reaction, like the melting of an ice cube. Physical properties can be used to describe the state of a chemical, which can be a solid, liquid, plasma, gas, etc.

In this experiment, a new non-newtonian substance will be created and its properties observed and recorded in the appropriate place in your notebook. For the measurement of the chemicals in this lab, please keep in mind that 1Tbsp = 3 tsp.

First you will need to prepare solution #1, the 50% glue solution, which is made up of half glue and half water.

- Add one cup of glue and one cup of water to one of the jars.
- Tightly secure the lid to the jar and shake until glue is fully diluted, and no gooey clumps remain.

Using a permanent marker, students will label this jar "Solution #1: 50% Glue".

- Next, they will make solution #2, the Borax solution, which is made up of 4% Borax in water. Usually you would weigh the borax, but you can approximate this solution by adding 2 tsp Borax to 1 cup of warm water to a jar. Tightly secure the lid to the jar and shake until no particles of Borax remain, and the solution is clear.

Using a permanent marker, students will label this jar "Solution #2: 4% Borax".

Now students will add Solution #1 and Solution #2 together in different ratios, to see what properties the final mixture will have. First we need to make a data table, like the following example:

Solution #1	Solution #2	Observations	Physical Properties
1 TBSP	3 TBSP		
2 TBSP	2 TBSP		
3 TBSP	1 TBSP		

For each mixture, first add the correct amount of Solution #1 (50% Glue) to a Zip-lock baggie.

Then add the corresponding amount of Solution #2 (4% Borax) to the baggie.

Seal the baggie, and using their fingers students will squish the mixture around to mix together the ingredients and then write down their observations in their data tables.

When the mixture begins to form a sticky glob, they can take it out of the baggie. The gak will thicken gradually. Once it is obvious that something has changed, the gak should be taken out of the cup and placed into the hands of a lab partner who will knead it. If it is still gooey and creamy, more borax will be needed the next time. If it is rubbery and brittle, probably too much borax was added.

They will then write down their description of the physical properties of the material in their table.

Remind students to use descriptive adjectives such as runny, slimy, sticky, hard, soft, bouncy, etc.

Scientists use properties to describe all of the unique qualities of a chemical or a mixture of chemicals. To do this they use descriptive language, or words that are used to describe objects.

Some descriptive words used to describe a chemical might be: hot, cold, squishy, hard, soft, crystalline, granular, smooth, liquid, clear, opaque, runny. There are many different qualities to be described. You just need to find the right words to use.

Which ratio of ingredients produced the best product? How much borax solution did you actually end up adding to the glue mixture in all? What will you call your new product?

Comparison Study: PVA Slime

Have students repeat the process they used to create Oobleck Putty, but instead of using white glue, they will use PVA (polyvinyl alcohol) and the borax solution.

PVA (polyvinyl alcohol) is used by the plastics industry to form surface coatings and to make surface films resistant to gasoline. It's also used to make artificial sponges, hoses, and printing inks. If you check out the ingredients of contact lens wetting solutions, you may find PVA used as a lubricant and a cleanser.

Clean up is easy if you have water and paper towels for slimy hands and for surfaces that have been "accidentally" slimed. When you're finished, you can just throw the slime and materials into the trash. Or, you could toss the slime back into the zipper-lock bag and send it home with your young scientists.

Compare and Contrast:

The properties of each material should be explored. Try to shape it and record what happens. Try to stretch it slowly, and record what happens. Then stretch it more rapidly, and record what happens. Try to bounce it. Record all observations in the appropriate place in your lab notebook.
For one last test, break the gak into two pieces. Then gently hold the two pieces in contact again (without forcing it) for at least a minute. Record what you observe.
Once students are finished with the basic observations, the gak should be stored in a plastic bag.

How does it work?

Discuss: Use information from the entire class to infer what each reactant (ingredient) does.
Slime stretches in a most unusual way. If you try to stretch slime quickly, it will literally break in half. If you stretch the slime slowly, however, it will get longer and longer and longer. Why? Scientists consider slime to be a "Non-Newtonian Fluid" which means that it behaves like both a solid and a liquid at the same time. When you apply pressure, it turns into a solid (so to speak) and breaks apart. When you let slime flow like a liquid, it stretches with no problem.
Most liquids, such as water, are made up of small, unconnected molecules bouncing around and tumbling over and into one another. These single, unconnected molecules are called *monomers*. Monomer liquids flow easily and are seldom gooey or sticky to the touch. In other substances, the monomers are linked together in long chains of molecules known as *polymers*. These long chains don't flow easily at all. Like a bowl of cooked spaghetti, they sort of roll over and around one another. Liquid polymers tend to be a lot gooier and flow more slowly than liquid monomers.
Using the example of cooking spaghetti we can better understand why this polymer behaves in the way it does. When a pile of freshly cooked spaghetti comes out of the hot water and into the bowl, the strands flow like a liquid from the pan to the bowl. This is because the spaghetti strands are slippery and slide over one another. After awhile, the water drains off of the pasta and the strands start to stick together. The spaghetti takes on a rubbery texture. Wait a little while longer for all of the water to evaporate and the pile of spaghetti turns into a solid mass -- drop it on the floor and watch it bounce.
Many natural and synthetic polymers behave in a similar manner. Polymers are made out of long strands of molecules like spaghetti. If the long molecules slide past each other easily, then the substance acts like a liquid because the molecules flow. If the molecules stick together at a few places along the strand, then the substance behaves like a rubbery solid called an elastomer. Borax is the compound that is responsible for hooking the glue's molecules together to form the putty-like material. There are

several different methods for making this putty-like material. Some recipes call for liquid starch instead of Borax soap. Either way, when you make this homemade Silly Putty you are learning about some of the properties of polymers.

Elmer's Slime, Oobleck, or silly putty is very easy to make, but it's not exactly what you'll find at the toy store. So, what's the "real" slime secret? It's an ingredient called polyvinyl alcohol (PVA). The cross-linking agent is still Borax, but the resulting slime is longer lasting, more transparent... it's the real deal.

You might use this analogy to help the kids understand what happened. Picture a box full of tiny, steel chains that slip and slide easily across one another. Each chain is made up of hundreds of individual links but one chain is not connected to another chain. If you reach in and grab one chain and pull it out, that's what you get: one chain. Suppose you stir a whole bunch of tiny magnets into the box of chains. The magnets randomly connect the chains together in many locations, making a single, large blob of chains. Now if you reach in and grab one chain, what will happen? You'll lift out the entire pile.

Adding Borax solution to the PVA does pretty much the same thing (only it's a chemical, not a magnetic, connection). Borax loves to connect with water and billions of Borax molecules randomly link trillions of water molecules found anywhere on the chains of PVA. Now when you pull out one PVA chain, all the rest come with it in a blob. In the chemical reaction that the kids made, they got a slow-moving, glistening mass that's known as a hydrogen-bonded, cross-linked polymer gel (slime is much easier to say).

In an effort to understand the world around them, scientists design models of what they can't see in order to understand and explain what they can see. The idea is to figure out how various molecules inside materials are arranged to produce the observable results. In general, molecules can be "seen" only with some serious electronic help and these images serve only to assist with the inferences of the model. If your kids understand how this inference modeling works, then they're way ahead of the game in their understanding of molecules.

What is PVA (polyvinyl alcohol) used for anyway?

PVA is used by the plastics industry to form surface coatings and to make surface films resistant to gasoline. It's also used to make artificial sponges, hoses, and printing inks. Also, if you look at the ingredients of contact lens wetting solutions, you may find this stuff as a lubricant and a cleanser. The PVA solution in this kit contains coloring and a special disinfectant to help resist pesky germs on those not-so-clean hands.

The Borax solution is used in the wood industry to protect against fungus and to make new wood look old. It's also used to solder metals, to glaze and enamel pottery, to whiten your wash, and serves as an excellent soap in the medical industry. The students can add more Borax to achieve a firmer slime, but there is a point of diminishing returns before the slime breaks down and turns back into a liquid.

Additional Info: Glacier GAK

The unique slow moving properties of the GAK simulate the movement of a glacier. At a molecular level, ice is comprised of stacked layers of molecules with relatively weak bonds between the layers. This is similar to the makeup of our GAK molecules. Ice can stretch or break depending on the amount of pressure applied. If there is a lot of pressure or a high strain rate, ice will crack or break (causing crevasses in glaciers). When the pressure is lower or the strain rate is small and constant, ice can bend or stretch. The steady pressure from the bulk of the ice mass and the pull of gravity cause the glacier to flow slowly (so slowly you can't see it) downhill, bending like a river of ice.

Ice Cube Rope

Some people may lasso the moon, but have you ever thrown a lasso around a block of ice?

Most normal people won't put effort into trying to catch a solid chunk of ice with a rope. Luckily, we aren't most people… and we certainly are not normal. We wondered if it was possible to pick up an ice cube by using a rope. Seems simple enough. But here's the catch... you can't tie the rope around the ice cube! Believe it or not, it is possible, you just need a little change of state.

Materials

- Kosher salt
- string
- cups
- water
- ice cubes

1. Take an ice cube out of your freezer and drop that chilly block in a glass of water.
2. The ice cube floats! But now you've got to get the ice cube out of the water… without grabbing it. All you can use is a length of string!
3. Try laying the string across the top of the ice cube. Let the string sit there for a few seconds and try to lift the ice cube out of the water. Did it work?
4. Now lay the string across the top of the ice cube again. This time, sprinkle some Kosher salt onto and around the string as it lays on the ice cube.
5. Again, wait a few seconds with the string sitting atop the ice cube.
6. Carefully lift the string. Did it work this time? (If it didn't, try adding some more salt and try it again.)

How does it work?

Water is a very fickle material. The introduction of a contaminant will instantaneously drop the freezing point below 32° and make it so that it won't freeze until it's colder than 32° and if it won't' freeze, that means it stays a liquid Crazy,right? It's true. You witnessed it with the experiment you just did. water freezes at a temperature of 32°Fahrenheit (0°Celsius). Salt dissolves in water pretty fast. When you sprinkle salt on ice, the salt lowers the freezing point of the water, keeping it from re-freezing as easily and helping to melt the rest of the ice. This is called lowering the freezing point. When you added the salt, you introduced a contaminant to the frozen water of the ice. The ice then melted and refroze around the string as the "contaminated" H_2O molecules were cooled by the surrounding molecules.

Additional Info

- What do students think would happen if they tried to freeze salt water?
- What about trying to boil salt water?

- What conclusions can they draw about the introduction of contaminants to water?
- How did they change the state of water? From what to what?
- Which stuff melts ice the best? Does the chemical called Melt-Away (which is made out of calcium chloride and magnesium chloride) work better than rock salt? Here’s an experiment you can try. Add one teaspoon of calcium chloride to 1/4 cup of water in a plastic bag. Feel the water - it’s getting hot! Why?

Freezing Point Depression and Colligative Properties (aka Ice Cream in a Bag)

Don't Freezing Point Depression and Colligative Properties just sound delicious? Use science know-how to create a tasty vanilla treat!

Legend has it that the Roman emperor, Nero, is credited as the first person to make ice cream. Nero commanded slaves to bring snow down from the mountains, which was then used to freeze the flavored cream mixture. The secret was to lower the freezing point of ice in order to freeze the cream. How? The scientific secret is salt! Here's a scientific recipe that you can use at home to make your own ice cream.

Materials

- 1/2 cup of Half & Half (per bag)
- 1 tablespoon sugar (per bag)
- 1/2 teaspoon vanilla extract (per bag)
- 1/2 to 3/4 cup sodium chloride (NaCl) as table salt or rock salt
- 2 cups ice
- 1-quart ZiplocTM freezer bag (per student) store brand bags or storage bags tend to leak
- 1-gallon ZiplocTM freezer bag (per student)
- measuring cups and spoons
- spoons
- Cheap thermometers
- Gloves or paper towels (those bags get cold!)
- Optional: add ins such as crushed sandwich cookies

1. Add sugar, half and half, and 1 vanilla to the quart ziploc™ bag. Seal the bag securely.
2. Put 2 cups of ice into the gallon ziploc™ bag.
3. Use a thermometer to measure and record the temperature of the ice in the gallon bag.
4. Add 1/2 to 3/4 cup salt (sodium chloride) to the bag of ice.
5. Place the sealed (check it again, you don't want leaks) quart bag inside the gallon bag of ice and salt. Seal the gallon bag securely.
6. Gently rock the gallon bag from side to side. It's best to hold it by the top seal or to have gloves or a cloth between the bag and your hands because the bag will be cold enough to damage your skin.
7. Continue to rock the bag for 10-15 minutes or until the contents of the quart bag have solidified into ice cream.
8. Open the gallon bag and use the thermometer to measure and record the temperature of the ice/salt mixture.
9. Remove the quart bag, open it, serve the contents into cups with spoons and ENJOY!

Explanation: What does the salt do?

Just like in our lasso experiment salt mixed with ice in this case also causes the ice to melt. When salt comes into contact with ice, the freezing point of the ice is lowered. The lowering of the freezing point depends on the amount of salt added. The more salt added, the lower the temperature will be before the salt-water solution freezes. For example, water will normally freeze at 32 degrees F. A 10% salt solution freezes at 20 degrees F, and a 20% solution freezes at 2 degrees F. When salt is added to the ice (or snow), some of the ice melts because the freezing point is lowered. Always remember that heat must be absorbed by the ice for it to melt. The heat that causes the melting comes from the surroundings (the warmer cream mixture). By lowering the temperature at which ice is frozen, you were able to create an environment in which the cream mixture could freeze at a temperature below 32 degrees F into ice cream.

Ice has to absorb energy in order to melt, changing the phase of water from a solid to a liquid. When you use ice to cool the ingredients for ice cream, the energy is absorbed from the ingredients and from the outside environment (like your hands, if you are holding the baggie of ice!). When you add salt to the ice, it lowers the freezing point of the ice, so even more energy has to be absorbed from the environment in order for the ice to melt. This makes the ice colder than it was before, which is how your ice cream freezes. Ideally, you would make your ice cream using 'ice cream salt', which is just salt sold as large crystals instead of the small crystals you see in table salt. The larger crystals take more time to dissolve in the water around the ice, which allows for even cooling of the ice cream.

You could use other types of salt instead of sodium chloride, but you couldn't substitute sugar for the salt because (a) sugar doesn't dissolve well in cold water and (b) sugar doesn't dissolve into multiple particles, like an ionic material such as salt.

Compounds that break into two pieces upon dissolving, like NaCl breaks into Na^+ and Cl^-, are better at lowering the freezing point than substances that don't separate into particles because the added particles disrupt the ability of the water to form crystalline ice. The more particles there are, the greater the disruption and the greater the impact on particle-dependent properties (colligative properties) like freezing point depression, boiling point elevation, and osmotic pressure. The salt causes the ice to absorb more energy from the environment (becoming colder), so although it lowers the point at which water will re-freeze into ice, you can't add salt to very cold ice and expect it to freeze your ice cream or de-ice a snowy sidewalk (water has to be present!). This is why NaCl isn't used to de-ice sidewalks in areas that are very cold.

Additional Info

In 1846, Nancy Johnson invented the hand-cranked ice cream churn and ice cream surged in popularity. Then, in 1904, ice cream cones were invented at the St. Louis World Exposition. An ice cream vendor ran out of dishes and improvised by rolling up some waffles to make cones.

Energy to Burn

Experiments:

1. UV Beads
2. Solar bag
3. Solar S'mores
4. Solar Power! Solar Powered Transforming Robots, Solar Bugs, or Solar Racing Cars
5. Solar Bottle Motor Boat
6. Magic Rollback Can
7. Color Mixing Wheel
8. Magic Pendulum Catch
9. Pendulum Perils
10. Build a Roller Coaster Project

Kindergarten

Key Terms:

- Sun
- Temperature
- Change
- Cloud
- Collect
- Day
- Night
- Tools
- Weather
- Observe
- Senses
- Air
- Position
- Rules
- Time
- Afternoon
- Morning

Key Standards:

- 7.10.2 Investigate the temperature differences in various locations, ex. around the school. Investigate the effect of the sun on a variety of materials. Discuss and record the results.
- 7.11.1 Use a variety of objects to demonstrate different types of movement. (e.g., straight line/zigzag, backwards/forward, side to side, in circles, fast/slow).

1st Grade

Key Terms:

- Heat
- Matter
- Location
- Investigate
- Prediction
- Property
- Push/Pull
- Light
- Invent
- Measure/Measurement
- Estimate
- Minute
- Direction
- Equal to
- Data
- Graph
- Greater than/Less than
- Unit (standard/non-standard)

Key Standards:

- 7.10.3 Compare the temperature at different places around the school such as black top driveway, lawn, concrete areas, side of the building, under a shade tree, wet area, in the ground and investigate the effect of the sun on land, water, and air.

- 7.11.1 Use familiar objects to explore how the movement can be changed and investigate how forces (push, pull) can move an object or change its direction.
- 7.11.2 Investigate and explain how different surfaces affect the movement of an object.

2nd Grade

Key Terms:

- Celsius/Fahrenheit
- Compare/contrast
- Depend
- Distance
- Energy
- Infer
- Investigate
- Observation
- Reasoning
- Scientific inquiry
- Scientist
- Similarities/differences
- Transform
- Type
- Elapsed time/time interval
- Second (time)
- Quarter-hour
- Unknown
- Reflect
- Inch
- Centimeter
- Foot
- Dimensions

Key Standards:

- 7.6.1 Observe and collect data on the sun's position at different times of the day.
- 7.10.1 Identify and explain how the sun affects objects on the surface of the earth.
- 7.10.2 Investigate how the sun affects various objects and materials.

3rd Grade

Key Terms:

- Atmosphere
- Conductor
- Force
- Cause
- Effect
- Tools
- Solar System
- Frequency table, tally chart
- Fact
- Opinion

Key Standards:

- CU 7.10.1 Associate the sun's energy with the heating of objects, ex. melting of an ice cube placed in a window.
- CU 7.10.2 Investigate various materials to explore heat conduction and design and conduct an experiment to investigate the ability of different materials to conduct heat.
- SPI 7.10.1 Use an illustration to identify various sources of heat energy.
- SPI 7.10.2 Classify materials according to their ability to conduct heat.
- CU 7.11.1 Plan an investigation to illustrate how changing the mass affects a balanced system and explore how the direction of a moving object is affected by unbalanced forces.
- SPI 7.11.1 Identify how the direction of a moving object is changed by an applied force.
- SPI 7.11.2 Demonstrate how changing the mass affects a balanced system.

4th Grade

Key Terms:

- Friction
- Convert
- Drawing Conclusions
- Radiant Energy
- Reflection
- Refraction
- Transparent
- Translucent
- Relationship

- Prediction
- Making inferences
- Accuracy

Key Standards:

- SPI 7.10.1 Identify different forms of energy, such as heat, light, and chemical.
- SPI 7.10.2 Determine which surfaces reflect, refract, or absorb light.
- SPI 7.10.3 Determine whether a material is transparent, translucent, or opaque.
- CU 7.10.2 Design an experiment to investigate how different surfaces determine if light is reflected, refracted, or absorbed.
- CU 7.10.3 Gather and organize information about a variety of materials to categorize them as translucent, transparent, or opaque.
- CU 7.11.1 Identify the position of objects relative to fixed reference points.
- CU 7.11.2 Design an investigation to identify factors that affect the speed and distance traveled by an object in motion.
- CU 7.11.3 Complete a coordinate graph to describe the relative positions of objects.
- CU 7.11.4 Plan and execute an investigation that demonstrates how friction affects the movement of an object.
- CU 7.11.5 Design and implement an investigation to determine that the speed of an object is equal to the distance traveled over time.
- SPI 7.11.1 Describe the position of an object relative to fixed reference points.
- SPI 7.11.2 Identify factors that influence the motion of an object.
- SPI 7.11.3 Determine the relationship between speed and distance traveled over time.

5th Grade

Key Terms:

- Convection
- Conduction
- Model
- Radiation
- Edge

Key Standards:

- CU 7.10.1 Design and conduct an investigation to demonstrate the difference between potential and kinetic energy.
- CU 7.10.2 Create a graphic organizer that illustrates different types of potential and kinetic energy.
- CU 7.10.3 Describe the differences among conduction, convection, and radiation.
- CU 7.10.4 Create a poster to illustrate the major forms of energy.
- CU 7.10.5 Demonstrate different ways that energy can be transferred from one object to another.
- SPI 7.10.1 Differentiate between potential and kinetic energy.
- SPI 7.10.2 Use data from an investigation to determine the method by which heat energy is transferred from one object or material to another.
- 7.11.1 Predict how the amount of mass affects the distance traveled given the same amount of applied force.
- 7.11.2 Prepare statements about the relationship among mass, applied force, and distance traveled.

- 7.11.3 Design and conduct experiments using a simple experimental design to demonstrate the relationship among mass, force, and distance traveled.
- SPI 7.11.1 Explain the relationship that exist among mass, force, and distance traveled.
- SPI 7.12.1 Recognize that the earth attracts objects without touching them.
- SPI 7.12.2 Identify the force that causes objects to fall to the earth.

6th Grade

Key Terms:

- Cause and effect
- Conductivity
- Control
- Criteria
- Design Constraint
- Elastic Potential Energy
- Energy Transformation
- Gravitational Potential Energy
- Protocol
- Prototype
- Variable
- Simulation

Key Standards:

- 7.8.2 Design an experiment to investigate differences in the amount of the sun's energy absorbed by a variety of surface materials.
- 7.10.1 Compare potential and kinetic energy.
- 7.10.3 Design a model that demonstrates a specific energy transformation.
- 7.10.4 Explain why a variety of energy transformations illustrate the Law of Conservation of Energy.
- SPI 7.10.1 Distinguish among gravitational potential energy, elastic potential energy, and chemical potential energy.
- SPI 7.10.2 Interpret the relationship between potential and kinetic energy.
- SPI 7.10.3 Recognize that energy can be transformed from one type to another.
- SPI 7.10.4 Explain the Law of Conservation of Energy using data from a variety of energy transformations.

7th Grade

Key Terms:

- Phenomenon
- Diffusion
- Momentum
- Speed
- Velocity
- Physical Processes
- Function

Key Standards:

- 7.11.3 Summarize the difference between the speed and velocity based on the distance and amount of time traveled.
- 7.11.4 Recognize how a net force impacts an object's motion and investigate how Newton's laws of motion explain an object's movement.
- SPI 7.11.3 Apply proper equations to solve basic problems pertaining to distance, time, speed, and velocity.
- SPI 7.11.4 Identify and explain how Newton's laws of motion relate to the movement of objects.

8th Grade

Key Terms:

- Variation
- Inferring
- Inductive Reasoning
- Deductive Reasoning
- Gravitation (universal law)
- Exchange

Key Standards:

Energy and Motion are not addressed at this grade level.

High School

Key Terms:

- Friction (sliding, rolling, static)
- Greenhouse effect
- Gravitational potential energy
- Resistance
- Thermodynamics (conduction, convection, radiation)

Key Standards:

- 3260.4.1 Differentiate between renewable and nonrenewable resources.
- 3260.5.5 Describe energy saving alternatives to common appliances and electronic devices and explore energy saving alternatives.
- 3260.5.1 Construct visual displays/models to illustrate the source, uses, advantages, disadvantages, availability, and cost of energy resources (i.e. coal, petroleum, nuclear, solar, hydro, wind, geothermal, biofuels, Hydrogen, tidal, "OTEC").
- 1.1.6 Investigate projectile motion.
- 1.1.15 Relate inertia, force, or action-reaction forces to Newton's three laws of motion.
- 1.1.17 Investigate the definitions of force, work, power, kinetic energy, and potential energy.
  Force: $F = ma$;
  Work: $W = Fd$;
  Power: $P = (F\Delta d)/ \Delta t$;
  Kinetic Energy: $EK = 0.5mv2$;
  Potential Energy: $EP = mg\Delta h$.
- SPI.1.1.3 Given Newton's laws of motion, analyze scenarios related to inertia, force, and action-reaction.

Color Changing UV Beads

Become a UV detective with amazing UV-sensitive beads.

Materials

- Color Changing UV Beads
- Zipper-Lock Bags
- Cord or white pipe cleaners (for bracelets)
- Sunscreens (a variety)
- Sunglasses

Show students some UV beads and allow them to play with them. Have them take them outside and watch what happens? What happened? Have students form hypotheses and test them to determine what is making the beads turn from white to colored and back again. Guide them towards a discussion of sunlight.

UV Beads have a chemical substance embedded into the plastic that will change color when exposed to UV radiation (sunlight). When indoors the beads will remain white as long as they are kept away from windows or doors where UV light can leak into the room.

Once students determine the cause of the change here are some good experiments to try with the UV Beads, though students are sure to come up with their own.

The Sunscreen Factor

Not all sunscreen lotions are the same, as evidenced by a lobster-like appearance after a day of playing outside. SPF 15 sometimes just doesn't do the trick. Instead of using your skin as a detector of ultraviolet light (UV), try experimenting with Energy Beads or UV Color Changing Beads.

UV Beads have a chemical substance embedded into the plastic that will change color when exposed to UV radiation (sunlight). When indoors, the beads will remain white as long as they are kept away from windows or doors where UV light can leak into the room. It's a simple and amazing way to test the effectiveness of sunscreen.

The UV Color Changing Beads experiment is a great experiment because it asks a question, runs a test, asks another question, runs a test, and finally comes to a conclusion about the effectiveness of different SPF's in sunscreen. The experiment clearly controls the variable by only changing the SPF. The SPF is the variable in the experiment. The brand of sunscreen stays the same and is the control in the experiment. If you use different brands of sunscreen, you don't know if the SPF or the brand causes the result.

UV Color Changing Beads are available from Steve Spangler Science. Just make sure you only use one color of beads so that you don't introduce another variable. Different colors of beads might have different UV-detecting powers!

- UV Color Changing Beads

- Sunscreen with a variety of SPF factors (all the same brand)
- Ziploc bags
- Permanent marker
- Camera

Helpful Hints:

- To prove that the UV Color Changing Beads really work, have students run their first test by just taking some of them outside on a sunny day. They should see that they turn color very quickly.
- Their second test will use a bag full of beads with no sunscreen as the control and several other bags of beads with a layer of sunscreen spread in an even coat on the outside of the bag. Have them try to apply the same amount of sunscreen to each bag and use the same number of beads in each bag.
- Label each bag with the permanent marker so they know which bag is which—label the bag as either the control (no SPF) or with the SPF number used on that particular bag.
- Expose the bags of beads to UV rays for the same amount of time in the same place so that you aren't introducing other variables. Try exposing them to the sunlight for 5 minutes and then note any color changes in the beads.
- The beads will always change color, despite the sunscreen because they are very sensitive. Students will need to develop some kind of rating scale (maybe 1-5) with 1 being no change in color and 5 being the most extreme color change or the most "burning."

Have students follow the Scientific Method:

Big Question

What do they want to find out? In this case, what SPF provides the best protection against UV rays?

Hypothesis

What do they predict will happen? Have them write it down. The hypothesis is also called the "I Think Statement" because it begins with "I think that ___________________________."

Materials

What supplies do they need to complete their experiment? Students can think of the materials list as the ingredients for a recipe. If something is left out, the experiment won't work.

Procedure

What steps will they take to run their tests and make their comparisons? The procedure is like a roadmap to get them to their final destination. In this case, they will explain how they set up the bags of beads and how they designed and ran their tests of the effectiveness of the SPF factor of the sunscreen.

Data

What were their results? In this case, document the effectiveness of each SPF as it compares to the bag with no sunscreen applied to it. Because there is no concrete way to measure their results, they can take photographs and design a rating scale (1-5) of the UV-protecting powers of each SPF.

Observations/Big Discoveries

What did they discover? List things they discovered along the way about the beads, the sun, and the effectiveness of sunscreen. Discoveries are not right or wrong; they are just statements about what they noticed during the experiment. The discoveries lead to their conclusion.

Conclusion

Was their hypothesis correct? Using their data and observations/discoveries, have students explain if their prediction was correct. Remind students, it is totally okay to be wrong! That's part of science. If their hypothesis was incorrect, why do they think so?

If they wanted to change this experiment, they could examine how your results change when they run the same tests on a cloudy day. They could also examine the effectiveness of different brands of sunscreen (using the same SPF for each one so that you only have one variable). You could change the experiment by examining the effect of the thickness of the coating of the sunscreen (using only one brand and one SPF – only changing the thickness of the layer of sunscreen). Other variations to the experiment might examine the effect of the time of day on the UV-protective powers of sunscreen or might determine if the "age" of a sunscreen makes a difference in its effectiveness (should you get rid of those old bottles of sunscreen in your closet or do they still work just as well?).

The Sunscreen Factor experiment clearly follows the scientific method and generates lots of other questions that would be great follow-up experiments. Does it pass the C^3 test? Does it *change* something, *create* an experiment, and *compare* results? Absolutely!

More ideas to test:

Light Test

Place a handful of UV beads near a fluorescent light. Do any of the beads change color? Can you get a sunburn or a tan by sitting next to a fluorescent light?

Black Light

"Black light" (long wave ultraviolet light) can also be used to change the color of the beads. You can purchase a black light at many specialty stores or hardware stores that have a large section of light bulbs. Steve Spangler Science also sells them. Sometimes those high intensity lights (mercury vapor) found in a gymnasium emit just enough UV light to make the beads barely change color.

Cloudy Day

Test to see if the beads change color on a cloudy day. If they change color, then you can see why doctors warn people to wear sunscreen even on a cloudy day. Observe how well the beads change color when exposed to sunlight at different times of the day. According to your data, what time of day does the sun give off its most intense UV light?

