SAVE THE BLACK FOOTED FERRETS

STEM TEACHING KIT

An Introduction to Circuits, Capacitors, and CAD

Teacher's Guide

This curriculum and all embedded documents can be found online at
http://www.auburn.edu/~cgs0013/ETK/SaveTheFerretsETK.pdf

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For more curriculum like this, visit http://www.auburn.edu/~cgs0013/engineering.htm

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UNIT OVERVIEW

Introduction and Background

This curriculum is all about designing and constructing an “off the grid” town. Students learn about how power plants and power transmission wires disrupt natural environments, and how communities can generate and store their own electricity locally. Capacitors can be used to store electricity generated by wind, solar, and human-powered energy. This curriculum is truly STEM as it targets the scientific concepts of electrical charge and electric circuits, the technological concept of Computer Aided Design, the engineering concepts of problem solving and design under constraints, and the mathematical concepts of geometric shapes.

Teaching Strategies

Design-Based Science

In design-based science activities, the teacher does not tell the students what to build. Instead, the teacher serves as a facilitator and allows students to take the primary lead in their own learning as they apply scientific concepts to engineering design problems. Problem solving through authentic tasks that relate to students’ lives increases student interest and deepens conceptual knowledge.

Whole-class demonstrations

While you may be tempted to jump into the design activity and skip over the science activities that lead up to it, please do not. The activities provide the cognitive scaffolding necessary for students to link the design challenge with the complex science of circuits and capacitors. They present students with cognitive dissonance through discrepant events; the opportunity to face their conceptions of electricity and refine any incorrect ones is imperative for the success of this STEM Teaching Kit. Without the activities and discussions that surround them, students will take away a fun activity that may or may not help them understand the science, or understand what engineers do. With the activities, students will gain increased conceptual understanding about electric circuits, electrical charge, and how capacitors work to store electrical charge.

Cooperative Learning Groups

Ideally, students should be placed in small groups of three or four. Each student should be assigned a role in the group. Either allow students to pick their own groups, or assign them based on what you know about how your students get along and work together. Since students will be working with the same group members for the duration of this unit, it is best if the students like one another and work well together. Have students sit together with their group members from the beginning of this unit, ideally around a table where they can each see and talk to one another.

Assessment

In the *Save the Ferrets* STEM Teaching Kit, assessment is an integral part of instruction and consists of two types:

A. Formative assessment – embedded within the lessons, providing continual feedback to the teachers and students for improving instruction. In this unit, formative assessments include:

- Whole-group discussions involving students' predictions of what will happen during activities and feedback from students/groups following each activity.
- Seeing how many lights can glow, and for how long, in the town they create.
- Storyboarding during each lesson. A storyboard is like a comic strip in that it tells a story through drawings and words divided up into sections that flow logically. Each time students learn a new concept, do an experiment, create a design, or test a design, it should be recorded on the storyboard for teachers and students to see and comment on.

B. Summative assessment – an evaluation of cumulative performance, given as written tests before and after the unit to determine students' content knowledge gains on electricity concepts. Teachers should have each student complete the "Electrical Circuits Pre-Test" at the start of the unit, collect the assessments, score them, but do not return or discuss the results with the students. The "Electrical Circuits Pre-Test" instrument is based on misconceptions research and has been assessed for face and content validity, construct validity, and reliability. The same evaluation will be given to each student at the end of the unit. Collect the post-tests, score them, and compare each student's pre- and post-test scores. The assessment will provide the teacher with information about students' misconceptions about electrical circuits, charge, and storage. For more information about this instrument and correct answers, contact Christine Schnittka at Schnittka@auburn.edu.

Safety considerations

Caution students not to short circuit batteries or capacitors by touching the positive (red) and negative (black) ends together or by connecting the battery or capacitor to a circuit that has no components, thus little resistance. This will make the wires very hot and could potentially cause burns or shocks.

Caution students to be careful when using scissors.

When using the lamp to power the solar cell, be sure students hold the lamp by the plastic handle, and keep the lamp at least 12" away from the solar cell or it will melt.

Technology

A computer with speakers, an LCD projector and screen will be needed to show WebQuests and videos. If laptops or tablets are available, encourage the use of the social networking educational space, Edmodo. Go to www.edmodo.com and set up an account for yourself and a "space" for your students to dialogue with each other, share ideas, photos, videos, websites, etc. It's also a good way for you to post questions and encourage students to respond.

Correlation to Standards

The *Save the Ferrets* STEM Teaching Kit is based on standards derived from the *Next Generation Science Standards*.

Next Generation Science Standards

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

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

MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

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

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

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

UNIT SUMMARY

UNIT BIG IDEAS

- Electricity can be stored in a capacitor or a battery.
- Engineers follow a general process to design solutions to problems.

LESSON 1 – Learning Targets

What is happening to Ferrets?

- Ferret populations are in decline due to loss of prairie.
- Engineers must identify the problem in order to solve it.

LESSON 2 – Learning Targets

Electric Circuits and Power Plants

- An electrical circuit is an unbroken path for electrons to flow.
- Large parts of the United States are linked by “the grid” which are electrical circuits connected to a power plant .
- Engineers design things AND systems like “the grid.”

LESSON 3 – Learning Targets

Storing Electricity

- A capacitor contains two pieces of metal, or any conductor, that are separated by a dielectric, which is essentially an insulator. Capacitors use the metals to store electrons.
- A battery contains two different kinds of metal separated by a conducting fluid or paste. A chemical reaction at one metal releases electrons to the other when the circuit is completed.
- Engineers must use their knowledge of science to brainstorm possible solutions to the problem.

LESSON 4 – Learning Targets

Design and Construct Village Dwellings

- Scientists and engineers create models that represent their ideas.
- Engineers use computer tools to design systems and things.

LESSON 5 – Learning Targets

Design and Construct Village Grid

- Scientific knowledge can be used in the design, construction, and evaluation of a device.
- Engineering is an iterative process of designing, testing, re-designing, and re-testing.
- Engineers must document their process of design and present their solution to the problem.

Each Lesson is designed for 70-80 minutes of instruction. Lessons do not necessarily correspond to a single day of instruction and may need to be adjusted depending on length of class periods. Lessons can be set up as stations that students visit throughout the week.

LESSON 1

The Black Footed Ferrets

Learning Targets

1. Ferret populations are in decline due to loss of prairie.
2. Engineers must identify the problem in order to solve it.

Purpose of the Lesson

The purpose of this lesson is to introduce students to the Black Footed Ferret and the environmental conditions that are affecting their survival.

Lesson Objectives

At the end of this lesson, students will be able to describe the Black Footed Ferret, including what kind of animal they are, where they live, what they eat, when they sleep, how they are doing as a population, and what is impacting their population size.

Lesson in a Nutshell

1. Pre-assessment on Circuits (10 minutes)
2. *Save the Ferrets* Introduction WebQuest (30 minutes)
3. Introduction to Storyboard poster (15 minutes)
4. Storyboard about Ferrets (15 minutes)

Background for the Teacher

The Black Footed Ferret, Mustela nigripes

In the prairies and grasslands of the midwestern United States, there is a small, nocturnal, creature who lives in the burrows of prairie dogs. This creature is known as the black footed ferret, and before Europeans settled the midwest, they were very abundant. Unfortunately, the ferret has declined so much that at one time it was thought to be extinct. A small group of ferrets was later found, and now many conservation and governmental groups are working hard to get these important creatures off the endangered species list. See https://worldwildlife.org/species/directory?direction=desc&sort=extinction_status

The black footed ferret is an important species because of the influence they have on prairie dog populations. The ferrets will not only inhabit the unused burrows of prairie dogs, but are active hunters of these rodents. With sharp teeth and fast movements, black footed ferrets are able to catch them. Recently, the prairie dog populations have been increasing too much without the predation of the ferrets.

The Decline of the Ferret

A few things have influenced the decline of the black footed ferret, the main reason being the loss of grassland habitat in the prairie. As Europeans settled in the Midwest, they found the soils of the prairie to be so rich and fertile that agriculture flourished. As time went by, much of the prairie was converted for agriculture purposes. As agriculture flourished, more and more people began to urbanize the grassland habitat the black footed ferrets and other grassland species need. Now, less than 2% of original grassland prairie has remained undisturbed by human practices. A new threat is now affecting prairie dog populations- the sylvatic plague. With the help of a new vaccine, and drones to deliver peanut butter-flavored vaccine pellets, the World Wildlife Fund is helping save the black-footed ferrets by helping their source of food. Watch the video and read the article here:
https://www.washingtonpost.com/news/animalia/wp/2016/10/24/watch-peanut-butter-drone-strikes-that-could-save-endangered-ferrets/

Restoring the Great Plains

Today, efforts throughout North America are protecting and restoring prairie habitat for all grassland species. Conservation and government agencies from the United States and Canada work hard to reintroduce ferrets and prairie dogs in protected habitats. With an ever growing and expanding human population in North America and globally, it is important to make sure we leave enough space for other inhabitants of this world we all call home.

