NEWTON'S APPLE® Multimedia

Electricity

Electric Guitar

Teacher's Guide

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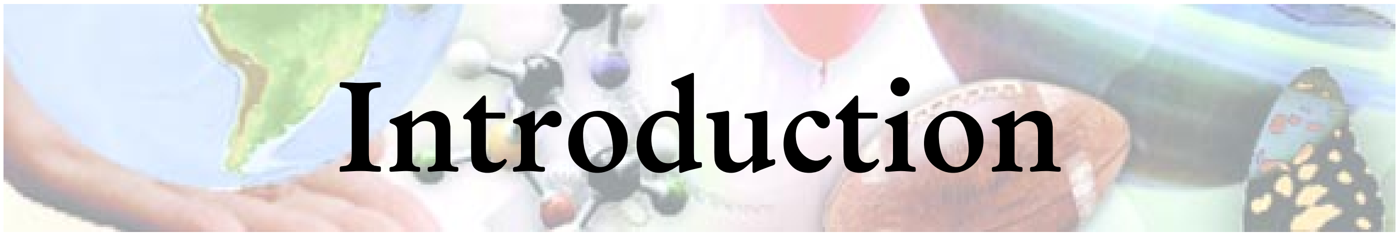
Introduction



Welcome to the *Newton's Apple Multimedia Collection*™!

Drawing from material shown on public television's Emmy-award-winning science series, the multimedia collection covers a wide variety of topics in earth and space science, physical science, life science, and health. Each module of the *Newton's Apple Multimedia Collection* contains a CD-ROM, a printed Teacher's Guide, a video with two *Newton's Apple*® segments and a scientist profile, and a tutorial video.

The Teacher's Guide provides three inquiry-based activities for each of the topics, background information, assessment, and a bibliography of additional resources.

The CD-ROM holds a wealth of information that you and your students can use to enhance science learning. Here's what you'll find on the CD-ROM:

- two full video segments from *Newton's Apple*
- additional visual resources for each of the *Newton's Apple* topics
- background information on each topic
- a video profile of a living scientist working in a field related to the *Newton's Apple* segments
- an Adobe Acrobat® file containing the teacher's manual along with student reproducibles
- UGather® and UPresent® software that allows you and your students to create multimedia presentations
- QuickTime® 3.0, QuickTime® 3 Pro, and Adobe Acrobat® Reader 3.0 installers in case you need to update your current software

The *Newton's Apple Multimedia Collection* is designed to be used by a teacher guiding a class of students. Because the videos on the CD-ROM are intended to be integrated with your instruction, you may find it helpful to connect your computer to a projection system or a monitor that is large enough to be viewed by the entire class. We have included a videotape of the segments so that you can use a VCR if it is more convenient. Although the CD-ROM was designed for teachers, it can also be used by individuals or cooperative groups.

With the help of many classroom science teachers, the staff at *Newton's Apple* has developed a set of lessons, activities, and assessments for each video segment. The content and pedagogy conform with the National Science Education Standards and most state and local curriculum frameworks. This Teacher's Guide presents lessons using an inquiry-based approach.

If you are an experienced teacher, you will find material that will help you expand your instructional program. If you are new to inquiry-based instruction, you will find information that will help you develop successful instructional strategies, consistent with the National Science Education Standards. Whether you are new to inquiry-based instruction or have been using inquiry for years, this guide will help your students succeed in science.

WE SUPPORT THE NATIONAL SCIENCE EDUCATION STANDARDS

The *National Science Education Standards* published by the National Research Council in 1996 help us look at science education in a new light. Students are no longer merely passive receivers of information recorded on a textbook page or handed down by a teacher. The Standards call for students to become active participants in their own learning process, with teachers working as facilitators and coaches.

Newton's Apple's goal is to provide you with sound activities that will supplement your curriculum and help you integrate technology into your classroom. The activities have been field tested by a cross section of teachers from around the country. Some of the activities are more basic; other activities are more challenging. We don't expect that every teacher will use every activity. You choose the ones you need for your educational objectives.

Teacher's Guide

We suggest you take a few minutes to look through this Teacher's Guide to familiarize yourself with its features.

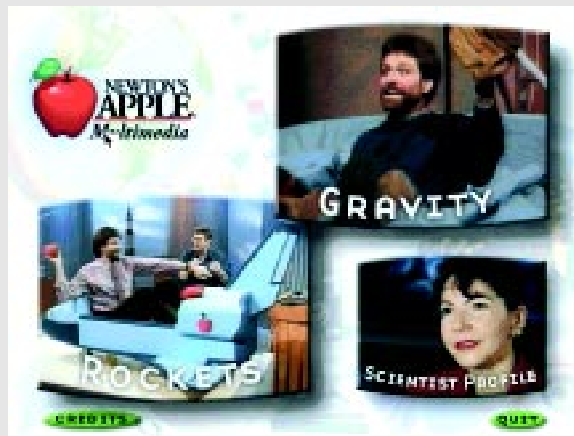
Each lesson follows the same format. The first page provides an overview of the activity, learning objectives, a list of materials, and a glossary of important terms. The next two pages present a lesson plan in three parts: ENGAGE, EXPLORE, and EVALUATE.

- ENGAGE presents discussion questions to get the students involved in the topic. Video clips from the *Newton's Apple* segment are integrated into this section of the lesson.
- EXPLORE gives you the information you need to facilitate the student activity.
- EVALUATE provides questions for the students to think about following the activity. Many of the activities in the collection are open-ended and provide excellent opportunities for performance assessment.

GUIDE ON THE SIDE and TRY THIS are features that provide classroom management tips for the activity and extension activities.

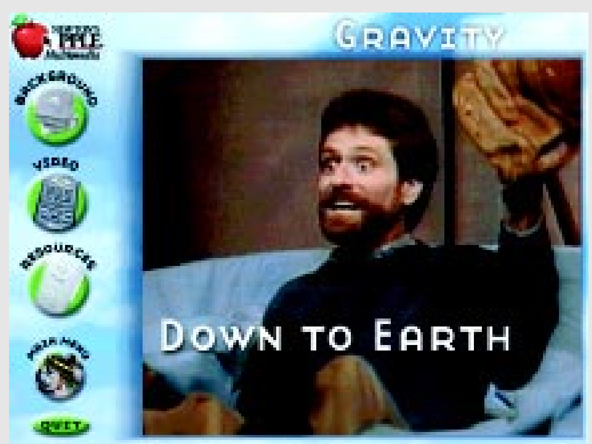
USING THE CD-ROM

When you run the *Newton's Apple* CD-ROM, you will find a main menu screen that allows you to choose either of the two *Newton's Apple* topics or the scientist profile. Simply click on one of the pictures to bring up the menu for that topic.



Main Menu

Once you have chosen your topic, use the navigation buttons down the left side of the screen to choose the information you want to display.



Topic Menu

The Background button brings up a short essay that reviews the basic science concepts of the topic. This is the same essay that is in the Teacher's Guide.

Playing the Video

The Video button allows you to choose several different clips from the video segment. We have selected short video clips to complement active classroom discussions and promote independent thinking and inquiry. Each video begins with a short introduction to the subject that asks several questions. These introductory clips can spark discussion at the beginning of the lesson. The Teacher's Guide for each activity presents specific strategies that will help you engage your students before showing the video. Each of the individual clips are used with the lesson plans for the activities. The lesson plan identifies which clip to play with each activity.

Video Menu

Once you select a video and it loads, you'll see the first frame of the video segment. The video must be started with the arrow at the left end of the scroll bar. As you play the video, you can pause, reverse, or advance to any part of the video with the scroll bar. You can return to the Clips Menu by clicking on the Video button.

Multimedia Tools

The *Newton's Apple* staff has designed a product that is flexible, so that you can use it in many different ways. All of the video clips used in the program are available for you to use outside the program. You may combine them with other resources to create your own multimedia presentations. You will find all the video clips in folders on the CD-ROM. You may use these clips for classroom use only. They may not be repackaged and sold in any form.

You will also find a folder for UGather™ and UPresent™. These two pieces of software were developed by the University of Minnesota. They allow you to create and store multimedia presentations. All of the information for installing and using the software can be found in the folder. There is an Adobe Acrobat® file that allows you to read or print the entire user's manual for the software. We hope you will use these valuable tools to enhance your teaching. Students may also wish to use the software to create presentations or other projects for the class.

Technical Information

Refer to the notes on the CD-ROM case for information concerning system requirements. Directions for installing and running the program are also provided there.

Make sure you have the most current versions of QuickTime® and Adobe Acrobat® Reader installed on your hard drive. The installation programs for QuickTime 3, QuickTime Pro, and Acrobat Reader 3.0 can be found on the CD-ROM. Double-click on the icons and follow the instructions for installation. We recommend installing these applications before running the *Newton's Apple Multimedia* program.

Trouble Shooting

There are several Read-Me files on the CD-ROM. The information found there covers most of the problems that you might encounter while using the program.

Integrating Multimedia

We suggest that you have the CD-ROM loaded and the program running before class. Select the video and allow it to load. The video usually loads within a couple of seconds, but we recommend pre-loading it to save time.

All of the video segments are captioned in English. The captions appear in a box at the bottom of the video window. You can choose to play the clips in either English or Spanish by clicking one of the buttons at the bottom right of the screen. (You can also choose Spanish or English soundtracks for the scientist profile.)

The Resources button provides you with four additional resources. There are additional video clips, charts, graphs, slide shows, and graphics to help you teach the science content of the unit.

Resources Menu

The other navigation buttons on the left side of the window allow you to go back to the Main Menu or to exit the program.

Electric Guitar Teacher's Guide

Turn It Up

What is feedback? How do sound waves work and what do they have to do with feedback? What is resonance and how is it produced? How do rock stars make their electric guitars "scream"?

