Battery Lesson Plan

Developed and distributed by the Rechargeable Battery Recycling Corporation and a partnership with the National Geographic Society.

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Dear Educator,

Today's life-styles demand increased mobility and the list of new portable electronic products continue to grow. A recent survey indicated that fifty-four percent of consumers say they power their daily lives with four or more cordless products. Products such as cellular and cordless phones, camcorders, laptop computers, cordless power tools, walkie talkies, CD players, remote control toys, PDAs, and digital cameras get their power from rechargeable batteries.

The Rechargeable Battery Recycling Corporation (RBRC), a nonprofit organization created in 1994, is dedicated to rechargeable battery recycling in the U.S and Canada. More than 20 million pounds of rechargeable batteries have been successfully diverted from entering our nation's solid waste stream.

As a public service for battery recycling awareness, RBRC presents the *Charge Up to Recycle*!® Battery Lesson Plan. Recommended for students ages 10 and up, the lesson plan can be implemented in its entirety or as a supplement to science course curriculums. Created by educators associated with Keep Indianapolis Beautiful and rechargeable battery industry experts, the lesson plan has also been endorsed by the National Geographic Society™ for comprehensive coverage of the science and recycling of batteries.

Students will utilize their skills in science, mathematics, history, economics, chemistry and language arts while participating in interactive experiments and activities ,and examining illustrations and graphs. The activities demonstrate how batteries work, explore different types of batteries, explain the need to recycle, and provide helpful battery usage and handling tips.

For additional copies of the RBRC Battery Lesson Plan, visit the RBRC web site at www.rbrc.org for a free download. RBRC welcomes your feedback to better educate our country's youth about the importance, ease and accessibility of rechargeable battery recycling for a cleaner, safer environment. Please contact us at teachingresources@rbrc.com with your questions, comments and feedback.

Thank you for your interest in battery science and rechargeable battery recycling. If it's rechargeable, it's recyclable!

Ralph A. Millard
Executive Vice President, RBRC

Getting Charged Up About Batteries

Recommended grade levels

The *Charge Up to Recycle!*® Battery Lesson Plan is suitable for grades 5 and up.

Subjects

The lesson plan, used in its entirety or divided by sections, will utilize the students' skills in Science, Mathematics, History/Social Studies, Economics, Chemistry, Language Arts, and Art.

Objectives

Students will:

1 follow the development of primary and secondary batteries
2 become familiar with the different types of batteries
3 explore the many uses for batteries
4 study the parts of a battery and how one works
5 learn which batteries can be recycled
6 realize the economic and environmental advantages of using rechargeable batteries
7 become familiar with the rechargeable battery recycling program

Materials

Required for activities

- pencils
- ruler
- scissors
- plastic tape
- scale
- aluminum foil
- paper clip
- metal nail
- coin
- rubber band
- wire strippers
- bowl
- paper tube (such as empty toilet paper or paper towel roll)
- two battery-run products (such as flashlights)
- secondary battery charger
- assortment of primary and secondary batteries: Alkaline-Manganese, Carbon-Zinc, Nickel-Cadmium in various sizes of A through D, button cells of Lithium or Silver Zinc, 1.5 V dry cell battery
- glass jar
- water
- electrical (cooper) wire
- small flashlight bulb
- light bulb holder
- plastic spoon
- wooden spoon
- lemons
- paper towels
- Charts A-E (pages 12-16)

Table of Contents

Vocabulary

alkaline
anode
battery
capacity
cathode
cell
charge
circuit
conductor
current
dry cell
electricity
electrode
electrolyte
electron
insulator
ions
primary cell
rechargeable
sealed cells
secondary cell
separator
terminal
vented cells
volt
wet cell

Historical Background

❑ Ask students if they know when batteries were first used.

1 Although the basics of electricity were established in 600 B.C. by the Greek philosopher Thales of Miletus and then refined by scientist William Gilbert of England in 1600, the first battery actually dates back to the 18th century.

2 Nearly 3,000 years ago, Thales and other Greeks discovered that by rubbing amber with goatskin, the amber could attract some objects. This attraction became known as electricity. Then in 1600, Gilbert performed some additional experiments to learn more about electricity. He is thought to have coined the word "electric" which may have come from the Greek word, "elektron," which means amber. The term "electric" was then applied to materials that behaved like amber.

❑ Let students rub a glass jar and then try to raise the hair on their heads, much as Thales did in 600 B.C. Students will recognize this as "static electricity."

3 The credit for the first battery goes to Count Alessandro Volta, Italian physicist and pioneer in electricity.

❑ Ask the class if they recognize his name.

The electrical unit called the volt is named in his honor. A volt is the unit for measuring the potential difference between two points in an electrical circuit.

One of Volta's first experiments in 1800 was a battery made from a pile of cardboard disks soaked in acid (possibly sea water) and layered between copper and zinc disks. The experiment resulted in the generation of an electric current that came to be known as the Voltaic cell, the first wet-cell battery.

Activity #1 - Make a home-made battery based on the Voltaic cell. (page 9)

4 In 1802, Johann Ritter, a German physicist, conducted research on electricity and discovered the possibility of a rechargeable battery. Research continued when in 1859, Raymond Gaston Planté, a French physicist, invented the first practical secondary battery, the lead acid battery. Though of limited use, research continued on the secondary batteries. In 1881, other scientists developed batteries with improved materials and manufacturing processes. In 1899, Swedish scientist, Waldmar Jungner, invented the Nickel-Cadmium storage battery.

5 For the next 50 years, rechargeable battery development was very slow. Then in the 1950s, European scientists developed a new form of Nickel-Cadmium battery that allowed them to seal the cell. However, the first rechargeable batteries were expensive, took up to 24 hours to recharge, and did not hold their charge as long as their carbon-zinc or alkaline disposable counterparts.

The sealed Nickel-Cadmium cell today performs well, is clean, has high energy, and finds a use in electronics. Now, companies such as Panasonic, SAFT America, SANYO Energy, Sony, and Varta Batteries, offer rechargeable batteries which cost less, recharge faster, and hold the charge longer.