Teacher Materials

- Ferret WebQuest http://savetheferrets.weebly.com/
- Copies of Circuits pre-test (Located in Appendix B)

Student Materials (for each group)

- Science notebook or journal for each student
- Posterboard
- Markers or colored pencils

Preparation

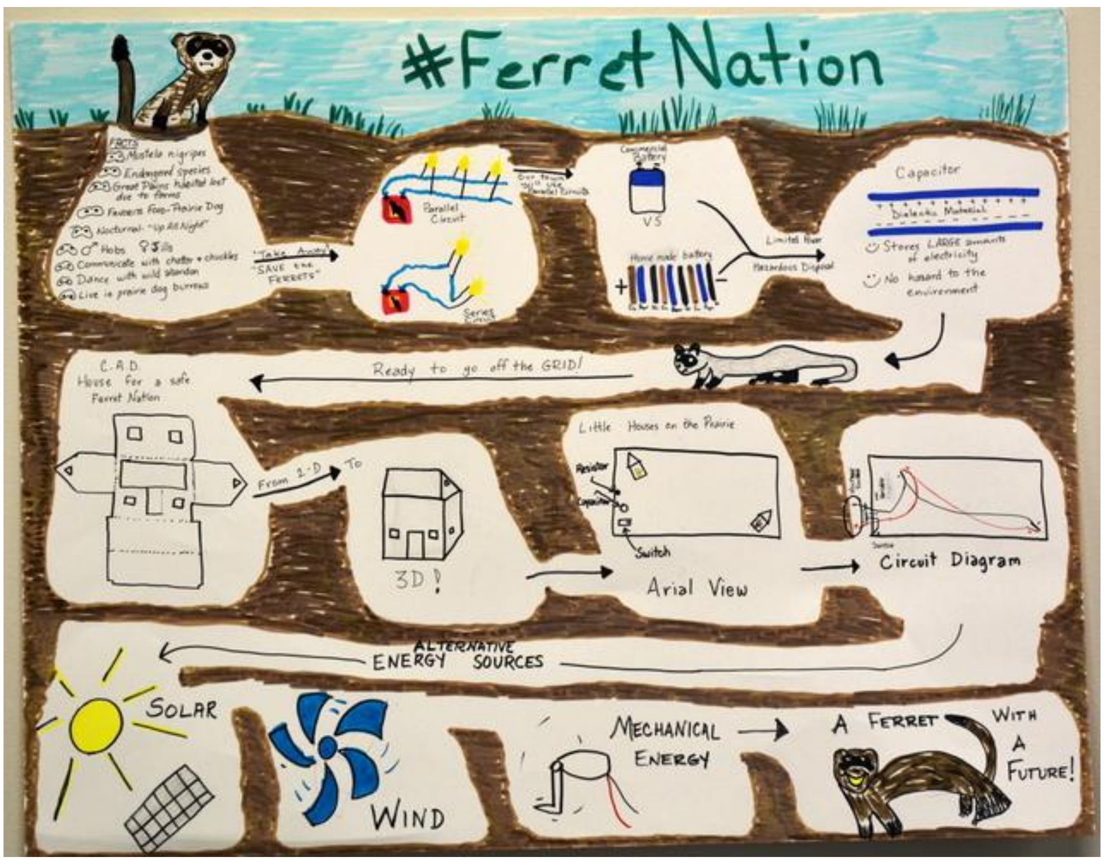
1. Photocopy the Circuits PreTest for students located in Appendix B
2. Read the background information about the Black Footed Ferrets.
3. Prepare to deliver the WebQuest as a teacher-directed exercise in the classroom, or in a computer lab with students at individual computers or working in pairs.

Procedures

1. Have students complete the Circuits PreTest and put the test away- do not hand it back to students. You should grade the pre-tests and look them over for common misconceptions.

2. Present the [Save the Ferrets WebQuest](). Engage students in a teacher-guided discussion using the discussion prompts in the WebQuest. This can be done as a whole class if a computer lab is not available. Have students record their answers in their science notebooks or journals. Or, if you are using Edmodo, post the questions as prompts for students to answer online.
3. Distribute one blank poster board to each group and show students an example of a completed storyboard. Have groups develop a team name and write it at the top of their storyboard. Explain that each time students learn a new concept, do an experiment, create a design, or test a design, it should be recorded on the storyboard for teachers and students to see and comment on.

Teacher note: *Use of storyboards in the engineering design process provides a visual experience that helps students conceptualize each of the steps needed to understand each part of the entire "Save the Ferrets" project. The storyboards allow the students to break down each important concept and provide key formative assessments throughout each of the lessons. Three points are covered in the engineering design process with the use of the storyboards: Finding Solutions, Developing an Initial Design and Presenting your Design at the end of the lesson.*



4. Have students complete at least one square of their storyboard with information they learned about ferrets. Encourage students to draw a model that represents the ferret and its environment and everything they learned about ferrets.

5. If using Edmodo to promote dialogue and discussion, provide the questions as prompts and allow students to discuss via Edmodo.

6. Close the lesson with the following question: If you wanted to establish a new town in the prairie where Black Footed Ferrets were living and thriving, what would you have to do to live with them in peace? Think about all the things a town needs and imagine your town is in the middle of a prairie with a thriving Ferret population.

Extension

Math Connection:
The lesson, Ferret Figures, was designed by The Futures Channel. It challenges students to use mathematics to predict Black Footed Ferret populations. See https://thefutureschannel.com/pdf/math/ferret_figures.pdf

Wrap-Up

Wrap up the lesson with a review of the learning targets. Ask students:

- What has impacted the lives of ferrets?
- What have people done to harm the ferrets?
- What can people do to help the ferrets?
- What would your prairie town need to have (or not have) in order to protect the ferrets?

LESSON 2

Electric Circuits and Power Plants

Learning Targets

1. An electrical circuit is an unbroken path for electrons to flow.
2. Large parts of the United States are linked by "the grid" which are electrical circuits connected to a power plant.
3. Engineers design things AND systems like "the grid."

Purpose of the Lesson

The purpose of this lesson is to introduce students to the concepts of electrical circuits with switches and parallel and series components connected to an electrical source.

Lesson Objectives

Using Play-Doh as the conductor, students will create:

- a basic series circuit with a switch, four lights, and a battery so that all four lights work.
- a circuit with four lights in parallel, a switch, and a battery so that all lights work.

Lesson in a Nutshell

1. Show simulation of circuits and engage students in inquiry, questioning, predicting, inferring.
2. Demonstrate that conductors come in many forms by having students form two types of circuits from conductive dough. Refer to the circuit with lights in parallel as a "grid".
4. Show map of the US electrical grid. http://en.wikipedia.org/wiki/File:UnitedStatesPowerGrid.jpg
5. Ask students why they think electrical sockets in the wall have two places for inserting conductors, not one. (They are wired in parallel.)