Sunglasses

Test the ability of your sunglasses to block out ultraviolet light by covering a few beads with the lens of your sunglasses. If the beads do not change color, your sunglasses block out harmful ultraviolet light from your eyes. If not, you paid too much for that UV coating!

UV Filters

1. Upon refilling a prescription at his local pharmacy, Jim Stryder, a solar science educator, noticed a marking on his brown prescription bottle that read – "UV BLOCKING PLASTIC." Being the solar science enthusiast he is, Jim immediately filled an empty prescription bottle with Energy Beads. To his amazement, the bottle blocked out nearly 100% of the UV light! Come to find out that many drugs are sensitive to damaging UV light, so the bottle is specially designed to preserve the life of your prescription. Jim Stryder suggests testing a variety of plastic bottles and transparent containers to see which ones block out the UV rays the best. Hmmm… this sounds like the making

of a great new science fair project! Jim Stryder's idea would be great to explore for a science fair project. However, we can't just put UV Beads in a prescription bottle and call the project finished. If you just put the beads in the bottle to show that the bottle blocks the UV rays, you've merely demonstrated that concept -- it is a science demonstration, NOT an experiment. To make the UV Beads and prescription bottle activity an actual science experiment, students have to use C^3. Change something (identify a variable), run some more tests, and make some comparisons.

- Find several different types of medicine bottles and test to see which one is the most effective in blocking the damaging UV rays. Be sure to use the same number and color of UV Beads and expose the beads to the light through the bottle for the same amount of time to standardize the conditions as much as possible.
- Examine the UV blocking powers of other types of bottles, such as plastic vs. glass bottles or different brands or styles of water bottles.
- What else claims to have UV blocking powers? Sunglasses? Window tinting films? Camera lens filters? Sunscreen? Choose a variable and run some tests to see if the UV blocking claims are true. For example, are polarized sunglasses really that much better than regular sunglasses at blocking out the harmful UV rays of the sun?

2. Test a variety of glass and plastic containers to determine which materials block out UV light. Some milk companies claim their special plastic containers block out UV light better than other companies containers and that preserves their milk’s flavor. Do they really work better?

Make a UV Bead Bracelet

Thread a few beads onto a piece of white pipe cleaner or string to make a bracelet. Remember to stay away from any door or windows where ultra-violet light could come into the room. When you're finished, cover the bracelet with your hand and walk outside into the sunlight. Don't take your eyes off the beads as you expose them to sunlight. Like magic, the beads change from white to a rainbow of colors.

How does it work?

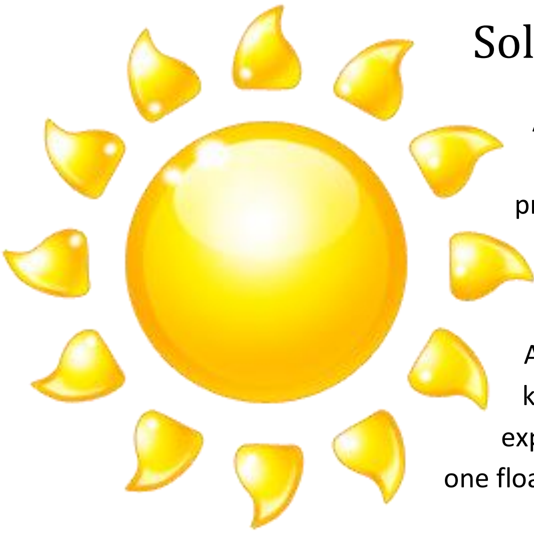
The UV Beads contain different pigments that change color when exposed to ultraviolet light from any source, including the sun. The beads are all white in visible light. In UV light, depending on the pigment added to each bead, you will see different colors. Each bead will change color about 50,000 times before the pigment will no longer respond to UV light.

The term "light" is often used as a generic word to describe many different forms of light such as incandescent light, fluorescent light, or sunlight, for instance. However, not all light is made up of the same energy. Using Energy Beads, you will be able to uncover an invisible form of light energy called ultraviolet light. None of the energy in the ultraviolet region of the light spectrum is visible to the naked eye. Just as there are many different colors of wavelengths in the visible spectrum (red, yellow, green, blue...), so are there many wavelengths of ultraviolet light.

First, there is long wave ultraviolet light (300 to 400 nanometers), which most of us recognize as "black light" - the light that is often used to make decorations glow in discos and theatrical productions. Long wave UV passes easily through plastic and glass.

Short wave ultraviolet light (100 to 300 nm) is used to kill bacteria, hasten chemical reactions (as a catalyst), and is also valuable in the identification of certain fluorescent minerals. Unlike long wave UV, the short wave UV cannot pass through ordinary glass or most plastics. The shortest wavelengths cannot even travel very far through the air before being absorbed by oxygen molecules as they are converted into ozone.

UV Beads are the perfect tool for understanding how solar radiation can be harmful and to recognize preventative measures that can be taken to reduce the risks associated with exposure to sunlight. When you expose bare skin to sunlight, your skin will either burn or tan (which doctors warn is still not healthy for your body). UV radiation wavelengths are short enough to break chemical bonds in your skin tissue and, with prolonged exposure, your skin may wrinkle or skin cancer may appear. These responses by your skin are a signal that the cells under your skin are being assaulted by UV radiation.



Solar Bag

A Solar Bag is a long plastic bag made from a very thin plastic and colored black to absorb solar energy. The heated air inside the bag provides buoyancy and causes the bag to float. Over the years, it's become a very popular science demo for teachers to share with their students as they explore the properties of air.

Although the Solar Bag looks similar to a regular, black trash bag, the key difference is the thickness of the plastic. But, a great science fair experiment might be testing bags of different thicknesses to see which one floats the highest!

Materials:

- Solar Bag (available from stevespanglerscience.com)
- String
- Large Black Trashbags
- Clear Packing Tape
- Old pillowcase

1. Notice that the bag is made out of a light weight plastic material. Use caution when handling the bag since the plastic will tear easily.
2. Carefully remove the plastic bag from the packaging and locate one of the open ends of the bag. Tie a knot in this end of the bag.
3. The best time for a launch is in the morning when the temperature of the air outside is cool. We have not had much success with a launch attempt in the middle of a hot day.
4. Select an appropriate location for the launch. Find a park or an open field clear of any buildings, trees, and power lines to conduct the launch. Select a day to do the experiment when it’s sunny and free of any wind.
5. Unroll the Solar Bag onto a soft surface like grass. Avoid pavement or gravel since the plastic material can easily tear. Have one person hold the bag open as you begin to run around and scoop up air. Believe it or not, you can inflate the bag in just a couple of minutes.
6. Fill the bag with air until approximately 2 feet of deflated plastic remains in your hand. Slide your hand along the plastic to make sure that the air in the inflated portion of the bag is stretching the plastic tight. Tie a knot in the end of the bag, and tether it to the ground with Solar Bag String.

How does it work?

The remainder of the work is done by the sun. Gather around the giant bag but try not to touch it - sharp fingernails will easily puncture the very thin plastic. Be careful, the outside of the bag also gets very hot to the touch. What is happening to the gas molecules inside the bag? Of course, as the sun warms the air molecules in the bag, their movement begin to speed up. Since the heated air inside the

bag is less dense, the molecules are spread farther apart, than the cooler air on the outside of the bag, the Solar Bag will float. It's important to remember that it may take as long as ten minutes for the air inside to heat up enough to cause the bag to float.

Testing it Further

Have students hypothesize whether or not a long black trash bag filled with air would work as well as the Solar Bag. Test it.

Is the black color necessary for absorption of solar energy? Will a long white bag work as well? Or another color? Test their theories.

Further Applications:

Discuss with the students what could the solar bags be used for besides teaching about energy and molecules? How would they use it?

Here's how space scientists put it to use!

Scientists from Pioneer Astronautics and Jet Propulsion Laboratory conducted successful tests of its Mars solar balloon inflation system using the Solar Bag.

These photos give you a bird's eye view of what a Solar Bag looks like at about 120,000 feet above the Earth! While you can purchase a Solar Bag, you'll need a few million dollars worth of gadgets to get the bag to float 120,000 feet above the Earth.

Scientists have yearned for many years to make use of Mars' thin carbon dioxide atmosphere to enable airborne exploration. Balloon carried instruments would return an amazing bird's eye view of Mars that you could not get through satellites orbiting or surface exploring. However as attractive as such a mission might be, Mars balloon missions have long been stalled by the challenge of inflating a balloon, very long distance, from a descending Mars entry capsule. Now scientists are working on using solar Bags that would inflate on the way down and heat up due to the sun's energy. On a recent test mission…they worked perfectly! Now, if only we could use them for air travel on Earth!

Additional Info: Storage and Repair

We store the deflated bag in an old pillow case, which helps prevent accidental punctures or tears when it's not being used. If a small tear is spotted, clear packing tape can be used to repair the damage.

A Little Light Cookin'

Most people in the United States use an electric stove, a microwave, or a natural gas stove to cook their food.This is not the case in much of the world. Approximately 50% of the people on Earth cook using fire from burning wood. However, due to overuse, wood is becoming a scarce commodity in many countries. In addition, burning wood is a major source of air pollution. Common fuel sources used for cooking include gas, electricity, microwaves, or wood. What if we ran out of all of these sources or if they were unavailable for use? What could we use instead? One alternative to cooking with wood is using solar cookers. These devices use energy from the sun to cook food without producing any pollution. The sun may shine all day, but is it really warm enough to cook anything? Can we simply put the food outside in the sunshine to cook it? While there are many designs for solar cookers, a simple solar cooker can be made from everyday materials. There are many factors that can influence the effectiveness of a solar cooker including the size of the collector, the orientation of the panel and the color of the container.

In this experiment we will investigate how to use solar power as a cooking fuel.

Why not take advantage of all that sunshine, and put the Sun to work? The idea is simple. If you have ever started anything on fire with a magnifying glass, you have used an uncontrolled solar cooker. The solar cooker you will build will concentrate the sun's rays in order to achieve a temperature suitable for cooking food.

Ask the students to come up with some ideas of how they could use **solar** energy to do some work for them.

Show the students several potential set ups and have to discuss among themselves which materials seem to make a better solar cooker.

- A plain cardboard box, covered with clear plastic sheets
- A cardboard box with black construction paper on the bottom
- A sample of each of the variants

Discuss: The sun's energy can be harnessed to heat water and cook food. The following experimentation demonstrates a simple method of constructing a solar cooker. Solar cookers can be built in a variety of ways, but there are three important elements necessary in building any solar cooker:

1. Directing sunlight: in this design sunlight is directed with reflectors, which help focus a wide area of light on a small space.
2. Absorbing sunlight: this design uses black paint to help gather and absorb sunlight.
3. Providing insulation: plastic wrap, a jar, or a plastic bag can be used to provide an isolative barrier between the food you are cooking and the air.

Depending on class size, students can work in groups of 3-5. Option: Make it a class competition to see whose cooker can most completely cook a certain type of food in a given time. Note: It may take 1-8 hours to cook food.

Have students list the materials they want to use, decide upon a design, create blueprints/draw it, and then build it using the provided materials. Test it, record the temperature on the thermometer every 30 seconds for 10 minutes. At the end of 10 minutes, ask them to report to the group. Whose cooker got to the highest temperature? Continue to keep track of temperatures and rate of cooking, have students graph the information in their journals.

Have students make a diagram of an effective solar oven in their science journals, label the diagram, and explain the role of solar energy and the role each part of the oven plays. Students will record the optimal temperature the oven must reach in order to melt the chocolate and marshmallows or cook their food.

What's Happening:

If students have learned about the greenhouse effect, they may have already guessed how the oven works. The foil flap gathers sunlight and reflects it through the plastic and into the oven, doubling the amount of incoming light. The black paper absorbs the light and converts it to heat, and the clear plastic allows the sun to shine in while keeping all that heat from escaping. (In the greenhouse effect, atmospheric gases allow sunlight to pass through to the earth's surface but keep the heat it generates from escaping back into space.) As more light hits the black paper, more heat is created and trapped. After an hour or so on a sunny day, the oven can be as hot as 275 degrees -- hot enough to melt chocolate and marshmallows.

Discuss: the pros and cons of each design with the students.

1. Have students use their experience, the graph, and the data table to answer the following question: If you were stuck outside on a brutally hot, sunny, summer day which place would be the coolest in terms of a spot to hang around; [1] a parking lot made of tar, [2] a plowed field with no crops, [3] a grassy field, or [4] the beach. Explain!
2. Have students use the graph and data table they tracked to describe the relationship between color of the solar cooker and the increase in temperature, and the effect of additional components.
3. Was the hypothesis (prediction) supported? Explain!
4. Explain [write] the procedure to carry out this experiment.
5. Identify the collector, storage and controls on your solar cooker.
   a. collector: the glass cover that lets the sunlight in the cooker.
   b. storage: the newspaper insulation prevents heat from escaping and the food also will absorb the heat.
   c. controls: the reflectors direct the sun's rays into the cooking area.
6. How does the sunlight cook the food? *The sun's rays are absorbed by the cooker's inside surface and transformed into heat energy.*

7. What parts of the world would a solar cooker work the best? The worst? *Areas that get lots of sunshine on a consistent basis would be the best. Areas where the sunlight is less intense such that it takes a long time to collect the same amount of energy as from a sunny place would be the worst.*
8. What are some advantages/disadvantages of using a solar cooker? *There isn't any waste product, and you can cook in the summer without heating the entire house. /Need a lengthy span of available sunlight, longer cooking times, smaller portions.*
9. What are some health benefits of using a solar cooker in developing countries?
   a. temperatures can reach the point to purify water and to kill bacteria and dangerous diseases, but only on sunny days.
   b. eliminates disease caused by inhaling toxins common to food cooked over wood.
   c. decrease health problems related to constant exposure to smoke and fire.
   d. decrease malnutrition due to the decreased availability of firewood
10. How are solar cookers beneficial to the environment? Ex. *They could reduce the need of fuel gathering (wood, coal, or gas) that can lead to the destruction of forest and agricultural lands. In addition, much of the waste products from burning fossil fuels would be reduced. However, remember that the majority of our energy is consumed for transportation, not cooking food.*
11. What other types of materials could be used in the construction of a solar cooker? Would cost have to be a consideration?
12. Do different interior designs of a solar oven affect its performance?
13. How might changing the type of material used as a reflector in a solar oven affect the temperature reached in a solar oven?
14. Does insulation make a difference in reaching higher temperatures? Why or why not?
15. Can they build a second solar oven that will work more efficiently than the first one?

Variation 1: Solar S'mores

You don't need to build a campfire for your kids to get their fill of gooey marshmallow-and-chocolate s'mores this season. Just tap into the sun, the fuel source that people around the world use to power solar ovens. Here's an easy pizza box model that will let you catch enough backyard rays to cook the coolest s'mores on the block.

Materials:

- Large pizza boxes or mailing boxes
- Pencil and ruler
- Craft knife
- Aluminum foil
- Scissors
- Glue sticks
- Thermometer
- Black construction paper or cardstock
- Clear packing tape
- Clear plastic (we used 2 sheet protectors, available at office supply stores)
- Graham crackers, chocolate bars, and marshmallows
- Stick or dowel

On the top of the pizza box, have students draw a square that is an inch smaller than the lid all the way around. Use the craft knife (adults only) to cut through the cardboard along three sides, as shown, and then fold the cardboard up along the uncut line to form a flap.

Glue aluminum foil, shiny side out, to the bottom of the flap, keeping it as wrinkle-free as you can. [Reflected sun light can permanently damage eyes. Remind students that they should NOT look directly into reflected light.]

Glue another piece of foil to the inside bottom of the box, then tape or glue black construction paper on top of the foil.

Tape clear plastic to the underside of the lid to seal the opening created by the flap. For the best results, the seal should be as airtight as possible.

Students should record the temperature on the thermometer before placing it in the box.

Place your oven outdoors in direct sunlight with the flap opened toward the sun (they may have to tilt the box so that there are no shadows inside). If it is a cloudy day, use the goose neck lamp with the 100W. For each s'more, center two graham crackers on the construction paper. Top one with chocolate and the other with a marshmallow. Students should close the box and then use a stick or dowel to prop the flap open at the angle that reflects the most sunlight into the box (check it periodically to adjust the angle).

Within an hour (or sooner if it's a really hot day), the chocolate squares and marshmallows should melt enough to assemble into s'mores.

Variation 2: Solar Cooker

Source: Solar4Schools. Solar Oven Variation from Solar 4R Schools Activity Guide & Teacher Manual L2: Grades 7-9 Bonneville Environmental Foundation (BEF) http://www.solar4rschools.org/sites/all/files/Activity%201%20-%20Homemade%20Solar%20Cookers-students.pdf. Accessed 4/11/12.

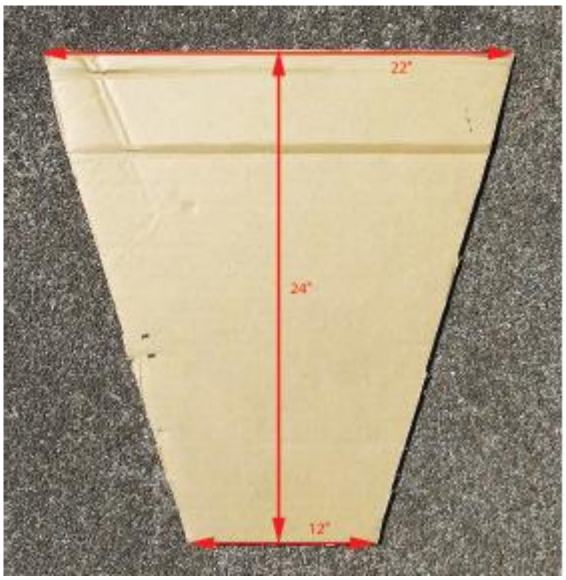
For each solar cooker, you'll need the following:

•Cardboard (4 2 x 3 feet pieces per cooker)

• A roll of heavy tin foil (18 inches wide)
• Glue (white glue or spray adhesive)
• Black paint or black paper
• Paint brush
• Scissors
• Duct tape

Construct the Reflectors

1. Cut four pieces of cardboard with the dimensions 22 x 24 x 12, as shown in the photo. When the pieces are assembled, these dimensions will create a 67º angle, which will maximize the focus of light at the base of your solar cooker.



2. Apply glue to one side of the cardboard pieces you've cut out and cover the glued side with tin foil.
3. Cover all four pieces of cardboard in tin foil, as smoothly as possible.
4. Tape the four pieces of cardboard together with duct tape or another heavy, durable tape. Then connect the far ends to complete the reflector.

5. To create the base of the solar cooker, cut a piece of cardboard that will fit the opening at the base of the solar cooker. Paint one side of this piece of cardboard black. Let the square dry. When the square

has sufficiently dried, tape the square to the base of the reflectors with the black side facing up. [Dashes have been added in the photograph to help you see where the panels are.]

7. Once the solar cooker is assembled, place it outside in the sun on a low-wind day. Shift the cooker until there are no shadows within the reflector area and have students place a thermometer inside. They'll notice that the reflector starts to heat up almost immediately.

Adaptation: Oven Box Design

One adaptation to this solar cooker design is to add a deeper box for cooking larger dishes. An oven-box design also allows for more insulation options. This design utilizes two boxes as the base of the solar cooker. One of the boxes needs to be slightly smaller than the other. Place the smaller box inside the larger box and fill the space between the boxes with isolative materials like rags, newspaper, or cut-up cardboard boxes. The smaller, inner box can be covered with Plexiglas or glass to add additional insulation when cooking.

The inside of the inner box should be painted black, or covered in black paper, to aid in capturing sunlight. The reflectors for this model should be designed to meet the dimensions of the inner box. When the food is cooked, you can fold the collectors down over the glass. This provides good insulation, so the food stays hot until you are ready to eat.

Note: You can find dozens of designs and recipes for solar ovens, learn how to pasteurize water for safe consumption, and read in-depth articles about the science of solar cookers at http://solarcooking.org/.

[Photo Courtesy of the Solar Cooker Archives]

Now they are ready to cook. To help speed up the cooking process, they can add an isolative barrier between the food and the air, ex. cover the dish of food with plastic for insulation.

To boil and steam food in your solar cooker, you can also place food in a jar or pot with a lid for insulation. The sealed containers act as a strong isolative barrier and helps foods heat faster and reach higher temperatures.

If you are using a jar, select one that is no larger than a half gallon. Painting the jar black will further reduce cooking time, but leave a clear strip on the jar for monitoring food. If using a pot, select a dark-colored pot and seal the pot in a large zip-lock bag for additional insulation.

When cooking, don't overfill jars or pots, as food expands over time. You can poke a hole in the lid or leave it on loose to avoid pressure buildup. If food is actively boiling, open jars and pots slowly to release any built-up pressure. If a lid sticks, tap it around the edges or pry up under it to release any vacuum pressure.

Here are some solar cooking ideas you might want to try with your students:

Vegetables: Vegetables and fruits cook well in jars with little or no water, or they can be added to things like pastas and grains. Lightly oiled potatoes cook well on a rack in the solar oven. Corn on the cob can be cooked in its own sheath.

Bread: Bread dough cooks well in one-pound coffee cans that are painted black. Oil the cans. Let dough rise in the cooker without collectors attached, then add the collectors when you're ready to bake. Bread shrinks, so it will come out of the cans with a gentle tapping when it is done.

Pizza: Bake the crust first. Then add toppings and cover the pizza with a clear lid to contain heat.

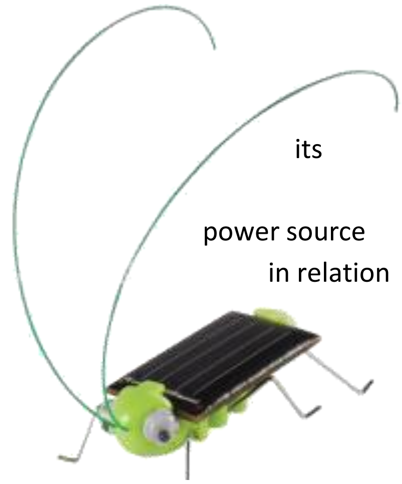
Solar Power!

Materials:

- Sunscreen
- Solar Powered Vehicles

Students will:

- Learn that solar energy is a renewable energy source, and its utilization has numerous benefits for our environment.
- Enumerate the pros and cons of using solar energy as a power source
- Determine that the angle at which a solar cell is positioned in relation to the sun affects its power output.
- Determine the effectiveness of a variety of levels of sunscreen to block the sun's rays



Variations: Super Solar Racing Car, Transforming Solar Robot, or Sunhopper—Solar Grasshopper

The Frightened Grasshopper and Solar Racing cars require no tools to put together and no batteries… they run by the power of the sun. Divide students into groups and have them snap the pieces together to make their own insect or car creation. [The robot requires a few basic tools, ex. screwdriver) Once each group has assembled their solar powered creation, have students take it outside, formulate hypotheses, and perform experiments.

- What happens when students put the Frightened Grasshopper in the sun?
- If they put him in the shade will he still move?
- How about if he has sunscreen on his solar panel? Teach your students about the importance of sunscreen by rubb ing a little on the car… will it still race in the sun?
- Cover the cell halfway or completely with a variety of different materials, how does it affect it?

Ask students to discuss what they already know about fuel efficiency in cars. Pose the following questions:

- Which types of cars are the most fuel efficient and why?
- What factors might contribute to a desire for increased fuel efficiency in cars?
- How fuel-efficient are cars today compared to 50 years

ago?
- The reasons why we might see changes in the way cars are powered.
- The changes that will occur in car technology in order to accommodate changing attitudes toward fuel efficiency and energy sources.
- What types of alternative energy sources are being developed for future cars? How do these energy sources power the car? What are the advantages and disadvantages of each type of energy source? Which energy sources seem most likely to be commonly used in cars of the future?
- What environmental, political, and cultural factors might contribute to a desire for cars with higher fuel efficiency or cars that use alternative energy sources?
- What factors might detract from creating cars with higher fuel efficiency or cars that use alternative energy sources?

Variation: Solar Bottle Motor Boat

A fun new project that focuses on engineering and renewable energy, the Solar Bottle Motor Boat allows student scientists a great lesson in engineering and construction as they build their boat, and the motor boat is also a great example of what can be accomplished to renewable energy and reusable materials. The Solar Bottle Motor Boat is powered through a solar panel that harnesses the energy of the sun's rays and would not float if it weren't for the use of plastic bottles. It's environmental ingenuity at its finest.

Materials

- Boat platform
- Solar panel
- Electric motor
- Propellor and shaft
- Motor base
- Wires
- Rubber bands
- Instruction manual
- Two 16 oz plastic water bottles
- Kiddie pool
- Water

How does it work?

The Solar Bottle Motor Boat works like a pontoon, utilizing two plastic bottles (16 oz works best) as pontoons to keep the engine apparatus above water. The Solar Panel transfers energy to the engine and then to the propeller, jettisoning the boat across the water.

Magic Rollback Can

Potential and kinetic energy at work in this magical demonstration

The Magic Rollback Can appears to be a normal can of coffee or oats, but after you roll it along the ground a little ways and watch it come back, you'll be wondering just how it works.

Materials

- Coffee or oats can
- Nail or other hard pointed object
- 9-volt battery or object with similar weight
- Rubber band
- 2 paperclips
- Tape

1. Using the nail, make a hole in the middle of the bottom of your coffee or oats can. Be extra careful when using sharp objects. Also, if you are using a coffee can, be careful around the sharp metal edges that you may create when making the hole.
2. Poke the same kind of hole in the lid of the can.
3. Tape the 9-volt battery to the middle of the rubber band. Make sure both sides of the rubber band are taped to the bottom of the battery.
4. Push one end of your rubber band loop through the hole in the bottom of the can and secure it there by attaching one of the paperclips. Once you have it secured, tape the paperclip down.
5. Stretch the rubber band across the length of the can and push the other end of the rubber band loop through the hole in the lid.
6. Secure the rubber band with a paperclip and tape it down.
7. Put the lid on the can. Does the battery rub against the side of the can? If not, you're good to go. If it does, try a shorter rubber band.
8. Getting the set-up just right may take a bit of experimentation, but you'll get it!
9. Set the can on its side on a hard surface or short carpet floor and give it a roll. Once the can comes to a stop, try to contain your excitement as it begins to roll back to you!

Variant:

Use a different small container that can be laid on its side and rolled and have a hole punched in its top and bottom (such as a clear plastic soda bottle or coffee can) Note: Using a clear soda bottle helps to demonstrate what is happening inside.

How does it work?

The Magic Rollback Can is a great example of transfer of energy. When you roll the can, it has kinetic energy. As it slows down, the energy is transferred into potential energy within the twisted rubber band inside the can. The twisted rubber band's potential energy is then transferred back to the can in kinetic energy as it untwists.

The secret to all this energy transfer comes from the weight that you've taped to the rubber band inside the can. While the weight is being pulled down by gravity, it is also being subjected to a twisting force from the rubber band. So long as the force being exerted by gravity on the weight is greater than the twisting rubber band's force on the weight (meaning the weight never goes over the rubber band), the rubber band will continue to twist.

Once all of the kinetic energy from the rolling can has been exhausted by converting to heat (friction) or potential energy (twisted rubber band), the can stops rolling and the weighted rubber band is able to unwind. Because of the weight in the middle of the rubber band, only the ends of the loop are able to unwind and, therefore, the can begins to roll backwards.

Additional Info

If you are looking to take the Magic Rollback Can to the next level, try painting it a solid color. If you do this, observers won't be able to see the apparatus on the ends of the can. This makes the Magic Rollback Can a perfect "Black Box" tool for teachers. Show your students what the Magic Rollback Can does, and have them observe and hypothesize how the can might work. The farther the toy is rolled the more potential energy. Release and watch the toy roll back towards you demonstrating kinetic energy. This would be a great activity to have races in the classroom to see who could devise the roll-back toy with the greatest potential energy

Color Mixing Wheel

Create a wheel that will show your students color and color mixing in a new way and show the power of momentum

Our visual division here at Steve Spangler Labs loves the science of color mixing. We've mixed gels, fizzing tablets, and even different colored lenses together to get the secondary colors. We needed something new. So, we found an amazing way to combine scientific principles of physics with the visual science of color mixing. Our discovery isn't just visually spectacular, it's scientifically sound!

Materials:

- White cardboard, cardstock, or posterboard
- Tapered cups, ex. a red plastic cup
- Soda bottle caps
- Red, blue, and yellow markers
- String
- Rulers
- Scissors

Creating the Color Mixing Wheel

1. Place the cup top down on the cardboard and trace around the rim.
2. Flip the cup over, placing it in the center and trace around the bottom
3. Place the soda bottle cap in the center and trace around it
4. Using the ruler, draw a single line through the middle of the disc that spans the entire diameter of the disc. Each of the three circles in the disc should now be divided in half.

5. Color half of the smallest circle blue and the other half yellow. Color the middle circle half red and half yellow. Finally, color the largest circle half blue and half red. The pattern should be, starting from the left edge: Red, yellow, blue, yellow, red, blue at the right edge.
6. Cut the traced circle out using the scissors.
7. ***Grab an adult for this step:*** Using the pointed tip of the scissors, place two holes in the cardboard disc. Make sure the holes are an equal distance from the center of the disc and are about 1 inch apart.
8. Use the scissors to cut a piece of string or yarn that is 4 feet long.

9. Thread the string or yarn through each of the holes in the disc and tie the ends of the string together. ***Make sure the knot you tie is reliable and able to withstand a substantial amount of force.*** You are going to be tugging pretty hard on it.