Themes and Concepts

- sound
- vibration and frequency
- waves and resonance
- transfer of energy

National Science Education Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard B: Students should develop an understanding of transfer of energy.
Content Standard G: Students should develop an understanding of the nature of science.

Activities

1. *Resonance—Approx. 10 min. prep; 60 min. class time*
How can one vibrating object affect a similar nearby object? Students explore mechanical resonance and how the natural frequency of an object can be amplified by another vibrating object of the same natural frequency.

2. *How Waves Behave—Approx. 20 min. prep; 40 min. class time*
What are waves and how do they behave? Students investigate vibration and resonance in sound. They experiment with waves and create a resonant sound in a vibrating column of air.

3. *Feedback—Approx. 15 min. prep; 40 min. class time*
What is feedback in an electric guitar? Students examine factors that produce feedback. They explore the relationship between the volume setting of an amplifier-speaker and the distance between the speaker and a microphone or guitar.

More Information

Internet
Newton's Apple
http://www.ktca.org/newtons
(The official *Newton's Apple* web site with information about the show and a searchable database of science ideas and activities.)

The Universe as a Guitar? -
New York University
http://www.nyu.edu/classes/neimark/!UNIVERS.html
(This neat little activity shows the design of sound.)

Sound Waves -
University of Manitoba, Canada.
http://www.umanitoba.ca/faculties/arts/linguistics/russell/138/sec4/acoustl.htm
(Illustrations of sound waves.)

Sound Simulations
http://www.explorescience.com
(Many interactive simulations, including a number of demonstrations of waves and sound.

Internet Search Words

resonance, sound waves, feedback, electric guitars

Electric Guitar

Books

Friedhoffer, Robert. *Sound. Book 4. Scientific Magic Series)*. New York: Franklin Watts, 1992. (Good source of experiments and clear explanations of the science of sound.)

Maculay, David. *The Way Things Work "Electric Guitar".* Boston: Houghton Mifflin Company, 1988. (A simple description of how the electric guitar works.)

Frier, G.D. and Anderson, F.J. *A Demonstration Handbook for Physics.* College Park, MD: AAPT, 1981. (A book containing a wide range of demonstrations for all topics in physics.)

Gardner, Robert. *Experimenting With Sound*. New York: Franklin Watts, 1991. (Good, clear discussion of sound waves and sound resonance.)

Talesnick, Irwin. *Idea Bank Collation*. Kingston, Ontario: S17 Science Supplies and Services Co. Ltd., 1991. (A great collection of all of the idea bank columns that appeared in the publications *The Crucible* and *The Science Teacher*.)

Amery, Heather. *Know-how Books of Batteries and Magnets*. London, England: ECIN 8RT, 1989. (A collection of simple to make gadgets to use in exploration of magnetism and electricity. It includes lists of materials for each activity, easy-to-follow instructions, and many interesting experiments.)

Zubrowski, Bernie. *Blinkers and Buzzers*. Morrow Junior Books, 1991. (Simple unique and simple projects related to electricity and magnetism.)

Community Resources

Audio shops
Music stores
Local rock guitarist
College and university physics

Background

Sound and Resonance

Science is probably the last thing most people think about when they listen to rock music. They hear the drums, vocals, and the powerful sound of electric guitars. However, it is the science of sound, resonance, and electricity that makes it all possible. The electric guitar is essentially a device that transforms the mechanical energy of a vibrating metal string into an electrical impulse of the same frequency in the guitar's magnetized pick up coil. The amplifier enlarges the electrical pulse and sends it to a speaker.

If you've been to a rock concert or watched a music video, you may have seen guitarists holding their instruments close to their amplifiers to create a loud, squealing sound. That squeal is feedback. Feedback occurs when a microphone or an electric guitar picks up sound waves from a loudspeaker and sends them back to the amplifier where they came from. The waves are then amplified again and rebroadcast through the speakers once more. This process repeats itself over and over very quickly. Each time the sound waves are amplified, the volume of the broadcast sound increases. The closer the microphone is to the speaker, the louder the original sound is, and this also contributes to the volume of the feedback. You've probably heard feedback in an auditorium or sports arena.

Resonance

All elastic objects, such as guitar strings, will vibrate at a characteristic frequency when struck. This is called the natural frequency of the object. An object will also vibrate at its natural frequency when it picks up the vibrations of another object of the same frequency. This phenomenon is called resonance. Resonance amplifies the vibrations. In the case of sound waves, the sound becomes louder.

Resonance can be noticed in everyday objects. The vibrations of a passing truck, for example, might start a window in a house rattling, provided the window and the truck have the same natural frequency.

Sound waves behave in a similar way. Pluck a string on a guitar and the same string on another, nearby guitar will emit a tiny sound of the same frequency. You can hear sound resonance when you listen to a tone coming from two speakers that are in a position so that the sound waves from the speakers hit your ears at the same time; the sound will be louder than if you are out of the direct path of the two sounds.

Feedback can be used to extend the range of sound from a guitar. It can also drive an audience from a concert hall and destroy very expensive speakers. Next time someone complains that you're playing your music too loud, you can tell them that you re just studying science!

Video & Stills

Video Segments

Introduction

36:00 to 36:44—Eileen Galindo strums an acoustical guitar and an electric guitar and notices an electrifying difference. (44 sec.)

Video Clip 1

36:50 to 39:44—Rock musician Ted Nugent explains the importance of vibration in sound. (2 min. 54 sec.)

Video Clip 2

39:46 to 40:51—Ted Nugent explains and demonstrates how rock musicians produce feedback on an electric guitar. (1 min. 5 sec.)

Multimedia Resources

Button A

Video: “Paper Cup” Newton’s Apple Science Try-It

Button B

Video: “Singing Wine Glass” Newton’s Science Try-It about resonance

Button D

Diagram: Wave shapes of sound and noise

Button C

Diagram: A comparison of the parts of electric and acoustic guitars

Unit Assessment Answer Key

The Unit Assessment on the following page covers the basic concepts presented in the *Newton’s Apple* video segment and the Background section in this guide. The assessment does not require completing all of the activities. The Unit Assessment may be used as a pre- or post-test. However, students should view the complete *Newton’s Apple* video before doing this assessment. There is additional assessment at the end of each activity.

Think about it

1. Resonance is a phenomenon that occurs when vibrations striking an object match the natural frequency of the object. The resulting sound has a greater amplitude—it is louder.
2. A sound wave from a loudspeaker vibrates an electric guitar string, producing electric impulses in the pick-up coil and sending them back to the amplifier.
3. The vibration in the string of a guitar is trans formed into electrical impulses in the pick-up coil. The amplifier increases the size of the electrical impulses, and the loudspeaker emits the vibrations as sound waves.
4. It is resonance when the pushes match the rhythm of the person on the swing. If the pushes are not synchronized with the swinging motion, the pushes will not have a resonant effect.
5. The windows have different natural frequencies. A window will not vibrate unless it has the same basic rate of vibration as the moving truck.

What would you say?

6. a 7. b 8. d 9. a 10. d

Unit Assessment

What do you know about Electric Guitars?

Write the answers in your journal or on a separate piece of paper.

Think about it

1. What is resonance?
2. Explain how sound from a loudspeaker can find its way back into an electric guitar amplifier.
3. How does an electric guitar change the vibration of a steel string into sound waves?
4. Someone is giving little pushes to a person on a swing. When is this an example of resonance, and when is it not?
5. A passing truck does not shake a window of a house close to the street, but it does shake a neighbor's window. Why?

What would you say?

6. Resonance will not occur—
   a. with objects that have different natural frequencies
   b. when vibration is very slow.
   c. with objects that have the same rate of vibration.
   d. when vibration is very fast.
7. Which of the following is not an example of resonance?
   a. feedback on an electric guitar
   b. listening to music with headphones
   c. increasing someone's height on a swing with small pushes
   d. the vibrations of a passing truck breaking a window in a house
8. Natural frequency is—
   a. a vibrating guitar string.
   b. very fast vibrations.
   c. the speed of sound waves.
   d. the basic rate of vibration of an object.
9. In an electric guitar, the pick-up coil—
   a. changes the vibrations of the string into electrical impulses.
   b. amplifies the sound of the string.
   c. changes electric pulses into vibrations.
   d. improves the sound of the guitar.
10. Resonance occurs when—
    a. the volume of a loudspeaker is turned up.
    b. the speed of sound waves are increased.
    c. the number of sound waves is increased.
    d. a vibration gets a boost from a similar vibration.

Activity 1

Resonance

What is vibration? Can one vibrating object affect another object? Does each object vibrate the same as other objects? What's an object's natural frequency? What is resonance? How is resonance created?

Getting Ready

Overview

What is mechanical resonance? Students learn about natural frequency and how a vibrating object can affect a similar, nearby object—strengthening vibrations and causing resonance.

Objectives

After completing this activity students will be able to—

- explain how and when a vibrating object can affect nearby objects;
- discuss how resonance strengthens vibrations.

Time Needed

Preparation: Approx. 10 min.
Classroom: Approx. 60 min.

Materials

For the teacher:

- pendulum suspended from a ring stand

For each group of students:

- piece of coat hanger wire approximately 45 cm (1 ft 6 in) long
- approximately 1 m (3 ft) of string
- numerous metal washers that are of equal size and weight
- scissors
- masking tape

Important Terms

amplify — To increase a sound or a vibration.

natural frequency — The rate at which an object tends to vibrate; The natural frequency of an object depends on its elasticity, shape, and other factors.

resonance — A phenomenon that occurs when vibrations striking an object match the natural frequency of the object; resonance can amplify the vibrations.