Background

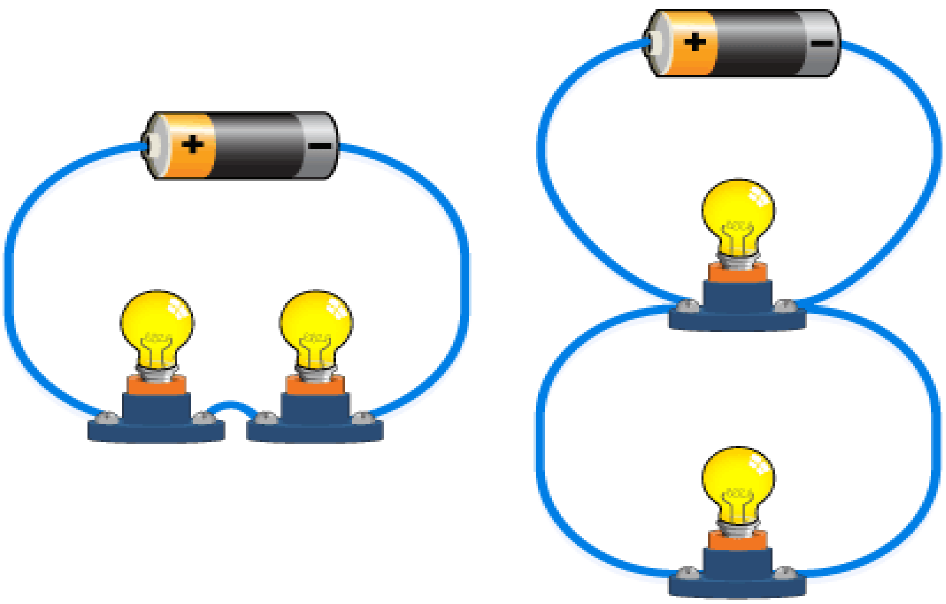
Concept 1: Conductors and the many forms they take

Electrical conductors allow electricity to pass easily. Metals are excellent electrical conductors, but some other materials are as well. Water is an electrical conductor ONLY WHEN the water contains electrolytes. Electrolytes are ions that accept and release electrons. Salt water conducts electricity but distilled water does not. The human body is an electrical conductor because it contains water with electrolytes. Nerve cells are electrical conductors. Salt dough is an electrical conductor because of the water and electrolytes present.

Concept 2:Series vs Parallel circuits

Series circuits allow electricity to pass from one device to another in a chain. Electricity goes in one light bulb and out, then into another light bulb and out. With each device in a series circuit, the voltage drops, but the current remains the same. When one device from a series circuit is removed, the circuit is "open" and electricity cannot flow. The "first" device in a circuit does not use up most of the electricity. This is a common misconception students have. Demonstrate this when students create a series circuit. They will see that the last light bulb is getting just as much electricity as the first one, but they will predict that the last one will be dimmer because the first ones "used it up."

Parallel circuits allow electricity to pass to all devices at once. Electricity goes to all the light bulbs and out simultaneously. Each device in a parallel circuit receives the same voltage, but the current is divided up between them all. When one device in a parallel circuit is removed, the circuit is still "closed" and electricity still flows to the other devices.



Series circuit and parallel circuit.

Teacher Materials

- Computer with projector

Student Materials (for each group)

- ½ sheet poster board
- 1 box colored markers or pencils
- Conductive dough (i.e. Play-Doh)
- 4 LEDs per group
- 9V battery and connector per group

Preparation

1. Test the simulations to make sure they run on your computer.

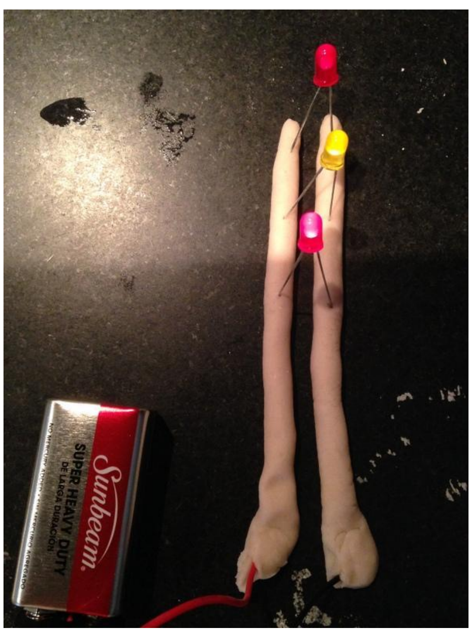
Procedures

1. Engage students in the following simulations as a whole class.

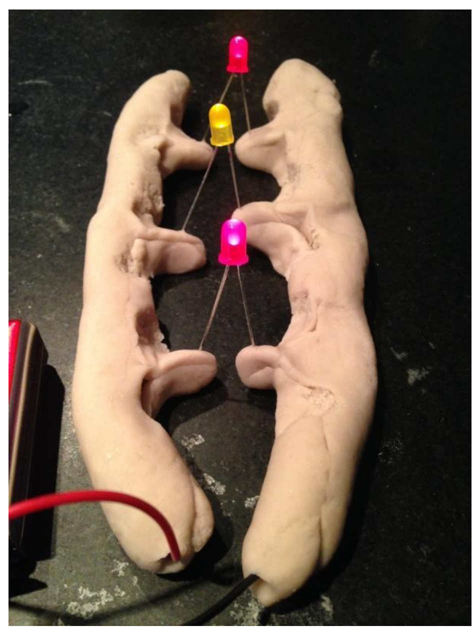
With the simulation, make a simple series circuit with a bulb, switch, motor, and buzzer. (The trick is to get the circle around the conducting screw. It takes some fiddling to get it right.) Then progress to Level 3 and make parallel circuits.
http://thefusebox.northernpowergrid.com/page/circuitbuilder.cfm

This simulation shows electron flow! Repeat step 1 with this different simulation.
http://phet.colorado.edu/en/simulation/circuit-construction-kit-dc

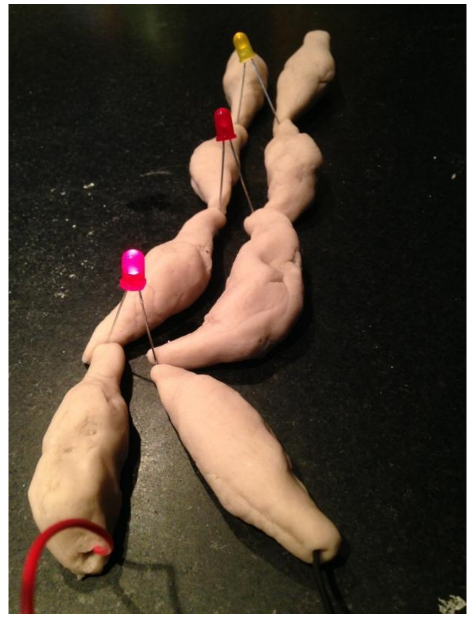
2. Pass out the conducting dough, LEDs, and 9V batteries with connectors to each group of students. Challenge students to repeat the steps they used before, (except without the buzzer and the motor). There are many ways to use the conductive dough, as seen in the following photographs. Have students imagine that the battery is a power plant, and that each LED is a house with electricity going to it. How many “houses” can one power plant (one battery) light up? Does the size or shape of the “wires” matter?



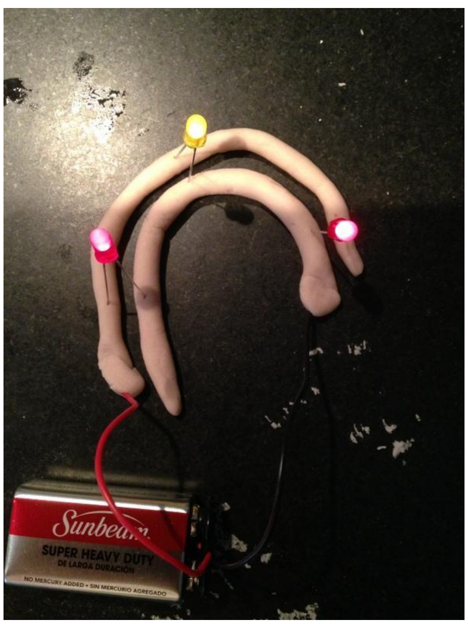
Two rods of dough, one positive and one negative.



Rods with “fingers”



Fingers of dough are like individual wires. They can be combined together to make a parallel circuit.



Curved rods of dough still work…

Even when they make a circle!

3. Ask students where they think the power plant is located that connects their house to the grid. Find out ahead of time, and let them know after they have guessed. Show the image of the electrical grids in the US. http://en.wikipedia.org/wiki/File:UnitedStatesPowerGrid.jpg

4. Is the power grid available to towns in the midwestern prairie land? What if you wanted to build a new town in the prairie that wasn't near a power grid line?

5. Have students create a model on their storyboard of what an electric grid might look like. Have them draw the most complicated squishy circuit they created.

Extension

Math Connection: Use this simulation to explore Ohm's Law
http://phet.colorado.edu/en/simulation/ohms-law

Wrap-Up

Wrap up the lesson with a review of the learning targets. Ask students:

- What is an electric circuit? (a continuous path of electricity)
- What material is the electric grid made of in the US? (copper wire, not Play-Doh!)
- Why are there two electrical connections in each wall socket? (all outlets are wired in parallel!)
- What does any of this have to do with ferrets? (Hmmm….)