Timeline of Electricty and Batteries

600 B.C. The Greek philosopher and scientist, Thales of Miletus - one of the Seven Wise Men of Greece - depicted the ability of picking up a sheet of paper or small straw with an amber rod made of fossilized resin that had been rubbed with a cloth - a form of static electricity.

1600 The basics of electricity are established by English physician and physicist, William Gilbert, the "Father of Electricity," and printed in a thesis entitled De Magnete.

1745 Ewald von Kleist developed the Leyden Jar.

1746 Pieter van Musschenbroek, Dutch mathematician and physicist, perfected the principle of the Leyden Jar, called the first capacitor, for the storage of electric charge.

1746 Benjamin Franklin experimented with the study of electricity, which led to the development of a practical condenser or capacitor for storage of static electricity.

1752 Franklin used the kite experiment to identify lightening as electricity after having experimented with electricity for several years. He later developed the Conventional Current Theory which assumes that electricity fluidly flows from plus to minus. Actually, electricity stored in a battery flows from negative to positive.

1784 French physicist, Charles Augustin de Coulomb demonstrated Coulomb's Law in which he showed the relationship of the forces between electric charges and that the electrical charge is on the surface of the conductor.

1791 Italian physician and physicist, Luigi Galvani, incorrectly believed that electricity was present in animals, a theory later corrected by Volta.

1799 – 1800 Count Alessandro Volta, an Italian engineer and physicist and a pioneer in electricity, invents the Voltaic cell, the first "wet primary battery" that could produce electricity through chemical action. The volt is named in his honor.

1802 Johann Ritter, a German physicist, discovered the possibility of a rechargeable battery.

1826 Georg Ohm discovered what is now known as Ohm's Law - the fundamental relationship of electricity.

1831 Michael Faraday from England, an English physicist and chemist, formed what is known as Faraday's Law, the foundation of the scientific study of electricity.

1836 Fellow English physicist and chemist, John Frederic Daniell, invented Daniell's cell.

1840 William George Armstrong, an English inventor, built the hydroelectric machine, a steam water-powered generator which produced frictional electricity.

1859 Raymond Gaston Planté, a French physicist, invented the Lead Acid battery, the first practical secondary battery.

1866 Werner von Siemens of Germany, a member of a scientific family of electrical engineers and industrialists, made innovative improvements to the generator.

1868 Georges Leclanché, a French chemist, developed a primary cell called the Leclanché cell that had an electromotive force of approximately 1.5 volts.

1888 Gassner from the United States made improvements to the dry-cell battery.

1899 Waldmar Jungner from Sweden, invented the Nickel-Cadmium storage battery.

1901 Thomas Edison, American scientist, invented the Nickel-Alkali storage battery.

1932 The duo of Shlecht-Ackermann from Germany, invented the sintered electrode.

1947 Neumann of France achieved the first successful complete sealing of the Nickel-Cadmium battery.

1960-62 Commercial use of sealed Nickel-Cadmium cells in portable devices begun.

1977-78 Lithium primary cells are commercialized.

1978 Sealed-Lead Acid cells become commercially viable.

1983-84 Solar cells introduced commercially.

1989-90 Nickel Metal Hydride introduced as a substitute for Nickel-Cadmium batteries.

1991-92 Rechargeable Zinc-Air batteries introduced for computers.

1992-93 Rechargeable Alkaline cells available to the consumer. Rechargeable Lithium batteries become commercially viable.

1990-92 Carbon-Zinc batteries no longer contain mercury.

1994 Reusable Alkaline batteries no longer contain mercury.

1996 *The Mercury-Containing and Rechargeable Battery Management Act* was signed on May 13th by President William Clinton. It established a system for collecting and recycling of Nickel-Cadmium batteries nationally; created a national labeling for these batteries; and phased out the use of mercury in nearly all batteries.

1996 RBRC's Ni-Cd battery recycling program launched in the U.S.

1997 RBRC's Ni-Cd battery recycling program launched in Canada.

2001 RBRC begins collection and recycling of all rechargeable battery chemistries.

What is a Battery?

❏ Ask the class to give their definition of a battery. *(NOTE: The public calls it a "battery," but the industry refers to it as a "cell." The lesson will use the term "battery" throughout.)*

1 A battery is an electrochemical device that contains two or more power cells connected electrically so that the chemical energy is converted into electricity.

See Charts A and B - Illustrations of the inside of a battery. (pgs. 12, 13)

Simply stated, a battery powers products that require electricity to work. They are useful because they allow us to transport electricity and use products in locations where there are no electrical outlets such as beaches, sports events, picnics, etc.

2 In a battery, each cell that stores the electrical energy in a chemical state has two electrodes that react with the chemical and each other to release energy. The battery's two metal ends are called terminals. Usually one terminal is flat (negative end) and the other is button-shaped (positive end). Most primary cell batteries have a center core or rod which is the positive terminal.

All rechargeable batteries have a connection from the positive electrode to the positive terminal. The negative terminal is usually the case that contains the chemicals. In a Carbon-Zinc battery, the positive terminal is a carbon rod and the negative terminal is the zinc case. The case is important also because it keeps the chemicals from leaking out.

❏ Ask the students to look for terminals on their batteries. How are they marked? The ends are marked with a + and -.

3 Each battery consists of four main parts:

a) Positive Electrode - the active material that allows electric current to be generated.

b) Negative Electrode - the active material that allows electric current to be generated.

c) Electrolyte - a paste-like substance or solution that contains charged particles that can move or conduct an electric current.

d) Separator - material that provides separation and insulation.

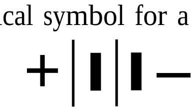
4 Electricity created by a battery consists of a stream of tiny invisible particles called electrons flowing from one metal end of the battery to the other metal end, just like a liquid. The path it follows is called a circuit. When electricity flows in a circuit, it is called current. Electricity only flows when it can go from one terminal to another. The positive and negative electrodes must have a pathway or circuit to follow.