Performing the Experiment

1. Start by holding the string on both sides of the disc with your hands**.** Make sure the disc is as close to the center of the string as possible.
2. Spin the disc in a motion similar to a jump rope. This is a quick way to get the string wound up.
3. Once the string on both sides of the disc is twisted, pull the string tight to get the Color Mixing Wheel spinning. It might take a little practice to get it just right. Tip: If you have some difficulty the first time getting it to spin correctly add a knot on each side of the string to make it center and it should work.
4. Once you have the hang of how the Color Mixing Wheel works, you'll be able to keep it going as long as you want.

Observations

You may have noticed that the colors you put on the Color Mixing Wheel were the three primary colors: red, blue, and yellow. Once you started spinning the wheel, what did you notice about each of the three color circles on the cardboard disc? What do you think makes this happen?

How does it work?

Let's start with the visual part of the experiment - color mixing. The colors you put on the Color Mixing Wheel are the three primary colors: red, blue, and yellow. When you combine two primary colors you get the secondary colors: green, purple, and orange. Obviously, the individual colors on the wheel are not mixing. The color mixing that happens is due to the speed at which the wheel is spinning as the string twists it. The colors are spinning at such a rate that your brain is unable to process them as the individual colors that are on the wheel. Instead, your brain takes a shortcut and creates the secondary colors.

Now, why does the string continue to twist? The answer lies in physics and, in particular, momentum. Once you have the string twisted, pulling on each end causes it to go tight. When the string is pulled tight, it wants to be completely straight. In going straight, the string unwinds from itself and causes the disc to spin one direction. But the string doesn't stop once it's unwound. It speeds past and gets twisted again. The momentum from pulling the string tight keeps the disc spinning until all the momentum is gone. Then you pull the strings tight again and set the disc spinning in another direction.

Magic Pendulum Catch

Will your hex nuts crash to the ground? Discover the shocking result yourself!

Have you ever seen a comedy bit from a black and white silent film? One of their favorite gags was someone hoisting a piano to a 3rd or 4th story window when someone cuts the string... CRASH! The piano comes crashing down as ivory keys and wood splinters go everywhere. The Magic Hex Nut Pendulum involves the same sort of thing, only on a much smaller scale. What will happen to your hex nuts? The result may surprise you.

Materials

- 15 hex nuts per person
- Shoe string or string/yarn of similar length (30" works well)
- Safety glasses

1. To get started, thread your string through 14 of the 15 hex nuts.
2. Take the end of the string you just threaded through the hex nuts and tie it back onto the string right above the stack of hex nuts. Basically, you are making a loop of hex nuts.
3. Thread the string through the middle of the remaining hex nut and knot the string so that you have a string with 14 hex nuts at one end and one hex nut at the other.
4. Trim off the excess from your knots.
5. With the string-hex nut apparatus you have constructed, grab the single hex nut end with one hand and drape the string with the loop of hex nuts over your opposite hand's index finger.
6. Pull the single hex nut end of the string so that the 14 hex nuts are touching your index finger. Make sure that the string is parallel or close to parallel with the ground.
7. From this position, let go of the string. Be sure to keep your index finger as still as possible. Oh no! This is going to be really loud! Wait... the hex nuts didn't hit the ground. What happened? You better try it again to make sure that it wasn't a fluke.

How does it work?

The apparatus that you've constructed out of some string and hex nuts is a pendulum. A pendulum is a weight suspended from a pivot (or fixed point) so that it can swing freely, back and forth. Common examples of pendulums can be found in time pieces such as grandfather clocks.

Pendulums like the one you constructed operate using acceleration from gravity. When you release the hex nut, gravity accelerates it towards the ground, giving it velocity. In a normal pendulum, the velocity decreases as the pendulum swings. The amplitude (how high the pendulum swings) also decreases the more the pendulum swings. This happens because of friction.

In our pendulum, the distance between the pivot (your finger) and the bob (the single hex nut) is decreased very rapidly when you release the string. As the distance between the bob and pivot decreases, the velocity of the pendulum increases. With the velocity increasing so rapidly, its amplitude

is increased to a point that it makes a number of full swings, wrapping the string around your finger. The scientific explanation as to why the Magic Hex Nut Pendulum works is this: as the length of the pendulum decreases, the velocity increases, thus increasing the amplitude.

Additional Info

Want to spend some more time experimenting with Magic Hex Nut Pendulums? Here are a couple of ideas:

- Try dropping the pendulum from different heights. Is there a point, either too high or too low, that the magic of your pendulum no longer works? Is there a height that works better than in our original experiment?
- How many hex nuts can you add to the "bob" side of the pendulum and still have it work? How few can you have on the heavier side?

Pendulum Perils: The Trial of Billy Tell

This experiment requires a lot of faith in the laws of science. When it is done at science centers, it usually involves a bowling ball rushing towards your face, but we will use a less dramatic version.

Materials

- string
- an apple that still has the stem on it, or other round object such as a tennis ball
- a high place to tie the string

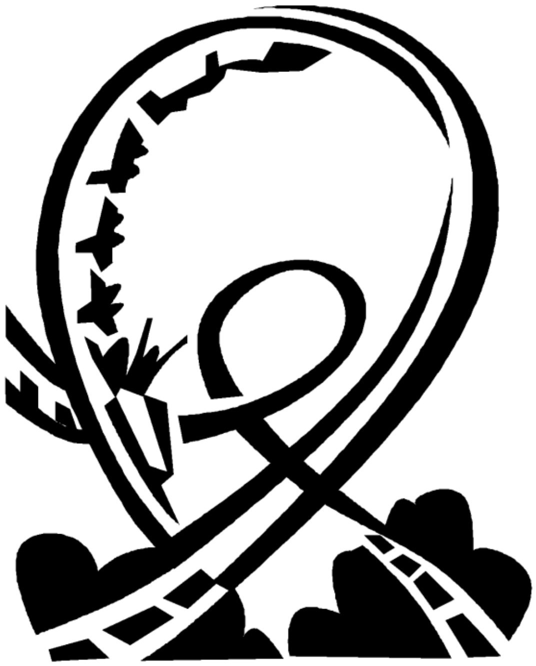
Tie the string to the stem of the apple or around the ball..
Tie the other end of the string a high object, such as a curtain rod. (Variant: tie the loose end of the string to a stick. Have a student stand directly against a wall while holding the tied apple to his or her forehead. Another student must hold the stick so the string is pulled tightly. Allow the student to let go of the apple and remain in position.)
You want to measure the string so that if you stand in front of it, facing the rod, you can pull the apple/ball over so that it touches your forehead.
Have your student or assistant lean their head back against the wall, so that it does NOT move forward or backwards. Have them pull the apple towards them until it touches their forehead. Now have them release the apple, letting it swing away from their face.
Now it is swinging back towards their face! While the student and the rest of the class think the apple might hit the student in the forehead when swinging back, this cannot happen.
Will it hit them? No, as long as they do not move their head, the ball will not hit them.
Why not? As the apple moves away from you, it is picking up speed. It is converting potential energy, from its height, into kinetic energy, the energy of motion. Once it passes the lowest point, the opposite begins to happen. It is now moving against gravity, and some of its kinetic energy is converted into potential energy. Once all of the kinetic energy has been converted, it stops and starts to move downwards again. The apple loses kinetic energy due to the pull of gravity and air friction. Thus, the apple never returns to the same heights and eventually loses all kinetic energy.
In a perfect system, this would keep happening over and over, with no energy lost.

What is causing the energy to be lost?

In reality, there is resistance from the air, friction with the string. What is friction? Friction is a force that when two objects rub together converts kinetic energy to heat. This means that each swing will not go quite as high as the one before it. Because we know that our apple on a string system is not perfectly frictionless, we know that the apple will not make it back up high enough to hit their face. Just be sure not to move, and use a small apple, just in case.

Coaster Challenge!

Using forces of nature students make a marble loop-de-loop on a track that they design.

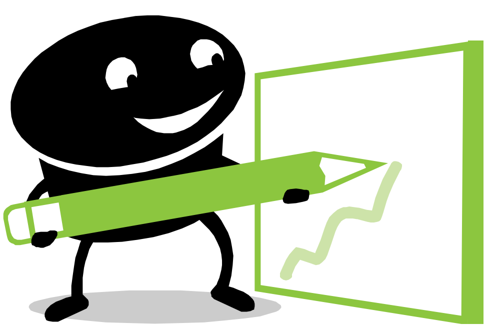


Each year, amusement park owners compete to earn some of the billions of dollars people spend on entertainment. In order to have customers come back year after year the parks need to have customers have fun the first time and newer, faster, more exciting rides the next time, especially roller coasters. But it takes time, money, work, and someone to build them. And before they can build them, someone has to get their new idea down on paper.

Have a student come to the front of the class and draw a 2-D (X-Y plane) roller coaster on the board. Discuss with the students what you would have to know in order to build this roller coaster. (What it was made of, etc). Bring in the concepts of scale factor. You have to know how high the tallest point is, how big the loops are… before you can do anything you have to have some idea of scale.

Scaled drawings are a means of communication between the contractor and the designer of a product, such as a house, or in this case, a roller coaster. Scaled drawings are used because they allow the designer to put a large amount on information into a relatively small, portable, easily changed, and easily read package. Discuss with the students any difficulties that might occur with a designer trying to put a life size drawing of their roller coaster on to paper.

One key part of every scale drawing is the scaling factor. This number represents the degree to which your scale drawing or scale model has been reduced in size when compared to the original. For example, a scaled drawing could show 1 inch for every 10 feet of the real object. That's a scale of 1/10.



Practice

Have students practice by doing the following activity on graph paper:
Students will draw a 2-D model of a roller coaster with the following dimensions. Their drawing should be a 1/32 scale drawing on graph paper. Have students turn their graph paper sideways to allow enough room for their rollercoaster to fit. Use of a ruler and other measuring/drawing devices is expected.

Start with a 20 cm level area

Then 96 cm vertical rise
Then a 80 cm 45 degree downward slope
Next a 360 cm level area with a 64 cm loop in the middle of the 360 cm length.
Finish with a 30 degree upward slope that is 264 cm long.

Have students determine the full scale dimensions of this roller coaster if the model is a 1/100 scale of a full scale roller coaster. Next, have students alter their drawing and draw it again at 1/16. How does that change the appearance of their coaster? Why? What do they note about the slope of the angled lines when they scale up and scale down? Have students consider both accuracy of drawing and capacity to draw the model in a reasonable overall size of graph paper.

The Project

The students are designers of roller coasters for a company that sells coasters and rides to amusement parks all over the world. The student's job also includes preparing a portfolio for prospective buyers that shows the roller coaster design, the speed of the coaster, and the cost of the coaster. Students also need to include information about financing the cost of the coaster. They have just developed a new roller coaster and need to prepare a portfolio of materials for the potential buyers.

Using the principles of potential and kinetic energy, the students should be able to construct a roller coaster. The potential energy at the top of the roller coaster should be enough to move the marble through all the loops and hills.

Potential energy at the top of the first hill should be sufficient to lift the marble to the top of the first loop. The potential energy there should be enough to continue moving the car through all the loops and hills. As the marble moves down, potential energy changes to kinetic energy. As the marble moves up, kinetic energy changes to potential energy. Friction is also a factor because it uses up some of the potential energy so there is not as much kinetic energy available.

Materials:

- marble
- oak tag
- popsicle sticks
- hot glue
- thin wire
- tape
- books
- cup

1.Have students [individually, in pairs, or in small teams] build a roller coaster using a marble, oak tag, tape, books, and a cup. (Option: Older students can use hot glue guns and popsicle sticks and/or wire for their tracks.)

2.Cut the oak tag into strips that are 2 inches wide and 11 inches long.

3.Tape these strips together to make your roller coaster track. The marble will be the cart that travels along the track.

4.They can use the books or popsicle sticks to build hills and ramps (or you can use a staircase).

5. As they build their design and adjust their design have the students consider the following questions. *(Science Link)*

- What forces are moving the ball around the track (Gravitational Potential Energy and Kinetic Energy)
- Can all the hills be the same height? If not, why? Can they get bigger or must they get smaller? How will you determine how big or how small the hills can be?
- Does the steepness of the hill count? Is it better to make the hills steep or not so steep? Why?
- How curvy should the tops of the hills and the valleys be? Should you design sharp turns or smooth turns? Why?
- What provides resistance on the roller coaster causing the ball to slow down? How can this resistance be reduced?

6. Once their tracks are built (with any due adjustments to drawings and projected data as construction warrants them) have students test and compare their projected data to the real-world data they record using their models. *Note: Leave students with enough time to make revisions to their original design—an important factor in the world of design and engineering.*

- When their roller coasters are completed, the students must then measure the roller coasters and begin calculating speed, acceleration, and momentum, the average speed, speed at different points, and time for these tracks using a stopwatch and a timer. Record the data on a chart.
- Students can find the average speed of their coaster and compare it with the rest of the class.
- How does the projected data from their scale drawings compare to the data from the model. Are they comparable? What factors are different between the two?
- Students may alter the design of their coaster to come up with the optimum speed and time of ride and to allow the marble to move through the entire track without assistance. (The potential energy at the top of the roller coaster needs to be enough to move the marble through all the loops and hills.) How do those adjustments affect the rest of their data? Have the students compare data with other groups.

7. Have students make a poster for their new ride, advertising the name, thrills, and statistics of their roller coaster in order to get riders on board.
8. Have students write a one-page summary of their project, including what they have learned from researching this topic and answering the following question. If a life-sized version of their roller coaster was built, would they want to ride it?
9. Students may also prepare a story board that documents their research and the construction of the roller coaster. In their storyboards students may answer the following questions: Does math apply in the "real world?" How did they build their coaster and did it work perfectly the first time? What are its measurements, rate of speed, etc? What formulas did they use to arrive at their conclusions? How do those formulas work? How many loops, turns, and hills did their roller coaster have? What did they have to do to make the ball go faster or slower? How did they make the ball turn? If a life-sized version of your roller coaster was built, would they want to ride it?

Optional Challenge Requirements:

- The roller coaster must have six drops, six turns, and a loop. The roller coaster must also have a realistic design that would not "injure" a rider. Points are deducted for fewer drops, turns, or no loop. Also deduct points if the roller coaster is not realistic.
- Options: Students get 3 points for each U-turn, 5 points for each loop, and 1 point each time you make the marble go up a hill.
- If they can get the marble to fly through the air and land in a cup, they earn an extra ten points.

Additional questions and ideas to have students consider while creating their portfolio/coaster.

1. How does changing the height or the length of a hill of a roller coaster affect the speed?
2. How does the rate of interest affect the payments that must be made on money that is borrowed? How does the length of time of the loan affect the total amount of interest paid when borrowing money?
3. How might students estimate the amount of money that can be generated by a roller coaster?

Calculations and Formulas:

Average Speed: Calculates average speed to ride a fixed distance in a given time. Formula: Speed = Distance ÷ Time

Time: Calculates time required to ride a fixed distance in a given average speed. Formula: Time = Distance ÷ Speed

Distance: Calculates distance covered from average speed and time elapsed. Formula: *Distance = Speed × Time*

Speed at Specific Points: Have students prepare calculations to show the speed of their new roller coaster at several points along the track, for example they will want to show the speed at the top of each of the hills. Ex: Suppose their coaster reaches its maximum speed of 72 miles per hour at the bottom of their second hill, which is 200 feet tall. The formula for determining the speed of a coaster at the top of any hill is

$v_1 = \sqrt{(v_2)^2 + 2gh_2 - 2gh_1}$, where

v_1 = speed at the top of the hill in ft/sec,
v_2 = speed at the bottom of the hill in ft/sec,
h_1 = height at top of hill in feet,
h_2 = height at bottom of hill in feet, and
g = 32 ft/sec^2, the constant for gravity.
Assume that the bottom of the hill has height 0 ft.

1. What will be the value of $2gh_2$? Why?

2. The value of v_2 in the formula should be expressed in ft/sec since the value of g is in ft/sec^2. What is the maximum speed of the coaster at the bottom of the hill in ft/sec?
3. List the values for each variable to use in the expression on the right side of the formula.
4. What is the speed of the coaster at the top of the second hill?

Financial Figures and Rates of Pay: While you are preparing a portfolio for your roller coaster design the company wants to know the total cost, how much money they will have to pay per months, and how many months it will take them to pay for your new ride. Ex: If you decide that the cost of your new roller coaster is $1,000,000. Assume that an amusement park wants to make a down payment of 10%, that would be $100,000. Then they will finance the remaining $900,000 for 30 years. The current rate of interest offered by the nearest bank is 7.25%. The amusement park wants to know the monthly payment, so use the formula $P = \frac{Cr(1+r)^N}{(1+r)^N - 1}$, where P = monthly payment, C = amount of loan, r = interest rate ÷ 1200, and N = total number of monthly payments.

1. Why do you think that the interest rate, 7.25%, is divided by 1200 in the formula?
2. List the values for each variable to use in the expression on the right side of the formula. Be sure you find the total number of monthly payments, not just the number of years of payments.
3. Find the monthly payment for the roller coaster.
4. What if they want to pay over 15 years, 60 years? Have students find the different payment rates for at least two options.

Laws of Attraction

Experiments:

1. Making a Magnet
2. Magnetic Sculpture/Other Magnetic Experiments to Try
3. Home-Made Magnetic Silly Putty/Home-made Silly Putty Recipe
4. That Mysterious "Something": A Magnetic Field/Lines of Force
5. Eddy Currents
6. North and South Poles/Creating Your Own Homemade Compass
7. 3D Magnetic Lines of Force
8. Magnetic Shielding
9. Two Kinds of Force/ Strange Attractor
10. Magnetic Materials/Magnetic Money
11. Eating nails for breakfast

Kindergarten

Key Terms:

- Change
- Collect
- Observe
- Globe
- Natural
- Shape
- Tools
- Position
- Pattern
- Classify
- Compare
- Difference
- Size

Key Standards:

Forces in Nature are not addressed at this grade level.

1st Grade

Key Terms:

- Location
- Magnet
- Property
- Push/Pull
- Classify

Key Standards:

- 7.12.1 Identify and classify objects in the classroom as magnetic or non-magnetic.
- 7.12.2 Make predictions about how various objects will be affected by a magnet.
- 7.11.1 Use familiar objects to explore how the movement can be changed.
- 7.11.2 Investigate and explain how different surfaces affect the movement of an object.

2nd Grade

Key Terms:

- Distance
- Compare
- Contrast
- Depend
- Infer
- Investigate
- Observation
- Interpret
- Type
- Reasoning
- Renewable/Non-Renewable

- Scientific Inquiry
- Scientist
- Similarities
- Differences

Key Standards:

- 7.12.1 Explain how two magnets interact and experiment with magnets to determine that objects can move without being touched.

3rd Grade

Key Terms:

- Conductor
- Force
- Tools
- Distribution
- Conclusion
- Cause
- Effect

Key Standards:

- SPI 7.12.1 Recognize that magnets can move objects without touching them.
- SPI 7.12.2 Identify objects that are attracted to magnets.
- CU 7.12.1 Experiment with magnets to determine how distance affects magnetic attraction.
- CU 7.12.2 Determine that only certain types of objects are attracted to magnets.

4th Grade

Key Terms:

- Friction
- Relationship
- Compare
- Contrast
- Drawing Conclusions
- Making inferences

Key Standards:

- CU 7.12.1 Explore the interactions between an electrically charged object and other materials and observe that electrically charged objects exert a pull on other materials.
- SPI 7.12.1 Identify how magnets attract or repel one another.

5th Grade

Key Terms:

- Core
- Conduction
- Convection
- Variable
- Model

Key Standards:

- CU 7.12.1 Explain and give examples of how forces act at a distance.
- SPI 7.12.1 Recognize that the earth attracts objects without touching them.

6th Grade

Key Terms:

- Cause and Effect
- Conductivity
- Control
- Criteria
- Design Constraint
- Power
- Variable
- Similarity

Key Standards:

Electromagnets are emphasized at this grade level

7th Grade

Key Terms:

- Property
- Impact
- Inferences
- Phenomenon
- Minerals

Key Standards:

Not addressed at this grade level

8th Grade

Key Terms:

- Electron
- Magnetic Field
- Neutral
- Proton
- Electron
- Variation

Key Standards:

Electromagnets are emphasized at this grade level

High School

Key Terms:

- Electron
- Buffer
- Innovation
- Gravitational effects
- Resistance
- Conduction

Key Standards:

Electromagnets are emphasized at this grade level

Laws of Attraction

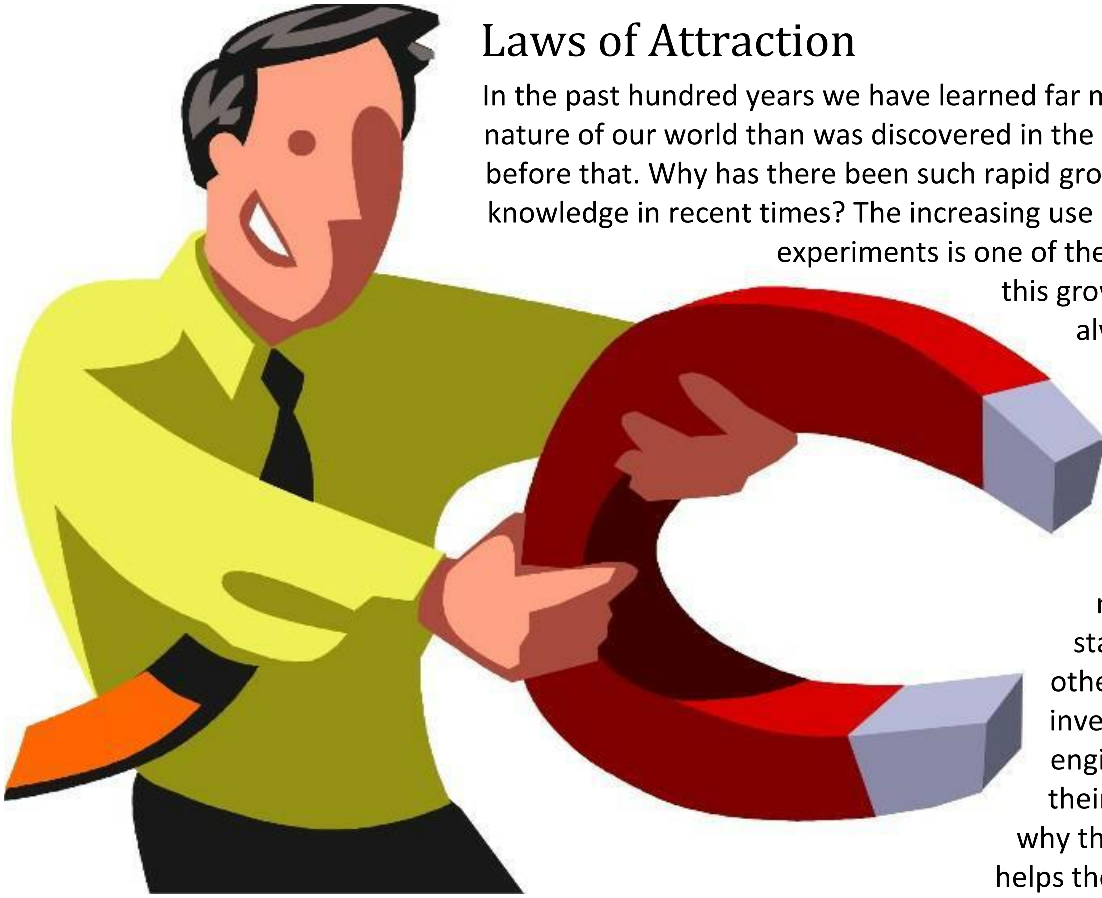


Image Credit: http://thevaluemarketingcoach.com/2011/04/15/the-simple-secret-to-mlm-success/law_of_attraction/. Accessed 9/6/11.

In the past hundred years we have learned far more about the nature of our world than was discovered in the half million years before that. Why has there been such rapid growth in our knowledge in recent times? The increasing use of scientific experiments is one of the main reasons for this growth. Scientists always want to know WHY things happen. Very often the search for an answer does not seem to be of much use at the start. But later on, other scientists, inventors, and engineers find that their ability to explain why things happen also helps them to create new products of great value to mankind.

Many so-called facts, or ideas, had been believed to be true for thousands of years, yet were not true at all. What is new in recent times is the understanding that "facts" are not really facts until they have been tested and proven to be true. And one of the best ways to do that is to design an experiment that tests the truth or falsity of the idea. If the experiment indicates that the idea is false, such evidence becomes far more important than long held opinions about the facts.

How do we learn to do experiments? By doing them, of course! Experiments don't have to be fancy or complicated; in fact, most of the time, simple ones are the best. They don't have to be original; repeating what others have done before is actually a really good way for us to learn. The important thing is that the experiments be new to us and that we practice observing for ourselves rather than always taking the word of others about what is supposed to happen.

Something important happens when students do experiments themselves and make their own observations. They begin to observe things that are not described in the instructions.

Sometimes what they see happen can be quite puzzling; at times it may contradict what they learned before. Then they are in the same situation as any scientist facing the unknown. If this happens to your students while doing an experiment, teach them not to drop the puzzle and quit. Rather, work together and face the contradiction squarely. Have them try to form a hypothesis and design a new experiment to find out more about the problem and to provide new observations for solving the puzzle. That's how new discoveries are made, answers are found, and mysteries are solved.

DID YOU KNOW?

Magnetic rocks called lodestones are made by bacteria!

A soil bacteria or organism known as GS-15 eats iron in the earth, changing ferric oxide to magnetite and, over billions of years, forming the magnetite layers in iron formations. These tiny bacteria act like tiny, self-propelled compass needles, aligning themselves to the local magnetic field and directing their swimming by it. Each tiny cell, deaf, dumb, and blind, will always keep doggedly swimming, always towards magnetic north. These bacteria have chains of tiny magnetic crystals that are used to tell where they are. The ability to find your way is as important for bacteria as it is for humans, in order to find food. Humans can use maps or GPS in order to find their way, bacteria face a huge challenge in finding food within the microscopic world. Crystals, made usually of magnetite, act as microscopic compasses in their bodies that allow bacteria to sense direction, like a tiny GPS. It's amazing, bacteria managed to shrink the compass hundreds of millions of years before humans first even noticed that an iron needle points north!

Hidden Attraction: The Mysterious Lodestone

Long ago certain rocks were found to attract iron. These rocks were the first magnets and the mineral from which the earliest human compasses were made. Long one of nature's most fascinating phenomena, magnetism was once the subject of many superstitions. When human beings in the past attempted to explain mysterious natural phenomena they didn't have the right tools or sometimes any tools to find out the truth so their answers had to be invented, using their imaginations. The mysterious magnets were thought useful to thieves, effective as a love potion or as a cure for sicknesses, like gout (a very painful kind of arthritis) or muscle spasms. They could bring love and luck into your life, remove sorcery from women and scare away monsters, fairies, or demons, and stop nosebleeds. It was even believed to help fighting married couples get back together. It was said that a lodestone (magnet) pickled in the salt of sucking fish had the power to attract gold. It was even used as a beauty treatment, Cleopatra, the Egyptian beauty mentioned in many western myths, was reported to have slept on a lodestone for a long time to take advantage of its anti-aging abilities.

Today, these beliefs have been mostly put aside, but magnetism is no less remarkable for our modern understanding of it. In the current times of technological revolution, magnetic technology has helped in the development everything from doorbells to floating trains. Some people say that mankind's discovery of the effects of magnetism is one of our greatest achievements, equal with the invention of the wheel and creating fire.


A lodestone attracting iron filings and nails.

Did you know that the name "magnet" was first used by the Greeks as early as 600 B.C. for describing the mysterious stone that attracted iron and other pieces of the same material? According to one Greek legend, a shepherd named Magnes was herding his sheep in an area of Northern Greece called Magnesia, about 4,000 years ago. Suddenly both the nails in his shoes and the metal tip of his staff became firmly stuck to the large, black rock on which he was standing. To find the source of attraction he dug up the Earth to find lodestones (load = lead or attract). Another, and perhaps more believable, theory says that the word magnet came from a city in Asia Minor, called Magnesia, where many of these mysterious magnetic stones were found.

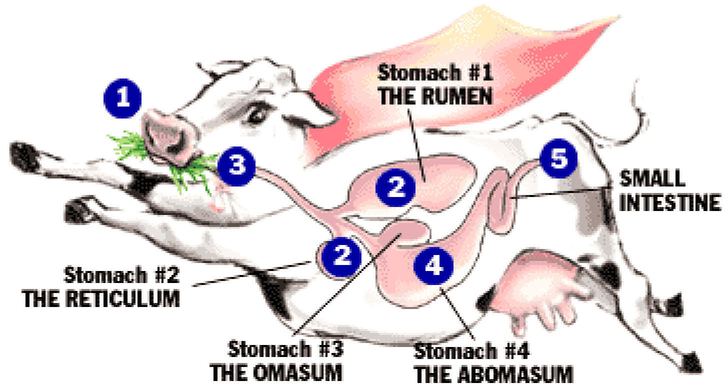
“The Magnet’s name the observing Grecians drew
From the Magnetic region where it grew.”
Lucretius, as quoted by William Gilbert in his book *De Magnete,* published in 1600.

The Greeks believed that there were whole islands of a magnetic nature that could attract ships by virtue of the iron nails used in their construction. Ships that thus disappeared at sea were believed to have been mysteriously pulled by these islands and their sailors were rumored to have used loadstones to remove nails from enemy ships thus sinking them.

During the Middle Ages, this stone started being called lodestone, which is the magnetic form of magnetite. (Magnetite is a black mineral that is an oxide of iron (made up of iron and oxygen) and is strongly attracted to magnets.)Today, you can buy magnets in all sorts of shapes including discs, rings, blocks, rectangles, arcs, rods, circles, twists, and bars and are made out of many different materials.