LESSON 3

Capacitors, Batteries, and Storing Electricity

Learning Targets

1. A capacitor contains two pieces of metal, or any conductor, that are separated by a dielectric, which is essentially an insulator. Capacitors use the metals to store electrons.
2. A battery contains two different kinds of metal separated by a conducting fluid or paste. A chemical reaction at one metal releases electrons to the other.
3. Engineers must use their knowledge of science to brainstorm possible solutions to the problem.

Purpose of the Lesson

The purpose of this lesson is to have students see that capacitors and batteries are simple devices that store or transform electricity, and make their own with a choice of materials.

Lesson Objectives

Given two pieces of metal (aluminum foil) and a choice of dielectrics (plastic plates), students will be able to create a capacitor that holds an electric charge, charge the capacitor with a wand and wool, and then discharge it through small neon lamp.

Given two types of metal (copper and zinc nails) and an electrolyte (citric acid in a fruit), students will be able to make a simple battery that produces an electric charge, and see the effects of that charge on an LCD clock that only needs a low current.

Lesson in a Nutshell

1. Battery and Capacitor web quest = http://howtosavetheferrets.weebly.com/
2. Make a simple capacitor from aluminum foil and a plastic dielectric.
3. Charge the capacitor with a wand and wool. See: http://youtu.be/jk6WD-zA5TQ
4. Discharge the capacitor through the neon bulb. See: http://youtu.be/sLKkMPkFWA8
5. Make a simple battery from a lemon and copper and zinc nails.
6. Briefly turn on a low current LCD clock with the battery.

Background

Electrical Concepts

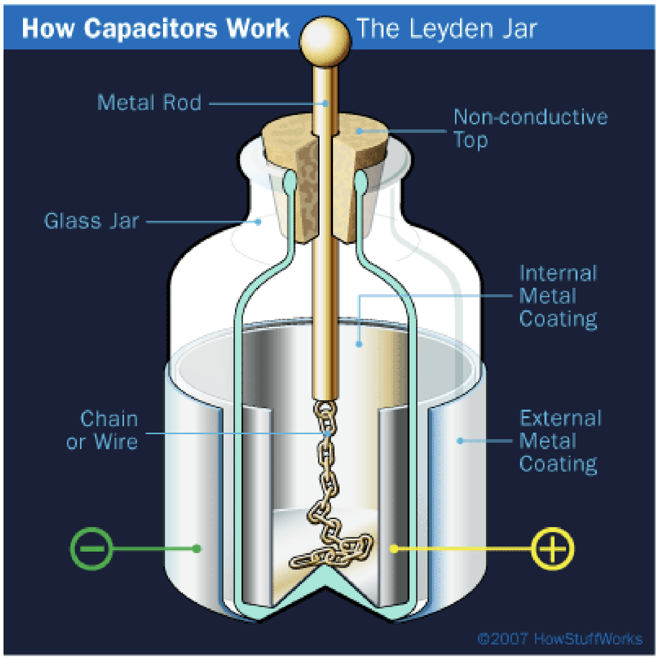
These links could be helpful to you. They provide a little bit more information than what is given in the paragraphs that follow.

http://electronics.howstuffworks.com/capacitor.htm
http://electronics.howstuffworks.com/everyday-tech/battery.htm
Your students will be seeing these websites in their capacitor and battery webquests.

Electricity- An invisible "fluid", something that makes things "go", a shocking "juice", a life "force". What is this thing called electricity? It's all around us, taking so many forms, seemingly filling up wires and batteries, always ready to dash out of the common wall plug, metal door knob, or empty light bulb socket. Don't touch! It's a frightening phenomenon, a fascinating thing to see at work, and a fundamental aspect of nature. It can be created and stored because it's simply the movement of electrons, and electrons are in everything! If you can make electrons move, you have made electricity. If you can capture electrons, they have the potential to move and BE electricity.

History of the Capacitor:

German scientist Ewald Georg von Kleist unknowingly invented the first capacitor in 1745 when he connected a generator by a wire to a glass jar filled with water that he was holding. His hand and the water acted as the conductors and the glass jar as a dielectric. When he removed the generator and touched the wire, Kleist was shocked, literally. This discharge of electricity showed him that charge could be stored on the wire. A short time later, Dutch physicist Pieter van Musschenbroek at the University of Leyden built a similar device that was initially called the first capacitor, since Kleist's records and notoriety was inferior to that of Musschenbroek's. Credit has been equalized since their research was independent and both are now acknowledged. It is Musschenbroek's design, however, that receives the most attention. His device is called the Leyden jar.



The Leyden jar consists of a glass lined on the inside and out with metal foil. The jar is topped with a cork that has a metal chain driven through it that hooks to something that will deliver a charge. Once a wire, or other conductor, touches the outside metal, a slight spark is discharged.

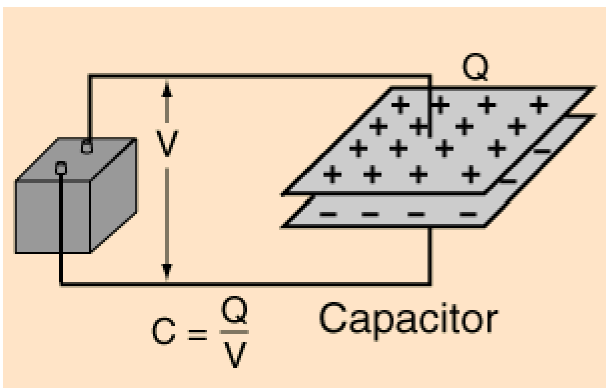
Benjamin Franklin tinkered with this design and discovered that a flat piece of glass worked well also, this became known as the flat capacitor, or Franklin square. Later, Michael Faraday pioneered the first practical applications for the capacitor and made huge advances in their use. As a result of his achievements the unit of measurement for capacitance became known as the farad.

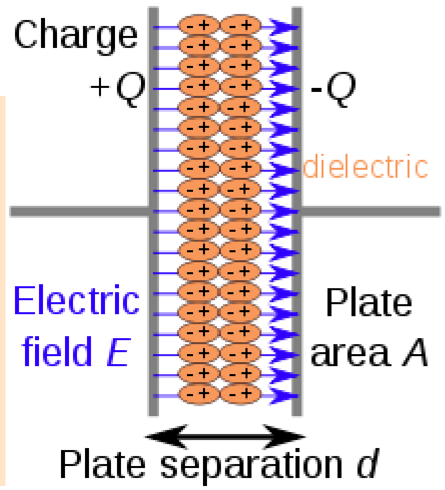
Leyden jar image courtesy of http://electronics.howstuffworks.com/capacitor3.htm.

Capacitors are used in most electrical devices. The most common example of when a capacitor is used is to power a camera's flash. Charge is stored and then rapidly discharged to produce the bright flash of light for pictures. They can also be found in Apple's capacitive touch screens and many other electronics.

How they Work:

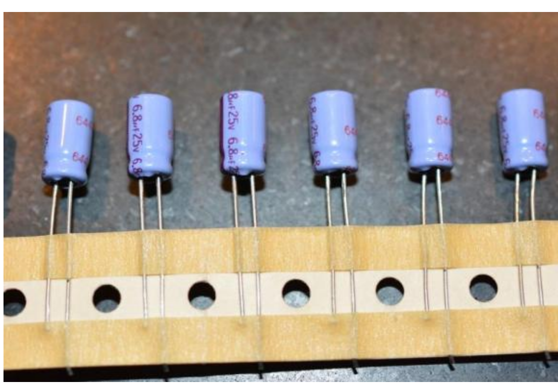
A capacitor contains two pieces of metal, or any conductor, that are separated by a dielectric, which is essentially a polarizable insulator that orients its charge according to surrounding flow but does not have charge flowing through it. Capacitors use the metals to store electrons. The capacitor has an electric charge that attracts and captures electrons.





Images courtesy of http://hyperphysics.phy-astr.gsu.edu/ and https://www.boundless.com/.

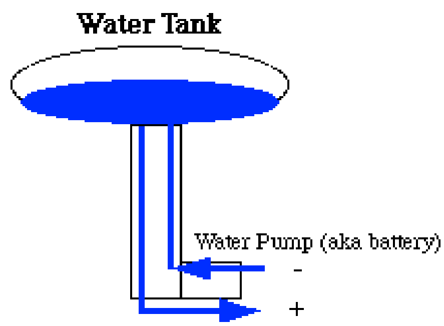
You will find capacitors in all shapes and sizes. Most commonly they look like little cans with two legs. Inside you will find the two plates, just rolled up. Some are small and others are quite large. The markings indicate the voltage they can produce, and the capacitance. These light blue ones pictured are only 6.8 microfarads. See what's inside? Coils of metal separated by a dielectric.