When the circuit is complete, electricity flows from an area of high electrical potential to one of low potential. The difference in electrical potential makes the electricity move. Electricity can flow through some things, but not through others. Materials that allow electricity to flow through it are called conductors. Metals usually make good conductors. If electricity cannot flow through the material, it is called an insulator.

❏ Ask the class if they can name some materials that make good conductors and insulators. Good conductors include aluminum, carbon, copper, salt water, water, and zinc. Insulators include dry salt, glass, plastic, wood.

Activity #2 - This experiment demonstrates current, circuit, conductors and insulators. (pg. 9)

5 The electrical symbol for a battery is



❏ Ask the students if they have seen this symbol before.

The longer lines indicate positive and the shorter lines indicate negative. All batteries have a number followed by the letter "V". The "V" stands for volts. *(Remember, the volt is an electrical unit that measures the potential difference between two points in an electrical circuit.)*

The voltage number is the number of volts in a battery and explains how hard the electrons are being pushed through the circuit from an area of high electrical potential to one of low potential. For instance, a 1.5 V battery contains a single cell whereas a 9 V battery contains six cells, with the current moving through all six cells.

❑ Ask the students what the number on a battery means - a stronger or weaker battery? Batteries with higher numbers have a higher strength. You can make a voltage stronger by using several batteries.

6 The chemical reactions in batteries occur when two dissimilar materials such as zinc and copper (called electrodes) react together when inserted into a chemical conduction solution called an electrolyte. The electrolyte solution begins to slowly dissolve the zinc electrodes which forms negative zinc ions (very tiny particles which carry the electrons). The electrons then travel around, completing the circuit to the positive terminal, thus creating an electrical flow of energy.

7 At the peak of a battery's life, the electrodes have given up their ion capability. With all ions having been taken up by the electrodes, the battery becomes exhausted. It no longer provides energy and is then disposed. Batteries are very sensitive to age, charge-discharge cycles, climate, location, temperature and usage patterns.

8 The most common household battery is a dry cell battery. One kind of dry cell is a primary cell battery. These batteries automatically convert chemical energy into electrical energy. This kind of battery CANNOT be recharged. It is designed to be used once. After the chemicals in the electrolyte solution (that transmits the electric currents) have been used up, the energy is no longer available and the battery is said to be exhausted, used, or "dead," and is then discarded. An example of such a primary cell battery would be a Carbon-Zinc battery, often used in flashlights.

9 A secondary cell battery CAN be recharged and used repeatedly. The discharged energy can be restored by supplying electrical current to recharge the cell. An example of a secondary acid battery that has been used for a number of years is the car battery. It is continually recharged with electric current from the car. Secondary cell batteries, including Lithium-ion, Nickel-Cadmium, Nickel Metal Hydride and Small Sealed Lead are becoming more common in everyday use. It is important to know that Lithium-ion, Nickel-Cadmium, Nickel Metal Hydride and small Sealed Lead batteries CAN BE RECYCLED once they can no longer hold a charge.

See Chart C and D - Different Types of Primary and Secondary Batteries. (pgs. 14, 15)

10 Most batteries have a specific use or purpose. The most common sizes of batteries are the "round cells" such as AAA, AA, C, and D.

❑ Ask students to think of items that use batteries. Bar code readers, beepers, camcorders, cellular phones, cordless power tools, cordless telephones, flashlights, hearing aids, heart monitors, laptop computers, pagers, electronic toys, and walkie-talkies. Point out that there are many battery types used in the commercial market.

Why is Recycling Important?

1 Every year, more than 3 billion batteries are used and then thrown away by American households who use both single-use and rechargeable dry cell batteries. That equals 125,000 tons of batteries discarded every year.

❑ Ask the class to imagine AA batteries placed end to end around the world. Have them estimate the number of times the batteries would encircle the planet. Placed end to end, AA batteries would circle the earth six times. This is the amount thrown away in one year. These batteries would fill 600 large yellow school buses each year.

Activity #3 - Chart household use of primary and secondary batteries. (pg. 10, 16)

Although the types of batteries used are varied, batteries that contain heavy metals such as mercury, cadmium, and lead — which can enter our air, ground and surface water when the batteries are disposed of in landfills and Waste-to-Energy (WTE) Facilities — should be recycled.

2 It is expected that the demand for more portability in the future will lead to a greater demand for higher quality batteries — those that offer a longer life span and a higher performance. Research has determined that the demand for both primary and secondary batteries will increase 7.8 percent per year to more than $17 billion worth of batteries sold by the year 2000. Annual growth through 1995, for secondary and primary battery growth was fairly even at 7.8-7.9 percent. However, it is estimated that rechargeable batteries use will grow at a greater rate in the future.

3 Each type of battery has been designed with a particular use in mind. Each must be disposed of properly. When rechargeable batteries are used, the overall waste is reduced because rechargeable batteries can be recharged and used again many times before they need to be disposed.

Most rechargeable batteries can be recharged up to 1,000 times, while rechargeable Alkaline-Manganese batteries can be reused up to 25 times before being discarded. Once the rechargeable batteries have run its course, they can be recycled. When used in high-power products, one rechargeable battery can replace from 50-300 throwaway primary batteries, depending on the usage. Some rechargeable batteries can supply power every day for up to three years.

4 By using a rechargeable battery, the consumer can save money, even after purchasing the recharger unit, the battery, and the cost of electricity to recharge itself. Initially, the batteries and charger may cost more, however, they are less expensive over time as the batteries are recharged and reused. Solar-powered chargers can also be purchased. Rechargeable batteries have a cost savings and a positive environmental impact.

Activity #4 - Calculate the number of batteries used and disposed. (pg. 10)

5 The nickel, cadmium and lead contained in Nickel-Cadmium and Small Sealed Lead Acid batteries can be recycled once the life of the battery is over. Most Nickel-Cadmium batteries now have the seal imprinted on it that informs the public that they are recyclable through the *Charge Up to Recycle!®* program run by the Rechargeable Battery Recycling Corporation (RBRC).