Multi-Purpose

Not only do the shape and material of magnets vary, so do their uses. At many companies, magnets are used for lifting, holding, separating, retrieving, sensing, and material handling. You can find magnets in a car and around your house. Magnets are used in the home to organize tools or kitchen utensils and can be found in doorbells, loudspeakers, radios, microwaves, engines, and televisions. Business offices and schools use magnetic planning boards to display schedules and charts. Farmers even put magnets inside of their cows! These super strong cow magnets have earned their name by saving countless cows from developing the dreaded hardware disease. How? The solid magnet is placed in a cow's first stomach to collect all of the metal objects that poor cow might accidentally eat. Cows just can't always tell the difference between grass and nails.



Cartoon Cow Stomach Diagram Image Credit: http://sciencerevolution.net/dict_r.html Accessed 8/22/11. All Rights Reserved.

While grazing, cows eat everything from grass and dirt to nails, staples, and bits of bailing wire (referred to as tramp iron). Tramp iron tends to get stuck in the honeycombed walls of the reticulum, threatening the surrounding vital organs (like the heart and lungs) and causing irritation and inflammation, known as Hardware Disease. (Hardware disease is actually an irritation or infection of the diaphragm, heart or lungs that is very hard to treat).Ouch! The cow stops wanting to eat and doesn't make as much milk (dairy cows), or can't gain the weight farmers need them to gain (feeder stock). Cow magnets help prevent this disease by attracting stray metal from the folds and crevices of the rumen and reticulum. One magnet works and stays inside for the life of the cow!

Reticulum Image Credit: *http://courses.washington.edu/chordate/453photos/gut_photos/mammal_digestive_photos.htm* *All Rights Reserved.)*

Some magnets are strong, and some are weak. The strongest magnets in the world are called Neodymium magnets or "rare-earth" magnets. They are 10 times stronger than standard ceramic magnets and are commonly used in speakers and computer disc drives. Neodymium magnets contain Iron and Boron, making them some of the strongest magnets in the world.

But what is a magnet?

Have the students look at a magnet. Do they see anything around it? Have them move their hand through the air near the magnet. Do they feel anything?

They see and feel nothing. Yet there is "something" around the magnet, like a force. So, a magnet is an object made of certain materials which create a force. But how to prove it and what is that "something?" When it comes to the mysteries of magnets, only when we work with them will we begin to understand how they work. And, the work always starts by simple observation (that's the fancy word for playing around with the stuff and watching what happens.) Let's get started.

Notes:

- Alnico or neodymium magnets will work best for your experiments. They are very strong and give great results, just one of these magnets will hold a small phone book to a steel filing cabinet (the things we do when we're bored!). They can even detect traces of iron in an ordinary $1 bill. You'll be amazed at the super strength of the magnets, and they are great and fun learning tools, but as with any other piece of equipment we must warn you to be careful, supervise every activity carefully, and teach your students proper handling and respect for the equipment. These large magnets are so strong that they may be dangerous if not handled properly. A pair of these magnets will leap into a deadly embrace from over 6 inches apart and as they are brittle they may knock chips off themselves from the force of the impact. Any type of magnetic media (credit cards, debit cards, computer disks, videotapes) will be history in the presence of one of these large neodymium magnets so don't carry them purse in hand!
- You will also need some iron filings (tiny bits of iron). Now, iron filings aren't exactly a common household item, but you can make or buy some pretty easily. You can make enough for your experiments if you crush or cut coarse a dry, fine-grade (grade 0000) steel wool pad, the kind without soap. Use gloves and of course be careful if you choose to do so. Do this in a plastic bag with a "zip" lock so the filings will not scatter or put on gloves, pull the steel wool pad into two halves, hold them over a piece of paper, and rub them together so that the iron filings fall onto the paper. Carefully pour the iron filings into a dry jar or container and over until ready to use. You can also take actually spend a few minutes with a file and a chunk of soft iron to make authentic filings or order some from the net. Pro tip for working with iron filings: do NOT ever let the filings touch the magnet directly; always keep a sheet of paper or plastic or some other barrier between the magnet and filings. If you don't, you'll never get them off!

Caution: When working with filings protect your eyes and do not rub your eyes with your fingers.

Making a Magnet

Long ago certain rocks were found to attract iron. These rocks were the first magnets. Soon, a way was found to make magnets starting with these natural rock magnets. How was this done?

Have students pick out a nail about 1 or 2 inches long. Try to pick up a smaller nail (or iron washer) with the larger nail. They will probably not succeed. Then have them touch or rub the nail against the pole of a magnet and it thereafter picks up several small nails by magnetic attraction. Have the students bang the larger nail against a hard object a few times and try to pick up the small nails. The magnetism of the nail has become much weaker. **What happened?** Note: *Students can get an approximate idea of the strength of a magnet by counting the number of small nails that it can pick up as compared with other magnets.*

Magnetic Sculpture

Materials

- Bar magnet
- Small paper clips

Directions

1. This activity challenges students' experience with gravity. Have them magnetize the clips by rubbing them on the bar in **one** direction.
2. Once they have acquired a magnetic field, they can be stood end to end vertically, connected horizontally, or moved to form amazing shapes.
   - See how tall they can make a sculpture.
   - Have students bring the clips out as far as they can horizontally without tipping them over.

Try it with other metallic objects like beads or bearings. Does it work?

Home-Made Magnetic Silly Putty

Bounce It! Stretch It! Make it come Alive?

The following instructions were created by Michael Sauras at Instructables.com. http://www.instructables.com/id/magnetic-silly-putty/. Accessed 9/6/11. All Rights Reserved.

Image Credit: http://www.geeky-gadgets.com/magnetic-silly-putty-07-07-2010/. Accessed 9/6/11. All Rights Reserved.

Thinking Putty (also known as Silly Putty) is a silicone polymer children's toy. Silly putty is fun because it has some unique properties: it is viscoelastic, meaning it can be stretched and shaped and mashed back together again; and as its apparent viscosity increases directly with respect to the amount of force applied (in other words, it can be torn or shattered with impact, if you yank on it, it breaks, but if you pull slowly it stretches really far). Silly putty is non-Newtonian viscoelastic polymers, better characterized as a dilatant fluid, try to say that three times fast! Also, it bounces, which is really fun! I'm sure we've all pla yed with Silly Putty, but how about magnetic silly putty?

By adding a ferrous (iron) component to an already wacky substance we can keep all characteristics of the original putty, but now have the additional dimension of magnetism!

Tools:

- disposable gloves (latex or other)
- disposable face mask (easy to find in the paint or pharmacy areas of your local store)
- disposable work area (paper plate)

Materials:

- Silly Putty ($2.00 or less) - any color (and/or make your own to compare using the Borax slime experiment recipe students developed earlier.)
- ferric iron oxide powder (artist supply stores)
- neodymium magnet

The secret ingredient that makes the putty magnetic is an iron oxide powder, which is ferric (magnetic). Ferric iron oxide is a fine powder used as black pigment and can be found at art stores. If your local artist supply store doesn't carry it, it is available online.

Start by clearing a space to work, make sure it is well ventilated. Iron oxide powder is very fine and inhaling it is probably not such a good idea. **Put on your gloves and face mask before you begin.**

Open the silly putty and remove from the container. Have students work the putty in their hands a little to warm it up, that makes it easier to stretch, then stretch it out like a sheet and lay it on your disposable work surface (sheet of paper or paper plate).

Thinking Putty or Silly Putty comes in different sizes, depending on where you purchase it. Many times it comes in an egg-shaped container and is about 24 grams (0.8 oz). For this size, use about a tablespoon of iron oxide, you may require more or less depending on your putty size and amount of magnetism desired. **(This would be a good opportunity for students to form hypothesis about how much powder is the ideal amount, or if you have it pre-made, then to hypothesize how much you put in. Have them follow C^3 and test their hypotheses.)**

Carefully spoon the iron oxide into centre of putty sheet, then close lid on iron oxide powder to reduce excess iron dust escaping. Gently fold edges of putty sheet into centre and work the powder into the putty. Go slow, the powder produces lots of dust.

Did You Know?

Silly Putty® has been around for 50 years now, and in the past half-century, it's become an American toy classic. From its origins in a scientist's laboratory in 1943 and its introduction to the world in 1950, to its addition to the Smithsonian Institution, the fun and colorful history of Silly Putty® is one for the books!

In the midst of World War 2, the Japanese were invading rubber making countries in the Far East, meaning the US couldn't get enough rubber to make truck tires and boots. As a result the government needed help. To save rubber, people in the United States were asked to donate old rubber tires, rubber raincoats, rubber boots, and anything else that was made at least in part of rubber, and American scientists were asked to try to make a new synthetic (fake) rubber.

James Wright, an engineer, combined ingredients that made a gooey substance in his test tube. He was so excited about what he had done that he threw some on the floor accidently and to his surprise, it bounced! But bouncing putty wasn't what the government was looking for so he put his creation on the shelf as a failure.

Though perhaps not useful, the substance continued to be fun! The "nutty putty" began to be passed around to family and friends and even taken to parties. In 1949, the ball of goo found its way to Ruth Fallgatter, an owner of a toy store. Advertising consultant Peter Hodgson convinced Fallgatter to place globs of the goo in plastic cases and add it to her catalog. Selling for $2 each, the "bouncing putty" outsold every other toy in the catalog but one. After a year of strong sales, Fallgatter decided to stop selling it.

Hodgson saw an opportunity. Already $12,000 in debt, Hodgson borrowed another $147 and bought tons of the putty in 1950. He then had Yale College students make the putty into one-ounce balls and place them inside red plastic eggs. Since "bouncing putty" didn't describe all of the putty's unusual characteristics, Hodgson thought hard about what to call it. After coming up with 15 different possible names, he finally decided to name the goo "Silly Putty" and to sell each egg for $1.

After several years it was admired and written about by a writer in the *New Yorker*. Silly Putty became a toy fad, and Hodgson got more than 250,000 orders from all around the country in less than three days. During the 60's Silly Putty became wildly popular all around the world, it was considered the ideal gift to give! Silly Putty even went to the moon on the Apollo 8 mission in 1968!

To see an original commercial for Silly Putty, follow this link:

http://www.sillyputty.com/history_101/timeline/50s/sillyad3.htm

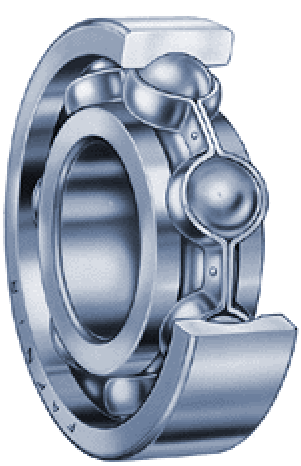
After a minute of massaging the putty it will lose its color and begin to look black as pitch. Have students keep massaging putty for about 3-4 minutes.
That's it, they're done! They can grab magnet and start experimenting with your new magnetic putty.
Students can stretch out a strand and make it follow their magnet; they can polarize the putty to work as a magnet itself *(you can magnetize the putty itself with the neodymium magnet, just like magnetizing other ferrous materials like they did with the nail. The strength of the magnetism depends on the amount of iron oxide in the putty, the length of time the magnet is in contact with the putty, and the strength of the magnet)*, and then there's the classic of placing the magnet directly on the putty and watching it envelop the magnet.
Of course, aside from being magnetic your putty still has all the properties of the original Silly Putty.
Caution: Putty has been known to leave a residue on some surfaces, even more so with the iron oxide powder. Use caution when playing with your magnetic putty not to leave stains or put it on fabric.

- If you can't find iron oxide powder, or for an extension, try mixing silly putty and iron filings. Does it work?
- Black iron oxide or red iron oxides aren't the only magnetic minerals that are used in pigments. There might be another color that works! Why not bring a magnet to the store and see which ones are magnetic?
- What about another type of putty?

Tip: Be aware that kids will try all things with it and that slime/putty on hair is not a good combination. If that should happen, a product like Goo Gone helps separate the slime from the kid.

Other Magnetic Experiments to Try:

- Do magnets work through water? Put a nail in a container of water. Tie a string around a magnet and lower it in, near the nail. Did the magnet attract the nail through the water?



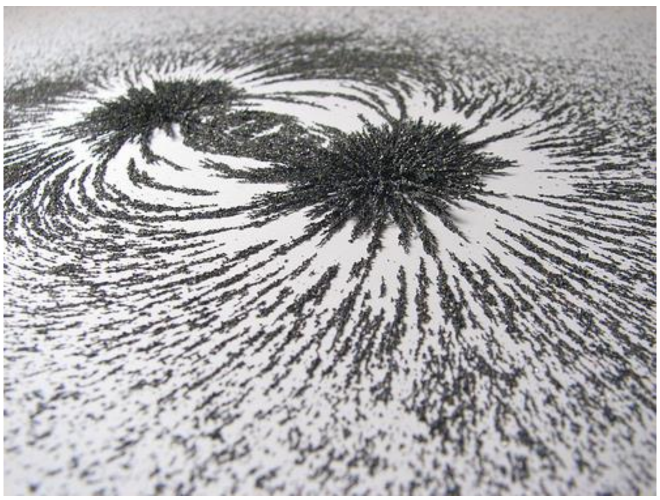
- Have students try to make a magnetic "building" using several strong magnets and various iron or steel objects, such as washers, nails, small steel plates, and parts cut from food cans.
- Place a pile of books between a compass and an alnico magnet held in your hand. The magnetism goes through the books as though they weren't there, and makes the compass needle move.
- Place a number of steel ball bearings (like those from an old skate wheel) in a cardboard box or plastic dish. The balls will "roll mysteriously" as you move an alnico magnet under the box.
- Make a record of music or speech of students on a tape recorder.

Play it back. Then move an alnico magnet near the tape. The sound is changed or may disappear (ask students why that might have happened) when you play it back. The tape makes a record of sounds by magnetizing the brown material on the tape. When you bring a strong magnet nearby you destroy the magnetic pattern and the tape may be re-used after this.

That Mysterious “Something”: A Magnetic Field

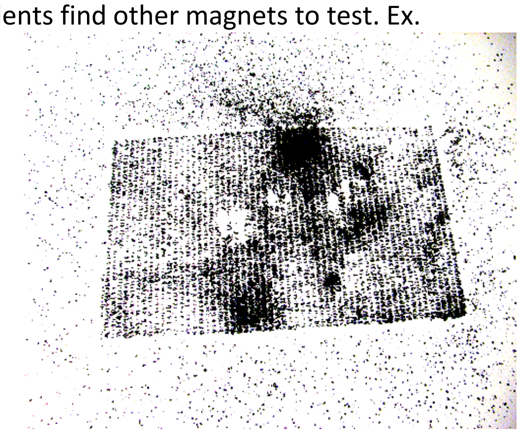
Magnetic fields are everywhere-- you just can't see them, or can you? Place a magnet flat on the table. Shake up the filings in the zip lock bag and put the bag on top of the magnet. Do you see the beautiful pattern formed by the filings? We call this pattern a “magnetic field.” *Another approach is to slowly and uniformly sprinkle the filings onto the paper from a few inches above, giving them an opportunity to arrange themselves in the field. As you add more filings the filings illustrate the field lines more clearly, up until a certain point.*

This “something” is not even like air, which can be trapped in a bottle, and has weight. The magnetic field around a magnet has no weight at all. It passes right through the plastic of the bag.



Repeat the experiment by placing a sheet of aluminum foil, or a piece of cardboard, or plastic or even several more sheets of plastic between the magnet and the iron filings. The bits of iron form the pat- tern just as though these materials were not there. Students can see that magnetism can go right through solid objects.

Have students find other magnets to test. Ex. Consider a simple rubberized refrigerator magnet-- the kind that appears as a business card that you stick on the fridge. Rather than using strong magnets to support the weight, they use a more complex field geometry, with lots of poles, to concentrate the field right by the magnet surface. What does that field look like under filings?



If you have access to a Magna Doodle, or a Wooly Willy toy, have students place your strong magnet on the Magna Doodle screen and remove it. **What do they see?** You can see the field lines show up. **Ask students what must be inside the Magna Doodle?**

Extension Activities:

- Challenge: Add some salt to the iron filings. How can students get them apart? Idea: Wrap their magnet in plastic and place it in the bag. When they lift the magnet, the salt remains.
- Place an index card in your filings bag with most of the filing on top of it. Hold the magnet under the card in the bag. What happens?

Lines of Force

So we've seen how iron filings can be made to reveal the magnetic field around a magnet. Why did the iron filings line up to form a pattern? As each filing fell, the poles of its atoms were attracted or repelled by the nearby poles of the magnet under the paper. So each

iron filing became a tiny magnet. The north pole of one iron filing then attracted the south pole of another. Thus, all the filings tended to stick together to form a curved line around the magnet, from the north to the south pole. The paths along which the filings form are called lines of force. Have students make a lines of force pattern with magnets having unlike poles near each other, then with like poles. They should discover that lines of force always go from one pole to an unlike pole, and never to a like pole.

Eddy Currents

In the following experiment students observe and determine why a magnet falls more slowly through a metallic tube than it does through a nonmetallic tube. The following activity was found at http://www.exploratorium.edu/snacks/eddy_currents/index.html. Science Snacks. ©The Exploratorium. Accessed 8/30/11. All Rights Reserved

When a magnet is dropped down a metallic tube, the changing magnetic field created by the falling magnet pushes electrons in the metal tube around in circular, eddy-like currents, like in water. These eddy currents have their own magnetic fields that oppose the fall of the magnet and try to push it back up. The magnet falls dramatically slower than it does in ordinary free fall in a nonmetallic tube.

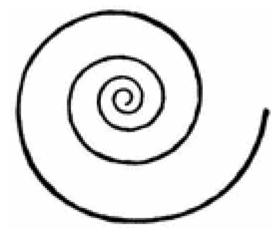
Materials:

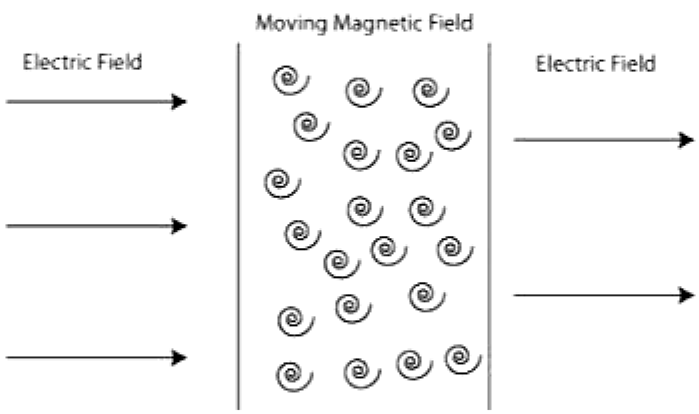
- A cow magnet or neodymium magnet.
- A nonmagnetic object, such as a pen or a pencil.
- One 3 foot (90 cm) length of aluminum, copper, or brass tubing (do NOT use iron!) with an inner diameter larger than the cow magnet and with walls as thick as possible.
- One 3 foot (90 cm) PVC or other nonmetallic tubing.
- Optional: 2 thick, flat pieces of aluminum (available at hardware and home-repair stores); cardboard; masking tape; rubber bands or cord.

Instructions:

Hold the metal tube vertically. Drop the cow magnet through the tube. Then drop a nonmagnetic object, such as a pen or pencil, through the tube. **Do students notice that the magnet takes noticeably more time to fall? Why would it do that?** Now try dropping both magnetic and nonmagnetic objects through the PVC tube.

In addition to dropping these objects through the tubes, a very simple, visible, and dramatic demonstration can be done by merely dropping the magnet between two thick, flat pieces of aluminum. The aluminum pieces should be spaced just slightly farther apart than the thickness of the magnet. A permanent spacer can easily be made with cardboard and masking tape if you don't want to hold the pieces apart each time. Rubber bands or cord can hold the pieces all together. The flat surfaces need to be only slightly wider than the width of the magnet itself. Thickness, however, is important. The effect will be seen even with thin pieces of aluminum, but a thickness of about 1/4 inch (6 mm) will produce a remarkably slow rate of fall. Allow at least a 6 inch (15 cm) fall.





The above figure demonstrates the reduction (shrinking) of the electric field due to the presence of eddy currents in a conductor.

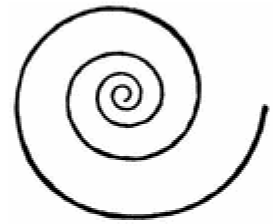
Image Credit: http://www.epuniversity.org/tech/emi8.html. Accessed 8/31/11. All Rights Reserved.

Why does it do that?

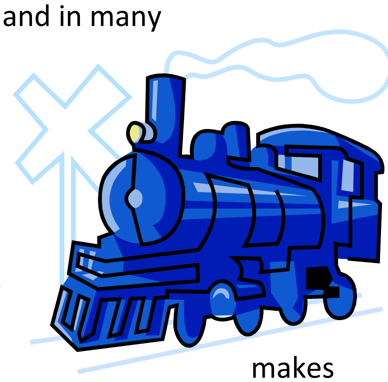
As the magnet falls, the magnetic field around it constantly changes position. As the magnet passes through a given portion of the metal tube, this portion of the tube experiences a changing magnetic field, as all the atoms try to turn towards the magnet's poles as they pass. This changing field starts the flow of swirling eddy currents in an electrical conductor (something that electricity can go through), such as the copper or aluminum tubing. The eddy currents create a magnetic field that exerts a force on the falling magnet. The force (swirling north and south poles) opposes the magnet's fall. As a result of this swirling magnetic repulsion (north vs. south pushing against each other), the magnet falls much more slowly.

Where are eddy currents?

Eddy currents are circular currents generated/created in the core of a motor or transformer. Eddy currents lower power quality and are a major source of electrical losses.



Eddy currents are often accidentally generated in electrical transformers and lead to power losses, and people like to keep their electricity on. So, to combat this, thin, laminated strips of metal are used when building power transformers, rather than making the transformer out of one solid piece of metal. The thin strips are separated by insulating glue, which keeps the eddy currents inside the strips, since electricity can't go through the glue. So by using strips, if there are going to be any eddy currents, they are going to be very small currents that provide very little bleeding off of the energy, thus reducing or even preventing the power loss in the transformer, keeping power flowing smoothly through, and people happy as their electricity stays on!

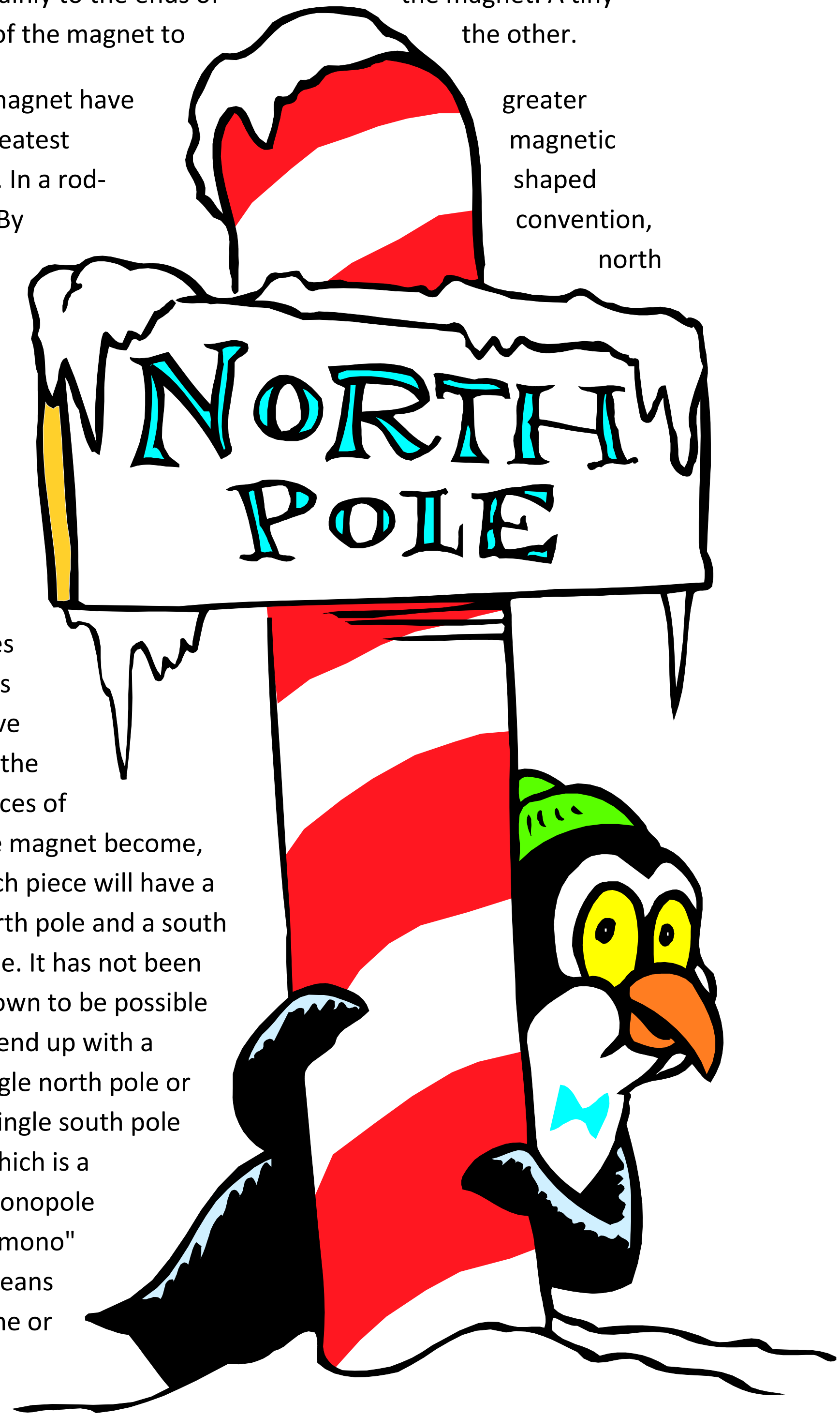


Now, eddy currents can be useful. How? Eddy currents transform more useful forms of energy, such as kinetic energy, into heat, which is generally much less useful and in many applications the loss of useful energy is not something people want, but there are some practical applications. One is in the brakes of some trains. During braking, the metal wheels are exposed to a magnetic field from an electromagnet, generating those swirling eddy currents in the wheels. The magnetic interaction between the applied field and the eddy currents acts to slow the wheels down. The faster the metal wheels are spinning, the stronger the effect, and the slower they spin, the weaker the effect. That means that as the train slows the braking force is reduced, which makes a nice smooth stopping motion.

Tip: With high-strength neodymium magnets, the effects of eddy currents become even more dramatic. These magnets are now available from many scientific supply companies, and the price has become relatively affordable.

Magnetic Poles

Bring the head of a small nail just underneath the middle of a rod- shaped alnico magnet, and let go. The nail tends to lump over to the end of the magnet and stick there Dip a magnet into a pile of small iron objects, such as washers or brads. They stick mainly to the ends of the magnet. A tiny bridge of Iron objects may form from one end of the magnet to the other.



These experiments show that the ends of the magnet have greater magnetic pull than the middle. The places of greatest strength in a magnet are called magnetic poles. In a rod-shaped magnet there are two poles, one at each end. By convention, we say that the magnetic field lines leave the north end of a magnet and enter the south end of a magnet. This is an example of a magnetic dipole ("di" means two, thus two poles). A magnet may have more than two poles. But no magnet has ever been found to have just one pole.

If you take a bar magnet and break it into two pieces, each piece will again have a north pole and a south pole. If you take one of those pieces and break it into two, each of the smaller pieces will have a north pole and a south pole. As we've seen with our iron filings, no matter how small the pieces of the magnet become, each piece will have a north pole and a south pole. It has not been shown to be possible to end up with a single north pole or a single south pole which is a monopole ("mono" means one or single, thus one pole).

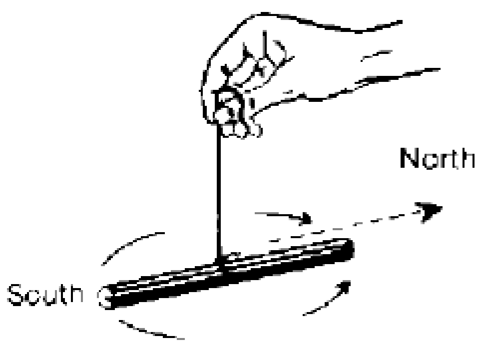


Image Credit: Don Herbert and Hy Ruchlis. *Mr. Wizard's 400 Experiments in Science*. http://www.arvindguptatoys.com/arvindgupta/400wizard.pdf Accessed 8/30/11. All Rights Reserved

North and South activity:

Have students suspend their magnet from a thread so that it can rotate freely. Keep it away from iron objects, such as pipes and radiators. See that no other magnets are nearby. Their magnet swings around and points in one particular direction, north. Have students mark one end with a permanent marker or nail polish.

Try to change the direction in which it points. When they let go it immediately comes back to the same direction. Place it in different parts of the room—away from iron objects. Take it outdoors. No matter what they do the magnet swings back to the same direction. Locate north in your room. You can use a magnetic compass for this purpose. Or you can obtain north from the direction of the sun's shadow at noon. You can also use a map. Your hanging magnet points in almost the same direction as north. The end of the magnet that points north is called a "north seeking pole". Most people shorten this name to north pole. The opposite end of the magnet points south. So it is called a south pole. Your swinging magnet is almost the same as a regular magnetic compass. The main difference is in the way the magnet swings. A regular compass has a magnet that pivots on a sharp point and usually has a case around it.