When a capacitor is connected to a voltage source the plate that attaches to the negative terminal accepts electrons that are flowing. The plate that attaches to the positive terminal loses the electrons. Once the capacitor reaches the same voltage as the source, it is done charging. If you have a bulb in series with a battery and capacitor, the light will stay lit until the capacitor is charged. When the battery is removed from the circuit and the capacitor becomes the source, the bulb with relight and stay lit until the capacitor is empty or the voltage decreases low enough that it cannot light the bulb.

Nature's capacitor is clouds. When we see lightning, we are seeing the discharge of electrons from the cloud to the ground. It's as if one conducting "plate" is a layer of clouds, while the other "plate" is the ground. When charges build up, particularly during a storm when clouds are moving past each other, charge builds up. When this charge overflows it is discharged, seen as a huge spark, known as lightning.

You have probably mentioned a water analogy for electricity to your students. Water can be used as an analogy for current flow through wires and circuit elements. The resistor limits flow, which can be thought as a partially clogged pipe. A capacitor is like a water tower. Water gets pumped up into the tower. Some water continues on out the other side of the water tower, but eventually enough excess gets pumped into the tank that it becomes full. When the water supply gets turned off the water in the tank drains out. It should be kept in mind that unlike in this analogy, when a capacitor gets fully charged by a DC source, current stops flowing and when the capacitor is the voltage source in a circuit, the capacitor dumps it's charge quickly. That's because the capacitor pushes on electrons that are already in the wire whereas water might need to flow through empty pipes. There are no empty wires. Wires are always full of electrons, thus, always ready to make electricity when "push comes to shove."



Although capacitors and batteries perform a common function, they are very different. While batteries store potential energy too, it is in the form of chemical potential energy. Chemical reactions have the potential to take place when a circuit is completed with the battery in it transforming chemical potential energy into electrical potential energy. With capacitors, no chemicals react. This makes capacitors more friendly to the environment since they do not contain harmful acids and harmful chemicals.

Water tank image courtesy of http://bnrg.eecs.berkeley.edu.html.

How to build a Basic Capacitor:

Probably the easiest capacitor to build is out of two sheets of aluminum foil and plastic plate. Draw a square on the front and back of the plastic plate (10cm x 10cm is a good size). Take a Q-tip dipped in mineral oil and coat one square. Then apply a piece of aluminum foil the same size. Smooth it out really well so there is no air between the foil and the plate. Air is a poor dielectric but oil and plastic are good dielectrics. Now, turn the plate over and repeat. The foil clings to the oil and you can hold the capacitor by the rim of the plate.

When building capacitors you should take the following equation into consideration. In simple terms, it states that in a parallel plate capacitor, capacitance increases when the area of the plates increases, when the distance between the plates decreases, and when better dielectrics are used.

Parallel Plate Capacitor:

$C = k\,\varepsilon_0 A / d$

Where:

C = capacitance
k is the relative permittivity of the dielectric material between the plates,
$\varepsilon_0 = 8.854 \times 10^{-12}$ F/m is the permittivity of space,
A is the area of the plates (or the overlapping area of the plates), and
d is the distance between the plates.

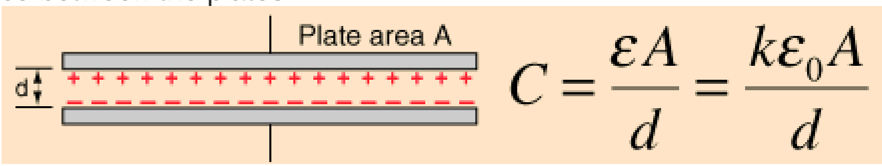


Image courtesy of http://hyperphysics.phy-astr.gsu.edu/hbase/electric/pplate.html.

Some common dielectric materials and their relative permittivity are listed below. The higher the permittivity, the better the material is at being a dielectric. As you can see, air is not a very good dielectric and Neoprene is an excellent one.

Air	about 1
Glass	5.0-10.0
PVC	3.18
Plexiglass	3.4
Teflon	2.1
Polyethylene	2.25
Neoprene	6.7

This video demonstrates other easy ways to build capacitors:
http://www.youtube.com/watch?v=GveI9gXIsHw

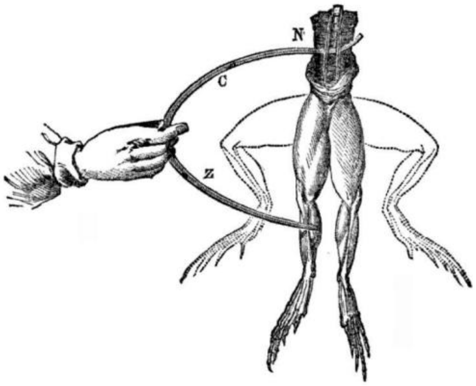
Film Canister Capacitor (3:28)
http://www.youtube.com/watch?v=ZYH9dGl4gUE
*This a very good video to watch all the way through to get more information about capacitors.

Cup with Liquid Capacitor:
http://www.wikihow.com/Build-a-Capacitor

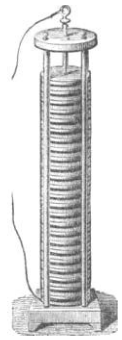
Homemade capacitor on a plastic plate.

History of the Battery:

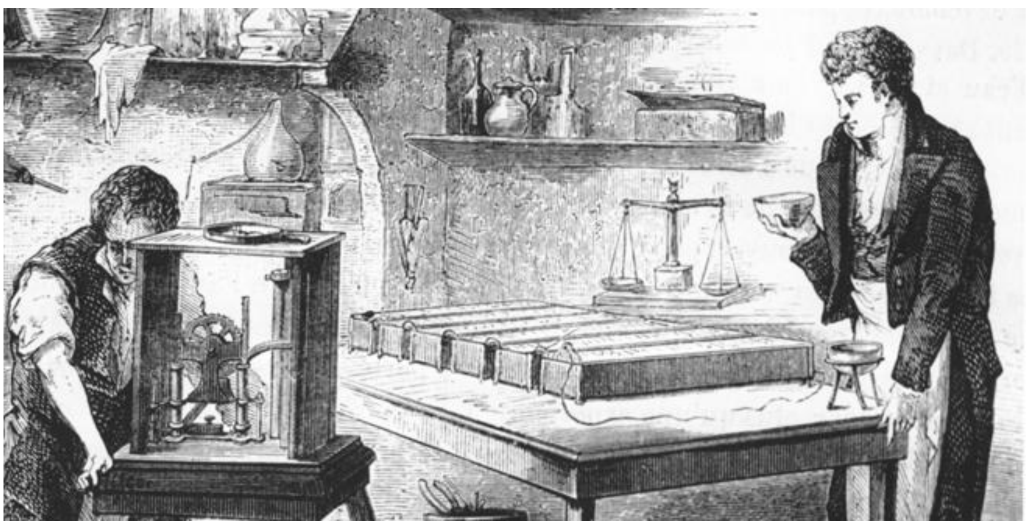
1791 Luigi Galvani: Galvani noticed while he was dissecting some frogs that he could make their legs twitch if he touched them with a metal probe. He thought he was causing the “life force” of the frog to escape, but actually he had the frog on a metal plate, and was touching it with a probe of a different metal. He was in fact creating a frog battery and jolting the poor dead thing with it.



1799 Allasandro Volta: Volta knew about Galvani’s work with frogs, and decided that the two metals were doing something. He put two metals on either side of this tongue and tasted the current flowing between them. Then he decided to use wet salty cardboard instead of his tongue (good idea!) and made a stack of these “cells” with zinc and silver. The whole pile was capable of producing quite a shocking result.

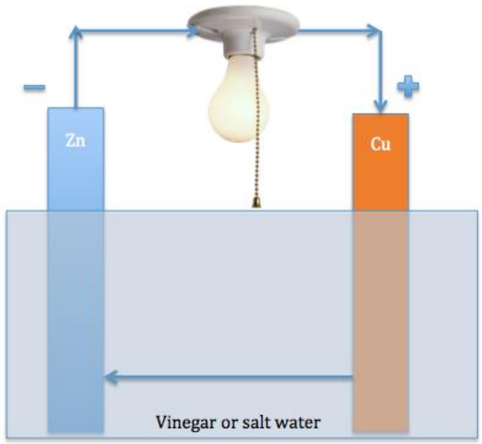


1807 Humphrey Davy: Davy used electricity from the newly invented battery to break apart substances. He figured out that electricity can break water into gases, so tried it on other things too. When he passed a current through molten potash, he obtained pure potassium. When he passed a current through soda, he obtained sodium. He later discovered calcium and other metals.