RBRC, founded in 1994 by five major rechargeable battery makers, operates a public education and collection program for rechargeable batteries. The program is funded by more than 300 of the industry's leading rechargeable battery manufacturers, importers, and distributors of consumer products that use rechargeable batteries.

Activity #5 - Compare primary to secondary batteries. (pg. 11)

6 Nearly 350 million units of Nickel-Cadmium batteries are used each year. Because rechargeable batteries contain potentially harmful chemicals they should not be disposed of in normal household waste. The battery recycling program allows the batteries to be properly disposed. They should never be placed in

the trash but recycled through the recycling program or dropped off at a household hazardous waste collection site.

7 Most products using rechargeable batteries have been redesigned so that the batteries can be removed and replaced. Many state legislatures require products with batteries to make the batteries more easily removable instead of being sealed into the product, such as portable vacuums or cordless phones, thus enabling the consumer to dispose of the battery separately. *(NOTE: Mercury has been phased out of most batteries. The exception is the button cell batteries. The mercury and silver contained in these batteries can also be recycled.)*

8 When a battery is recharged, the stored energy that has been discharged is replaced. During the charging period, gas is generated by chemical reactions and then is consumed by the electrodes as the battery is recharged. Care must be taken to recharge only secondary batteries.

9 Batteries should be stored in a discharged state since they can self-discharge and therefore, may become inactive after a long storage period. They should not be stored for any length of time while connected to the product. Care must be taken to use the correct charger for each kind of battery. Storage should be within the temperature range specified for the batteries. If there is high humidity or temperatures, the battery materials may deteriorate, causing leakage or corrosion of the metal parts. If the battery short-circuits, it may overheat and possibly rupture. Batteries should not be disassembled because the corrosive electrolyte solution may damage the skin and eyes. They should not be incinerated or immersed in water.

See Chart F - Helpful battery tips. (pg. 17)

10 An increased environmental awareness of the harmful effects of mercury in batteries has led to a 99.4 percent drop in the consumption of mercury batteries from 1984-1994. In that 10 year period, alkaline battery use in the United States increased 150 percent. Prior to 1992, batteries were the largest source of mercury entering the municipal solid waste.

Due to the law known as *The Mercury-Containing and Rechargeable Battery Management Act*, enacted in May of 1996, the nationwide disposal of mercury in batteries has substantially decreased. The act, signed into law by President Bill Clinton on May 13, 1996, states that all Nickel-Cadmium and Sealed Lead batteries must have the chasing arrows logo or similar recycling symbols and a phrase that says the “battery must be recycled or disposed” through regulated battery collection programs. It also phases out the use of mercury in nearly all batteries.

11 Since Carbon-Zinc and Alkaline batteries no longer contain mercury, any decision to recycle them must include the considerations of the overall cost and time needed to collect, transport and recycle them. In the United States, battery companies are investigating the possibility of recycling the zinc, manganese and/or steel in the batteries. Under federal law, Carbon-Zinc and Alkaline Manganese batteries are no longer considered to be hazardous waste since they no longer contain mercury. They can be disposed of in the normal manner. However, they are short-lived and contribute to the municipal solid waste. Many communities have passed laws that regulate the sale, disposal or mandatory recycling of all kinds of batteries.

12 The rechargeable batteries collected in this program are recycled at the International Metals Reclamation Company (INMETCO), a major North American recycling facility of metal wastes. The facility is located in Ellwood City, Pennsylvania. Cadmium is recovered in a special high-temperature metal recovery process with no by-products being sent to a landfill. The recovered cadmium is purified before being used once again to make new rechargeable batteries. The recycled nickel and iron go back to the steel industry to be used in making stainless steel products. Cobalt and lead are also extracted through a high temperature process. The plastic cases that have been separated from the cells prior to processing are used as a fuel in a special furnace.

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13 To learn how to recycle rechargeable batteries, look for the RBRC Rechargeable Battery Seal. There are separate plans for consumers, retailers, businesses and communities. For retailers, RBRC handles the shipping costs and provides containers with pre-addressed, prepaid shipping labels, bags, shipping instructions, safety instructions and point of-sale materials once the retailer has signed up. Communities and governmental agencies are asked to consolidate their batteries and RBRC will pay the cost of shipping and recycling the rechargeable batteries. Businesses pay only transportation costs. For more information about the *Charge Up to Recycle!*® program and to find the collection site nearest you, visit www.rbrc.org or call 1-800-8-BATTERY.

❑ Have students locate a participating collection site in their neighborhood or near the school by visiting the RBRC web site, www.rbrc.org or calling the toll free help line, 1-800-8-BATTERY.

Evaluations and Extensions

Evaluations

1 What scientists were responsible for inventing the first primary cell and the first secondary cell battery?
2 Explain the difference between primary and secondary dry cell batteries.
3 What components make up a battery? Explain each part. *(See Chart C and D on pages 14 and 15.)*
4 What was the significance of the bill President Clinton signed in 1996?
5 Discuss when it is advisable to use a primary cell battery and when it is better to use a secondary cell battery.
6 Explain how a rechargeable battery can be recycled.

Extensions

1 Research companies that use rechargeable batteries. Learn what they are used for; why they are used; do they have the seal; how is it publicized on the packages. *(More than 350 companies have the seal.)*
2 Call the toll-free help line at 1-800-8-BATTERY or visit the web site at www.rbrc.org to learn how to recycle rechargeable batteries in your community, in your neighborhood, near your school.
3 Ask the students to write a creative story in which they imagine living without the luxury of having batteries to run their appliances, games, electronic equipment, etc.
4 Research the properties of the different chemical elements used in the various batteries. Discuss the chemical reactions that occur through the use of the metals.
5 Investigate other elements with positive and negative electrodes that might work in specific electrolyte solutions.
6 Research what kind of battery provides the longest charge, the strongest. Devise an experiment to measure each kind of battery to compare charges, strength, etc.
7 Invent a product that is dependent on a battery to make it run.
8 How do other countries manage battery disposal? Divide the class into teams to research other countries.
9 Create a time line with historic references and art work to show the development of the primary and secondary batteries.
10 Write a paragraph to explain why the Battery Recycling Seal may have been designed as it was.