Electric Guitar

Here's How

Preparation
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 1 for each student.
- Review the Background information on page 8.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [36:00 to 36:44]. Find out what students already know about electric guitars and amplification. As a class, discuss the questions posed by Eileen Galindo.

- Students need to understand that the reference to vibration in the discussion of arm and leg movement in the Engage section is the swinging of arms and the pace of walking.

- Two of the pendulums must be the same length. If they vary more than four percent in length, they may not vibrate (swing) at the same frequency.

- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on the electric guitar.

Engage (Approx. 15 min.)

Begin by asking students why they swing their arms back and forth as they walk. Accept all answers. If space permits, have the students stand up and walk at a quick pace. Tell them to let their arms swing naturally at their sides. Ask the students what they notice about the rhythm—or vibration—of their arms? (It matches the rhythm of their walking pace.)

Ask the students to try to walk while swinging their arms more quickly than they are moving their legs. Ask them what they feel. (It is awkward—but more than that, they have to exert themselves more to walk.) Explain that swinging your arms so that they match the movement of your legs actually makes walking easier; it requires less effort and saves energy. Explain that when their arms swing in rhythm with their legs, it amplifies their walking pace—or vibration of their legs. If their arms and legs are not synchronized as they walk, they do not benefit from resonance.

Tell students to let their arms drop to their sides and make no effort to swing them. Have them walk at a brisk pace. Ask students what happens. (Your arms automatically begin to swing. The vibration of the moving legs transfers to the arms.)

Ask students if they can think of other examples of mechanical resonance. (A person pushing someone on a swing is one example.) The vibration of a swing—the movement back and forth—can be amplified if a small push is provided that matches the vibration of the swing. Explain that this is true with any two similar objects; if a vibrating object is given a push that corresponds to its natural frequency, the amplitude of its vibrations become larger.

Use a simple pendulum to demonstrate this phenomenon. Explain that the amount of energy in the push does not have to be large. It can be increased with small, properly timed forces.

Activity 1

Explore (Approx. 45 min.)

Have students work in groups. Explain that they are going to investigate natural frequency and resonance using pendulums.

Have them prepare four pendulums. Two of the pendulums should be equal in length and weight. The other two should be different lengths and/or weights. Have students rest a coat hanger wire at least 45 cm in length across a space between two chairs or tables. Tape the ends of the wire to keep it from moving.

Have students suspend the two equal pendulums from the wire. Have them give one pendulum small, short pushes—just as they would push a person on a swing—to increase the vibration of the pendulum. Have them record their observations. Explain that the phenomenon they observed is mechanical resonance.

After they have recorded their observations, each group should formulate a hypothesis about the resonance between the various pendulums they constructed. Have them create and carry out a plan for testing their hypotheses.

Each team should report their findings to the class

Evaluate

1. The natural frequency of a ship in the ocean is its rocking motion—just as the frequency of a swing is its movement back and forth. If the frequency of the ocean waves match the natural frequency of the ship, what will happen? (The ship's rocking motion will increase dramatically due to resonance.)

2. The vibrations of an earthquake could match the natural frequency or vibration rate of a building. Why is this dangerous? (They would increase or amplify the natural frequency rate of the building, increasing the chance for damage to the structure.)

3. How could it be dangerous for a group of elephants to walk in step across a bridge? (The vibration of their pace could match the natural frequency of the bridge, resulting in the amplification of the vibration of the bridge and destructive shaking.)

Try This

Turn a clear plastic cup upside down and place it on a flat surface. Put a small ball about the diameter of a dime under the cup. If the cup is moved back and forth at the right frequency the ball will travel around and around faster and faster. This is due to resonance. The same can be done in a bathtub with water. If a little energy is added to a wave in the tub at the right time, the wave will grow until water spills out of the tub.

RESONANCE

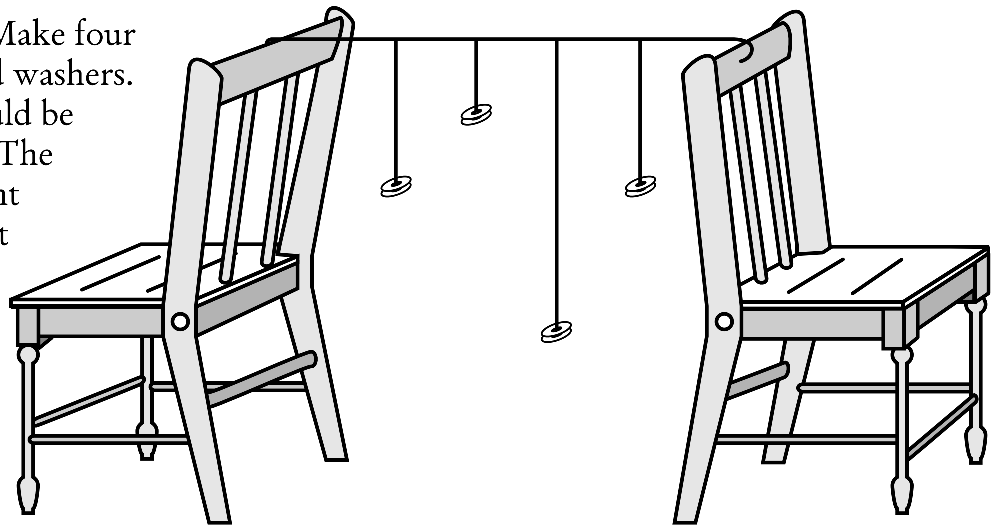
Activity Sheet 1

NAME ______________________________ **CLASS PERIOD** __________

WHAT YOU'RE GOING TO DO

You re going to investigate natural frequency and resonance using pendulums.

HOW TO DO IT



1. Work with your group. Make four pendulums out of string and washers. Two of the pendulums should be equal in length and weight. The other two should be different lengths and/or weights. Rest a coat hanger wire across a space between two chairs or desks. Tape the ends of the wire to keep it from moving.

2. Suspend the two equal pendulums from the wire. Give one pendulum small, short pushes—just as you would push a person on a swing—to increase the vibration (swinging) of the pendulum. Record your observations.

3. Discuss your observations with your group. Then formulate a hypothesis about the resonance between the various pendulums you constructed.

4. Develop a plan for testing your hypothesis. Then carry out your plan. Be sure to record your plan and observations.

RECORDING YOUR DATA

Write your hypothesis below. Record your observations and plan in your science journal. Create a data table to record information and observations from your experiments.

Hypothesis______________________________

WHAT DID YOU FIND OUT?

How is resonance demonstrated in the movement of the pendulums?

Did your test prove or disprove your hypothesis? Why or why not?

What ways could your experiment be changed to make it better?

Compare your results with the results of other groups. How can you explain the differences?

Activity 2

How Waves Behave

What are sound waves? Can one sound wave amplify another? How? How are sound waves reflected?

Getting Ready

Overview

Students investigate waves, sound waves, and resonance. They explore how to set an air column vibrating and determine how to amplify a sound wave by producing resonance.

Objectives

After completing this activity, students will be able to—

- explain how sound waves resonate
- explain constructive and destructive interference in waves
- define and describe the characteristics of a standing wave

Time Needed

Preparation: Approx. 20 min.
Classroom: Approx. 40 min.

Materials

For the teacher:

- Slinky®
- piece of rope about 3 m (10 ft) long
- two tuning forks with the same pitch

For each group of students:

- container of water about the size of a one-quart jar
- tuning fork
- paper towel tube

Important Terms

antinodes — The point in a standing wave having maximum motion.

constructive interference — Reinforcement. When the peak of one vibration or wave falls on top of the crest of another. The effect amplifies the vibration.

destructive interference — Destructive interference occurs when the trough of one vibration or wave falls on the crest of another. The effect is to cancel out the vibration.

nodes — The points in a standing wave that do not appear to move.

standing wave — A wave in which parts of the wave remain stationary and the wave doesn't appear to be moving. It is caused by the interference between the original wave and its reflection.

Electric Guitar

Here's How

Video Clip 1
36:50 to 39:44— Rock musician Ted Nugent explains how the sound of a vibrating string on an electric guitar is amplified. (2 min. 54 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [36:00 to 36:44]. Find out what students already know about electric guitars and amplification. As a class, discuss the questions posed by Eileen Galindo.
- Standing waves may be observed in water. Fill a large, flat, glass container, such as a cake pan, with water. Set the pan on top of an overhead projector so that the class can observe the waves. Prepare two glasses of water. Begin pouring one glass of water into one end of the pan so that waves are created. Do the same at the other end. Notice that the waves pass through each other and create a standing wave.
- This is a somewhat open-ended activity. Some groups may become frustrated. Circulate and ask questions that will lead these groups to figure out how to proceed.
- Tell students to avoid splashing the water. Have extra paper towels available just in case!
- Have a supply of dry paper towel tubes available. They can become difficult to work with when they become saturated with water.
- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on the electric guitar.

Preparation
- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 2 for each student.
- Review the Background information on page 8.

Engage (Approx 20 min.)

Stretch a Slinky® out on the floor. Tie a light string or thread about 30 cm (1 ft) long to one end and have a student hold the string. Shake the other end of the Slinky® to create a wave that travels the length of the Slinky®. Ask students what happens to the wave. (It comes back on the same side of the Slinky®.)

Next, have a student hold one end of the Slinky® firmly so that it does not move. Shake the other end of the Slinky® again and have students observe what happens to the wave after it travels the length of the Slinky®. (It is reflected. If the wave travels down the left side of the Slinky®, it will return on the right side.)

Constructive Interference and Destructive Interference
Ask students what they think will happen when a wave is started from both ends of the same side of the Slinky®. Have two students shake each end of the Slinky® at the same time and in the same direction. Ask students what they observed. (When the two waves meet, they pass through each other, creating a larger wave.) This is called "constructive interference" and is an example of amplification or resonance. When waves are started at opposite ends and opposite sides of a Slinky®, the waves cross each other and cancel each other out. This is called "destructive interference."