How they Work:

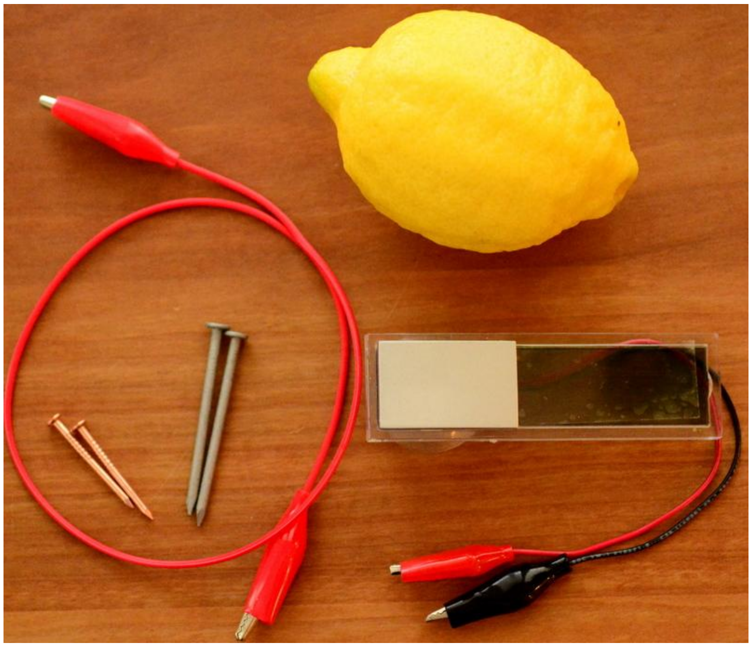
Batteries work because one metal, the anode, releases electrons when in contact with the electrolyte fluid or paste. These electrons can flow into a circuit if there is something to attract them. The other metal in the battery, the cathode, attracts and captures these electrons in another chemical reaction. The captured electrons then are free to move through the battery from the cathode back to the anode. In a simple battery, the anode is zinc and the cathode is copper.



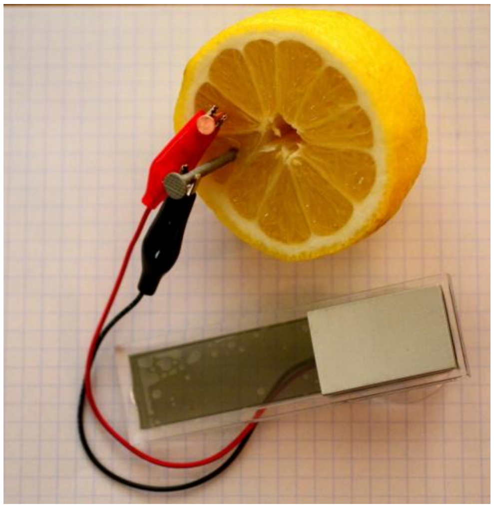
How to build a Basic Battery:

The most simple battery can be made with a penny, a quarter, and your mouth. While I don't recommend this in classrooms, you (the teacher) might want to try it for yourself! Put a clean penny on top of your tongue and a clean quarter underneath it. Close your lips around the "sandwich" and touch the ends of the coins together and taste the zing of electricity flowing through your taste buds.

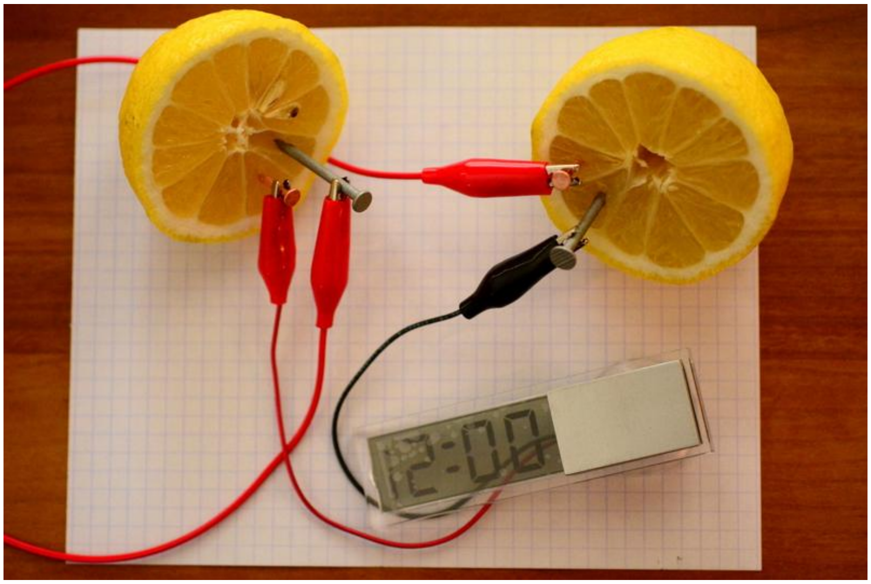
Batteries can be made with any two metals and a replacement tongue. Potatoes, lemons, and other fruits can replace your tongue because they contain electrolytes- elements that electrons can hitch a ride on. Even salty cardboard can be a tongue replacement because salt water contains the electrolytes sodium and chlorine. Metals are easy to find- copper pennies, nickel nickels, copper nails, zinc nails, aluminum foil, and iron nails all make good batteries. The two metals simply need to be different, because one has to give up electrons easily and the other has to accept them easily.



Batteries are made from a stack of “cells.” Each cell contains two metals separated by an electrolyte. If you cut a lemon or other citrus fruit in half, you can make two cells to connect. Stick a copper nail and a zinc nail in one half, and do the same with the other half. Using only one cell, there is not enough electricity to make the LCD clock work.



However, if you connect the two cells in series, the clock works!



Teacher Materials

· Hand held generator
· 1 Farad capacitor with 30 ohms ESR
· LED

Student Materials (for each group)

- ½ sheet poster board
- 1 box colored markers or pencils
- Aluminum foil cut into squares
- Plastic plate to be used as a dielectric
- Mineral oil
- Q-tips
- Neon light bulb
- Plastic PVC pipe for a wand
- Piece of wool fabric
- Lemon or Orange or Lime
- 2 copper nails, two zinc-coated nails
- Wire with alligator clips at each end
- Low current LCD clock

Preparation

1. Review all the teacher content in this curriculum and watch the videos.
2. Prepare the squares of foil.
3. Prepare the wool rags.
4. Cut the fruit in half.
5. Prepare small containers of mineral oil.

SAFETY WARNING:

The capacitors used in these procedures are safe and age appropriate. If you purchase your own 1 Farad capacitors to use, be sure they have internal resistance equivalent to 30 ohms ESR. Do NOT pull capacitors from old electronics to use this this curriculum. Some may not have internal resistance and may be dangerous.

Procedures

1. Have students practice rubbing their plastic wand with a wool rag. Allow them to observe the sound of the crackling static electricity and possibly see sparks. Have them hold the wand near their hair or near bits of paper on the table to see the effects. This works best in low humidity, say on a cold dry day.
2. Have students hold the neon light bulb by one of the electric leads, and touch the wand to the other lead after charging the wand with the wool rag. Have students discuss what they think is going on.
3. Ask students, “How can we save this electricity you are making with the wand and the wool?”
4. Show students a 1F manufactured capacitor and simply say that it is a capacitor and that it can store electricity. Charge it up with a hand held generator, and show students that when it is charged, it will make the generator actually turn, or it can light up an LED bulb.
5. Have students go through the capacitor and battery Webquest: http://howtosavetheferrets.weebly.com/
6.Have students make a simple capacitor with two sheets of aluminum foil and a plastic plate in-between them. Take a plastic plate— hard plastic, thin, not styrofoam— and draw a square in the middle on the front and back. Say the square is 3" x3". Take a Q tip and dip it in a bit of mineral oil. Color in one square with oil (a thin coat!) and then apply a square of aluminum foil that is the same size as the oil. If oil gets on your finger and onto the top of the foil, that's OK. Then, turn the plate over and repeat. You don't have to tape the foil down… it sticks to the oil and when you smooth it out there is no air. Air is a bad dielectric. Put the plate upside down so that it's like a little hill. Charge up the part you see (the foil on the bottom of the plate) 20 times with a piece of pvc pipe and a wool rag or hat or glove or scarf. It will discharge through the neon light very well. However if you want REAL hands-on science, pick up the plate, rest it on your left hand so that your left hand is touching the foil on what is really the top of the plate, and then touch the other side with your index finger. Woah baby! See: http://youtu.be/jk6WD-zA5TQ for a look at how to charge the capacitor. Do this over and over until the capacitor has built up a charge. When you place the neon bulb near the capacitor, it will discharge through it and light up. See: http://youtu.be/sLKkMPkFWA8
7. Next, have students build a simple battery from the fruit and the metal nails and power a clock. To do this, put a copper and zinc nail in each fruit half. Connect the copper from one piece of fruit to the zinc in the other. Connect the clock with the positive lead attached to the free copper nail and the negative lead attached to the free zinc nail.