Activities and Experiments

Activity #1

Make a home-made wet cell based on the Voltaic cell.

Meets objective 1, 4

Materials Lemons, coins (such as copper pennies), paper towels, aluminum foil (or coins such as dimes), bowl, scissors, lemon juicer, wire strippers, plastic tape, paper tube (toilet paper or paper towel tube will work), plastic-covered electrical wire.

Steps

1 Wrap foil over one end of the paper tube and then secure it by taping it down.
2 With the wire cutters, strip 1-2'' of the plastic from the wire. Tape one end to the foil.
3 Squeeze the juice from the lemons. Soak the paper towels in the juice. Start with a small rolled piece of toweling, then a coin, followed by a piece of foil. Continue to layer the three materials, filling the tube and ending with a coin. Tape a second stripped wire to the coin.
4 Moisten a finger tip on each hand and touch the ends of the two wires. (Students will experience a small shock or tingle but it will be very harmless. Students may also try attaching a light bulb to each end of the battery. The battery will be weak, but the bulb may have a faint glow.)
5 This is an example of a wet cell, the parent of today's battery. The lemon juice acts as the electrolyte that conducts the electricity created by the coins and the foil. This battery is an example of the very first one created by Alessandro Volta in 1800.

Activity #2

Experiment with various materials to determine how conductors and insulators work and circuit and current flow.

Meets objective 4

Materials:
1.5 V dry cell battery, aluminum foil, coin, electrical (copper) wire, glass jar, light bulb holder, metal nail, paper clip, plastic spoon, rubber band, small flashlight bulb, water, wooden spoon, wire strippers.

Steps

1 Cut the copper wire into three 8-inch lengths and scrape off the plastic coating on all ends.
2 Connect one end of one wire to the demonstration bulb holder and the other end to one of the terminals on the 1.5 V dry cell battery.
3 Place the bulb into the bulb holder. Attach the second piece of wire to both the second terminal and the bulb holder. The bulb should light.
4 Disconnect the wire from the bulb holder. Attach the third wire to the bulb holder and begin to touch both that wire end and the terminal wire end with each of the collected materials — aluminum foil, coin, nail, paper clip, plastic spoon, rubber band, wooden spoon — forming a bridge between the two.
5 When using water or salt water, dip both the wire ends into the water contained in a glass jar.
6 The students will see that the light bulb lights up when the material used to complete the circuit is a conductor. It does not light up when the material is a nonconductor or insulator.

(continued from page 9)
Activities

Activity #3
Investigate and list batteries used in students' homes and graph data to show primary vs. secondary battery use.

Meets objectives 1, 2, 3, 7

Materials Research of battery usage in students' homes as outlined from Chart E (pg. 16).

Steps:

1 Take a poll of the kinds of batteries used in each student's home.

2 Record data on Chart E (pg. 16) to show primary and secondary use for each item.

3 Following the poll, students should understand that the way a product is used is the key to purchasing the most efficient battery.

Note: Use the following guidelines:

- used less than one hour/day = primary
- more than one hour/day = secondary
- low-power usage = primary
- high-power usage = secondary

Activity #4
Calculate the number of batteries used and disposed.

Meets objective 6

Materials Ruler, scale, pencil, worksheet, assorted batteries.

Steps

1 Measure the length of a single AA battery. If you placed AA batteries end to end;

a) how many would it take to create a straight line from your home to your school? You will have to know the length of that distance. *(Hint: measure the distance and convert to inches or determine how many batteries make up a linear foot.).*

b) How many would it take to reach from one end of your state to the other? *(Hint: Check in your geography book to discover that distance.)*

2 If you used primary cell batteries to create the line, and the average cost of the batteries is $2.99 for a package of two,

a) how much would it cost to line up the batteries from your home to your school.

b) How much from one end of your state to the other?

3 Nearly three billion batteries are used and thrown away every year. If the number of batteries being used grows by 7.8 percent this year,

a) how many additional batteries will be used by next year?

b) How many will be used in two years?

c) What is the total number of batteries expected to be used and discarded in three years?

4 If a package of 4 AA primary batteries cost $4.79, and a package of rechargeable Nickel-Cadmium secondary batteries cost $8.64,

a) what is the difference in the cost of the two kinds of batteries? If the recharger costs $21.78,

b) what is the total cost for the secondary batteries? If a portable radio is played for a constant week, and you need to replace the primary batteries eight times,

c) what is the cost of the batteries now?

d) which is the best buy after two weeks of constant use?

Activity #5

Compares primary batteries to secondary batteries economically and environmentally.

Meets objectives 6, 7

Materials Primary batteries, secondary batteries, two battery-run products such as flashlights, pencils, secondary battery recharger, completed date on Chart E (pg. 16)

Steps

1 Students will compare the overall life expectancy and cost of primary cell batteries compared to secondary cell batteries. *(NOTE: For ease of experimentation, use flashlights. However, normally flashlights that are turned off and on infrequently are better served with primary batteries. Secondary batteries are more useful in frequent and repetitive on and off usage.)*

2 Have students create a cost comparison chart as well as a lifetime chart.

3 Purchase two same volt cells — one a primary cell and one a secondary cell — and place them in two identical products such as a flashlight. Make sure that the flashlight bulbs are both new. Keep track of the costs of the two kinds of batteries.

4 Turn the flashlights on after noting the time. Leave the flashlights on. Assign a student the responsibility of carrying the flashlights home at the close of the school day and bringing them back the next morning, keeping the light on the whole time. Keep track of the number of hours that the flashlight bulbs are on.

5 When either flashlight light burns out, note the time and whether it is a primary cell battery or a secondary cell battery. *(Make sure it is not the flashlight bulb that has burned out instead.)*

6 If it is a primary cell battery, replace the battery immediately and continue to note the date and time for that battery.