Creating Your Own Homemade Compass

Knowing what direction you are facing is a very valuable piece of information. This is especially true if you are traveling: because you can use the information to help find your way or guide your safe return. There's nothing much worse than getting hopelessly lost in the woods or successfully exploring a new frontier, only to find that you have no idea how to make it back home.

No matter where you stand on Earth, you can hold a compass in your hand and it will point toward the North Pole. What an unbelievably neat and amazing thing! In fact, the compass was probably the first important magnetic device discovered. Around the 12th century, someone noticed that when allowed free movement, a magnet always points in the same north/south direction. This discovery helped sailors who often had trouble navigating when the clouds covered the sun or stars. Imagine that you are in the middle of the ocean, and you are looking all around you in every direction and all you can see is water, and it is cloudy so you cannot see the sun. How in the world would you know which way to go unless you had a compass to tell you which way is "up?"

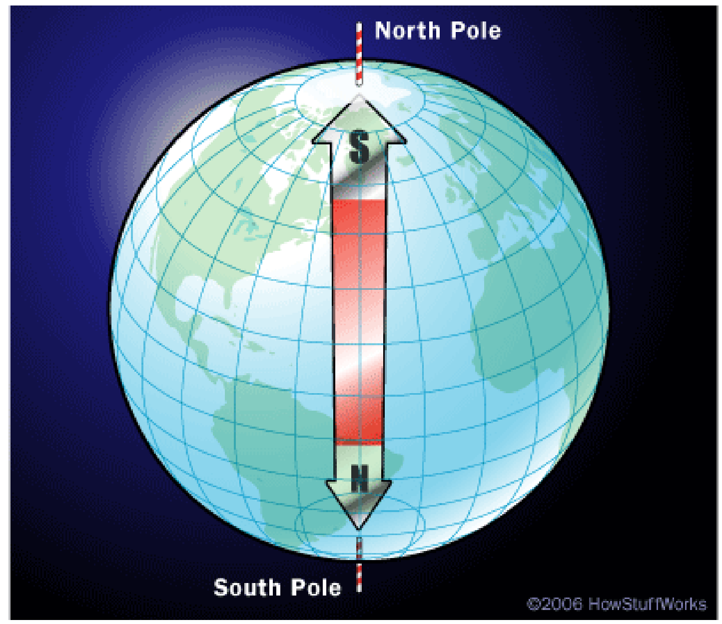


Image Credit: How Stuff Works. http://adventure.howstuffworks.com/outdoor-activities/hiking/compass2.htm. Accessed 8/31/11. Copyright 2006. All Rights Reserved.

Long before GPS satellites and other high-tech navigational aids, the Ancient Chinese sometimes determined direction with a device consisting of a wooden fish containing a magnetized needle placed in a bowl filled with water. This and a different spoon-type compass paved the way for more precise instruments that allowed explorers to accurately navigate the seas, instead of having to sail close to land to know where they were, effectively changing the course of history. If you don't have a compass, you can create your own in much the same way people did hundreds of years ago. A compass is an extremely simple device. A magnetic compass is made up of a small, lightweight magnet balanced on a nearly frictionless pivot point, meaning it doesn't rub against anything to slow it down. The magnet on a compass is called a needle. One end of the needle is often marked "N," for north, or colored in some way to indicate that it points toward north. On the surface, that's all there is to a compass.

The reason why a compass works is quite interesting. It turns out that we can think of the Earth as having a gigantic bar magnet buried inside. **In order for the north end of the compass to point toward the North Pole, what end of the "bar magnet" has to be at the top of the earth?** We have to think of the buried bar magnet having its south end at the North Pole, as shown in the diagram. It might sound confusing at first, but if you think of the world this way, then you can see that the normal "opposites attract" rule of magnets causes the north end of the compass needle to point toward the south end of the buried bar magnet. A magnetic compass does not point toward the true physical tip top North Pole of the Earth. Rather, it more closely points toward the North *Magnetic* Pole of the Earth. The North Magnetic Pole is currently

Fun Fact

Did you know the moving North Pole is affecting, of all things, Florida air travel? Tampa International Airport had to shut down its main runway in 2011 until it could repaint the signs at each end to account for the shift, the Tampa Tribune reported. Changes in the Earth's core are responsible for the moving North Pole, forcing the runway to change its designation (where it is) on maps and aviation charts from 18R/36L to 19R/1L.

located in northern Canada. It wanders in an elliptical (egg shaped) path each day, and moves, on the average, more than forty meters northward each day and almost 40 miles a year toward Russia. Evidence indicates that the North Magnetic Pole has wandered over much of the Earth's surface in the 4.5 billion years since the Earth formed. So the compass points toward the Magnetic North Pole, which was enough to help sailors find their way.

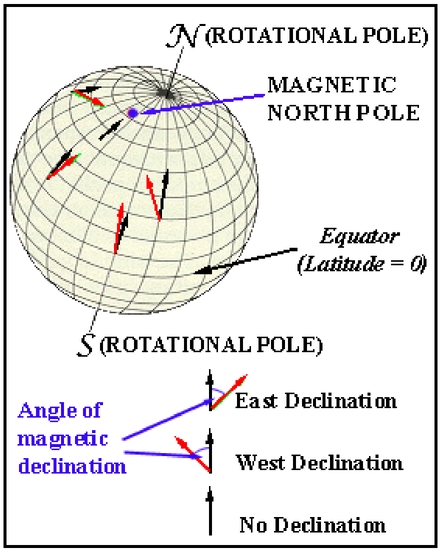


Image Credit: Solcomhouse. http://www.solcomhouse.com/arctic.htm. Accessed 9/1/11.

To be completely accurate, the bar magnet does not run exactly straight up and down along the Earth's rotational axis. It is skewed, or shifted, slightly off center. This skew, or shift, is called the declination, and most good maps indicate what the declination is in different areas (since it changes a little depending on where you are on the planet) so that you don't get lost and wander off too far.

The magnetic field of the Earth is actually fairly weak on the surface. After all, the planet Earth is almost 8,000 miles in diameter, so the magnetic field has to travel a long way from the middle of the earth to affect your compass. That is why a compass needs to have a lightweight magnet and a frictionless bearing, meaning it's not rubbing against anything or having to pull against anything. Otherwise, there just isn't enough strength in the Earth's magnetic field to turn the needle.

The "big bar magnet buried in the core" analogy works to explain why the Earth has a magnetic field, but obviously there isn't really a giant magnet running through the middle of our planet. So what is really happening?

No one knows for sure, but the Earth's core is thought to be made mostly of molten (melted) iron, but at the very center of the core, the pressure is so great that this superhot iron crystallizes and turns back into a solid. Convection *(hotter and therefore less dense material rises, and colder, denser materials sink*) caused by heat radiating from the core, along with the rotation of the Earth, causes the liquid iron to rotate, rising up as it heats and sinking back down as it cools. It is believed that the spin and currents in the liquid iron layer, lead to weak magnetic forces around the axis of spin. Because the Earth's magnetic field is so weak, a compass works as a detector for very slight magnetic fields created by anything, this is why it can be changed or pulled to

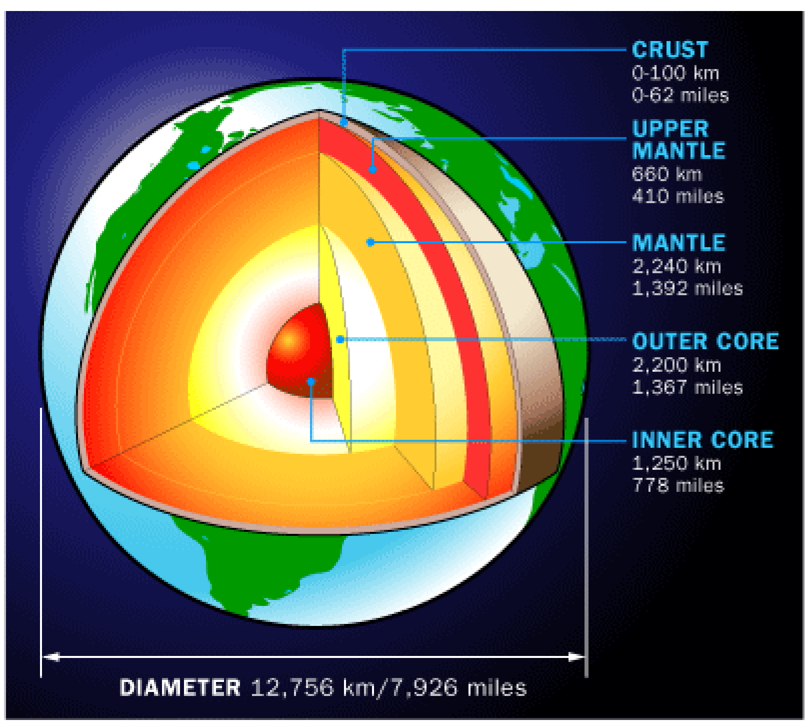


Image Credit: How Stuff Works. http://adventure.howstuffworks.com/outdoor-activities/hiking/compass2.htm. Accessed 8/31/11.

the north pole of a strong magnet or a large enough piece of magnetic metal.

To create your own compass, you will need the following materials:

- A needle or some other wire-like piece of steel (a straightened paper clip, for example)
- Something small that floats such as a piece of cork, the bottom of a Styrofoam coffee cup, a piece of plastic, a small piece of straw (put the needle inside) or the cap from a milk jug
- A dish, like a pie plate, 9 to 12 inches (23 - 30 cm) in diameter, with about an inch (2.5 cm) of water in it

The first step is to turn the needle into a magnet. The easiest way to do this is with another magnet -- stroke **one** of the poles of the magnet along the needle 10 or 20 times in the same direction.

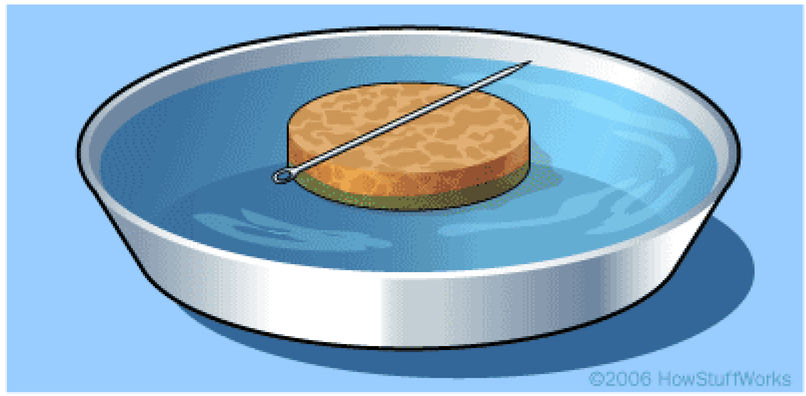


Image Credit: How Stuff Works. http://adventure.howstuffworks.com/outdoor-activities/hiking/compass2.htm. Accessed 8/31/11. Copyright 2006. All Rights Reserved.

Place your float in the middle of your dish of water. The "float on water" technique is an easy way to create a nearly frictionless bearing. Center your magnetic needle on the float. It very slowly will point toward north. You have created a compass like ancient sailors used. A magnetic compass like this one has several problems when used on moving platforms like ships and airplanes.

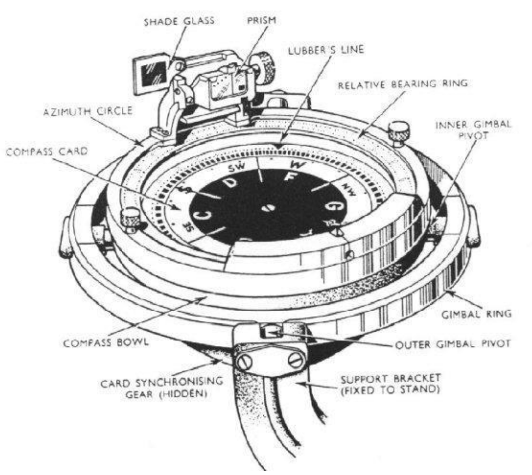
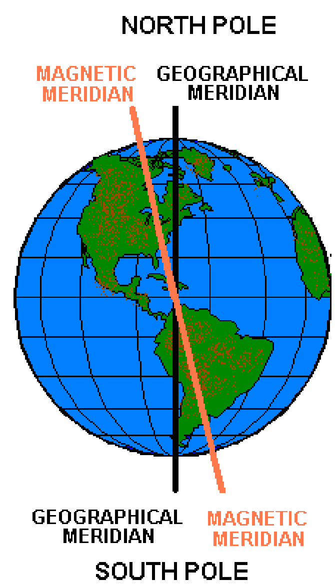


Image Credit: http://www.thursoseacadets.com/page20.htm. Accessed 9/1/11. All Rights Reserved.

(Ask students what they think might be some of the difficulties) It must be level, and it tends to correct itself rather slowly when the platform turns.

Modern ships and planes use a gyrocompass and GPS systems. This type of compass gets its guidance from the rotation of the earth and as it rotates it uses gravity and the Earth's own rotation to find true north, i.e., the point of the Earth's rotational axis on the Earth's surface, as opposed to magnetic north, –an extremely important aspect in navigation. This helps ships and planes know where they are on the planet, and gyrocompasses aren't bothered or changed or confused by external magnetic fields which might affect or deflect normal compasses, such as those fields created by some metals in a ship's hull (outer walls). It is dependent on the ships power and maintenance in order to keep working and they are often put as close to



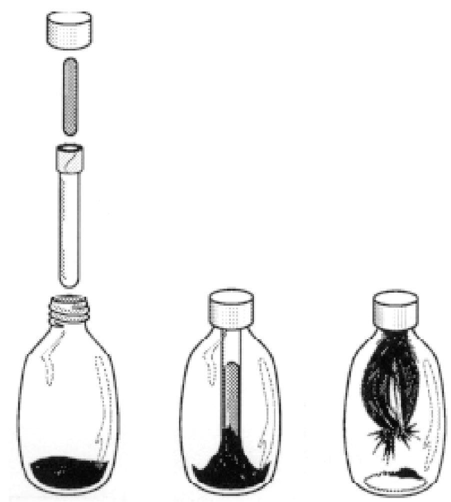
the middle of the ship as possible, to help it be as accurate as possible and it sends information to the bridge, which is used by the captain and sailors to guide the ship.

3D Magnetic Lines of Force

Now that we know more about poles, let's go back to the lines of force and see if we can understand even better what those little filings are up to. In this experiment iron filings will trace out the lines of a magnetic field in three dimensions. Iron filings will line up parallel to a magnetic field, making the pattern of the field visible. This is a simple experiment to build - and because the filings are trapped in a bottle, they don't make a mess! Even better, right?

Materials:

- A plastic soda bottle, 16 oz. (0.5 liter) size.
- A plastic test tube that fits into the mouth of the bottle and is about 75% as long as the bottle is tall.
- A cow magnet or other cylindrical magnet that fits into the plastic tube. (A stack of Radio Shack button magnets works fine.)
- Masking tape.
- Iron filings (available at science museums or from scientific suppliers). You can use magnetic sand (black sand) collected by dragging a magnet through iron-rich beach sand.



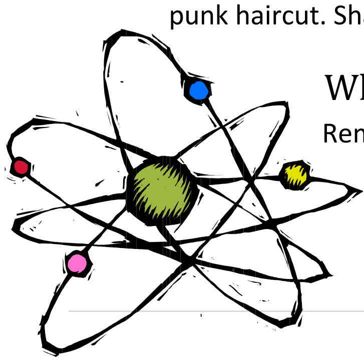
Preparation:

Remove the label from the soda bottle. Fill the bottle about one-fifth full of iron filings. Wrap the top of the test tube with masking tape so that the tube fits snugly into the mouth of the bottle, plugging the opening completely. After you put the iron filings into the bottle, jam the tube into the mouth of the bottle.

Instructions:

Slide the cylindrical magnet into the test tube and put the bottle cap back on. Turn the bottle on its side and rotate it. Watch what happens to the iron filings. They will form a three-dimensional pattern that traces out the magnetic field of the magnet.

Pay particular attention to what happens at the end of the magnet. Here, the iron filings stand out like a punk haircut. Shake the magnet out of the tube, and watch the filings collapse.



Why does it do that?

Remember, each atom in a piece of iron is a magnet, with a north pole and a south pole. Most pieces of iron are not magnetic, since the atomic magnets all point in different directions.

When you bring a magnet near a piece of iron, the iron-atom magnets line up with the applied magnetic field: The north poles of the iron atoms all point in the same direction. Because the iron atoms line up, each tiny piece of iron becomes a magnet and is attracted to the original magnet.

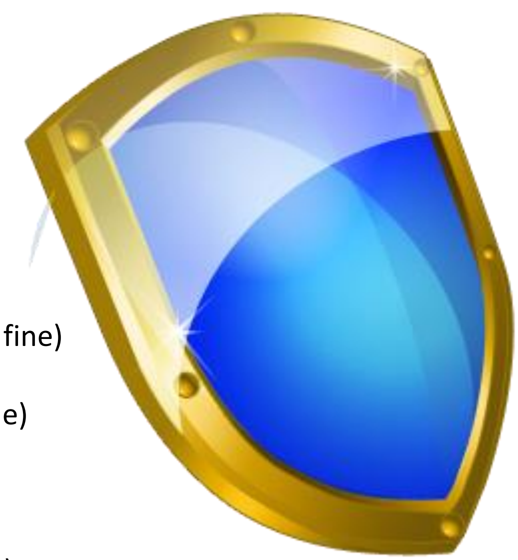
In a rod-shaped piece of iron, the atoms will tend to line up so that all the north poles face one end of the rod and all the south poles face the other end. Since iron filings are rod-shaped, the atoms line up pointing along the length of the rod, and the rods line up parallel to the direction of the applied magnetic field. The field of a cylindrical magnet comes out of the end of the magnet and then loops around next to the side. The iron filings stick out like a crew cut on the ends of the magnet but lie flat on the sides.

Because the iron filings become magnets themselves, their presence slightly changes the shape of the magnetic field. Even so, this exhibit gives an indication of the shape of the magnetic field in three dimensions.

FYI

If you use a plastic bottle and seal it well by jamming the test tube into its mouth, the sides of the bottle will begin to collapse inward after a few hours - particularly if the inside of the bottle is damp. This happens because the iron filings are rusting. As the iron rusts, it combines with and removes oxygen from the air trapped in the bottle. To prevent the bottle's collapse, simply punch a small hole in the plastic with a pin.

Magnetic Shielding



Magnetic lines stop here!

The following experiment was found at The Exploratorium in their Science Snacks section. http://www.exploratorium.edu/snacks/magshield/index.html. Accessed 9/1/11.

Materials:

- Donut or circular magnets (rectangular magnets work fine)
- Two pieces of cardboard (about 5 x 7 cm)
- Two 1/4- inch dowels, 7 cm or longer (pencils work fine)
- Five or six paper clips
- Popsicle stick, straw, any non-metallic material
- Strip of metal strapping tape (or a butter knife)
- Hot glue gun (school glue or rubber bands are fine too)

Preparation

Attach dowels (or pencils) to one piece of cardboard. Placing the dowels close to the edges will give you more room to experiment. Attach the second piece of cardboard to the dowels so that you end up with a "cardboard-dowel-cardboard" sandwich. Hot glue (or tape) the magnet onto the top piece of cardboard. For the best results, center the magnet near the edge.

Instructions:

Raise the paper clips up to the bottom of the shielding sandwich one at a time and notice what happens. The paper clips should be attracted to the magnet on the top piece of cardboard and will hang from the bottom of the cardboard sandwich. If this does not happen, the magnet may too weak, the pieces of cardboard too thick, or the dowel thickness too large. In any case, you can remedy this situation by adding another magnet to the first one. As you add more paper clips, notice what happens. If you add them carefully, they will arrange themselves so that they are evenly spaced. Insert the popsicle stick into the shielding sandwich, move it around, and notice what happens. The paper clips should be unaffected. Now insert the metal packing strap (or butter knife) into the shielding sandwich, move it from side to side and notice what happens. The paper clips should fall off. Try experimenting with various metallic coins and different materials. Make a list of the materials you tested and what happened.

Why does it do that?

The magnetic field lines from the magnet pass through the cardboard and air. Materials like the popsicle stick that allow magnetic lines of force to pass through them are called *non-permeable.* The metal strapping tape (or butter knife) acts as a magnetic shield. The force lines coming from the pole of the magnet do not pass through the metal strap. Instead, they are gathered in, travel down the metal strap, and re-enters the magnet at the other pole. Materials that gather magnetic lines of force are said to be *permeable.* Only magnetic materials are permeable.

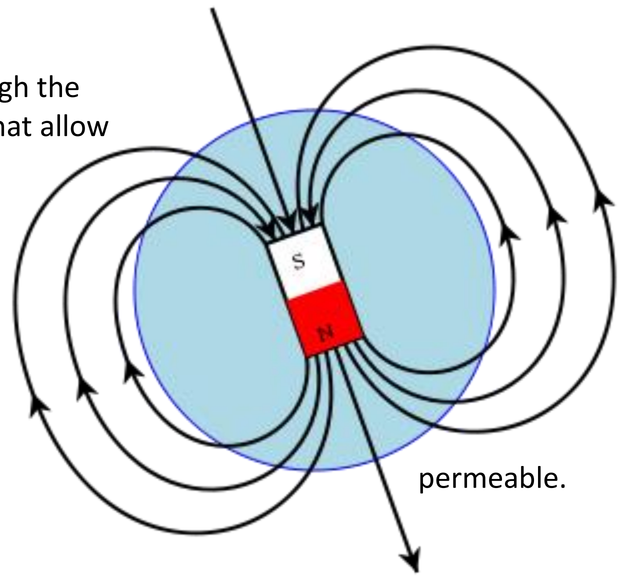
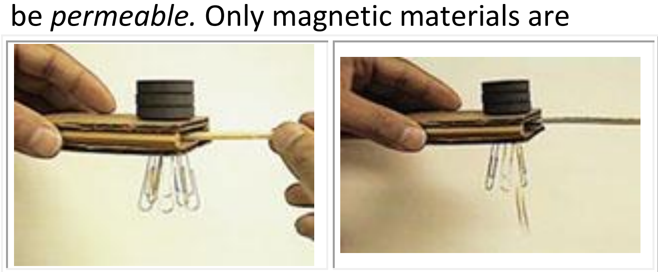


Image Credit: Wikipedia. http://en.wikipedia.org/wiki/File:Earths_Magnetic_Field_Confusion.svg. Accessed 9/1/11. All Rights Reserved.



Non-permeable material   Permeable material

FYI

Scientists model magnetic forces using field lines. A compass lines up along a field line, so you can trace field lines with a compass. Iron filings also line up along field lines. As we've learned, by sprinkling iron filings on a piece of paper laying on top of a magnet (or a couple of magnets), you can see the field lines. Field lines are defined as coming from the north pole of a magnet and returning to the south pole. Magnets have field lines that exert a force on magnets or iron. If there are no field lines, there is no force, and the result is magnetic shielding.

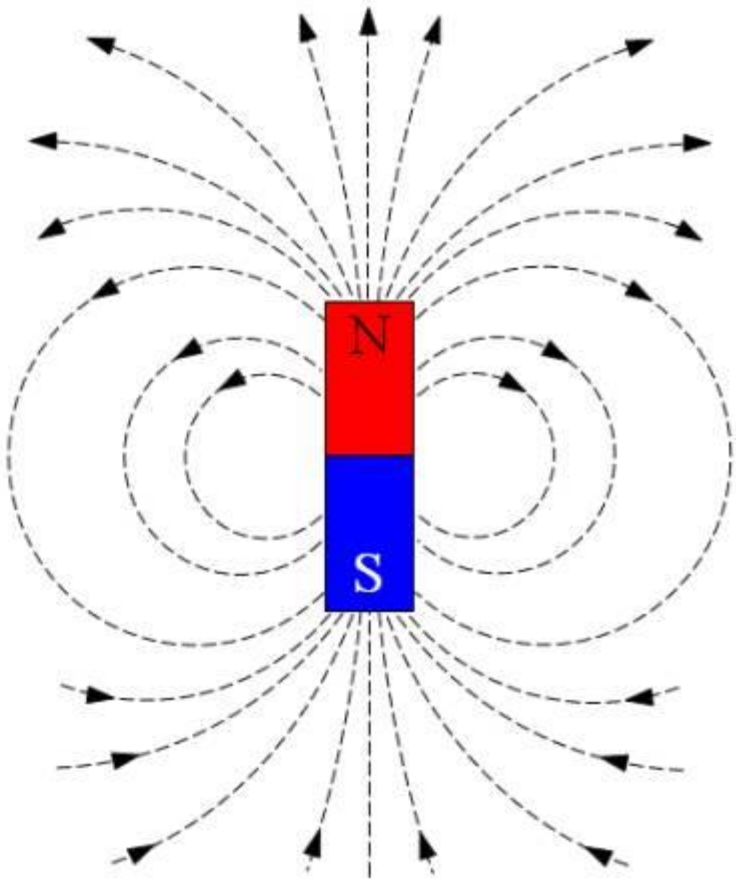
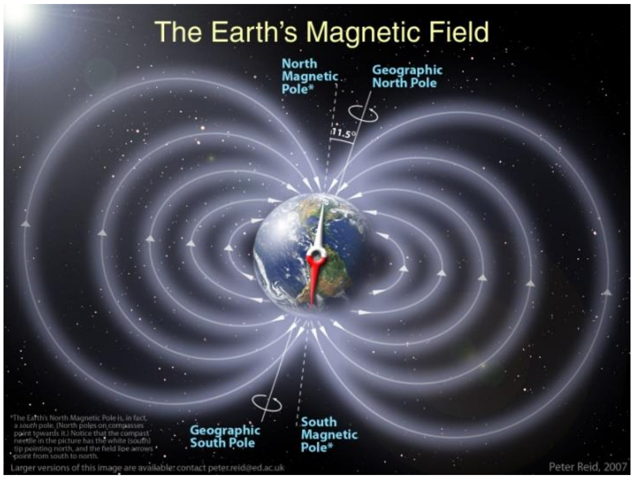


Image Credit: DiracDelta Science and Engineering Encyclopedia. http://www.diracdelta.co.uk/science/source/m/a/magnetic%20field/source.html. Accessed 9/1/11.

Discuss with students in what kind of situations might a person or companies want magnetic shielding? What kinds of things do strong magnetic fields affect? What if you had lots of delicate computer equipment? Would you want it protected?

Two Kinds of Force

Locate the north pole of an alnico magnet by suspending it from a string. Use a crayon to mark the pole that points north. Do the same with another alnico magnet.



Now have students hold a magnet in each hand with the north poles facing each other. Bring them together. They almost wriggle out of their grasp as they resist being pushed together.

The magnets repel each other.

Try bringing the south poles together. They repel in the same way. *Tip: Don't try this too often, because the magnets tend to get weaker as you repeat the experiment.*

Now try bringing a north pole near a south pole. This time they attract and pull together tightly. Try pulling then apart. Students can get some idea of the strength of the magnets by the amount of force they must exert to separate them.

These facts are expressed in the following rules:

Like poles repel.

Unlike poles attract.

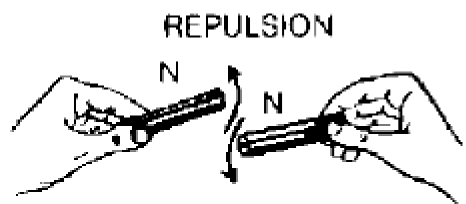


Image Credit: Don Herbert and Hy Ruchlis. *Mr. Wizard's 400 Experiments in Science*. http://www.arvindguptatoys.com/arvindgupta/400wizard.pdf Accessed 8/30/11. All Rights Reserved

In other words, opposites attract. Like poles push away from each other and unlike poles pull together. Students can quickly check the truth of these rules by bringing the north end of the magnet near a compass. In most compasses the north seeking end is darker in color than the south end. The north end of the compass swings away from the north pole of your magnet, and the south end comes closer. The reverse happens when you try it with the south pole.

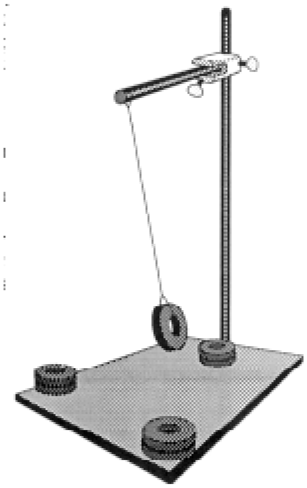
Have students touch the point of a nail to the north pole of a magnet. Bring the point of the nail near a compass. It repels the south pole and is therefore south. They will find that an opposite pole always forms on the part of a piece of iron that is touched to a magnetic pole.

Do students remember why the magnetic needle of a compass points north?

The earth behaves as a giant magnet with two magnetic poles. One magnetic pole appears to be in Northern Canada. Compasses therefore point towards this region.

Strange Attractor

The attraction and repulsion of magnets produces amazing, unpredictable motion.



Patterns of order can be found in apparently disordered systems. This pendulum - a magnet swinging over a small number of fixed magnets - is a very simple system that shows chaotic motion for some starting positions of the pendulum. The search for order in the chaos can be very engrossing.

Materials

- A ring stand and a clamp. (or another improvised stand, the stand can also be easily made from Tinkertoys™ or pieces of wood, see illustration to get ideas)
- 4 to 6 ceramic magnets
- Paint, masking tape, or correction fluid.
- Fishing line or string.

Preparation

Put all the magnets together in a stack so that they stick together magnetically. By doing this, you are orienting the magnets so that all of the north poles point in one direction and all of the south poles point in the other direction. Mark the top of each magnet with paint, tape, or correction fluid, thus identifying all the matching poles.