Standing Wave
Tie a rope to a doorknob and give the rope a shake. The rope should be about 3 m (10 ft) long. Students will observe a wave travel down the rope and return on the opposite side of the rope. Next, move the rope up and down more quickly to form a standing wave. A standing wave occurs when successive waves move back and forth so quickly that they form antinodes—oval shapes. The points where the rope is attached to the door and held in the hand are called nodes. If the rope is shaken more quickly, it is possible to create two antinodes and three nodes. This is one wave length.

Show Video Clip 1 [36:50 to 39:44]. Ask students how sound vibrations are amplified on an electric guitar. (The vibrations of the guitar string produce electric impulses in the pickup of the same vibration. The electric impulses are carried to an amplifier, which makes the impulses larger and then louder as they are converted to sound energy in the speakers.)

Activity 2

Explore (Approx. 40 min.)

Tell students they are going to explore how vibrations of a column of air can produce resonance.

Have students work in small groups. Explain that their goal is to use resonance to amplify a sound. Provide them with the materials they need. Tell students that the tube can be used to create a column of air. A tuning fork will be used to create the sound waves. The surface of the water can be used to reflect the sound waves.

Students should decide how they are going to create the effect of resonance with the tools provided. They should then test their idea. After each trial they should discuss their observations and adjust their experiment accordingly.

After most groups have achieved the goal, discuss their observations and results. Most groups should discover that they can place the tube upright in the water and sound the tuning fork at the open end of the tube. By slowly moving the tube up or down—lengthening or shortening the column of air in the tube—they will find the point where the frequencies resonate.

Ask the students what happened to cause the resonance. Lead students to understand that when the tone from the tuning fork reached the water in the tube, it was reflected. When the air column is the right length, the vibration of the returning air molecules matches the vibration of the incoming tone. The result is resonance, which amplifies the sound.

Evaluate

1. An airplane passes over your house, and the windows shake. Another airplane passes over and the windows do not vibrate at all. Why would one affect the windows and not the other? (For the window to rattle, the natural frequency of the window must be the same as the frequency of vibrations from the airplane. In the first instance they are the same frequency and in the second instance they aren't.)

2. A column of vibrating air may be lengthened or shortened so that it is in resonance with the vibrations of a tuning fork. Explain how a vibrating string of an electric guitar is amplified. (The vibration's of the guitar string are turned into electric impulses that have the same vibration. The impulses are amplified by the amplifier. This answer is based on information in the video.)

3. Explain how the sound of a violin string is amplified by the violin. (The string vibrates the sounding box, which is stronger than the string. The sounding box vibrates the air in the box.)

Try This

For a classroom demonstration, remove the ends of tin cans and tape them together to form a tube. Lower the tube into a deep pail of water and repeat the activity with a tuning fork.

Tape the top of a piece of paper to the front of a loud speaker. Turn on the radio—low volume at first and gradually louder. Vary the treble and bass settings. What are your observations?

Fill a soda bottle half full with water. Blow across the mouth of the bottle to produce a sound. Do the same with the bottle next to a guitar or violin. A sound comes from the instrument. Add more water and try it again. Why does the vibrating air set off one string and not another?

Listen to the sea. Put a seashell or a can to your ear. What do you hear? The air inside the seashell is vibrating in resonance with some of the sounds outside the shell.

Research how marimbas and pipe organs work and report to the class.

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HOW WAVES BEHAVE

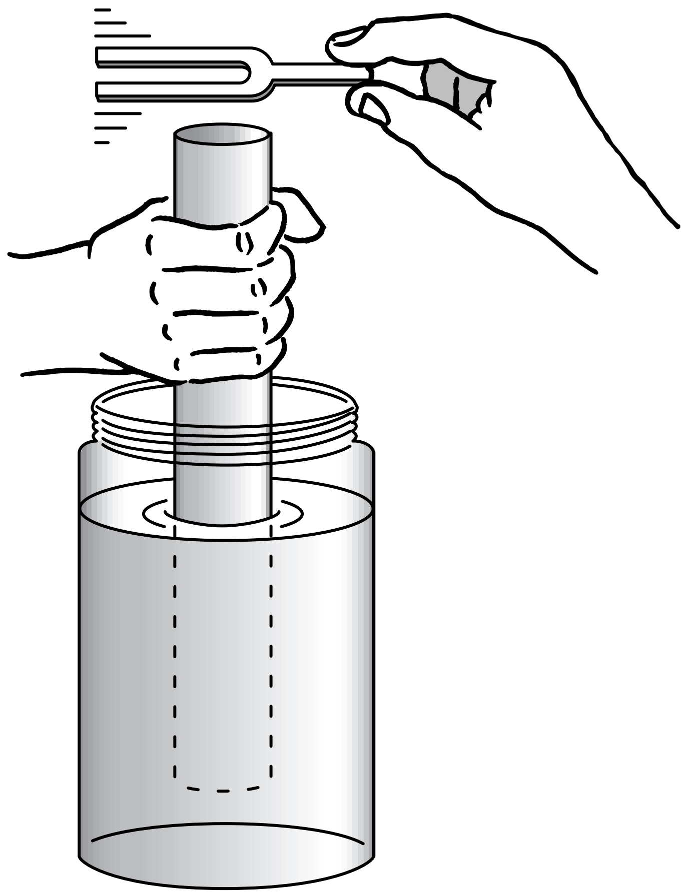
Activity Sheet 2

NAME ______________________________ CLASS PERIOD __________

WHAT YOU'RE GOING TO DO

You re going to explore how vibrations in a column of air can produce resonance.

HOW TO DO IT



1. Work with a group of classmates. Your goal is to create a resonance that will amplify a sound. The tube can be used to create a column of air. The tuning fork will be used to create the sound waves. The surface of the water can be used to reflect the sound waves.

2. With your group, decide how you can create the effect of resonance with the tools provided. Think about what you know about resonance and apply it. Test your idea. After each trial discuss your observations. Adjust your experiment and try again.

RECORDING YOUR DATA

In your journal record how your group went about creating the effect of resonance. Record your observations.

WHAT DID YOU FIND OUT?

What variables were important in this activity? How did you control them?

Which factors were most important in achieving the desired results? Why?

What does the length of the air column have to do with resonance?

Feedback Frenzy

What makes feedback happen? What factors create feedback in an electric guitar system? How do rock musicians control the amount of feedback in the system?

Getting Ready

Overview

Students investigate feedback with a microphone, a speaker, and an amplifier. They examine feedback through the relationship between the volume of a loudspeaker and the distance between the microphone and the speaker.

Objectives

After completing this activity students will be able to—

- explain what factors affect feedback in a guitar system
- discuss feedback and how it relates to the volume of an amplifier and the distance between a loudspeaker and microphone

Time Needed

Preparation: Approx. 15 min.
Classroom: Approx. 40 min.

Materials

For the teacher:

- a system that will produce feedback: a microphone connected to a loudspeaker and amplifier

For each group of students:

- access to a microphone and amplifier-speaker system
- measuring tape
- non-permanent fine tip markers (for marking the volume dial incrementally)
- graph paper

Important Terms

amplifier — A device that uses voltage to increase the size of electric impulses that are converted to sound by the loudspeakers.

feedback — The continual return of a portion of the output of a speaker into the sound-amplifying system.

input — The energy or electric impulse fed into an amplifier.

output — The sound vibrations emitted by a loudspeaker.

Electric Guitar

Here's How

Video Clip 2
39:46 to 40:51—Ted Nugent cranks up his guitar and gets some heavy feedback. (1 min. 5 sec.)

Preparation
- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 3 for each student.
- Review the Background information on page 8.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [36:00 to 36:44]. Find out what students already know about electric guitars and amplification. As a class, discuss the questions posed by Eileen Galindo.
- You may wish to conduct this activity in an auditorium or other space where other classes will not be disturbed by the sound.
- For students to get a measurement for the volume setting, they may have to mark increments on the volume dial. They should be able to measure distance between the speaker and microphone with a centimeter ruler to the nearest millimeter.
- Remind students to measure and record their data carefully.
- Remind students to follow good laboratory procedures to eliminate variables that could affect their results.
- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on the electric guitar.

Engage (Approx. 10 min.)

Begin by asking students how the sound of an electric guitar string is amplified. (The string vibrates, creating electric impulses in the pick-up coil. The electric impulses are sent to the amplifier where they are strengthened. These impulses are sent to a speaker where the impulses are converted into sound waves.)

Have students view Video Clip 2 [39:46 to 40:51] in which Ted Nugent explains feedback and the feedback loop. Ask students which factors they think are important in creating feedback. (The distance of the guitar or microphone from the speaker or amplifier, the volume of the speaker, the direction of the microphone.) Accept all answers and record them on the board. Tell students they are going to have to find out for themselves if they are correct.

Using a microphone and an amplifier, demonstrate feedback for the students. Begin with the volume control turned off. Hold the microphone to the speaker. Slowly increase the volume until feedback occurs. Do not move the microphone, but use the volume control to start and stop the feedback.

Explore (Approx. 30 min.)

WARNING: The feedback produced by this activity has the potential for causing serious hearing loss. Students should be strongly cautioned to increase volume levels very slowly. As soon as feedback is present, the volume level should be turned down immediately to the lowest setting.

Tell the students that they are going to investigate and test various factors affecting feedback.

Activity 3

Have students work in groups. Have groups begin by brainstorming and listing the variables that affect the creation of feedback. (volume of the speaker, size of the amplifier, distance between microphone and speaker, direction of the microphone, etc.) They should then develop a plan to test and evaluate the relationship between any two variables. The plan should explain the procedure they will follow and how they will collect and organize the data that's generated. Before groups carry out their plans, check to make sure the variables and procedure are realistic.