Extension

Math Connection:

Have students examine the equation to calculate capacitance. What happens to the capacitance when the distance between the plates gets smaller or when the size of the plates increase? What other formulas are like this?

http://formulas.tutorvista.com/physics/capacitance-formula.html

Wrap-Up

Wrap up the lesson with a review of the learning targets. Ask students:

- What is inside a capacitor? (two pieces of metal separated by an insulator)
- How are capacitors used? (to store electrons)
- How could they be used if your house was not connected to the US electrical grid? (to store electrons)
- What does any of this have to do with ferrets?

LESSON 4

Computer Aided Design: Designing and Printing Village Structures

Learning Targets

1. Scientists and engineers create models that represent their ideas.
2. Engineers use computer tools to design systems and things.

Purpose of the Lesson

The purpose of this lesson is to give students practice visualizing 3D shapes flattened out, called geometrical nets, and design and print and assemble these nets into houses. Students will learn that these houses are models of real houses.

Lesson Objectives

At the end of this lesson, students will be able to:

- Modify an existing 2D net into a house with windows and doors.
- Print the 2D net out and fold it into a house.
- Articulate that the house is a model- a representation of a real thing.

Lesson in a Nutshell

1. Have students practice folding nets into objects with these printable items:
   http://www.senteacher.org/worksheet/12/NetsPolyhedra.html
   Here is a handout you can print on cardstock that contains three nets.
2. Show students how to use the Silhouette Studio design software and begin to modify the simple house nets into new shapes.
   Download the house design files here and import them into the Studio design software:
   House 1
   House 2
3. Print out, fold, and save at least 4 houses per group. Encourage students to modify houses.

Background

Concept 1: 3D solid objects can be visualized in 2D, and 2D drawings can be folded into 3D objects.

Concept 2: The 2D representation of a 3D object is called a "net."

Concept 3: A model is a representation of a real idea or object. Models can be drawn or created.

Teacher Materials

- Silhouette Studio online tutorials can be found here: http://www.youtube.com/watch?v=fFuCfKgdk3k&feature=share&list=PL06853E4B16F141C6

Student Materials (for each group)

- ½ sheet poster board
- 1 box colored markers or pencils
- Glue sticks or tape
- Scissors

Preparation

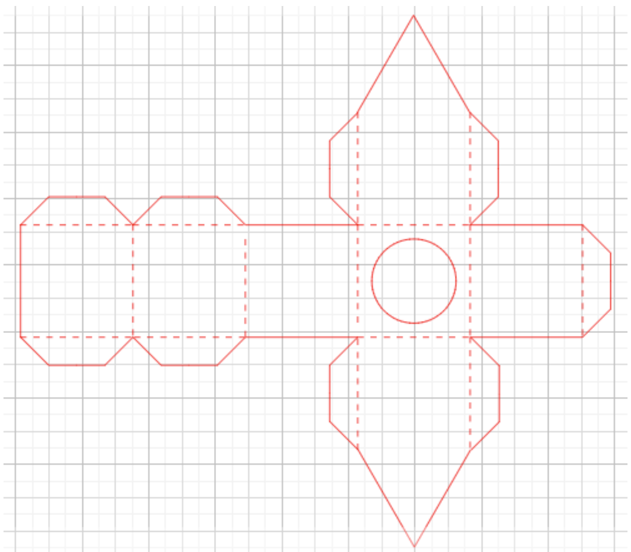
1. Print and copy the 2D geometric figure nets onto card stock.
2. Practice using the Silhouette design software. If you do not own a Silhouette, try to find the free Version 2 online to download. Do not download the free Version 3 from the Silhouette website, as it does not allow perforated lines for folding unless you purchase an upgrade. For now, if you use the older V2 software. Many websites still host it.

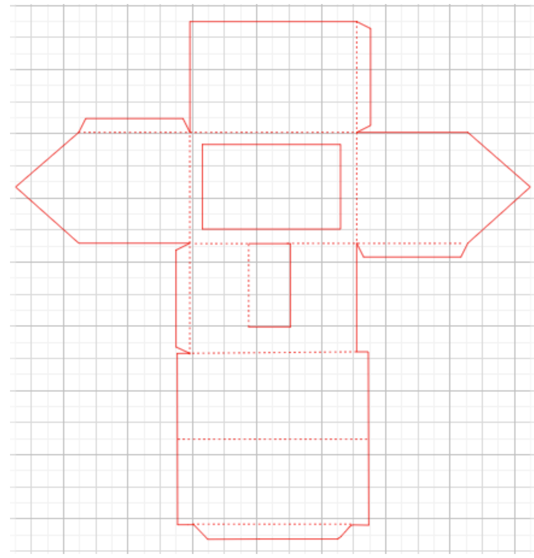
Procedures

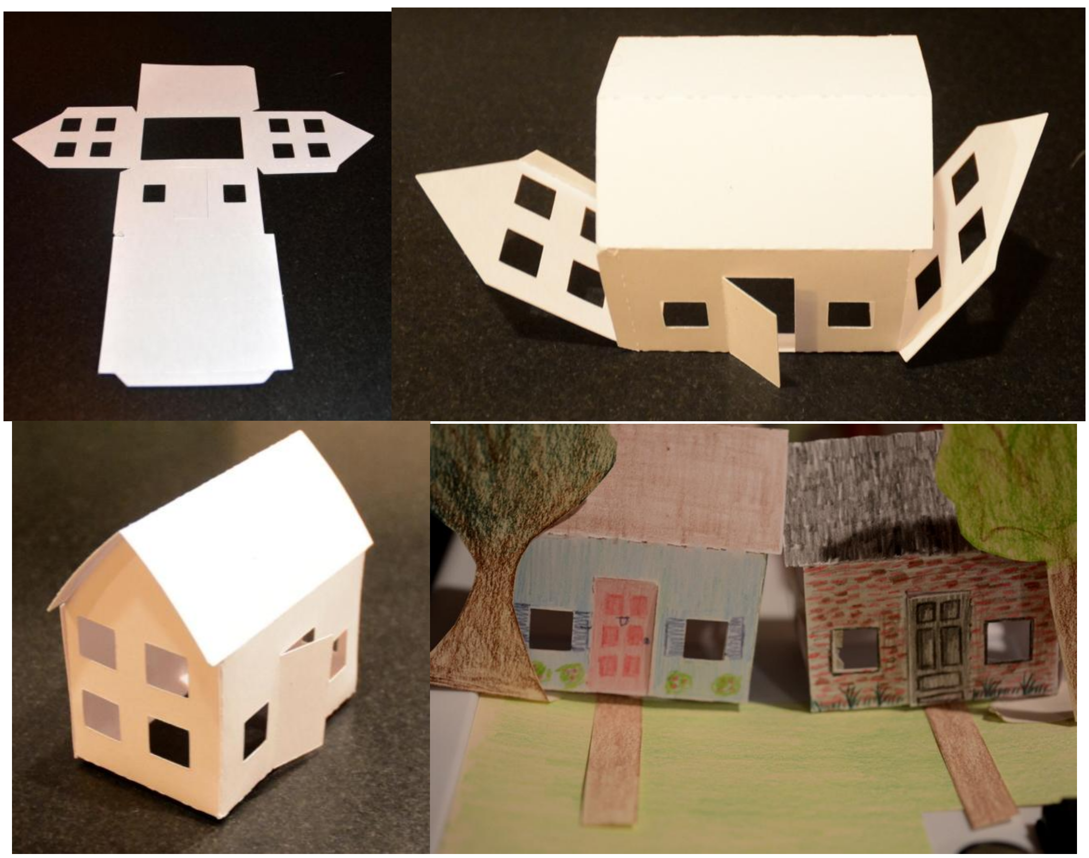
1. Pass out the 2D geometric figure nets and have students try to build 3D objects from them without the benefit of the clear plastic frames in the kit pictured below. Helpful handout.