Use the string or fishing line to hang one magnet from the ring stand so that it is a free-swinging pendulum. You can hang the magnet in any orientation.

Arrange the other magnets on the ring stand base in an equilateral triangle measuring a couple of inches on a side. Position the magnets so that they all have the same pole up.

Adjust the length of the pendulum so that the free-swinging magnet will come as close as possible to the magnets on the ring stand base without hitting them or the base itself. You can accomplish this either by changing the length of the string or by adjusting the position of the clamp.

Instructions

Have students give the pendulum magnet a push, and watch!

Vary the location and poles of the magnets to develop other patterns. You can arrange the magnets so that all of them have the same pole up, or you can mix them up. Notice that a tiny change in the location of one of the fixed magnets or in the starting position of the pendulum magnet may cause the pendulum to develop a whole new pattern of swinging.

Why does it do that?

The force of gravity and the simple pushes and pulls of the magnets act together to influence the swinging pendulum in very complex ways. It can be very difficult to predict where the pendulum is going to go next, even though you know which magnets are attracting it and which are repelling it.

This sort of unpredictable motion is often called *chaotic motion*. Strangely enough, there can be a subtle and complex kind of order to chaos. Scientists try to describe this order with models called *strange attractors*.

FYI

The new sciences of chaos and turbulence are unveiling hidden relationships in nature. Diverse phenomena, such as the patterns of Saturn's rings, measles outbreaks, and the onset of heart attacks all follow chaotic patterns.

Often, a system that is predictable in the long run shows chaotic variations in the short run. Although it is quite difficult to predict specific daily weather behavior in the San Francisco Bay Area, the overall long-term patterns are generally known. The individual motion of insects may be random and insignificant, yet the behavior of the population as a whole can be analyzed.

As shown in this experiment, a very slight difference in the starting position of the pendulum can grow to a tremendous difference in the pattern of motion in a short time. This is characteristic of chaotic systems. Weather scientists recognize this characteristic of chaos when they argue over the "butterfly phenomenon." That is, can a butterfly flapping its wings in China drastically alter the weather in New York?

Magnetic Materials

Have students bring a magnet near paper, wood, glass, plastic, a copper penny, aluminum foil and a rubber band. What happens? Nothing seems to happen.

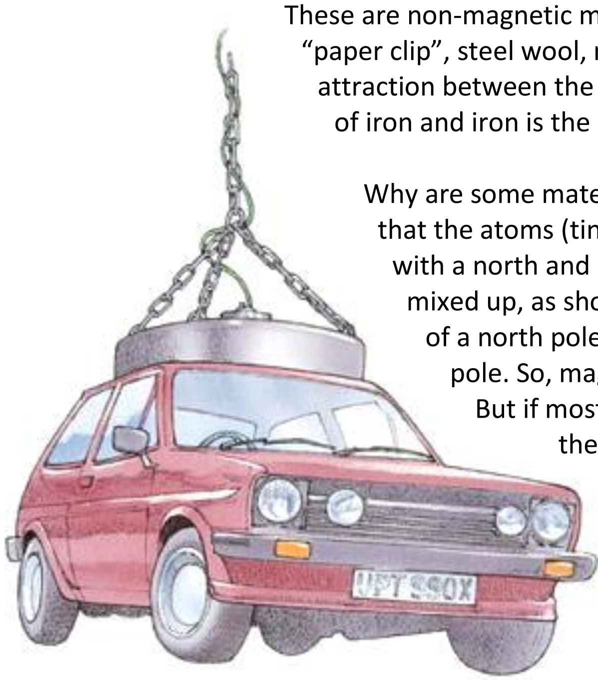


Image Credit: http://greenanswers.com/q/93962/ideas-philosophies/what-are-electro-magnets-used. Accessed 9/6/11.

These are non-magnetic materials. Then have them bring the magnet near a "paper clip", steel wool, nails, washers, a tin can, or a radiator. Now there is attraction between the magnet and the object. All of these objects are made of iron and iron is the most common magnetic material.

Why are some materials magnetic while others are not? Scientists think that the atoms (tiny particles) of all materials are little magnets, each with a north and south pole. If the atoms are arranged with their poles mixed up, as shown in the drawing, then the attraction or repulsion of a north pole is cancelled by the opposite force of a nearby south pole. So, magnetic force is not noticed outside the magnet. But if most of the atoms have their poles lined up as shown in the drawing then the attraction or repulsion of all the north poles at one end are not cancelled out, and the magnetic force is therefore noticed. At the other end of the magnet the forces exerted by the south poles of the atoms build up into the strong force of a south pole. The center of a magnet is weak because the force of every north pole is cancelled by the force of a nearby south pole.

Materials differ in the ease with which their atoms can be lined up. In nonmagnetic materials the atoms don't turn around and lineup. But in a magnetic material like iron they line up very easily. Have students think back to the first experiment, when an iron nail was brought near the north pole of a magnet, the south poles of the atoms of the nail were pulled around and lined up facing the north pole. Thus, the nail became magnetized. But if the nail was taken away from the magnet, its atoms get out of order by themselves and then the magnetism is not noticed outside the nail. Actually, it is there all the time, but in a jumbled condition, banging the magnet helps to shift the atoms so that they lose then lined-up condition.

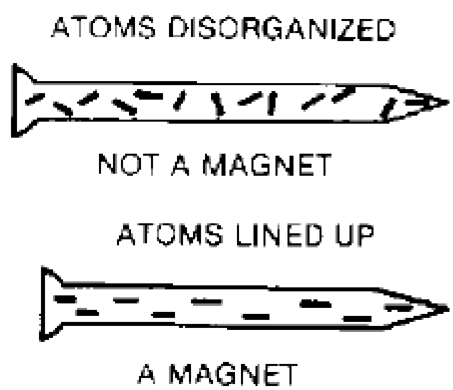


Image Credit: Don Herbert and Hy Ruchlis. *Mr. Wizard's 400 Experiments in Science*. http://www.arvindguptatoys.com/arvindgupta/400wizard.pdf Accessed 8/30/11.

Like iron, certain other metals, (nickel and cobalt) are magnetic, but not as much as iron. Certain alloys (mixtures of metals) are also magnetic. For example, alnico is an alloy of aluminum, nickel, cobalt and iron. When non-magnetic aluminum is alloyed with (mixed with) the magnetic materials, nickel, cobalt and iron, it makes one of the strongest magnetic materials known.

Not everything that contains iron is magnetic. **Have students try lifting a stainless steel spoon with a magnet. In most cases no attraction will be noticed, even though the spoon is made mainly of iron.**

Test a variety of metallic items to see which are magnetic. Are any U.S. or foreign coins magnetic? If you have one, students will find a Canadian nickel to be magnetic. The U.S. nickel is not magnetic because it has a lower percentage of nickel metal.

Now there is one kind of paper that's magnetic…one we use all the time. Money! Believe it or not, dollar bills are printed with magnetic inks as a way to reduce counterfeiting (people making fake money and using it as real money.) Not sure what to believe? Try it out. You'll need to get your hands on a super strong neodymium magnet to uncover the truth. Fold the dollar bill in half as shown and hold the neodymium magnet near the bottom of the bill. Notice how the bottom of the bill moves when the iron in the bill is attracted to the magnet. Now, the only logical question that follows is, "Can you get the iron out of a dollar bill?" Your students will be amazed at how much iron is in a single dollar bill.

Magnetic Money

Materials

- $1 bill (be sure to borrow it from a friend)
- Kitchen blender
- Water
- Quart size zipper-lock bag
- Super strong Neodymium Magnet

1. You'll need a dollar bill. Now you could just dig down deep into your own pocket to find a bill or you can borrow the bill from a friend. Hey, why should you have to provide the entertainment and pay for it too?
2. Have a student hold the neodymium magnet near the bottom of the bill. Notice how the bill is attracted to the magnet.
3. Fill the blender half full with water (between 3 and 4 cups).
4. After the bill has been thoroughly examined by your students, to verify that it's real, drop the dollar bill into the blender and put on the lid.
5. What's next? Make dollar bill soup! Grind it, blend it, liquefy it... just make sure it's torn into thousands of little pieces.
6. After the money has been grinding away for at least a minute, stop the blender and pour the contents into a quart size zipper-lock bag. Seal the bag.
7. Place the neodymium magnet in the palm of your hand and place the bag of money soup on top of the magnet. Place your other hand on top of the bag and rock the slurry back and forth in an effort to draw all of the iron to the magnet. Flip the bag over and look closely at the iron

that is attracted to the magnet. You can slowly pull the magnet away from the bag to reveal the iron!

A student might suggest repeating the experiment with a $5 or a $10 or even a $20 bill, but don't waste your money. A higher dollar amount doesn't mean it has a higher iron content!

How does do that?

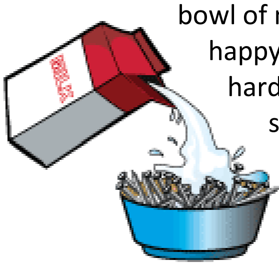
Neodymium magnets (Nd-Fe-B) are an alloy made of neodymium, iron, boron and a few transition metals. These magnets are extremely strong for their small size. As it turns out, at least some of the iron in the dollar bills is elemental or basic pure iron. The inks are magnetic which makes it easy to read the bills with machines.

Share the following information to help students better understand the real-world application:

1. What evidence is there that the ink in a dollar bill is made of iron, instead of some other metal? *The ink is strongly attracted to a magnetic field. Iron is one of only a few metals that is attracted to a magnet.*
2. Is the iron in currency present as ions or elemental iron? *Elemental iron. The ions are not that strongly attracted to a magnetic field.*
3. What are the advantages to having magnetic materials in currency? *The bill may be read by machines more easily. It may also help prevent counterfeiting.*

Wait... isn't it illegal to destroy money? The officials at the U.S. Mint tell us that ***the law only prohibits you from destroying or defacing money if you still intend to use it as money****. If you're destroying it for some other reason, it's legal. Destroying a one dollar bill for the sake of extracting the magnetic ink probably means that you are not going to try to return the liquefied bill into circulation. So, there's your get out of jail free card.*

Money isn't the only place to find Iron! You've been eating nails for breakfast.



How would you feel if someone poured you a big bowl of nails for breakfast? Not too happy? True, they might be a little hard to swallow. Okay, and the shape might be a problem - so how about eating a bowl full of iron shavings? Believe it or not, some breakfast cereals contain actual iron shavings - on purpose! Don't believe us? Well, the next time you're eating a big bowl of breakfast cereal, you

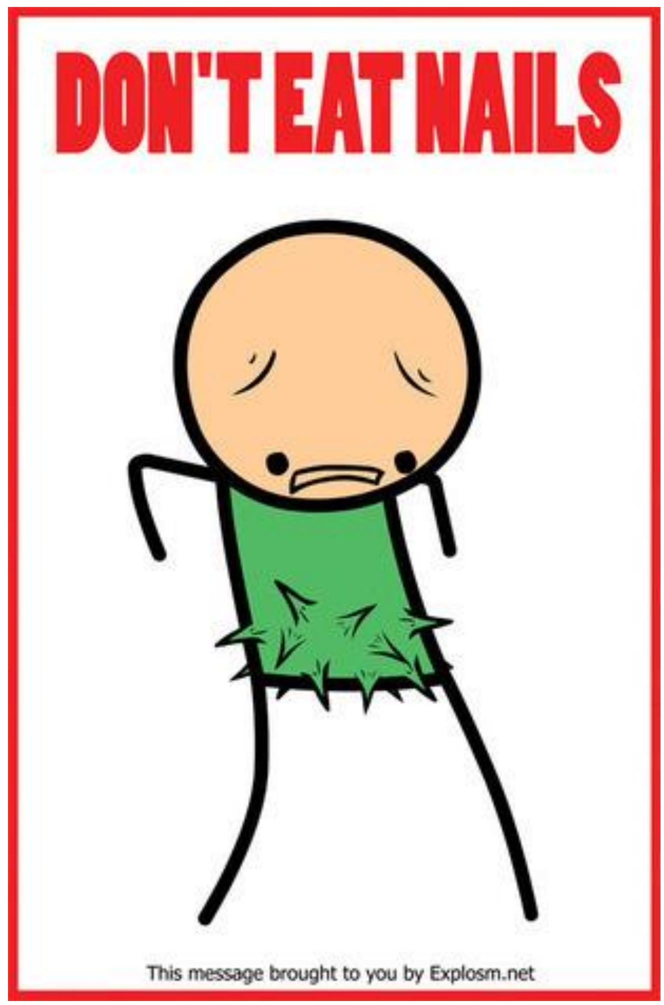


Image Credit: FanPop http://www.fanpop.com/spots/rebcam13/images/19330353/title/not-eat-nails-photo . Accessed 8/31/11. All Rights Reserved.

might want to take a slightly closer look at the ingredients. You'll find that your cereal contains more than just wheat and corn. Look closely and you might find something called FERRIC ORTHOPHOSPHATE, that's iron... you know, the metal... the stuff used to make nails. Here's an experiment to see if we're right and there really is metallic iron in your breakfast cereal. *Experiment instructions and step by step images found at Steve Spangler Science. http://www.stevespanglerscience.com/experiment/00000034. Accessed 8/31/11. All Rights Reserved.*

Materials

- Box of iron-fortified breakfast cereal (Total works the best or Gerber Graduates Arrowroot Cookies work great too)
- Measuring cup
- Super strong magnet
- Quart size zipper-lock bag
- Water
- Dinner plate

1. Open the box of cereal and pour a small pile of flakes on the plate. Crush them into tiny pieces with your fingers. Spread out the pile so it forms a single layer of crumbs on the plate. Bring the magnet close to the layer of crumbs (but don't touch any) and see if you can get any of the pieces to move. Take your time. If you get a piece to move without touching it, that piece may contain some metallic iron.
2. Firmly press the magnet directly onto the crumbs but don't move it. Lift it up and look underneath to see if anything is clinging to the magnet. Several little pieces may be stuck there. Is it the magnet being attracted to static electricity or just sticky cereal? It could be the iron. Throw away the small pile of cereal and clean off the magnet.
3. Pour water into the plate and float a few flakes on the surface. Hold the magnet close to (but not touching) a flake, and see if the flake moves toward the magnet. (The movement may be very slight, so be patient.) With practice, you can pull the flakes across the water, spin them, and even link them together in a chain. Hmmm... there must be something that's responding to the magnet. Could it be metallic iron? In your cereal?
4. Measure 1 cup of cereal (that's equal to one serving according to the information on the side of the cereal box) into a quart size zipper-lock bag. Fill the bag half full with water. Carefully seal the bag, leaving an air pocket inside.
5. Mix the cereal and the water by squeezing and smooshing the bag until the contents become a brown, soupy mixture. (It's not pretty.) This may take a long time. In fact, you may want to let it sit for an hour so the cereal softens completely. Tip: Warm water will speed up the process. Don't move on to the next step until the cereal is completely dissolved!
6. Make sure the bag is tightly sealed and position it on a flat side in the palm of your hand. Place the super-strong magnet on top of the bag. Put your other hand on top of the magnet and flip the whole thing over so the magnet is underneath the bag. Slowly slosh the contents of the bag in a circular motion for 15 or 20 seconds. The idea is to attract any free moving bits of metallic iron in the cereal to the magnet.
7. Use both hands again and flip the bag and magnet over so the magnet is on top. Gently squeeze the bag to lift the magnet a little above the cereal soup. Don't move the magnet just yet. Look closely at the edges of the magnet where it's touching the

bag. You should be able to see tiny black specks on the inside of the bag around the edges of the magnet. That's the iron!

8. Keep one end of the magnet touching the bag and draw little circles. As you do, the iron will gather into a bigger clump and be much easier to see. Few people have ever noticed iron in their food, so you can really impress your friends with this one. When you're finished, simply pour the soup down the drain and rinse the bag.
9. Repeat the experiment with two or more kinds of cereal. Is there a big difference between them? Check the side of the box and compare the percentage of "recommended daily allowance" (RDA) of iron that is in each cereal. Ex: Honey Bunches of Oats says they have 45% and Raisin Bran says they have 60% of your daily allowance.

Why would they do that?

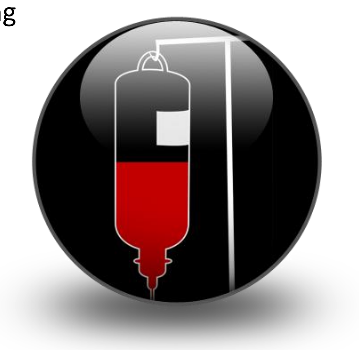
The top question on your mind is probably, "Why are there iron shavings in my cereal?" Your body needs iron to survive. This is because red blood cells need iron to carry oxygen from the lungs to the rest of the body - and our bodies need oxygen to function! Red blood cells are constantly being replaced, so we need to intake iron often.

Because some people don't get enough natural iron in their diets (commonly found in red meat and green, leafy vegetables), iron is often added to foods like cereal and infant formula. These foods are usually marked "iron fortified." Small pieces of iron are added to fortified cereal along with the rest of the ingredients, and the iron added to your cereal is the same iron that is used to make nails! Iron can be sprayed onto the flakes or added as a powder to the mixture.

Many breakfast cereals are fortified with food-grade iron particles (metallic iron) as a mineral supplement. Total® cereal is the only major brand of cereal that claims to contain 100% of your recommended daily allowance of iron. The chemical symbol for iron is Fe. Metallic iron is digested in the stomach and eventually absorbed in the small intestine. If all of the iron from your body was extracted, you'd have enough iron to make only two small nails. However, there are a growing number of nutritionists who do not buy these claims and believe that the metallic iron simply passes through your system. Sounds like some great research for a science fair project!

Think About It!

The RDA (recommended daily amount) of iron is about 14-18 milligrams. The average 2-inch nail weighs about 2.51 grams (2,510 milligrams). If you got your RDA of iron each day by eating iron fortified cereal, how many nails worth of iron would you eat in one year if you had cereal every morning, 365 days a year?



Iron is found in a very important component of your blood called hemoglobin. Hemoglobin is the compound in red blood cells that carries oxygen from your lungs so that it can be used by your body. It's the iron in hemoglobin that gives blood its red appearance.

A deficiency of, or having not enough iron actually has a special term, it's called anemia, and it can cause people to be weak, tired, have trouble concentrating, and be more likely to get infections and diseases, and increase heart and respiratory rates which is hard on your heart and lungs. Food scientists say that a healthy adult requires about 18 mg of iron each day. So, as you can see, iron is a very important part of what you need to stay healthy. And since magnets apply forces on other magnetic objects, like iron nails and the iron shavings in your cereal, you got to see that 18mg first hand! Eat up! Cereal for dinner!

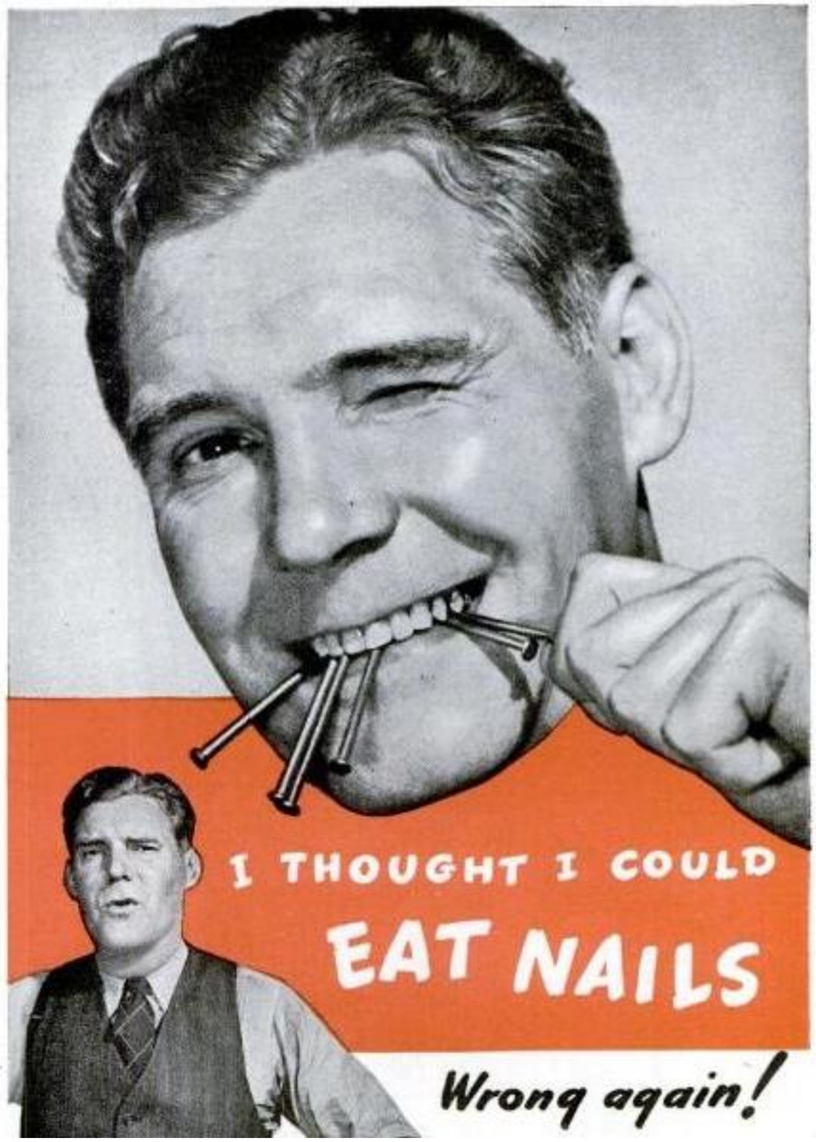


Image Credit: http://nerd8bit.tumblr.com/post/662597749/eating-nails. Accessed 8/31/11.

Forces at Work

Experiments:

Forces & Motion

1. Marble Gravitron
2. Centripetal Force Board/Spinning Buckets
3. Egg Drop Experiment with Falling Ring Catch
4. Flying Film Canisters
5. Mentos Geyser /Depth Charge Kit /Mentos Geyser Rocket Car

Electricity & Electromagnets

6. Energy Ball/Energy Stick Demonstration
7. Fruit-Power Battery Experiment
8. Light Circuit
9. Electromagnets
10. (Electro)Magnetic Suction
11. Electromagnetic Motor

Kindergarten

Key Terms:

- Change
- Collect
- Natural
- Observe
- Parts
- Senses
- Shape
- Size
- Tools
- Classify
- Compare

Key Standards:

7.11.1 Use a variety of objects to demonstrate different types of movement. (e.g., straight line/zigzag, backwards/forward, side to side, in circles, fast/slow).

1st Grade

Key Terms:

- Balance
- Classify
- Invent
- Investigate
- Location
- Magnet
- Matter
- Prediction
- Property
- Push/pull
- Direction
- Predict
- Sequence

Key Standards:

- 7.11.1 Use familiar objects to explore how the movement can be changed.
- 7.11.2 Investigate and explain how different surfaces affect the movement of an object.
- 7.12.1 Identify and classify objects in the classroom as magnetic or non-magnetic.
- 7.12.2 Make predictions about how various objects will be affected by a magnet.

2nd Grade

Key Terms:

- Compare/contrast
- Depend
- Distance
- Energy
- Infer
- Investigate
- Observation
- Reasoning
- Renewable/non-renewable
- Scientific inquiry
- Scientist
- Similarities/differences
- Transform
- Type

Key Standards:

7.12.1 Explain how two magnets interact and experiment with magnets to determine that objects can move without being touched.

7.12.2 Describe what happens when an object is dropped, realize that things fall toward the ground unless something holds them up, and record the observations in a science notebook.

3rd Grade

Key Terms:

- Conductor
- Force
- Conservation
- Physical Change
- Factor
- Fact
- Opinion
- Tools

Key Standards:

- 7.11.1 Plan an investigation to illustrate how changing the mass affects a balanced system.
- SPI 7.11.1 Identify how the direction of a moving object is changed by an applied force.
- SPI 7.11.2 Demonstrate how changing the mass affects a balanced system.
- 7.12.1 Experiment with magnets to determine how distance affects magnetic attraction.
- 7.12.2 Determine that only certain types of objects are attracted to magnets.
- SPI 7.12.1 Recognize that magnets can move objects without touching them.
- SPI 7.12.2 Identify objects that are attracted to magnets.

4th Grade

Key Terms:

- Electricity
- Mass
- Friction
- Making inferences
- Prediction
- Convert
- Accuracy

Key Standards:

- 7.11.1 Identify the position of objects relative to fixed reference points.
- 7.11.2 Design an investigation to identify factors that affect the speed and distance traveled by an object in motion.
- 7.11.3 Complete a coordinate graph to describe the relative positions of objects.
- 7.11.4 Plan and execute an investigation that demonstrates how friction affects the movement of an object.
- SPI 7.11.1 Describe the position of an object relative to fixed reference points.
- SPI 7.11.2 Identify factors that influence the motion of an object.

- 7.12.1 Explore the interactions between an electrically charged object and other materials.
- 7.12.2 Design an experiment to investigate how a simple electromagnet affects common objects.
- 7.12.3 Describe how electricity passes through a simple circuit that includes a battery, wire, switch, and bulb.
- SPI 7.12.1 Identify how magnets attract or repel one another.
- SPI 7.12.2 Determine how an electrically charged material interacts with other objects.
- SPI 7.12.3 Determine the path of an electrical current in a simple circuit.

5th Grade

Key Terms:

- Conduction
- Dissipate
- Data Collection Methods
- Model
- Variable
- Gravity

Key Standards:

- 7.11.1 Predict how the amount of mass affects the distance traveled given the same amount of applied force.
- 7.11.3 Design and conduct experiments using a simple experimental design to demonstrate the relationship among mass, force, and distance traveled.
- SPI 7.11.1 Explain the relationship that exist among mass, force, and distance traveled.
- 7.12.1 Explain and give examples of how forces act at a distance.
- SPI 7.12.1 Recognize that the earth attracts objects without touching them.
- SPI 7.12.2 Identify the force that causes objects to fall to the earth.
- SPI 7.12.3 Use data to determine how shape affects the rate at which a material falls to earth.

6th Grade

Key Terms:

- Cause and effect
- Conductivity
- Control
- Criteria
- Design constraint
- Elastic potential
- Electrical conductor
- Energy transformation
- Prototype
- Protocol
- Simple circuits
- Variable

Key Standards:

- 7.12.1 Illustrate how electricity passes though a simple circuit to produce heat, light, or sound.
- 7.12.2 Determine a material's electrical conductivity by testing it with a simple battery/bulb circuit.
- 7.12.3 Compare and contrast the characteristics of objects and materials that conduct electricity with those that are electrical insulators.
- SPI 7.12.1 Identify how simple circuits are associated with the transfer of electrical energy when heat, light, sound, and chemical changes are produced.
- SPI 7.12.2 Identify materials that can conduct electricity.
- SPI 7.10.3 Recognize that energy can be transformed from one type to another.

7th Grade

Key Terms:

- Acceleration
- Momentum
- Phenomenon
- Property
- Impact
- Speed
- Velocity

Key Standards:

- 7.11.3 Summarize the difference between the speed and velocity based on the distance and amount of time traveled.
- 7.11.4 Recognize how a net force impacts an object's motion.
- SPI 7.11.3 Apply proper equations to solve basic problems pertaining to distance, time, speed, and velocity.
- SPI 7.11.4 Identify and explain how Newton's laws of motion relate to the movement of objects.

8th Grade

Key Terms:

- Electromagnet
- Electron
- Gravitation (universal law)
- Magnetic field
- Neutral
- Neutron
- Proton
- Atom
- Variation
- Inductive reasoning
- Deductive reasoning

Key Standards:

- 7.12.1 Create a diagram to explain the relationship between electricity and magnetism.
- 7.12.2 Produce an electromagnet using a bar magnet and a wire coil.
- 7.12.3 Experiment with an electromagnet to determine how to vary its strength.
- 7.12.4 Create a chart to distinguish among the earth's magnetic field, and fields that surround a magnet and an electromagnet.
- 7.12.5 Explain the difference between mass and weight.
- 7.12.6 Identify factors that influence the amount of gravitational force between objects.
- 7.12.7 Explain how the motion of objects in the solar system is affected by gravity.
- SPI 7.12.1 Recognize that electricity can be produced using a magnet and wire coil.
- SPI 7.12.2 Describe the basic principles of an electromagnet.
- SPI 7.12.3 Distinguish among the Earth's magnetic field, a magnet, and the fields that surround a magnet and an electromagnet.
- SPI 7.12.4 Distinguish between mass and weight using appropriate measuring instruments and units.
- SPI 7.12.5 Determine the relationship among the mass of objects, the distance between these objects, and the amount of gravitational attraction.
- SPI 7.12.6 Illustrate how gravity controls the motion of objects in the solar system.

High School

Key Terms:

- Friction (sliding, rolling, static**)**
- Electron
- Electromagnet
- Buffer
- Voltage

- Resistance
- Conduction
- Carrying Capacity

Key Standards:

- 1.5.1 Create a simple electromagnet.
- 5.2.4 Explore the physical and chemical properties of minerals.
- 1.5.2 Draw an electric field, given a scenario of charged particles.
- 1.5.6 Build series and parallel circuits to demonstrate how they function and understand magnetic poles, magnetic fields, and investigate electromagnetic induction.
- 1.5.7 Demonstrate a generated current by electromagnetic induction and understand that moving charges give rise to magnetism.
- 1.5.8 Design a lab to demonstrate the flow of charged particles and an electric current.
- 1.5.10 Distinguish between charged particles related to repulsion and attraction.
- 1.5.13 Describe how current is generated by electromagnetic induction.
- SPI.1.5.1 Given a scenario of charged particles; predict and sketch the resulting electric fields.
- SPI.1.5.3 Explain the relationship between magnetism and current.