7 If it is a secondary battery, turn off the primary cell battery while recharging the secondary. When the secondary is recharged, replace it, and turn the primary cell back on. Keep track of the times.

8 Continue to do this until you get an average life span for the primary cell battery (possibly 4-5 times) and an average time before the secondary battery must be recharged.

9 You are now ready to compare the life of the batteries and their costs.

10 Although the original cost of the secondary battery is much higher, the secondary costs should level out and then decrease the longer the product is used.

11 Students may want to try this test with different kinds of products as well as batteries with different voltages.

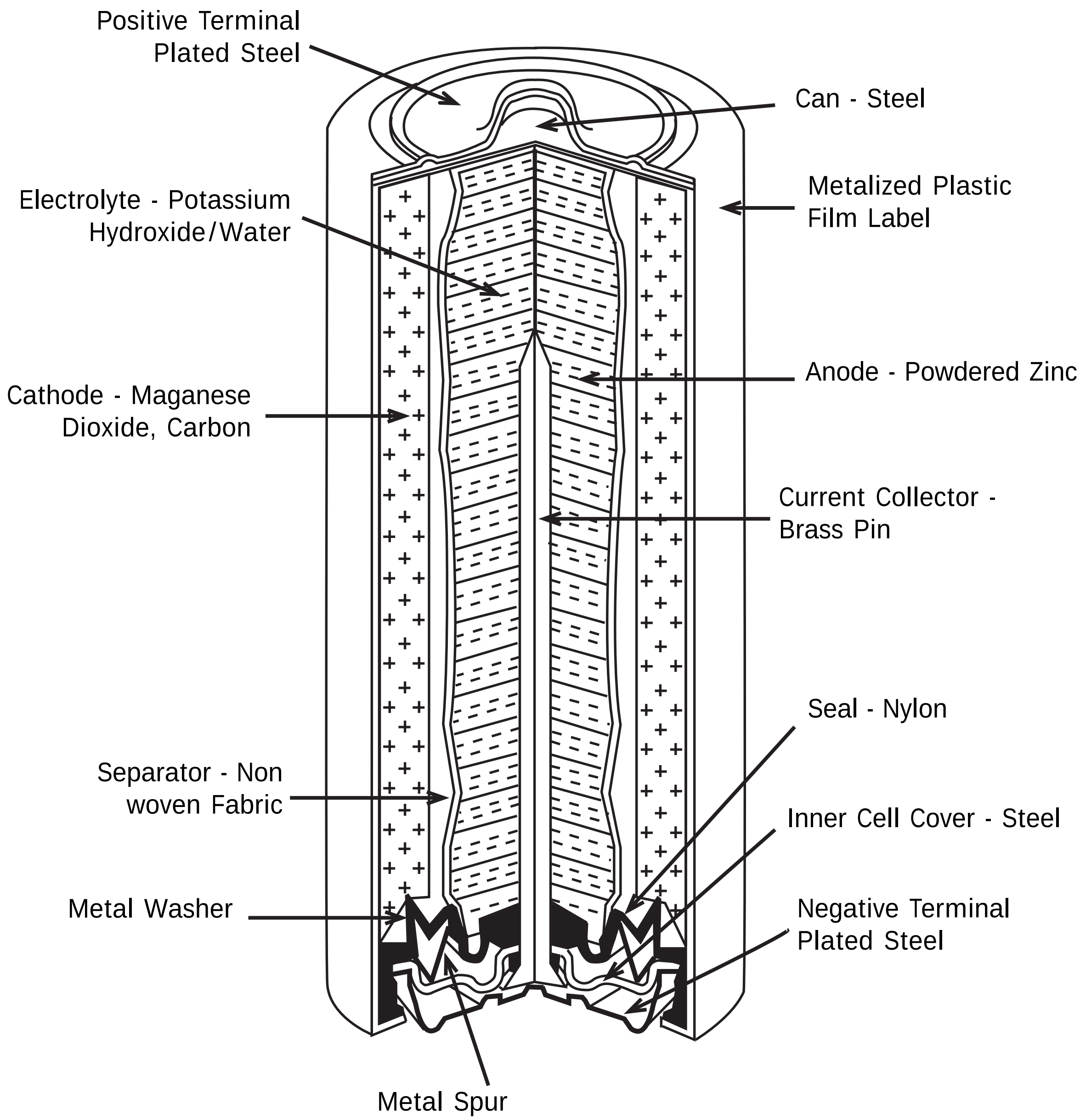
For expensive products with long life spans, a secondary battery may prove to be a better buy. For items with built-in obsolescence or smaller products, primary cells may work better. Secondary batteries do not hold their charge for an extended period of time, and therefore SHOULD NOT be used in smoke detectors and other items that are infrequently used. They work well with equipment that requires a high flow of current for a longer period of time.

❏ Answer the following questions:

- How many primary cell batteries are equal to a secondary cell battery life (when it must be recharged).
- Which battery is exhausted first?
- What are the initial costs of each kind of battery?
- Assuming that a secondary cell battery can be recharged up to 1,000 times, how long could this battery run continuously? How many primary cell batteries would have to be pur chased to equal that time period?
- Once you have the number of primary cell batteries you would need to equal the life span of the secondary cell batteries, multiply the cost of all those primary cell batteries. Then compare it to the cost of the secondary cell batteries.
- If you included the costs of all the primary cell batteries in the cost of the product, what does that do to the price of that product? (Would escalate the cost of the product.)
- In the life span of the product, which battery becomes more economical to use?
- Which battery is more environmentally friendly?
- Why?
- What have they learned from this activity?
- When does it make sense to use a primary battery and when a secondary battery?