For example, students might choose to test the relationship between D (the distance between the speaker and microphone) and V (the volume level of the amplifier). They would carry out this test by setting the microphone a given distance from the loudspeaker and slowly turning up the volume until feedback occurs. They would then turn down the volume and move the microphone farther away and perform the procedure again. The data could be easily graphed on a simple x-y axis. They should then draw some conclusions from their data and observations.

When all groups have finished, each group should discuss its results with the entire class. What common factors did they discover? What might account for differences in data?

Evaluate

1. Can feedback be created by directing one loudspeaker toward another? Why or why not? (No. The sound must be fed electronically back into the amplifier.)

2. Rock musicians often move toward and away from their amplifiers during a performance. What is the reason for this? (Distance from the amplifier is one of the factors that affects feedback.)

3. Sometimes public address systems produce feedback. What advice would you give someone with a microphone who wants to avoid this? (Advise the person not to direct the microphone toward any of the speakers. Turn down the volume.)

Try This

Get a real electric guitar and amplifier and investigate feedback using the same variables. Compare the results.

Find out what could happen to a speaker system if feedback were not prevented. Could any physical damage be done to a speaker or amplifier? Use audio shops as resources for information.

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FEEDBACK FRENZY

Activity Sheet 3

NAME ______________________________ **CLASS PERIOD** ____________

WHAT YOU'RE GOING TO DO

You re going to design an experiment and test the factos that cause feedback.

HOW TO DO IT

1. WARNING: The feedback you produce in this activity can cause serious hearing loss. Increase volume levels very slowly. As soon as feedback is present, turn the volume level down immediately.

2. Work with a group of classmates. Brainstorm and list answers for this question: What factors or variables contribute to feedback in a sound system?

3. Choose two variables and figure out a way to test how they affect feedback. Write down a plan for carrying out your test and collecting data. Before you try your plan, have your teacher approve it.

4. Try to control all the variables so that you get accurate data. You may want to perform several trials and average the results.

RECORDING YOUR DATA

In your journal, list the variables that you are testing. Write out a plan for testing the variables. Your plan should include the procedure your will follow, how you will collect data, and how you will use the data to form a conclusion. Create a data table in your science journal to record your measurements and observations. If possible, create a graph that displays your data.

WHAT DID YOU FIND OUT?

What variables did your group test?

Did your experiment provide you with useful information? Why or why not?

Explain how each of the variables affected the creation of feedback.

Did the variables have an equal effect on creating feedback? If not, which was the most important? Why?

Go with the Flow

What is electricity, and how can you make it? How do electrical wires bring electricity to your home? Why do you sometimes get a shock when you touch a doorknob? What is lightning? How do batteries provide electrical power?

Themes and Concepts

- static electricity
- electrons and electric charges
- potential difference
- conductors and insulators
- the flow of electricity in electric circuits

National Science Education Content Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard B: Students should develop an understanding of motions and forces and transfer of energy.
Content Standard G: Students should develop an understanding of the nature of science.

Activities

1. *Plus and Minus—approx. 20 min. prep; 45 min. class time*
What is static electricity? Students learn about the role static electricity plays in causing objects to attract and to repel one another. Students charge several different objects and investigate how these charges interact with objects.

2. *Battery Required—approx. 45 min. prep time; 45 min. class time*
How do batteries work? Students construct a wet cell battery and study how it provides the electric current necessary to run electrical devices. Students use various metals for electrodes and study the amount of voltage (potential difference) that the wet cells are capable of supplying.

3. *Wired—approx. 30 min. prep time; 60 min. class time*
How does electricity move through a circuit? Students explore how electric circuits are wired. Using batteries and flashlight bulbs, they investigate the difference between series and parallel circuits. Students also observe the amount of electric current that is available in each wiring arrangement. They increase the amount of potential difference and observe what effect this has on the circuits.

More Information

Internet

Newton's Apple
http://www.ktca.org/newtons
(The official *Newton's Apple* web site with information about the show and a searchable database of science ideas and activities.)

Work, Energy, and Potential Difference—Cyberschool Africa
http://www.cyberschool.co.za/science/electricity/ELECTRIC/wepdques.htm
(Interesting information about electricity with activities for students.)

Electroscope—Exploratorium
http://www.exploratorium.edu/snacks/electroscope.html
(A good activity with an electroscope.)

Internet Search Words

static electricity
electrostatics
electroscope

CAUTION: This unit involves use of static electricity and electrical devices. Care should be taken that students handle the devices correctly, and that no medical device—such as a pacemaker—is disturbed.

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Electricity

Background

At 6 a.m. your clock radio buzzes you out of a sound sleep. You stumble out of bed, flip on the lights and, after a hot shower, get dressed and head to the kitchen for breakfast. A couple pieces of toast with some fruit and milk do the trick. You check the clock and see it's 7:28, time to head out to catch the bus. How would your morning have been different without electricity? No clock radio, no electric lights, a cold shower, no toast—the list goes on and on.

Virtually everything we do in the course of a typical day is dependent in some way upon the uninterrupted flow of electrical energy. But what is electricity and how does it work? As with so many other things, it starts with the atom—actually part of an atom.

Electrons are one of the particles that make up an atom. Electrons can escape from one atom and move to another when the conditions are right. Electrons have a negative charge. The atom with the missing electron becomes positively charged, while the atom that gained the electron becomes negatively charged. The negatively charged atom can pass that extra electron on to another atom. This process of electrons moving from one atom to another is the heart of electricity. Electric current is the flow of electrons from one place to another.

To flow, electrons must have a source (a battery or generator) and a material through which they can move (a conductor). A conductor, often a copper wire, allows the electrons to move through it as an electric current. Current will only flow when a power source, such as a battery or generator, pushes the electrons. Furthermore, the electrons won't flow in a current unless the conductor forms a closed loop (circuit) with the power source. The circuit may include a number of electrical devices such as light bulbs, computers, and appliance, but it must still be a circuit.

If the circuit is interrupted or broken, the electrons can no longer flow and the system won't work. When the circuit is broken, the electrons have nowhere to go and the flow of electricity is stopped.

Electrical science has a long history. In 600 B.C., Thales of Miletus, a Greek philosopher, noticed that a piece of amber, after being rubbed with wool, would attract small, light objects somewhat like a magnet. When Miletus rubbed the amber, it was able to attract and hold some of the electrons from the wool. As a result, the amber had more electrons than it started with. The excess of electrons stored on the amber is referred to as static charge or static electricity.

In the 1700s, over 2000 years later, experiments by Benjamin Franklin and Augustin de Coulomb showed that electric charges could attract or repel one another. They also showed that the force of attraction or repulsion varied with the distance. The greater the distance, the weaker the interaction. While discharging static electricity was scientifically interesting, it was hardly a source of useful power. That began to change in 1800 when Alessandro Volta (the "volt" was named after him) invented the electric cell, called a "battery." It provided the first sustainable flow of electrons.

Electricity has sparked a lot of interest among scientists. It s a good thing they figured it out, otherwise we d be spending a lot of time in the dark!

Books and Articles

Nye, Bill. *Big Blast of Science*. New York: Addison-Wesley, 1993. (Full of wonderful activities and ideas for communicating and investigating scientific concepts.)

VanCleave, Janice. *Physics for Every Kid*. New York: John Wiley Publishers, 1991. (A good resource book containing topic-specific activities and ideas geared for upper elementary to middle school students.)

Williams, John. *Projects with Electricity*. Milwaukee: Gareth Stevens Children's Books. (Contains numerous, easy-to-construct electricity experiments. Appropriate for upper elementary to middle school students.)

Bauman, Robert P., and Adams, Saleh. "Misunderstandings of Electric Current." *The Physics Teacher*. May 1990, p. 334.

Willis, Courtney W., and Nicholson, Lois. "The Lemon Screamer, the Lasagna Cell, and the Physics Teacher." *The Physics Teacher*. May 1990, p. 329.

Community Resources

Local electric utility company
Physics department at a local college or university

Video & Stills

Video Segments

Introduction

26:03 to 26:44—Eileen Galindo asks interesting questions about the energy source that modern technology relies on—electricity. (41 sec.)

Video Clip 1

26:46 to 29:38—Physicist Dr. Al Green demonstrates the power of static electricity. (2 min. 52 sec.)

Video Clip 2

29:38 to 30:27—David Heil cranks a generator to light up a light bulb. (49 sec.)

Video Clip 3

30:27 to 31:38—David Heil and Al Green use a ring of beach balls to demonstrate the behavior of electrons in an electric circuit. (1 min. 11 sec.)

Video Clip 4

31:41 to 35:46—Northern States Power Company's Fran Csera explains how a circuit is completed and David Heil splices a power line. (4 min. 5 sec.)

Additional Resources

Button A

Video: "Crazy Jumping Rice," a *Newton's Apple* Science Try-It about static electricity

Button B

Video: Animation of how a solar cell works

Button C

Diagram: How electricity is delivered from a power plant to customers

Button D

Video: Lemons—electric devices that just never made it

Unit Assessment Answer Key

The Unit Assessment on the following page covers the basic concepts presented in the *Newton's Apple* video segment and the Background section in this guide. The assessment does not require completing all of the activities. The Unit Assessment may be used as a pre- or post-test. However, students should view the complete *Newton's Apple* video before doing this assessment. There is additional assessment at the end of each activity.

Think about it.

1. The clothes have been charged by rubbing together as they tumbled in the warm, dry air of the clothes dryer. This leaves the clothes with residual charges, causing them to stick together.
2. Yes. Wall outlets usually have more than one socket. These are on the same circuit.
3. An ampere is a measure of current and a volt is a measure of potential difference (voltage).
4. Initially the spheres are neutral and they attract the negative charges. Then they acquire a surplus of negative charges and they move away from the charged rod because similar charges repel each other.
5. Yes.