Marble Gravitron

Watch as physics makes a spinning marble defy gravity

Last summer, Spangler Labs took a company trip to an amusement park. We didn't go for a company retreat, we didn't even go on a day off. We went to do research on physics, the science of motion. One amusement park ride that really got Steve thinking was the Gravitron. As we all stood in a circular room with our backs against the wall, the walls began to spin. Faster and faster the walls spun until the floor dropped out from under us. There were shrieks of terror as everyone thought they were about to fall, but, to our surprise, we didn't drop! Steve wanted to find a way to recreate this phenomenon on a small, kitchen-science scale.

Divide students into pairs or small groups, or have them work individually, depending on class size. Give students the materials, and the challenge:

Tell students you want them to figure out a method to put the marble in their glass without picking it up and then how to keep it there, with the cup remaining upside down. Is it possible? Have them follow the scientific method and then present their ideas to the group as a whole. Discuss what forces they are having to fight to get the marble in the glass and to keep it there…gravity. Then show them the following demonstrations. Discuss the differences and how it works…

The Marble Gravitron

1. Begin by holding the glass upright. Grip the flat base of the wine glass with one hand and drop the marble in the top with the other.
2. Spin the glass to get the marble going around in a circle on the inside.
3. While still spinning the glass, tilt the glass so that it is on its side. The marble is staying in the glass!
4. Are you still spinning the marble in the glass? Good. Turn the glass upside down.
5. Were you expecting the marble to drop out the bottom of the glass? Did it?

Put the Marble in the Glass… Without Picking it Up!

1. Hold one of your hands flat with the palm facing up.
2. Place the marble in the middle of your palm and put the glass over the top of the marble.
3. Spin the glass like you did in the last experiment, getting the marble to spin against the inside of the glass.
4. Slowly tilt the glass so that it is right-side-up.
5. You've put the marble in the glass without even picking it up with your hand!

How does it work?

The Marble Gravitron is a smaller version of what you can experience on the amusement park ride of the same name. The inertia of the spinning marble is a "push" force. The glass supplies another "push" force that keeps the marble moving in a "uniform circular motion." The force of the glass is centripetal force, a force that makes a body follow a curved path. The combined forces of the spinning marble and the glass create a relative force greater than gravity. This is a small scale artificial gravity demonstration.

A real life application of this demonstration is how artificial gravity is created aboard a spacecraft. In this instance, the rotating body is much larger (the spacecraft) and the spinning body (the astronaut) needs to go around much more slowly to recreate the feeling of gravity. However, the same phenomenon is present as the astronaut is able to stand upright against the outside of the spacecraft. Can students think of any other real-life scenarios where this is used or could be used?

High and Dry

Who can resist the temptation of swinging a pail of water over their head?

Materials:

- Buckets
- Water
- Centripetal Force Boards
- Cups

What to Do:

Fill your bucket with water, it is probably best to start with a little rather than a lot.

Stand so you can swing the bucket really easily, but make sure that there is no-one and nothing breakable in line with where you are about the swing the bucket (in case you let go or the handle breaks)

Swing the bucket back and forth with bigger and bigger swings.

When you think you will make it swing the bucket all the way over your head in a smooth motion.

Did the water fall out?

Alternate Versions:

This demo is a slight modification of the classic swinging pail of water demo. The picture shows the construction of the "spinning platform." The base is made from a square piece of Plexiglass or wood measuring approximately 12 inches. If you aren't ordering one, you can drill holes in all four corners large enough to accommodate a piece of rope. Attach the ropes to each corner of the platform and join them together in a knot about 2 feet above the platform.

Now that all of the difficult work is finished, or you received your order, it's time to swing the tray and plastic cup (several plastic cups if you're feeling lucky) around in a complete circle without spilling the liquid or flinging the cup around the room. It's the tendency for the plastic cup and its contents to go in a straight line that allows it to seemingly defy gravity. The centripetal force provided by the tension in the cords is large enough to create enough friction to hold the plastic cup(s) in place.

Here's a little advice... practice swinging the tray around without the cups in order to get the feel of a smooth, circular motion. Then add the cup filled half full with water. The liquid adds mass to the cup and helps to keep the cups in place. Some demonstrators even glue a thin piece of rubber to the bottom of the cup to give it a little gripping power (okay, friction) to help the cups stay in place. Shhhh! That's a little secret between you and me.

Spinning Hoop & Cup Trick - This is yet another variation on the classic "swing the pail over your head trick," but this version uses a large hoop and a cup of... whatever you want spilled on the floor! Steve Spangler learned this juggling stunt from Mike Caveny, a world-class entertainer who gave

Steve this advice: "There's really no trick to it... just start practicing your spins and hoop twirls until the cup doesn't fall on the floor. Good luck." When asked about the origins of the stunt, Mike recalls reading about the trick done by a Russian circus performer at the turn of the.

How does it work?

According to Newton's First Law of Motion, objects in motion tend to remain in motion unless acted upon by an external force. In this case, Newton's Law requires the water to continue moving along a tangent to the circle. Thus a force is required to keep it always turning toward the center of the circle, instead of flying out straight. Centripetal force is the force that makes something move in a circular path. According to the law of inertia, in the absence of forces, an object moves in a straight line at a constant speed. An outside force must act on an object to make it move in a curved path. When you whirl a stone around on a string, you must pull on the string to keep the stone from flying off in a straight line. The force the string applies to the object is the centripetal force. The word centripetal is from two Latin words meaning to seek the center.

Centripetal force acts in other ways as well. For example, a speeding automobile tends to move in a straight line. Centripetal force must act on the car to make it travel around a curve. This force comes from the friction between the tires and the pavement. If the pavement is wet or icy, this frictional force is reduced. The car may then skid off the road because there is not enough centripetal force to keep it moving in a curved path. Or, another way of saying it…

The experiment works due to some very fundamental physics worked out by Isaac Newton. If an object is not pushed by anything it will continue moving at a constant speed and direction, so to make it travel in a circle you have to push or pull it towards the centre of the circle. If you have ever played on a roundabout or merry-go-round in a playground this is the force you have to provide by hanging on tight to avoid being thrown off.

This means that you are pulling the bucket downwards while it is over your head. If you are pulling the bucket downwards faster than the water is being pulled down by gravity, the water will get left behind towards the base of the bucket and so, stay inside and not fall out, keeping you nice and dry.

Falling Ring Catch

Engage your students with this puzzling trick

Is it possible to catch a falling ring with a loop of string? Sure it is! All it takes is a little science. Don't believe it? Try it out.
You may be thinking, "How will I apply this experiment?" This activity is a great tool for teaching observation, trial and error, and experimentation. Give students the materials and a challenge. Encourage kids to keep trying to get the tape roll caught by the string and washer loop.
It's going to take a bit of experimentation and trial and error, but they'll get the hang of it in no time! They'll see how motion and force can sometimes create unexpected results.

Materials

- Thin string or yarn
- Scissors
- Rolls of masking tape
- Metal washers

1. Cut approximately 1 meter of string (or yarn) for each group.
2. Run the string through the hole in the middle of the washer and then loop it through the washer two or three more times.
3. Fashion the ends of the string into a knot, forming the string into a loop with the washer at the bottom. Trim off the excess from the knot.
4. Use your non-dominant hand to hold the string with the washer at the bottom of the loop. Spread your fingers so that the top of the loop has a slightly larger width than the roll of masking tape.
5. Use your dominant hand to hold the roll of masking tape parallel to the floor. Lift up the string and guide your washer/string loop down through the middle of the roll of masking tape.
6. Keeping the tape parallel to the floor, bring it all the way up to the top of the string loop.
7. Let go of the ring. Does it fall to the floor?
8. If it fell to the floor, repeat the steps and try it again. But this time, as you let go, flick one side of the tape downward. Bet it doesn't fall to the floor this time!

How does it work?

The combination of gravitational force and friction caused by the tape roll falling toward the ground is to blame for the washer/string loop tying itself to the tape roll. Giving the tape roll just the right flick at the top of its fall will cause the washer to loop around both the roll of tape and the string loop, forming a lark's head knot.

Egg Drop Experiment

Once upon a time an apple fell from Sir Isaac Newton's tree, and ever since we've heard about Newton's Laws. But did you know that if you just look, you can see Newton's Laws in action everywhere around you? The Egg Drop is a classic science demonstration that illustrates Newton's Laws of Motion, namely inertia. The challenge sounds so simple... just get the egg into the glass of water, but there are a few obstacles. The egg is perched high above the water on a cardboard tube, and a pie plate sits between the tube and the water. Still think it's easy? Sir Isaac Newton does.

Newton's first law of motion: an object at rest will remain at rest unless acted on by a force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by a force. This law is often called, "the law of inertia".

Materials:

- Small ball to practice with, if desired, but you don't need it, you're brave!
- Cardboard tube
- Pie pan
- Raw eggs
- Water
- A large drinking glass
- Oh, you might need a few paper towels

Warning: Always wash your hands well with soap and water after handling raw eggs. Some raw eggs contain salmonella bacteria that can make you really sick!

1. Fill the large drinking glass about three-quarters full with water and Invite a student up to be your assistant. Tell the students, Sir Isaac Newton said that an object will stay at rest, won't move at all, until some force acts upon it. We're going to hope that's true with this today. Now the object here is for you (the student) to get the egg in the glass. Have the student pick an egg. *(That's the one I would have picked! Perfect!)* How would they get it in the glass? Just drop it? No.
2. Tell the student if you just let them drop the egg into the glass then gravity would be the winner and we don't want to do that, it's too easy, so that's why the pie pan is here. So the pie pan is going to go in place. Center the pie pan on top of the glass. Place the student's egg in the pie pan and (demonstrate the motion) tell them that when they put their hand there and hit the pie pan they will transfer the energy from their hand, to the pie plate and it will go to the egg and . . .(*what do they think will happen?)* it will pop it up into the air and…well, we want it to go into the glass. So we're going to add in something else to make it even easier.

3. Place the cardboard tube on the plate, positioning it directly over the water. Have the student carefully set the egg (or practice ball) on top of the cardboard tube.
4. Demonstrate for your student, your hand is going to go here, and you'll pull back about this far, and then, you're going to hit the pan, straight in and smack the edge of the pie pan horizontally.

Make sure you follow all the way through (tennis, anyone?). It's important that you use a pretty solid hit, so plan on chasing the plate and tube, but don't knock over the glass!

5. Ask the students what they think is going to happen. What will the pie pan do? What about the tube? Tell them, I'm thinking (hoping) the pie pan will knock the tube out of the way and the inertia of the egg (remember, it doesn't really want to move) is going to hold it there for just a second and bam! It will fall right in. Do they agree?
6. Have your student take their shot at the pie plate. Your astonished student and students will watch the egg plop nicely into the water. Clap! Science is so cool!

How does it work?

Credit for this one has to go to Sir Isaac Newton and his First Law of Motion. Who was Newton? Isaac Newton was one of the most famous scientists in the world. He studied many different types of science. He wrote one of the most important science books in history Philosophiæ Naturalis Principia Mathematica, which is Latin for Principals of Mathematics. Published in London, England in 1687 this book contained Newton's Laws of Motion. Newton observed how objects moved. He studied how forces like gravity changed the motion of an object. He found that forces change when the speed or mass of an object changes.

He said that since the egg is not moving while it sits on top of the tube, that's what it wants to do - not move, ever. You applied enough force to the pie pan to cause it to zip out from under the cardboard tube (there's not much friction against the drinking glass). The edge of the pie pan hooked the bottom of the tube, which then sailed off with the pan. Basically, you knocked the support out from under the egg. For a brief nanosecond or two, the egg didn't move because it was already stationary (not moving). But then, as usual, the force of gravity took over and pulled the egg straight down toward the center of the Earth.

Also, according to Mr. Newton's First Law, once the egg was moving, it didn't want to stop. The container of water interrupted the egg's fall, providing a safe place for the egg to stop moving so you could recover it unbroken. The gravity-pushed egg caused the water to splash out. Did someone get wet?

Was it luck of the law, or was it skill?

Have students try testing longer tubes, more or less water, different liquids in the glass, different water containers, and heavier or lighter falling objects and multiple eggs at the same time. If one is good, how about five? Wouldn't five be amazing?

Where else can we find the law of inertia?

Have students determine how inertia relates to Newton's first law. Ask students for other examples of Newton's first law in their daily life.

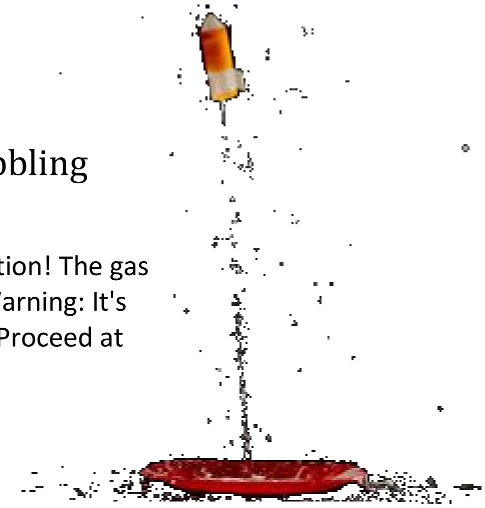
Newton's laws are demonstrated when a goal is scored in soccer, a baseball hit with a bat, or a three point basket is made on the court. Examples of Newton's Laws are found in our machines, work, homes and sports.

Newton's Laws of Motion

Law 1 - An object at rest will remain at rest unless acted on by a force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by a force. This law is often called, "the law of inertia".

Law 2 - Acceleration is produced when a force acts on a mass. The greater the mass - of the object being accelerated - the greater the amount of force needed to accelerate the object. Force = Mass X Acceleration.
Law 3 - For every action there is an equal and opposite reaction

Alka-Seltzer Film Canister Rocket



How to fuel a film canister rocket with that famous bubbling tablet

What happens when you have a build-up of gas? Don't answer that question! The gas in question is carbon dioxide and the explosion is nothing short of fun. Warning: It's impossible to do this activity just once. It is addicting and habit-forming. Proceed at your own risk! Really, you have been warned.

Materials

- Film canister with a snap-on lid. Look for a clear film canister, if possible. (Fuji brand works best) also available from stevespanglerscience.com
- Soda
- Alka-Seltzer® tablets
- Empty paper towel roll (the cardboard tube) or a similar-sized plastic tube
- Duct tape
- Paper towels for cleanup (you already know that this one is going to be good!)
- Water
- Watch or timer
- Notebook
- Adult helper
- Safety glasses

IMPORTANT: This experiment requires you to wear protective safety glasses.

Pre-Flight Testing

1. Put on those safety glasses. See, we knew they were required.
2. Fill the film canister three-fourths full with soda. To avoid a sticky mess, seltzer water can be used, which is simply carbonated, sugarless water.
3. Quickly seal the canister with the lid and shake the thunder out of the canister! Be careful to aim it away from your eyes. If you're lucky, the lid will pop off and fly into the air at warp speed.
4. What are you waiting for? Do it again!

The Amazing Alka-Seltzer Rocket

1. Put on your safety glasses, yep, still required.
2. Divide an Alka-Seltzer tablet into four equal pieces.
3. Fill the film canister one-half full with water.
4. Get ready to time the reaction of Alka-Seltzer and water. Place one of the pieces of Alka-Seltzer tablet in the film canister. What happens?
5. Time the reaction and write down the time. How long does the chemical reaction last? In other words, how long does the liquid keep bubbling? Why do you think the liquid stops bubbling? Empty the liquid in the film canister into the trash can.
6. Repeat the experiment, but this time place the lid on the container right after you drop in the piece of Alka-Seltzer. Remember to start timing the reaction as soon as you drop the tablet into the water. Stand back! If you're lucky, the lid will pop off and fly into the air at warp speed! Write down your observations.

If you really want to see the rocket fly, start by sealing the end of the cardboard tube with several pieces of duct tape or use a plastic tube with one end sealed. Divide the Alka-Seltzer into four equal pieces. Fill the film canister one-half full with water. Place one of the pieces of Alka-Seltzer tablet in the film canister and quickly snap the lid on the container. Turn the film canister upside down and slide it (lid first) into the tube. Point the open end of the tube AWAY from yourself and others and wait for the pop. Instead of the lid flying off, the bottom of the film canister shoots out of the tube and flies across the room.

If you're really creative, you can use construction paper to turn the bottom part of the film canister into a rocket. Wrap some paper around the canister, add some fins, top the whole thing off with a nose cone, and you've got an Alka-Seltzer powered rocket.

Observations
You may need to experiment with several different film canisters before you are successful at building a rocket that launches with a blast. If the lid fits too tightly or too loosely, it won't work.

How does it work?
The first part of this experiment is just a variation of the classic Alka-Seltzer film canister rocket. The same principle is at work here. In both cases, carbon dioxide gas builds up so much pressure the lid is forcibly launched. With an Alka-Seltzer tablet, the CO_2 is produced as a result of a chemical reaction. With the soda, the CO_2 is produced as a result of vigorous shaking. This provides a good contrast between a physical and chemical change.
The fizzing you see when you drop an Alka-Seltzer tablet in water is the same sort of fizzing that you see when you mix baking soda and vinegar. The acid mixes with the sodium bicarbonate (baking soda) to produce bubbles of carbon dioxide gas. If you look at the ingredients of Alka-Seltzer, you will find that it contains citric acid and sodium bicarbonate (baking soda). When you drop the tablet in water, the acid and the baking soda react to produce carbon dioxide gas. The gas keeps building up until finally the top pops off. The lid of the canister is the path of least resistance for the gas pressure building up inside, so it pops off instead of the stronger sides or bottom of the canister bursting open.

We can thank Sir Isaac Newton for what happens next. When the build up of carbon dioxide gas is too great and the lid pops off, Newton's Third Law explains why the film canister flies across the room: for every action there is an equal and opposite reaction. The lid goes one way and the film canister shoots out of the tube in the opposite direction.

C^3: Making it an Experiment/Science Fair Connection
Launching Alka-Seltzer rockets is tons of fun, don't you think? So how could you use this simple and engaging experiment? The trick is to *change* a variable, *create* a new experiment, and then *compare* the results.

- Repeat the experiment using another of the pieces of Alka-Seltzer, but this time change the amount of water you put in the film canister.
- Once you've mastered the film canister rocket technique described above, it's time to measure how far the film canister rocket flies across the room. After each trial, write down the amount of water you used in the film canister (the *variable*), the size of the piece of Alka-Seltzer (this should not change because it is your *control*), and the distance the canister traveled. What amount of water mixed with a quarter piece of Alka-Seltzer produces the best rocket fuel?
- After you've determined the best amount of water to use, try changing the temperature of the water. How does temperature affect the speed of the reaction? Does warmer or colder water change the distance the film canister travels?

Use another piece of Alka-Seltzer to make up your own experiment. What do you want to find out? How are you going to do it? What are you going to measure? Go ahead and experiment! Just make sure you only change one variable at a time. Document your discoveries and get ready to share them.

Mentos Geyser Science Project

How to Turn the Mentos Geyser into a Great Science Project

You might be thinking to yourself, "Can we really use the Mentos Geyser for an actual experiment?" The answer is YES, but you'll need to learn how to turn a cool science activity into a real science experiment. The secret is to turn your attention away from the spraying soda and concentrate on setting up an experiment where you isolate a single variable and observe the results. Tests and trials will lead you to more and more questions, which will eventually lead to a discovery. The examples below are a good place to start, but and your students will stumble upon even more questions and ideas once you get rolling.

Materials

The materials you'll need will change depending on which variables you're testing, but it's safe to say you'll need the following ingredients:

- Several rolls of Mentos chewy mints
- Several 2-liter bottles of soda
- Mentos Geyser Tube
- Video camera

Note: It's very important to use fresh soda for your experiment. Two-liter bottles of soda will lose their fizz (carbonation) over time and you'll get poor results. Always use new, unopened bottles of soda for the best results.

The Fairness Factor

Before the invention of the Geyser Tube, everyone had a different method for dropping Mentos into the bottle of soda. You might have used the test tube method while someone else made a tube out of notebook paper. Unfortunately, the method for dropping the Mentos was never consistent. The Geyser Tube removes the inconsistency because it makes the drop the same every time, letting you focus on the true *variables* (what you're trying to test).

The Scale

To make any of these tests meaningful, you need to find a way to measure the explosion. A friend or parent with a video camera is a great way to watch and document the results of your experiment, but you'll also need some specific measurements or data. Try placing the soda bottle next to the wall of a brick building (after getting permission from the building's owner). Measure the height of the explosion by the number of bricks that are wet once the geyser stops. If you want a more specific measurement, use chalk to mark off 1-foot increments on the brick wall before you drop the Mentos into the bottle of soda. Make comparisons, create a chart with your data, and draw some conclusions. Be sure to thank the building's owner and to hose off the wall of the building when you are finished!

If you want to examine the *volume* of the explosion instead of the height, make note of the volume of a full bottle of soda (2 liters) before you drop the Mentos into it. Once the geyser stops, pour out the remaining contents of the bottle and measure how much liquid is left. You'll have to find a way to measure in liters. Remember that 1 L is equivalent to 1000 mL. Subtract the remaining amount of liquid from the original volume of the bottle to calculate the volume of the explosion. Then make comparisons, create a chart with your data, and draw some conclusions.

You might want to enlist the help of an adult who owns a camcorder. By recording every launch, you'll be able to replay the footage of the explosion in slow motion in order to get the best measurement possible.

How Many Mentos?

It's a question that everyone who does this project asks... What is the best number of Mentos to use to make the highest shooting geyser? In science project terms, "What is the effect of the number of Mentos on the height of the geyser?" This is a great topic for a science fair project, but you'll need lots of soda and Mentos and a few friends to help record all of the data.

Be sure that the soda bottles are all the same brand and type (diet vs. regular) and are at the same temperature. Use the Geyser Tube to make sure every launch is the same. You want the conditions to be as standardized as possible.

Attach the Geyser Tube to the top of the 2-liter bottle of soda. Push the trigger pin through the holes and load one Mentos into the tube. Remove the top cap of the Geyser Tube – this makes it easier to record how high the soda goes because it's not spraying everywhere. The column of soda is bigger and stays together better when the cap is not in place. The launch site is ready... the Mentos is loaded... the video camera is recording... now pull the pin! Record the height (at least your best guess for right now). Repeat this same procedure for 2 Mentos, 3 Mentos... you get the idea. Based on your data, how many Mentos do you need to make the highest shooting soda geyser?

The Brand Test

You guessed it... it's time to put your favorite soda to the test. Does one brand produce higher flying geysers? How does generic soda stack up against the big name brands? In scientific terms, "What is the effect of the brand of soda on the height of the geyser?" Using the procedure outlined above, it's easy to determine the clear winner. Remember, it's important to conduct each test the same way using the Geyser Tube and the same number of Mentos for each launch. You'll also want to make sure all of the soda is at the same temperature because temperature plays an important role in the reaction. The brand of soda is the only thing that changes (the variable).

Just think... your results could help determine the next Mentos Geyser craze!

The Temperature Test

What is the effect of temperature on the height of the geyser? Does warm soda shoot up higher than cold soda? The key is to keep every launch fair and to make sure the only variable is the temperature of the soda. You'll need a thermometer to record the temperature of the soda just before you launch it.

It's best to stick with one brand of soda for the entire test. Let's use Diet Coke. You'll want to purchase three bottles of Diet Coke and several rolls of Mentos. You're going to set up three tests - warm soda, room temperature soda, and cold soda. Place one bottle of Diet Coke in the refrigerator and let it sit overnight. Place the second bottle in a place where it can reach room temperature overnight. There are two safe ways to warm the other bottle of soda. The simplest method is to let the unopened bottle sit in the sun for several hours. You can also place the bottle of unopened soda in a bucket of warm water. Never use a stove or microwave to heat a bottle of soda.

It’s time to return to your launching site. Check to make sure your measuring scale is in place and the video camera is ready to roll. Let’s start with the bottle of cold Diet Coke. Open the bottle and dip the thermometer down into the soda. Record the temperature on your data table. Attach the Geyser Tube with the trigger pin in place. Load seven Mentos into the tube and get ready to launch. Keep the cap of the Geyser Tube off. Pull the pin and record the data. Repeat the same procedure for the bottle of soda at room temperature and the bottle of warm soda.

Geyser Rocket Car Variation: stevespanglerscience.com

The phrase, "Start Your Engines" has never been this fun or foamy.

The whole process is a blast (literally)! From the time you open the package, you'll have fun with the Mentos Geyser Rocket Car. Putting the durable plastic car together is simple with the step-by-step instructions, and once you have a 2-liter soda bottle strapped in, the eruption is as simple as pulling a pin. Once the eruption starts, the car rockets across the ground - WOW!

Materials:

- Soda Geyser Car (13"x6"x7")
  - 4 wheels
  - 2 axles
  - 2 Velcro straps
  - 1 plastic chassis
  - 1 nose cone
  - 1 flag pole
- 1 Fizz Injector Tube with red "trigger pin"
- 1 Air Blaster Cork with inflation needle
- 1 clear, 2-liter plastic bottle
- 1 Mentos candy roll
- Decorative decals
- In-depth experiment and activity guide

How does it work?

The Mentos Geyser Rocket Car is a great demonstration of Newton's Third Law of Motion. The Third Law states: "For every action, there is an equal and opposite reaction." So when the Mentos geyser erupts out of the 2-liter bottle in one direction (action), the car rockets off in the other direction (reaction)!

What does it teach?

The Mentos Geyser Rocket Car is a great visual tool as well as hands-on demonstration of valuable lessons in physics and motion as well as physical reactions. The included experiment and activity guide will also supply young scientists with great ideas for possible science fair experiments.

Mentos and Soda: How does all of this work?

Why do Mentos turn ordinary bottles of diet soda into geysers of fun? The answer is a little more complicated than you might think. Let's start with the soda...

Soda pop is made of sugar or artificial sweetener, flavoring, water, and preservatives. The thing that makes soda bubbly is invisible carbon dioxide, which is pumped into bottles at the bottling factory using lots of pressure. If you shake a bottle or can of soda, some of the gas comes out of the solution and the bubbles cling to the inside walls of the container. When you open the container, the bubbles quickly rise to the top pushing the liquid out of the way. In other words, liquid sprays everywhere.

Each Mentos candy has thousands of tiny pits all over the surface. These tiny pits are called *nucleation sites* - perfect places for carbon dioxide bubbles to form. As soon as the Mentos hit the soda, bubbles form all over the surface of the candy. Couple this with the fact that the Mentos candies are heavy and sink to the bottom of the bottle and you've got a double-whammy. When all this gas is released, it literally pushes all of the liquid up and out of the bottle in an incredible soda blast.
Warm soda tends to fizz much more than cold soda. Why? The answer lies in the solubility of gases in liquids. The warmer the liquid, the less gas can be dissolved in that liquid. The colder the liquid, the more gas can be dissolved in that liquid. This is because as the liquid is heated, the gas within that liquid is also heated, causing the gas molecules to move faster and faster. As the molecules move faster, they diffuse out of the liquid, leaving less gas dissolved in that liquid. In colder liquids the gas molecules move very slowly, causing them to diffuse out of the solution much more slowly. More gas tends to stay in solution when the liquid is cold. This is why at the bottling plant carbon dioxide is pumped into the cans or bottles when the fluid is very cold—around 35 degrees Fahrenheit. This low temperature allows the maximum amount of carbon dioxide to dissolve in the soda, keeping the carbonation levels as high as possible.

Boom Splat Kablooey - Depth Charge Variation

You've seen the amazing reaction that occurs when Mentos and Diet Coke mix... but what else can you use to make a geyser and what's the best way to get those geyser starters into your bottle of soda? The Geyser Tube works great for a roll of Mentos, but for everything else you can imagine we've found something even better... the Geyser Tube Depth Charge.

Materials

- Geyser Tube
- Geyser starters, such as Skittles, rock salt, table salt, etc.
- 2-liter bottle of soda
- Depth Charge

1. You'll need a 2-liter bottle of diet soda (diet doesn't make a sticky mess) and an outdoor location for your geyser. Select a flat surface on the lawn or driveway to place the bottle.
2. Choose a geyser starter... remember you're the scientist. What do you think would make the best geyser? Try anything from table salt to dog food. Use what you've learned in Mentos Geyser experiments to decide what to try. Remember that the reason Mentos work so well is because of the tiny (almost microscopic) pits and craters on the surface of the mint. Use the Depth Charge to test what you think will make the biggest geyser.
3. Unwrap the string from your Geyser Tube and put the trigger pin into the hole at the base of the Geyser Tube.
4. Unscrew the cap from the top of your Geyser Tube.
5. Open the bottle of soda and attach the Geyser Tube.
6. Load the Depth Charge with your geyser starter and carefully slide the loaded Depth Charge, open end up, into the Geyser Tube. Screw the cap back on the Geyser Tube.

7. Countdown... 3-2-1... and pull the string. The Depth Charge will fall to the bottom of the soda and instantly release your geyser starter! If you selected a good geyser starter, the soda will begin to erupt right away. How high did your soda fly?
8. Pour the remaining soda out of the bottle and reclaim your empty Depth Charge. Rinse and dry the Geyser Tube and Depth Charge parts and you're ready to try out your next experiment.

How does it work?

The Depth Charge was specially designed to allow you to test how well other materials work when it comes to creating a soda geyser. It's tough to test how well table salt works if there's not a good (and consistent) way to drop it into the soda. With the Depth Charge, it's possible to really conduct tests under scientific conditions.