Diagram of a Primary Cell Battery - Chart A

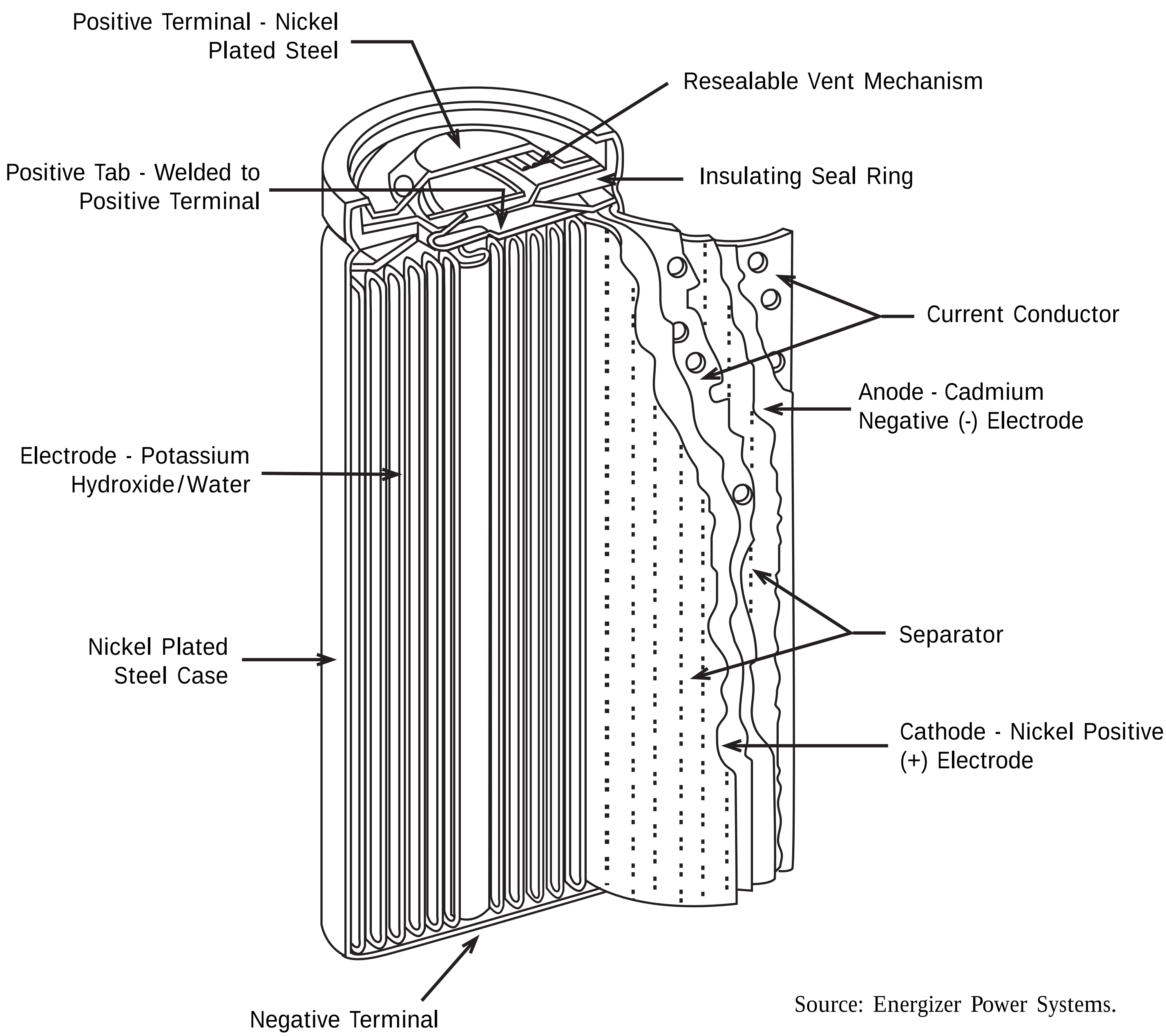
Cutaway View - Typical Alkaline Cell



Source: Energizer Power Systems.

Diagram of a Secondary Cell Battery - Chart B

Cutaway View - Typical Nickel-Cadmium Cell



Source: Energizer Power Systems.

Battery Characteristics - Chart C

Primary Batteries (non-rechargeable)

Carbon Zinc The most popular and cheapest primary battery; average performance; good storage life; numerous sizes and shapes available. No mercury is contained in these batteries.
Characteristics - Low energy density, lowest cost
Disposal - Check with your local authority
Electrolyte - Ammonium Chloride, Zinc Chloride
Major Components - Zinc, Carbon
Uses - Flashlights, toys, remote controls
Voltage - 1.5 V

Alkaline Manganese Gaining in popularity; has better performance than the carbon-zinc primary battery; costs more due to better performance. Batteries manufactured after May 13, 1996, contain no added mercury with the exception of button cell batteries which contain a minute quantity of mercury.
Characteristics - Higher energy density, moderate discharge rate, and more expensive than carbon zinc
Disposal - Check with your local authority
Electrolyte - Potassium Hydroxide
Major Components - Zinc, Manganese Dioxide
Uses - Radios, smoke detectors, toys
Voltage - 1.5 V

Lithium Light weight; high energy density; long storage life; expensive. Lithium has a great reactivity with water and air, and disposal requires special attention.
Characteristics - High energy density, long shelf life, expensive
Disposal - Check with your local authority
Electrolyte - Organic Solvents
Major Components - Lithium and Manganese Dioxide or Polycarbonmonofluoride
Uses - Cameras, pagers, keyless locks
Voltage - 3.0 V

Zinc Air Specialty battery; light weight; good performance; inexpensive; safe.
Characteristics - High energy density, low discharge rate, inexpensive
Disposal - Check with your local authority
Electrolyte - Potassium Hydroxide
Major Components - Zinc, Carbon
Uses - Hearing aids, pagers
Voltage - 1.4 V

Silver Primarily found in button cell batteries; high energy density; moderately expensive; safe.
Characteristics - High energy density, low discharge rate, expensive
Disposal - Check with your local authority
Electrolyte - Potassium Hydroxide
Major Components - Zinc, Silver Oxide
Uses - Watches, calculators, hearing aids
Voltage - 1.55 V