What would you say?

6. b   7. b   8. d   9. d   10. d

Unit Assessment

What do you know about Electricity?

Write the answers in your journal or on a separate sheet of paper.

Think about it

1. Why do socks and other pieces of clothing stick together after being tumbled in a dryer?
2. In your house, can more than one electrical device be plugged into the same circuit?
3. What is the difference between an ampere and a volt?
4. A charged rod is brought near a pile of tiny plastic spheres. Some of the spheres are attracted to the rod, but as soon as they touch the rod, they fly away in different directions. Explain.
5. A simple circuit consists of a battery, a light bulb, and some connecting wires. Is it possible to use these components to make the light bulb glow? Draw a circuit that would allow this to happen.

What would you say?

1. Similarly charged objects—
   a. attract each other strongly.
   b. repel each other.
   c. a and b
   d. none of the above
2. Rubbing two objects such as wool and plastic together creates a static charge because—
   a. atoms are transferred from one object to another.
   b. electrons are transferred from atoms in one object to atoms in the other object.
   c. the electrons in one object are attracted to the electrons in the other object.
   d. electrons become more widely distributed in each object.
3. An important difference between insulators and conductors is that in conductors—
   a. electrons can be removed from atoms easily.
   b. electrons are free to move around.
   c. electrons carry electric charges.
   d. All of the above are true.
4. In an electrical circuit, charged particles—
   a. flow around in a closed loop.
   b. flow from higher potential to lower potential.
   c. get energy from an external source.
   d. Do all of the above.
5. The energy carried by an electric current depends on—
   a. the charge transferred.
   b. the potential difference.
   c. the total number of charges in the circuit.
   d. both a and b.

Activity 1

Plus and Minus

Why does a door knob sometimes give you a shock? Have you ever noticed how clothes right out of the dryer cling together? And why does a computer monitor collect dust so easily? How does an electric charge collect on an object?

Getting Ready

Overview

Students learn about static electricity and the how a transfer of electrons can cause objects to carry a positive or negative charge. Students use an electroscope to explore the charges that are transferred between different materials.

Objectives

After completing this activity, students will be able to:

- describe how a static charge is accumulated on an object
- explain how charged objects repel and attract
- identify positively and negatively charged objects

Time Needed

Preparation: approximately 45 min.
Classroom: approximately 60 min.

Materials

For the teacher:

- two plastic rulers
- piece of paper
- tiny slivers of paper
- ring stand
- thread
- aluminum foil
- aluminum pie plate
- Styrofoam meat tray
- cardboard square larger than the meat tray
- paper cup
- masking tape

For each group of students:

- hard rubber rod
- flexible, plastic, one-inch diameter water pipe
- glass rod
- piece of fur
- piece of silk
- foam rubber
- pith ball with silk thread attached and ring stand
- electroscope
- Styrofoam packing “peanuts”
- tiny pieces of paper

Important Terms

electron — A negatively charged particle that can be found in all atoms.

electroscope — A device that detects the presence of an electric charge on an object.

static electricity — An electric charge that builds up and is stored on an object.

NOTE: If you do not have access to enough electrocscopes, instructions for building simple electroscopes can be found at these web sites:

http://www.mos.org/sln/toe/simpleelectroscope.html

http://www.exploratorium.edu/snacks/electrocscope.html

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Electricity

Here's How

Video Clip 1
26:46 to 29:38—Physicist Dr. Al Green demonstrates the power of static electricity. (2 min. 52 sec.)

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 1 for each student.
- Review the information in the Background on page 24.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [26:03–26:44]. Find out what students already know about electricity. As a class, discuss the questions posed by Eileen Galindo.

- This is a very open-ended activity. Be prepared to work with some groups to provide some examples and help them design their own procedures. Remind students to follow good laboratory procedure and eliminate as many variables as possible in each of their tests.

- You may wish to ask questions such as: "How far will a charge travel through air?" "Does the duration or pressure of the rubbing items together make any difference?" "What do you observe when a charged object is held near the pith ball?"

- The plastic pipe used in underground sprinkler systems works particularly well for this activity.

- Activities with static electricity are best done on a dry, cool, winter day. However, with the exception of a very humid day, good results can be obtained anytime. On a humid day, use a hair dryer to dry the test materials and to provide good results with this activity.

- If it is appropriate, view the entire *Newton's Apple* video segment on electricity after completing the activity.

Engage (Approx. 15 min.)

Ask your students about their experiences with static electricity. Have students give examples of when they've felt a discharge of static electricity. What caused it? Make it clear that *static* means "not moving," and the spark that they may see is not *static* electricity.

Tell students you are going to demonstrate how objects store static electrical charges. Charge a plastic ruler by rubbing it vigorously on a sheet of paper. Suspend the ruler from a ring stand with a piece of thread tied around the middle of the ruler. Charge an identical plastic ruler the same way. Bring this ruler close to the suspended ruler. The suspended ruler will move away from it. Ask students what they observed. (The rulers repelled each other because they have the same electrical charge.) Ask students for their ideas about why this happens. Accept all reasonable responses. Rub the ruler on the paper again and bring it close to some tiny scraps of paper. The small scraps of paper will be attracted to the ruler. Ask students if this is similar to the two rulers. Accept all answers.

Explain that almost all objects are naturally neutral—that is they have the same number of positive and negative charges. However, when two objects touch or are rubbed together, one of them may attract electrons from the other, giving one of the objects excess electrons—or extra negative charges—and leaving the other object with a shortage of electrons. A substance with excess electrons is negatively charged, and one that has lost electrons is positively charged. Tell students that objects with different charges attract each other, and objects with the same charge repel each other.

Show Video Clip 1 [26:46 to 29:38] in which Dr. Al Green demonstrates the power of static electricity. According to the video, why does static electricity discharge quickly? What is necessary for a sustained electrical discharge? (A generator or battery.)

Activity 1

Explore (Approx. 45 min.)

Demonstrate and explain how to use an electroscope. Touch the probe of the electroscope to show students how to discharge the device. Students should not touch the leaves of the electroscope or disassemble the device.

Transfer a negative charge to the electroscopes before students begin their experiments. Wrap aluminum foil around a sheet of cardboard. Tape a paper cup to the inside center of an aluminum pie pan. Place a Styrofoam meat tray on top of the aluminum-covered cardboard and rub the Styrofoam with fur. Place the pie pan on top of the meat tray. Touch the aluminum foil with one finger and the top of the pie pan with another. Using the paper cup as a handle, lift the pie pan and touch it to the probe on the electroscope. The electroscope now has a negative charge.

Have students work together in small groups. Explain to the students that they are going investigate the transfer of electrons between objects. The groups should have a rubber rod, glass rod, and plastic pipe, along with fur, silk, and sponge to rub on the rods and pipe. They can then use the pith ball, electroscope, Styrofoam peanuts, paper disks or other materials of their choosing to test the kind and strength of the charges.

Tell students that the electroscopes are negatively charged. Students should design and conduct their own tests that will help them quantify or evaluate the type of charge that is transferred and the strength of the charge. They should test which materials work best for transferring electrons from one to another, which materials develop the strongest charge, and any other tests they may wish to design. Tell students to record all their observations.

Evaluate

1. What is transferred and changes the charge on objects when they are rubbed together? (electrons)

2. A small glass bottle is suspended from a string. It is free to spin around. A negatively charged comb held nearby is seen to attract the bottle. Does this mean that the bottle is positively charged? Explain. (Yes. Because opposites attract, the bottle would carry a positive charge to be attracted to the negatively charged comb.)

3. If the comb repelled the bottle, what could you conclude, if anything, about the charge on the bottle? Explain. (You could conclude that the bottle was negatively charged, because objects with the same charge repel one another.)

Try This

Your teacher produced a negative charge for the electroscope with styrofoam, foil, and fur. Use the Internet to research exactly where and how the electrons transfer from one material to another.

Charge a balloon by rubbing it with fur. Touch the balloon to the knob of an electroscope and watch the leaves. Describe the result. Neutralize the electroscope by touching the knob with a finger. Rub the balloon again and this time touch the fur to the knob of the electroscope and watch the leaves. Describe the result. Try charging the balloon by rubbing it on your hair. Check results with electroscope. Rub the balloon on a variety of materials, such as wool, silk, cotton, polyester, or plastic, and check the balloon's charge with the electroscope. What gives the balloon the greatest charge? What gives the balloon the least amount of charge? Can you explain the difference in charges that the balloon acquires?

Rub a hard rubber rod with fur. Demonstrate (using an electroscope or a pith ball) that it has a charge. Rub the rod vigorously to give it a large amount of charge. Adjust a water faucet so that a small but steady stream of water is coming out of it. Bring the rod near the stream of water. What happens? Why?

PLUS AND MINUS

Activity Sheet 1

NAME ______________________ CLASS PERIOD __________

WHAT YOU'RE GOING TO DO

You re going to observe the behavior of objects that have been charged with static electricity.

HOW TO DO IT

Work with several classmates. You will be given a rubber rod, a glass rod, a plastic pipe, a piece of fur, a piece of silk, and a piece of foam rubber. Your task is to design and carry out a series of experiments to test how these objects transfer, hold, and discharge static electricity. You can use the electroscope to determine the type of charge. The electroscope will carry a negative charge. Your teacher will need to recharge the electroscope if you touch it with your finger.

Here are some ideas to get you started:

- Test the strength of the charge
- Determine the type of charge (+) or (–)
- Test which materials work best with one another
- Test how far the charge will travel
- Test how long an object will hold a charge
- Test different ways to transfer electrons between objects

You can choose one or more of the ideas above, or come up with your own. Make sure you set up your experiment so that you are testing as few variables as possible with each trial. Make detailed notes about your observations.