You probably noticed the small weight on the end of the Depth Charge. This causes it to drop quickly to the bottom of the soda bottle. When the Depth Charge hits the bottom, the two sides split apart and release the material (whatever you picked for your geyser starter) into the soda. It's important to get the starter material to the bottom of the bottle as quickly as possible to get the greatest geyser effect. Also remember that the secret is to select a geyser starter that has a rough surface - a place for carbon dioxide bubbles to collect and finally escape. Filling the Depth Charge with smooth marbles will produce no geyser while tiny particles of sand or rock salt produce great geysers.

Science Fair Connection:

The Mentos Geyser Science Project is an excellent example of an experiment because it clearly shows how to isolate a *variable* (the thing that changes in the experiment) and standardize all other conditions so that you can see the true effect of the variable on the geyser reaction. You know that dropping Mentos into Diet Coke causes a geyser to erupt. That is a fun demonstration, but it isn't a science fair project. A true experiment *changes* a variable, *creates* a new experiment, and then *compares* results.

Energy Ball/Energy Stick

Materials:

- Energy Ball or Energy Stick
- Activity Guide
- Students

The Energy Ball helps children visualize circuits. This is a great little device to use when describing open and closed circuits. This 38 mm (1.5 in) ball contains two small metal electrodes. When the electrodes are touched simultaneously, the Energy Ball flashes and makes a buzzing sound. A great group activity is to have the participants hold hands. Have one participant touch one of the electrodes while another person at the other end of the circle touches the other electrode. Two people can touch the electrodes and make the Energy Ball buzz as long as everyone around the circle is holding hands (or noses & chins).

The Energy Stick is the newest tool in experimenting with open and closed circuits. Completely safe to touch and handle, the Energy Stick features electrodes on each end of its 7.5" long tube. When these electrodes are touched simultaneously, long-lasting LED lights inside the tube flash and the tube makes a noise. Release one or both of the electrodes and the flashing lights and noise stop. Do it over and over again... it works every time!

Have the entire class complete the circuit and when someone lets go - (a sneaky trick)- locate the "circuit breaker"

Test various materials by two students taking hold of a wooden ruler, a pencil, a book, an aluminum can, and inserting their fingers in a bowl of water, etc. Fantastic for teaching the scientific method.

Fruit-Power Battery

Convert chemical energy from the acid in a lemon into electrical energy

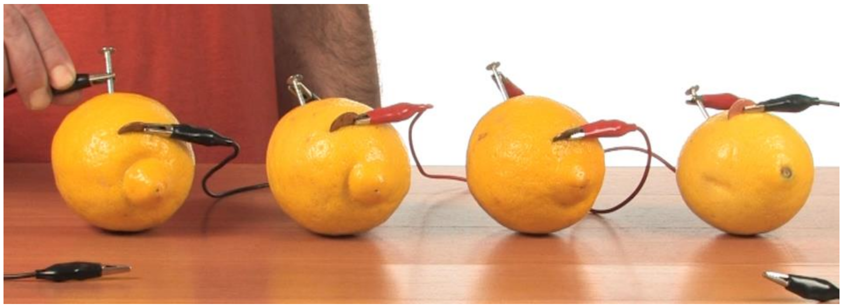
Voltaic batteries of all shapes and sizes are objects that convert chemical energy into electrical energy. You probably use batteries to power your cell phone, iPod, or any number of wireless gadgets. But did you know that you can actually use chemical energy stored within a lemon to power a small LED light? It's true, and we'll show you exactly how in the Fruit-Power Battery experiment.

Materials

- Four lemons (the bigger and juicier the better)
- Four pennies
- Five zinc-galvanized nails
- Five sets of alligator clips
- LED light
- Kitchen knife
- Use a kitchen knife to cut a penny-sized slit in all four lemons.
- Insert a penny halfway into each of the four slits that you cut.

Push a zinc-galvanized nail into each of the lemons, opposite the penny. Be sure you don't let the nail and penny touch each other.

1. Connect all four lemons together with alligator clips. Each set of alligator clips should connect a nail with a penny.
2. Attach the two loose alligator clips to the LED light.
3. Check that out! The energy from the lemons lights up the LED.



How does it work?

Batteries are comprised of two different metals suspended in an acidic solution. With the Fruit-Power Battery, the two metals are zinc and copper. The zinc is in the galvanization of the nail, and the penny is actually copper-plated zinc. The acid comes from the citric acid inside the lemon.

The two metal components are electrodes, the parts of a battery where electrical current enters and leaves the battery. With a zinc and copper set-up, the current will flow out of the penny and into the nail. The electricity also passes through the acidic solution inside the lemon.

Once the Fruit-Power Battery is connected to the LED, you create a complete circuit. As the electrical current passes through the LED, it lights the LED, and passes back through all of the lemons.

Have students calculate how many lemons it would take to run an air conditioner or car—of course it would take an awful lot. It takes something like five million lemons to run a car.

If you squeezed the lemon, can you get more electricity out of it? Why?

Test it out: will other fruits and vegetables work?

Light Circuit

Build a battery powered circuit lantern that lights up the night!

Discuss: When you need to light up a room, what do you do? You plug a lamp into the wall! But what if you only have a 9-volt battery, some wire, and a couple of Christmas lights? Is there any way to create light? We've got you covered with the Light Circuit experiment. It's like a Christmas tree in your hand!

Materials

- 9-volt battery
- Christmas lights
- Alligator clip wires
- Toggle switch
- Scissors

1. Have students use the scissors to cut two lights off of a working strand of Christmas lights. Leave 1-2 inches of wire hanging from each light.
2. Have them strip the rubber insulation off half of the wire's length on both ends. If they are using the scissors, caution them to be careful not to cut through the wire, only the insulation.
3. It's time to create a simple circuit... Have students touch one of the stripped wires to the negative side of the 9-volt battery and the other wire to the positive side of the battery. Both of the Christmas lights should light up. If they don't, you may need to find two more lights.
4. If you don't have a toggle switch and alligator clip wires, it's okay. You've already created a circuit. If you do have a toggle switch and alligator clip wires, keep reading to discover how to create a circuit that you can open and close with the flip of a switch!
5. Use one alligator clip wire to connect the positive side of the 9-volt battery to one ground on the toggle switch. Use another alligator clip wire to connect the negative side of the 9-volt battery to the other ground on the toggle switch.
6. Now use two more alligator clip wires to connect the positive and negative sides of the battery to the exposed light wires.
7. Play with the toggle switch to turn your lights on and off. You have created an open and closed circuit!

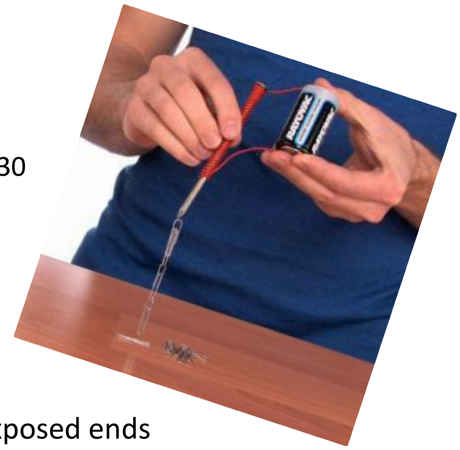
How does it work?

What you have created here is a battery powered circuit. Circuits work by electricity cycling through the conducting parts of wires, lights, and batteries. In the first part of the experiment without the toggle switch, you built a closed circuit when you connected the light wires to the positive and negative sides of the 9-volt battery. The battery supplies electricity, the exposed wires (made of conductive copper) carry the electricity, and the lights use the electricity to "turn on" before releasing the electricity back into the system.

When you implement the toggle switch, you've introduced the ability to control the flow of electricity in the circuit. When the toggle switch is "off," the electricity is stopped because the circuit is incomplete. But when the toggle switch is "on," you have a complete circuit and the electricity can flow freely. You have essentially created a simplified version of a light switch in your house. Flipping the light switch "on" or "off" is the same as opening and closing the toggle switch.

Electromagnets

About 150 years ago a way was found to make a magnet using electric current. Students can make such a magnet as follows.



Materials

- One C battery
- An iron nail
- Obtain a length of thin, insulated magnet wire (about 20 feet of 30 gauge) with exposed ends (Be sure that the clean copper wire shows through all around the wire at both ends.)
- Paper clips, staples, or other small metal objects

1. To start off, have students try picking up the small metal objects with the nail. It doesn't work, does it? It's fair to assume that the nail is not a magnet.
2. Now let's turn the nail into a magnet. Take the wire with exposed ends and wrap it tightly around the nail.
3. Make sure that the wire covers about two-thirds of the nail. Leave about an inch of each end of the wire not coiled around the nail.
4. Place one of the exposed ends of the wire on the positive end of the battery.
5. Take the other exposed end of wire and place it on the negative end of the battery.
6. With the apparatus you've created, try picking up the paper clips again. It works! When you pull the wire away from the battery the current stops and the iron objects drop off.

How does it work?

What you have created with the tightly wound wire is called a *solenoid*. A solenoid is a coil wound tightly around a metallic core. When an electrical current passes through the wire, it creates a magnetic field. When you wrap the wire around the iron nail, you create a simple electromechanical solenoid. These electromagnets are typically very weak but useful at short range - like when picking up paper clips with a nail.

Now that you know how it works, have students try experimenting with some variables:

- Try using a smaller or larger nail. Does the size of the nail affect how large of an object you can pick up?
- Try using an A, AA, or AAA battery instead of the C battery. What happens with the other size of battery?

Warning: You may want to test the previous experiment and determine if gloves are needed as the "magnet" may get VERY hot VERY fast....

That's very interesting, but what can it be used for?

Using Magnetism

With such an electromagnet, as you've seen, you can make a distant iron object move by simply turning current on and off. **(Ask students how they might think it would be useful.)** This fact makes the electromagnet useful in telegraph sets, electric bells, telephone receivers, and electric motors.

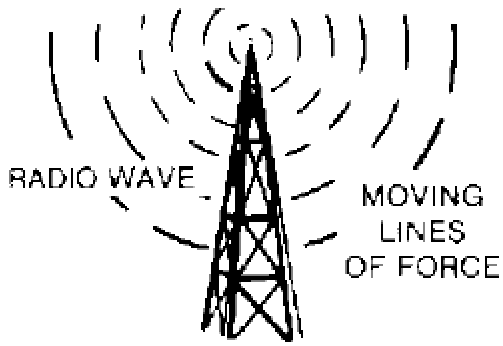


Image Credit: Don Herbert and Hy Ruchlis. *Mr. Wizard's 400 Experiments in Science*. http://www.arvindguptatoys.com/arvindgupta/400wizard.pdf Accessed 8/30/11.

In fact, all of radio and television is based upon electromagnetism. A radio wave is made up, in part, of a moving magnetic field. A moving version of what we saw with the iron filings, in which the lines of force spread out like a wave spreads out from a dropped pebble. Scientists therefore call a radio wave as an "electromagnetic wave". The light which enables you to see is also an electromagnetic wave. In fact, radio waves were discovered because an English scientist named Maxwell developed a theory that light was an electromagnetic wave. Other scientists, looking for different kinds of electromagnetic waves then discovered radio waves.

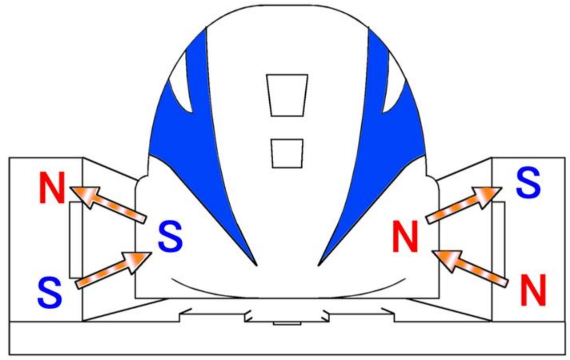
Image Credit: Future Cities. http://www.freewebs.com/futurecities/transportation.htm. Accessed 9/1/11.

You can see that magnetism plays a very important part in your life. It is all around you, in the form of light, radio, TV and the many electrical devices that you use every day.

Even transportation can be based on electromagnets, in fact that's how maglev (magnetic levitation) trains work. Levitation is when something rises and floats in the air in apparent defiance of gravity. Remember, every magnet has a north pole and a south pole. **(Does an electromagnet have poles? Have students bring each end near a compass while the current is on. They will find that the electromagnet has a north and south pole just like a regular rod-shaped magnet.)** Similar poles of two magnets repel each other; opposite poles attract each other. These principles govern the levitation of maglev trains. **To help students picture how a maglev train is propelled forward, have them think of three bar magnets lined up on the floor, you may want to try it and see if your magnets work too.** The magnet in front is pulling with an attracting (opposite) magnetic pole and the magnet in back is pushing with a repulsing (similar) magnetic pole. The magnet in the middle moves forward. A maglev's guideway has a long line of electromagnets. These pull the train from the front and push it from behind. The electromagnets are powered by controlled alternating currents, so they can quickly change their pull and push poles, and thus continually move the train forward.

Discussion points: Some maglev trains are levitated by magnetic repulsion. Other maglev trains are levitated by magnetic attraction. Have students describe how the magnets for magnetic repulsion are used differently than the magnets that are used for magnetic attraction.

Have students imagine that instead of cars, people had small passenger vehicles that used propulsion and levitation magnets. What would be needed in order to make this system useful for transporting people from their homes to other places? What might be some benefits of this kind of system? What might be some drawbacks?



Maglev Levitation System

Image Credit: http://commons.wikimedia.org/wiki/File:JR_Maglev-Lev.png. Accessed 9/1/11. All Rights Reserved

(Electro)Magnetic Suction

Solenoids have plenty of uses. As we've learned coils of wire called solenoids, a coil of wire with current flowing through it, form an electromagnet that acts very much like a bar magnet. But did students know solenoids are also used (working with iron bars) to turn electricity into short quick motion, such as in doorbells or pinball flippers? They also activate the starter in your car, and close valves in washing machines. A solenoid will magnetize an iron nail and attract it in a remarkable way that we'll get to see. This experiment shows students how a doorbell works. The following activity was found at http://www.exploratorium.edu/snacks/magnetic_suction/index.html Science Snacks. ©The Exploratorium. Accessed 8/30/11. All Rights Reserved.

Materials:

- 40 feet (12 m) of insulated bell wire.
- A plastic or cardboard tube 4 to 6 inches (10 to 15 cm) long and about 1/4 inch (6 mm) in diameter.
- A large battery, 6 volts or more. (An ordinary 1.5-volt D battery will work just fine, but it may go dead very quickly and will require more coils to get the same effect.)
- The largest iron nail that will fit in the tube loosely.
- Adult help.

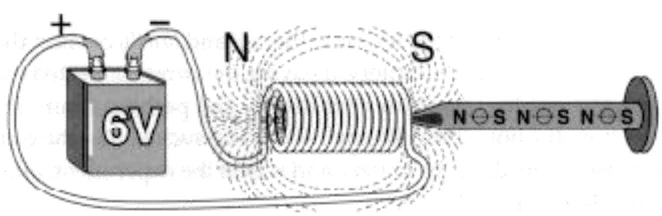


Image Credit: http://www.exploratorium.edu/snacks/magnetic_suction/index.html Science Snacks. ©The Exploratorium. Accessed 8/30/11. All Rights Reserved.

Have students tightly wrap as many coils of wire as possible around the tube, leaving the two ends free so that you can strip the insulation off them and connect them to a battery.

Have students insert the nail part of the way into the coil and let go. Have them watch what happens when you **briefly** connect the ends of the wires to the battery. (Leaving the wires connected too long will result in death for your battery and heat up the wires.) The nail should be sucked into the coil. Reverse the leads to the battery **(have students predict what will happen)** and repeat the experiment.

Why does it do that?

Any moving electric charge creates a magnetic field around it. A loop of wire with a current creates a magnetic field through the loop. You can increase the strength of this field by piling up a lot of loops. The more loops, the stronger the magnet. Like a bar magnet, this coil of wire now has a north pole and a south pole.

Because of the motion of electrons around its nucleus, each iron atom can be thought of as a tiny loop of moving charge. Each atom therefore acts like a small magnet. Ordinarily, all these "loops" point in different directions, so the iron has no overall magnetism (have students . But suppose you bring a nail near the south pole of your electromagnet. **(Have students try it)** The north poles of the iron atoms will be attracted to the south pole of the electromagnet and will all line up pointing in the same direction. The nail is now magnetized, with its north poles all facing the south pole of the electromagnet. The opposite poles attract each other, and the nail is sucked into the electromagnet.

When the direction of current is reversed, the poles of the electromagnet reverse. Knowing this, students might have thought that when you brought the nail near the same end of the electromagnet as they did previously, the nail would now be repelled by the electromagnet, rather than attracted and sucked into it again. But when they try it, the nail does the same thing it did before. **(Discuss why that might be the case.)**That's because the nail's iron atoms all reorient (change direction) so that they line up with their opposite poles pointing toward whatever pole the electromagnet presents, if it’s north, all the south poles in the nail point that way and vice versa. Thus the nail will always be attracted to the electromagnet and will never be repelled.

Students can find which end of the coil is the magnetic north pole by wrapping the fingers of their right hand around the coil in the direction the current is flowing; their thumb will point to the north end of the coil. They can also use a magnetic compass.

What is magnetic suction used for?

(Ask students what practical applications they think this phenomenon might be good used for.) The principle of magnetic suction is used to make a variety of devices, from doorbells (in which an iron rod is sucked into a coil to strike a chime) to pinball machines (in which current goes through a coil, sucking in a rod that is attached to the flipper) to the starter switch on your car.

To extend the original activity

- Have students hold the coil vertically and repeat the experiment.
- Then have them try using smaller nails and straightened paper clips in the coil.
- Remove the nail from the coil and test its magnetic properties by seeing if you can pick up some paper clips with it. If the electromagnet is not strong enough, the nail will not stay magnetized after the battery is disconnected, so to see this effect use as large a current source as possible. If the electromagnet is strong enough, the nail may stay magnetized for a while, until the random jiggling of the iron atoms eventually moves them out of alignment again.

- To demagnetize the nail rapidly, drop it onto a solid surface, such as a cement floor, a couple of times. This knocks the iron atoms out of alignment. Try to pick up paper clips with the demagnetized nail.

Motor Effect

A magnet exerts a force on current-carrying wire.

This simple device shows that when an electrical current flows through a magnetic field, a force is exerted on the current. This force can be used to make an electric motor.

Materials:

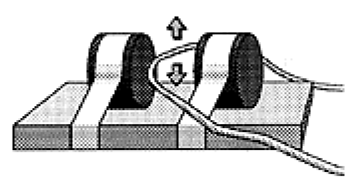
- 4 to 6 small disk magnets. (inexpensive 1-inch (2.5 cm) diameter disk magnets work perfectly.)
- One or two 1.5 volt flashlight batteries.
- Approximately 2 feet (60 cm) of flexible wire, such as solid or multi-stranded hookup wire, or magnet wire (available at places like Radio Shack).
- Masking tape.
- A wooden board approximately 2 x 4 x 6 inches (5 x 10 x 15 cm).
- A knife or sandpaper.
- Adult help.

Preparation:

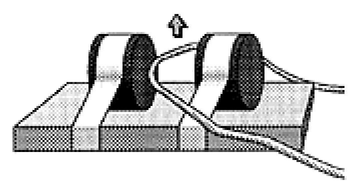
Group the disk magnets into a single cylindrical pile. Place the pile on the board so that it can be rolled along the board. Split the pile in the middle, leaving a gap of about 1/2 inch (1.3 cm) between the faces of the two groups. Tape the two groups to the board. A north pole will face a south pole across the gap.

Tape the battery onto the board as shown in the photo. Remove the insulation from the ends of the wire. (Use a knife for stranded wire, or use sandpaper to remove the nearly invisible insulating enamel from magnet wire.) Loop the wire through the gap between the magnets, with the ends of the wire close enough to the battery to touch it.

Instructions

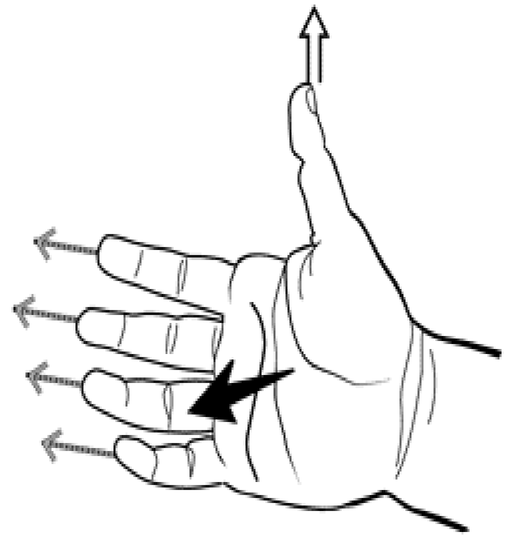


Touch one end of the wire to the positive side of the battery and simultaneously touch the other end of the wire to the negative side. The wire loop will jump either up or down.



If you reverse the direction of current flow, the wire will jump in the opposite direction. To reverse the current, attach the lead that was connected to the positive end of the battery to the negative end and vice versa.

Why does it do that?



The magnetic field of the disk magnets exerts a force on the electric current flowing in the wire. The wire will move up or down, depending on the direction of the current and the direction of the disks' magnetic field.

To predict the direction of movement, you can use a mathematical tool called the *right-hand rule*. Put your right hand near the section of wire that goes between the disk magnets. Make your hand flat, with your thumb sticking out to the side. (Your thumb should be at a right angle to your fingers.) Place your hand so that your thumb points along the wire in the direction that the electric current is flowing (current flows from the positive terminal of the battery to the negative terminal) and so that your fingers point from the north pole of the disk magnets toward their south pole. (You can find the north pole of the magnets by using a compass; the south end of a compass will point toward the north pole of a magnet.) Your palm will then naturally "push" in the direction of the magnetic force on the wire.

The deflecting force that a magnet exerts on a current-carrying wire is the mechanism behind the operation of most electric motors. Curiously (and happily for our sense of symmetry!), the reverse effect is also true: Move a loop of wire across the pole of a magnet, and a current will begin to flow in the wire. This, of course, is the principle of the electric generator. The electric current you generate by moving this single loop of wire through the weak magnetic field of the disk magnets is too weak to detect with all but the most sensitive of microammeters (electrical measuring devices).

FYI

This experiment creates just a short pulse of motion. A motor requires continuous motion. This problem was solved originally in the early 1800s by the invention of commutators. A commutator is a sliding contact that not only makes electrical contact with a rotating loop of wire but also allows the current direction to reverse every half-cycle of rotation. The first electric motors were constructed in 1821 by Michael Faraday in England and improved in 1831 by Joseph Henry in the United States

Electromagnetic Motor!

An amazing, spinning machine using household items

When it comes to creating something out of nothing, Steve Spangler takes the cake. The Steve Spangler Science team recently challenged Steve to create a simple homopolar motor (an electric motor that works without the need for a commutator, so the electrical polarity of the motor does not change) by using objects that he could find around his home. The trick to homopolar motors is the use of electromagnets and a lack of polarity change. It's complicated, so they were sure that Steve would have trouble. Much to the surprise of everyone, Steve not only accomplished the (what they thought to be) impossible, but he did it twice. Steve was so proud that he wanted to give both of his designs to you. It's a 2-for-1 with the Electromagnetic Motor.

Materials

Design 1

- A single AA battery
- Copper wire
- Neodymium magnets
- Pliers

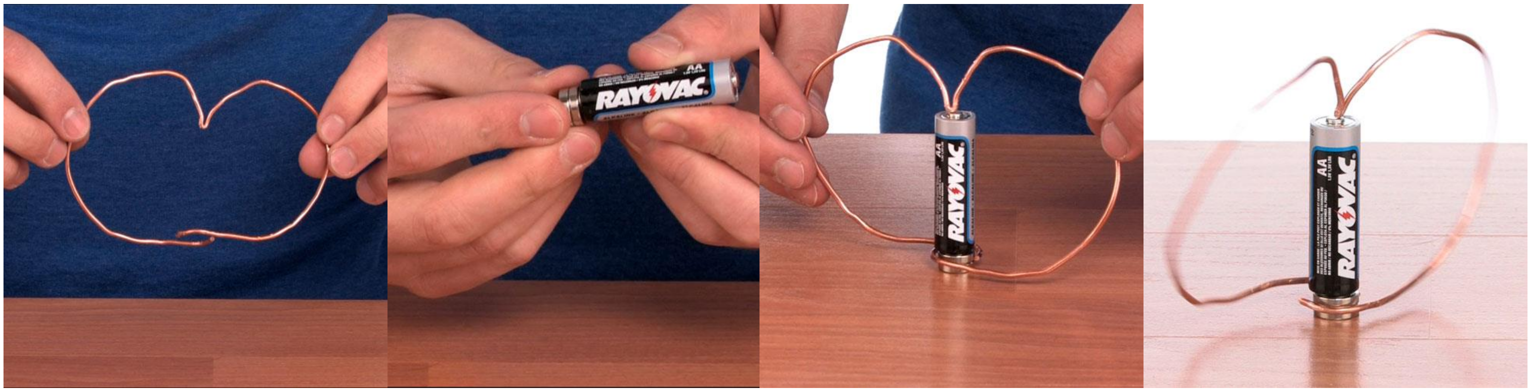
Design 2

- A single C battery
- Copper wire
- A neodymium magnet
- A watch battery
- LED lights
- A screw
- Tape

Design 1

1. Use the pliers to bend a copper wire into the shape you see in the picture below, on the left. The top of the wire should resemble a heart shape. The bottom of the wire, where the two ends meet, should make a slightly open circle.
2. Place both of the neodymium magnets onto the negative side of the AA battery.
3. Slide the open circle end of the wire around the battery and balance the heart shaped end of the wire on the positive end of the battery.

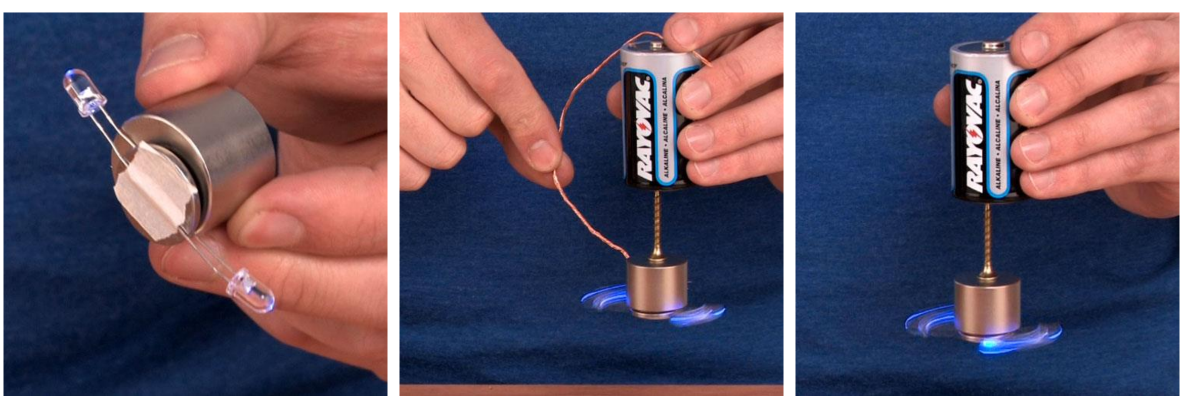
4. Make sure the bottom of the wire (the slightly open circle) is touching the magnets and... voila! You've got a spinning motor.



Design 2

1. Use the watch battery to power one of the LED lights. To do this, slide the watch battery between the wires of the LED light. Press one of the LED wires against the positive side of the battery and the other wire against the negative side of the battery.
2. Tape down the LED wire that is touching the negative side of the battery.
3. Slide one wire from the other LED light underneath the piece of tape. The LED light's second wire should be against the positive side of the battery.
4. Carefully place the neodymium magnet against the positive end of the watch battery. At this point, both LED lights should be lit up.
5. Place the head of the screw in the center of the magnet opposite the LED lights.
6. Place the tip of the screw in the center of the negative end of the C battery.
7. Use the copper wire to touch the positive end of the C battery and the neodymium magnet and the motor will begin spinning.

You don't need the LED lights to perform this experiment, but it looks incredible! And hey, looks count for something, right?



How does it work?

What you have created is called an electromagnetic (scientifically, homopolar) motor. An electromagnetic motor works through a magnetic field along the axis of rotation and an electric current that, at some point, is not parallel to the magnetic field. Sound complicated? It is! So let's try to make it a bit simpler.

In Electromagnetic Motor Design 1, you have an electric current flowing throughout the circuit. The current, at some point while traveling through the system, is not parallel to the magnetic field of the neodymium magnet. At the point where the forces of the current and magnetic field are not parallel, there is a force called a Lorentz force. The Lorentz force occurs in electromagnetic fields, such as the one we've created with this system. It is the Lorentz force that causes the copper wire to rotate.

The same principles are applied to Electromagnetic Motor Design 2. However, in Design 2, there are no copper wires to rotate. But that's ok, we don't need them because the screw and the magnet spin! When you connect the positive end of the battery to the neodymium magnet (attached to the negative end of the battery by way of the screw) you create the necessary electromagnetic field to produce the Lorentz force. But since there is such a small amount of friction between the screw and battery, the Lorentz force directly affects the magnet. The magnet and screw continue to spin long after you've removed the wire that closes the system because of the small amount of friction.

Extension: Test which battery brand lasts the longest. Is Rayovac right when it says on the package "lasts longer than Duracell"?