Mercuric Oxide Primarily found in button cell batteries for electronics. This battery contains mercury. Federal legislation was enacted on May 13, 1996, that minimizes the amount of mercury contributed by batteries to municipal solid waste (MSW). No consumer recycling program (similar to RBRC's) has been established. (Button cells cannot be sold in US)
Disposal - Check with your local authority; special handling required
Electrolyte - Potassium Hydroxide
Major Components - Zinc, Mercuric Oxide
Uses - Specialized medical, military, emergency response equipment
Voltage - 1.35 V

Battery Characteristics - Chart D
Secondary Batteries (rechargeable)

Nickel-Cadmium Most popular rechargeable battery; good performance; can be recharged up to 1,000 times; least expensive of the secondary batteries. This battery contains cadmium which is toxic, therefore it is important to recycle these batteries. They can be recycled through a national program offered by the Rechargeable Battery Recycling Corporation (RBRC).
Characteristics - Rapid discharge, moderate energy density, relatively inexpensive
Disposal - Recycle through RBRC program
Electrolyte Type - Potassium Hydroxide
Major Components - Nickel, Cadmium
Uses - Power tools, cordless telephones, professional radios
Voltage - 1.2 V

Nickel Metal Hydride Cadmium-free replacement for Nickel-Cadmium; more expensive; good performance; can be recharged up to 1,000 times; can be recycled. They can be recycled through the national program offered by RBRC.
Characteristics - Moderate discharge rate, high energy density, relatively expensive
Disposal - Check with your local authority
Electrolyte Type - Potassium Hydroxide
Major Components - Nickel, Various Rare Earth Metals
Uses - Computers, cellular phones, camcorders
Voltage - 1.2 V

Lithium-ion Newest rechargeable technology; light weight, excellent performance; can be recycled. They can be recycled through the national program offered by RBRC.
Characteristics - High energy density, moderate discharge rate, expensive
Disposal - Check with your local authority; special handling required
Electrolyte Type - Organic Solvent
Major Components - Graphite, Lithium, Cobalt Oxide
Uses - Computers, cellular telephones
Voltage - 3.0 V

Lead-Acid These batteries are the main source of power for cars, trucks, boats, motorcycles, tractors, etc. These batteries contain lead. Because lead is a toxic material, it is important to recycle these batteries. Lead batteries are being recycled at a rate exceeding 90 percent. The active ingredient of lead and sulfuric acid can be very toxic if improperly disposed. Can be recycled. They can be recycled through the national program offered by RBRC.
Characteristics - High discharge rate, moderate energy density, inexpensive
Disposal - Recycling program exists
Electrolyte - Sulfuric Acid
Major Components - Lead
Uses - Emergency power, automobiles
Voltage - 2.0 V

Rechargeable Alkaline Moderate performance; can be recharged only a few times; requires special charger; costs less than Nickel-Cadmium; does not have to be recycled.
Characteristics - Moderate discharge rate, more expensive than primary alkaline
Disposal - Check with your local authority
Electrolyte Type - Potassium Hydroxide
Major Components - Zinc, Manganese Dioxide
Uses - Radios, toys, walkmans
Voltage - 1.5 V

Zinc-Air (see description on Primary Battery chart)
Characteristics - Moderate energy density, moderate discharge rate, expensive
Disposal - Check with your local authority
Electrolyte Type - Potassium Hydroxide
Major Components - Zinc, Carbon
Uses - Computers
Voltage - 1.4 V

Battery Usage - Chart E

Product	High/Low Powered	Usage	Best Battery Option	Ease of Removal
Cordless Drill	High	1 hr/mo	Secondary	Yes
Flashlight	Low	1 hr/mo	Primary	Yes
Cell Phone	High	2-4 hrs/ day	Secondary	Yes
Watch	Low	24 hrs/ day	Primary	Somewhat

Battery Tips - Chart F

✔ You Can

1 Use rechargeable batteries whenever possible and then recycle them when they can no longer hold a charge.

2 Recycle your button batteries. Check with your community's solid waste program to determine where.

3 Remove your batteries from equipment that will be stored for any length of time because the battery terminals may leak, corrode and ruin the equipment.

4 Clean the contact surfaces when installing your batteries so power will not be wasted.

5 Purchase batteries as you need them since they do have a limited shelf life.

6 Remove the button batteries in disposable toys, watches, and calculators and recycle them before disposing of the item.

7 Follow the charging guidelines provided by the manufacturer. Depending on the individual product, there are specific initial battery charging times (usually overnight) before using the product for the first time. This will enable you to obtain maximum battery capacity.

8 Let your battery cool to room temperature before recharging. The charge efficiency of most batteries is greatly reduced at elevated temperatures.

9 Recharge batteries when they are near to fully discharged. You can tell that a battery is discharged by a sharp drop in power or speed.

10 Recycle your used rechargeable batteries when they can no longer hold a charge.

✘ You Should Not

1 Mix old batteries with new ones because this will shorten the life of the new battery.

2 Place batteries or equipment with battery included where it will overheat since the heat will speed up the chemical reaction and shorten the battery's life.

3 Recharge a battery unless it is actually a rechargeable battery.

4 Mix batteries with other objects such as metal keys or change since this can short circuit the battery, causing heat and sparks.

5 Mix different kinds of batteries in the same piece of equipment or use rechargeable batteries with common disposable batteries. It may ruin the equipment, shorten the life of the batteries, or cause an explosion.

6 Throw away items powered by batteries with the batteries still inside. Remove the batteries and dispose in the proper manner.

7 Take apart or tamper with the case of the battery.

8 Reverse the positive and negative terminals of the batteries when installing in equipment or in a recharger.

9 Dispose of a battery in a fire or immerse in water.

10 Leave the battery in the equipment after it has been fully discharged.

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Aditional copies can be downloaded from www.rbrc.org/school.

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RECHARGEABLE
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CORPORATION

1000 Parkwood Circle, Suite 450, Atlanta, GA 30339, Ph: 678-419-9990 Fax: 678-419-9986