RECORDING YOUR DATA

Record the following information in your journal.

What we're testing:

How we're going to test it (include what you are going to do and how you will measure the results):

Observations and measurements for each trial:

WHAT DID YOU FIND OUT?

In your journal write a short paragraph that describes the information that your group learned from your tests.

Compare your tests with the tests of other groups. How were the results similar and different? What might account for any differences in results?

What other questions came to mind as a result of your experiments?

Activity 2

Battery Required

How does a battery provide electric power? How does electricity move from a battery to a flashlight bulb and back to the battery again? What happens when a battery goes dead? What makes a battery work?

Getting Ready

Overview

Students construct a wet-cell battery and investigate how it provides the current necessary to run an electrical device. The students use various metals for electrodes and explore the amount of voltage potential difference that the wet cells are capable of supplying. Students learn the difference between static electricity and current electricity.

Objectives

After completing this activity, students will be able to—

- discuss the role of electrons in generating and maintaining electric current
- identify and describe the key components of a wet-cell battery
- apply their understanding of a battery to other electricity-producing devices

Time Needed

Preparation: approximately 45 min.
Classroom: approximately 60 min.

Materials

For the teacher:

- 14-gauge copper wire
- iron nail
- lemon
- voltmeter

Each team of students:

- apron
- goggles or safety glasses
- 250 ml beaker or battery jar
- 2 glass rods
- 2 wire leads (banana plug on one end and alligator clip on the other, about 60 cm long)
- copper strip
- tin strip
- zinc strip
- iron nail
- 75 ml of vinegar
- 75 ml of lemon juice
- 75 ml of weak sulfuric acid
- voltmeter
- AA battery
- flashlight bulb and holder
- lemon
- potato

Important Terms

battery — A device consisting of two dissimilar conductors and an electrolyte that converts chemical energy to electrical energy.

electrolyte — A conducting medium, such as a conducting liquid, in which the flow of current is accompanied by the movement of matter.

generator — A device that transforms mechanical energy into electrical energy.

volt — A unit for measuring potential difference.

voltage (potential difference) — A measure of electrical force (or push) between two points.

NEWTON'S APPLE. Multimedia

Electricity

Here's How

Video Clip 2
29:38 to 30:27—David Heil cranks a generator to light up a light bulb. (49 sec.)

Video Clip 3
30:27 to 31:38—David Heil and Al Green use a ring of beach balls to demonstrate the behavior of electrons in an electric circuit. (1 min. 11 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [26:03–26:44]. Find out what students already know about electricity. As a class, discuss the questions posed by Eileen Galindo.
- Battery jars, available from science supply catalogs, eliminate the need for the glass rods and beakers. These jars have a porcelain top with brass connectors for attaching the metal strips.
- Remind students to follow established safety procedures when handling the materials, especially the acid. Caution students that they must not mix the electrolytes.
- If the voltmeter doesn't register, tell students to switch the wires. They may have hooked up the negative conductor to the positive connection.
- This is a very open-ended activity. You may have to work with some groups to help them figure out variables to test.
- Students should carefully wash and dry all the materials they have used after each trial. A residue of acid in the beaker or on one of the conductors could affect the results of later trials.
- If the students observe "bubbling" at the electrodes, tell them it indicates a chemical reaction is occurring.
- If it is appropriate, view the entire *Newton's Apple* video segment on electricity after completing the activity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 2 for each student.
- Review the information in the Background on page 24.

Engage (Approx. 20 minutes)

Ask students what the function of a battery is. Ask students to think of devices that are run by batteries. Ask them what is inside a battery that produces electricity and whether all the batteries are the same. Accept all answers. Take out a lemon and ask students if they have ever seen this kind of battery. Can a lemon light up a light bulb?

Insert a 14-gauge copper wire and an iron nail into the lemon. Wire it up to a flashlight bulb. Have the students describe what they observe. Given what they have just observed ask them if they can figure out what is necessary to make a wet-cell battery. (two different conductors and an acid or electrolyte)

Show Video Clip 2 [29:38 to 30:27], in which David Heil cranks a generator to push electrons through a circuit and light up a light bulb. Ask your students what happens when the batteries are removed from a portable CD player. Does the current still flow? Why or why not? Could something else take the place of the batteries and provide the "push"? What would it be? (a generator or an electric line) Ask students how a generator is similar to a battery. (They both provide the necessary push to keep electrons moving.)

Show Video Clip 3 [30:27 to 31:38]. David and Al Green use beach balls to illustrate how electricity must be able to move through a complete loop to be useful. Furthermore, this loop must have something to push the electricity through it.

Introduce the students to a voltmeter. This may be done by demonstrating its use in a simple circuit. It should be pointed out that the voltmeter is measuring the amount of potential difference (push) of the power source, and that it is measuring this in volts.

Activity 2

Explore (Approx. 40 min.)

Have students work in small groups. Explain to the students that they will be exploring wet cells and measuring, in volts, how much potential difference each wet cell can provide. Stress that goggles and aprons must be worn at all times when performing this activity.

Tell students that they will be constructing various wet cells and measuring how much potential difference each one generates. Demonstrate and explain how to connect the metal strips to the glass rods using the alligator clip ends of the wire leads (see illustration on Activity Sheet 2). Demonstrate the hook-up and use of the voltmeter. Explain that students will use the voltmeter to measure the strength of the current from their wet cells. Demonstrate how to create a wet cell by placing the two glass rods across the top of the beaker and using the alligator clips to attach the conductor strips.

Students can construct several different wet cells from the materials. Students should predict which one will produce the strongest current and test their predictions. Students may experiment with different variables including the kinds of conductors, the amount or kind of electrolyte, the distance between the conductors, etc.

Groups should present their findings to the class and discuss the similarities and differences in their results.

Evaluate

1. What would happen if the two metal conductor strips touched one another? Would the circuit still be complete? (They would break the circuit and no current would be produced.)

2. When a battery is connected to a complete circuit, charges flow in the circuit almost instantaneously. Explain. (The electrons in a conductor easily transfer this charge. When the battery is connected, it provides a push for this transfer of the charge.)

3. Why is it possible for foods such as lemons, limes, bananas, apples, cucumbers, tomatoes, and potatoes to be used as part of a wet cell? And why do some foods work better than others? (These foods work well because they are somewhat acidic. The more acidic a food is, the better conductor it is.)

Try This

Most local power companies have good educational outreach programs. You may wish to call one and have them send you the path that the electricity follows to get from the power generating plant to your school. You may wish to study the diagram found at Resource Button C on the CD-ROM. Have them include the output voltage at the power plant and the incoming voltage to your school. Use this path as a map for a field trip to the power generating plant and take a tour of the plant.

Test several different types of batteries to determine which have the largest potential difference and which put out the most current. Try to wire together several of the different battery types and measure the same two quantities. After you have obtained your results, speculate on which batteries will be best for particular applications.

BATTERIES REQUIRED

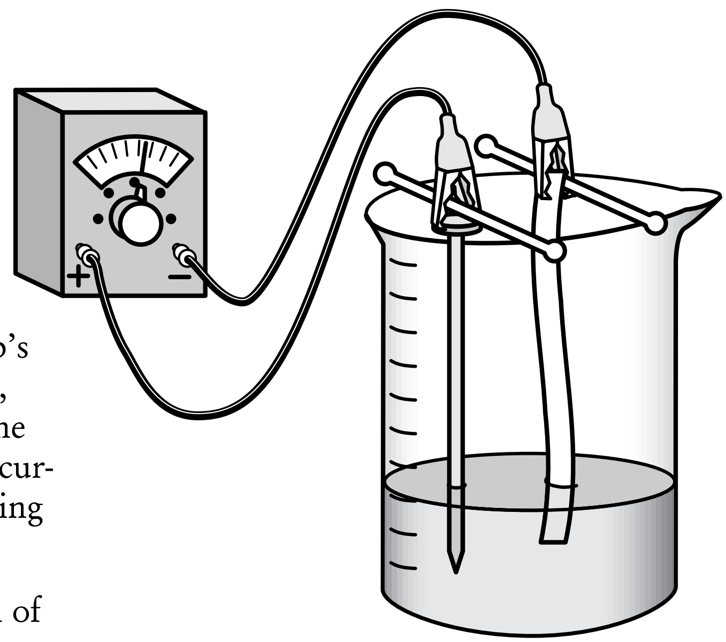
Activity Sheet 2

NAME ______________________________ **CLASS PERIOD** __________

WHAT YOU'RE GOING TO DO

You re going to construct different wet-cell batteries and investigate how they supply electricity.

HOW TO DO IT



1. Work with a group of classmates. Be sure you are wearing an apron and goggles and follow standard safety procedures. You are to construct at least three different wet cells and measure the current they generate. First, decide which conductors and which electrolyte to use for each of your group's wet cell. Record this information. Then, predict which of the three will deliver the strongest current. You can measure the current by using a voltmeter or by connecting the wet cell to a light bulb.

2. Be sure to carefully wash and dry all of the materials you use after each trial.

RECORDING YOUR DATA

Create a data table for each of your trials. You should include the following information for each trial:

Trial #_______
Conductor 1 __________
Conductor 2 __________
Electrolyte __________
Amount of electrolyte ____________ml
Prediction ___________________
Observations___________________
Conclusions ___________________

WHAT DID YOU FIND OUT?

Which wet cell provided the greatest potential difference?

If you could do the activity over, what would you do differently? Why?

Compare your results with the results of other groups. What similarities and differences do you discover?

Activity 3

Wired

How is electricity carried through a circuit. How does a battery light a bulb? Could you feel the electricity if you were part of a circuit? How is it possible to run several electrical devices from the same outlet? Does the electricity get used up in an appliance?

Getting Ready

Overview

How does an electric circuit bring power from a battery to a light bulb? Students explore how electric circuits are wired. Using batteries and flashlight bulbs, they investigate the difference between series and parallel circuits. Students also observe the amount of electric current that is available in each wiring arrangement. They increase the amount of potential difference (more batteries) and observe what effect this will have on these circuits.

Objectives

After completing this activity, students will be able to—

- discuss the flow of electricity in a circuit
- describe the key components of an electric circuit
- construct both series and parallel circuits
- differentiate between insulators and conductors and explain their characteristics
- recognize some the symbols used in an electric circuit diagram

Time Needed

Preparation: approximately 30 min.
Classroom: approximately 60 min.

Materials

For the teacher:

- extension cord or piece of typical electric cord

Each team of students:

- 2 size D dry cell batteries and a battery holder
- 3 flashlight bulbs
- 3 bulb holders
- 1 ammeter
- 2 wire leads (banana plug on one end and alligator clip on the other) about 60 cm long
- 8 pieces of bare copper wire about 20 cm long

Important Terms

fuse — A device that breaks or opens a circuit when the current is too great.

parallel circuit — Circuits in which the current divides and flows in two or more separate paths, or branches.

series circuit — A circuit in which the current can only flow in one path.

Electricity

Here's How

Video Clip 4
31:41 to 35:46—Northern States Power Company's Fran Csera explains how a circuit is completed and David Heil splices a power line. (4 min. 5 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [26:03–26:44]. Find out what students already know about electricity. As a class, discuss the questions posed by Eileen Galindo.
- If you choose to make the results of this activity more quantitative through the use an anammeter, it will be necessary to introduce the students to its use and purpose. This may be done by demonstrating its use in a simple circuit. It should be pointed out that it is measuring the amount of current (charge/second) being moved by the power source (battery), and that it is measuring this in amperes. If an ammeter is used in this activity, it will need to be wired in series with the light bulbs to get a reading.
- Wiring the bulbs in parallel can be a source of frustration for students. You may have to provide some additional guidance for some groups.
- Have extra batteries available.
- If they are available, short wire leads with small alligator clips on each end make this activity easier to perform.
- Students may wonder where fuses, breakers, and switches fit into a circuit. These can be added by the students or demonstrated by you. This often helps complete the picture in student's minds.
- If it is appropriate, view the entire *Newton's Apple* video segment on electricity after completing the activity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 3 for each student.
- Review the information in the Background on page 24.

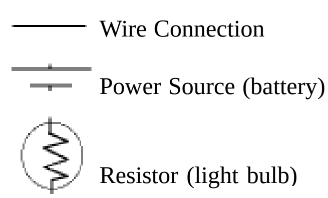
Engage (Approx. 15 min.)

Hold up the extension cord. Have students describe the construction of a typical electric cord. Ask the students why most electrical wires are wrapped in an insulating material. What purpose does the insulating material serve? (It prevents contact with other objects.) What would happen to the circuit if the insulating material were not present? (People could be shocked or electrocuted; circuits would fail.) What is the difference between an insulator and a conductor? (Insulators do not allow electricity to flow through them; conductors do.)

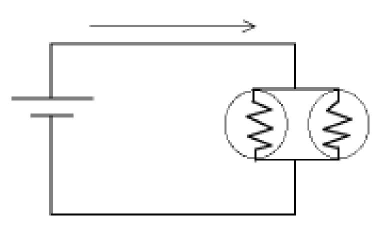
Show Video Clip 4 [31:41 to 35:46] in which Fran Csera demonstrates how electric circuits must be completed to have a flow of electric current. Ask the students the following questions: How many examples of electric circuits can you think of? Can you think of electric circuits that are wired in different ways? How do the wires that electric companies use to carry electricity from one point to another compare to an extension cord or a lamp cord? (Both are parts of complete circuits.)

In the video, why was David Heil insulated when he went near the wires? (For protection. It reduces the possibility that David might complete a circuit and be electrocuted.)

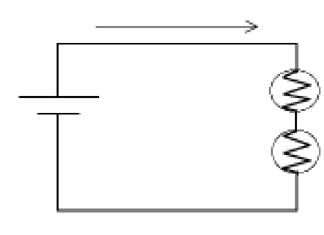
Ask students how electricians or engineers know how to wire complicated circuits. Explain that they follow wiring diagrams that use special symbols. Introduce them to these electrical symbols:



Parallel Circuit with Resistors



Series Circuit with Resistors



Activity 3

Explore (Approx. 45 min.)

Explain to the students that they will be making circuits and measuring qualitatively, by the brightness of the bulbs, how much current is able to reach each bulb in different wiring arrangements. Tell them that they will be making two different types of circuits: series circuits and parallel circuits.

Inform students that when two or more electrical devices (such as resistors or light bulbs) are connected end to end so that the same current passes through each one, they are said to be wired in series. When two or more electrical devices are wired so that the current from the source splits into separate branches, one for each device, they are said to be wired in parallel.

Tell students that they will be using a battery and three light bulbs. Tell them that they will have enough pieces of wire to try a variety of wiring arrangements and that it is their responsibility to carefully record the way that the bulb or bulbs are wired with the battery and also to record the results of the wiring arrangement.

Have students work in small groups. Encourage them to make careful notes of their observations in their journals and to use the proper electrical circuit symbols.

Evaluate

1. While testing strings of holiday lights (by plugging each string into an outlet), you find that one bulb in burned out in the middle of one string of lights. The rest of the bulbs, however, are shining brightly. Is this string of lights wired in series or in parallel? Explain your choice. (It is wired in parallel. This allows current to pass to other bulbs and keep them lit. If wired in series, the circuit would be interrupted, and the remainder of the bulbs would not light.)

2. Sometimes people say that a certain appliance "uses up a lot of electricity." Do appliances use up electricity? (Appliances do not use up electricity; however, they do use up energy.)

3. Suppose you fall from a building and on the way down you grab a high-voltage power wire. Assuming that the wire holds you, will you be electrocuted? If the wire then breaks, should you continue to hold on to the end of the wire as you fall? Explain. (You would not be electrocuted due to the fact that you are not grounded to any other object and are not completing a circuit. Once the wire breaks, you would be wise to let go in an effort to avoid touching the ground with the wire in your hand and completing the circuit.)

Try This

Locate the kilowatt hour meter for your house or apartment and record the reading. Monitor the meter for three straight days, reading the meter every day at exactly the same time. How much does the reading change each day? Monitor the change for one hour during a time of normal activity at home. Do this three days in a row, using the same time interval each day. Next (with a parent's permission), turn on many electrical appliance at home for one hour. Compare the amount of energy (not electricity!) used in this one hour to that used in a normal hour on a normal day.

Auto repair manuals are good sources of circuit diagrams. Locate and identify as many different circuit components as possible on these diagrams. Try to identify the circuits as series, parallel, or some combination of the two. Share your results with the class and discuss the function of each and its placement in a circuit.

WIRED

Activity Sheet 3

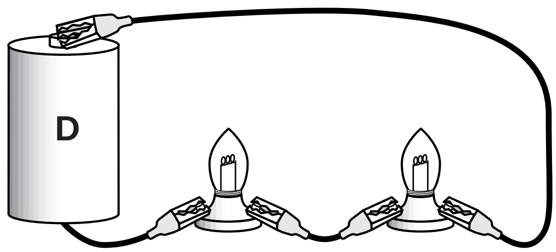
NAME_______________________________________ CLASS PERIOD ____________

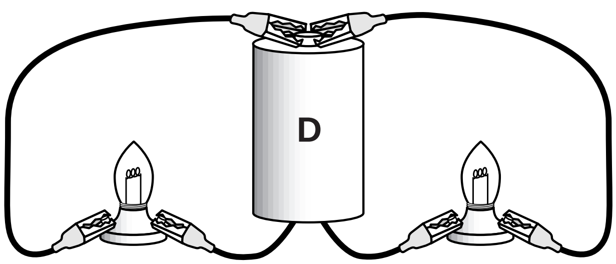
WHAT YOU'RE GOING TO DO

You re going to construct electric circuits and investigate how different wiring arrangements can affect a bulb's brightness.

HOW TO DO IT

1. Work in small groups. Using one flashlight bulb and bulb holder, one battery, and two wires, devise as many different ways as you can to make the light bulb light up. In your journal, make a diagram of each of your arrangements and indicate whether the bulb lit up or not.





2. Try the activity again. Use one battery and two bulbs. Use as many wires as you need. Devise as many different ways as you can to make both light bulbs light up. In your journal, make a diagram each of your arrangements and indicate if the lights were dim or bright. Then do the same with one battery and three flashlight bulbs.

3. Finally, try lighting two and three bulbs using two batteries. Try several variations of each circuit, adding either additional light bulbs or batteries. Carefully observe the results.

4. Identify each circuit as either series or parallel.

RECORDING YOUR DATA

In your journal, record the following information about each of the circuits you create. Include a diagram of each circuit.

Circuit # _________
Number of bulbs __________
Number of batteries __________
Series or parallel? __________
Observations __________

WHAT DID YOU FIND OUT?

How did you test if a circuit was series or parallel?

What did you learn when you wired two bulbs using one battery? Were the bulbs equally bright? Did it matter whether the circuit was a series or parallel?

When you used two batteries, did the brightness of the bulbs change? Were all of the bulbs equally bright?

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(651) 296-6104
http://clf.state.mn.us

Fender Musical Instruments Corporation
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Scottsdale, AZ 85258
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http://www.fender.com

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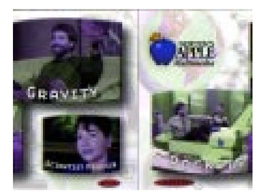

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