Image courtesy of http://learnheaps.com.au

2. Ask students to predict what a house would look like if it were a 2D drawn net. Have them draw this prediction on their storyboards.
3. Allow students to use a ruler and pencil on card stock and test their prediction.
4. Introduce students to the Silhouette design software and show them the two basic house designs. Let students watch the four tutorial videos (below) and learn to use the software.







5. Allow students to print out these basic designs (or pre-print them) on card stock, modify and/or decorate them, and cut and fold them into houses.
6. Encourage students to figure out how to design their own houses. If you have the Silhouette Cameo die cutter, students can easily print out designs with more detailed windows and doors. Ferrets are fun to print out and color too. A Silhouette Studio template for these three ferrets can be found here: www.auburn.edu/~cgs0013/ETK/ferret_outlines.studio

The following tutorial videos can be used to introduce students to the software:

How to add windows and make the house smaller: http://screencast.com/t/uRv3zNcFVl
How to add a door: http://screencast.com/t/iGQLkGGx
How to make shapes and modify them: http://screencast.com/t/U0fn2vjbwmpl
How to move, duplicate, mirror, scale, and weld: http://screencast.com/t/5EQAwcGAy6k

Extension

Math Connection:
Webquest made by Andrea Schnittka: www.auburn.edu/~cgs0013/ETK/NetWebquest.doc

Wrap-Up

Wrap up the lesson with a review of the learning targets. Ask students:

- What is a net?
- What does the net of a cube look like?
- What does the net of a cone look like?
- What does any of this have to do with ferrets?

LESSON 5

It Takes a Village: Getting a Village off the Grid

Learning Targets

1. Scientific knowledge can be used in the design, construction, and evaluation of a device.
2. Engineering is an iterative process of designing, testing, re-designing, and re-testing.
3. Engineers must document their process of design and present their solution to the problem.

Purpose of the Lesson

The purpose of this lesson is to have students design a town that is "off the grid" and powered by a capacitor that stores electricity generated from sun, wind, or motion.

Lesson Objectives

At the end of this lesson, students will be able to:

- Create a parallel circuit using jumper wires and LEDs to light up a town.
- Charge a capacitor with wind, solar, and mechanical energy.
- Attach houses and decorate their town.

Lesson in a Nutshell

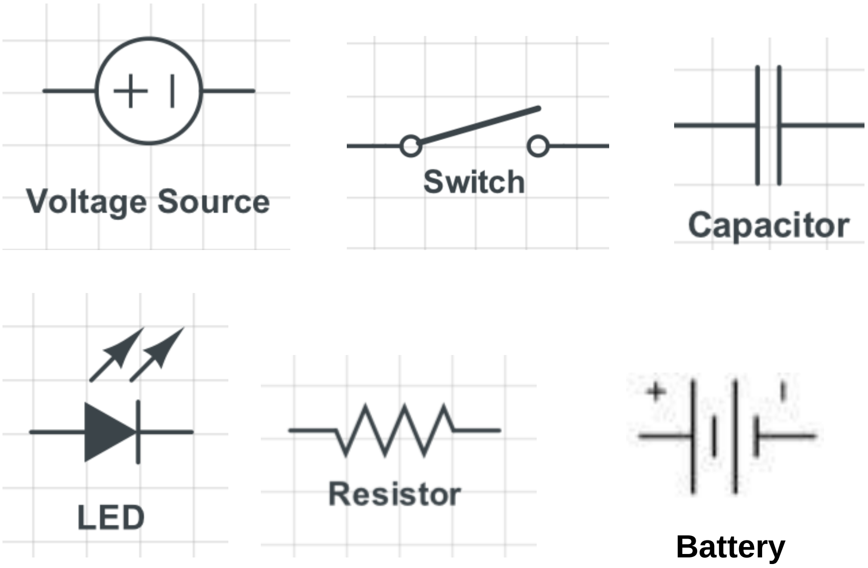
1. Plan out a town.
2. Use push pin to create holes for LEDs.
3. Insert LEDs and use jumper wires to connect them in parallel to the capacitor.
4. Attach houses to the town and decorate the town.
5. Charge up the capacitor with solar, wind, and/or mechanical energy
6. Light up your town!
7. Take post test.

Background

Electrical Symbols and Drawing Circuits:

When students begin thinking about how to design their town, you should suggest that they draw an outline of their circuit on their storyboard.

They will need to know the symbols for the parts of their circuit:



Light Emitting Diodes (LEDs)

LEDs only work when wired correctly. The electricity can only pass through one way. If you look closely at an LED you will see that one wire is longer than the other, and that one side of the dome has a little flattened section around the rim. These are clues for you to share with your students. To learn more about LEDs, read this Wikipedia page:
http://en.wikipedia.org/wiki/Light-emitting_diode
The side with the flattened section on the LED is the negative side. It must be connected to the negative side of the power source. The longer lead is positive. Connect the longer lead to the positive side of the power source.

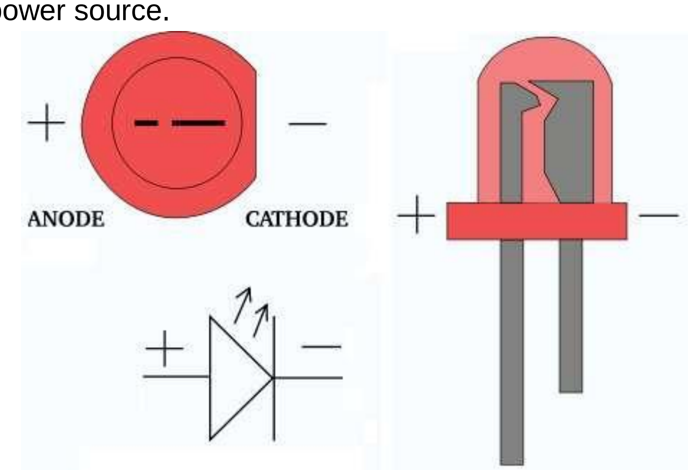


Image from http://makezine.com/2012/02/22/ask-make-modding-vacuum-tubes-with-leds/

Linking This All Together

Through building a self-sufficient town, students will realize that as people expand we can easily get what we need without taking more space away from other animals. We do not need to build large power plants and expansive wire grids anymore. It is not only the black footed ferret that is negatively affected from habitat loss and conversion, but almost every other endangered species such as: tigers in India; pandas in China; and lions, elephants, and gorillas in Africa. If people can learn to utilize the space they occupy in the most efficient manner using renewable natural resources, we can not only increase space needed for other species but create a healthier world.

Teacher Materials

- Charging station with a 5V solar panel with leads, a wind generator with a blow dryer, and a hand crank generator.

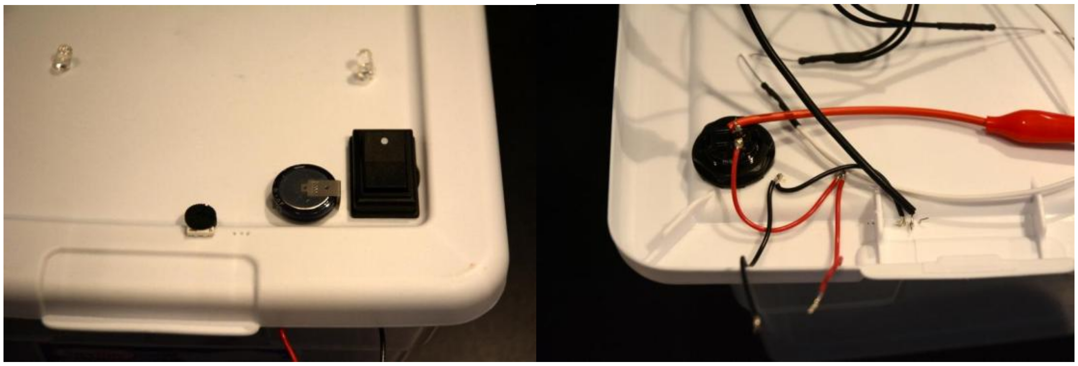
Student Materials (for each group)

- ½ sheet poster board
- 1 box colored markers or pencils
- Box lid with 1F capacitor and switch mounted.
- 2 eight-node jumper chain cables (see Appendix A for purchasing source)
- 10 LEDs in various colors
- Push pin
- Tape
- Houses made during previous lesson.

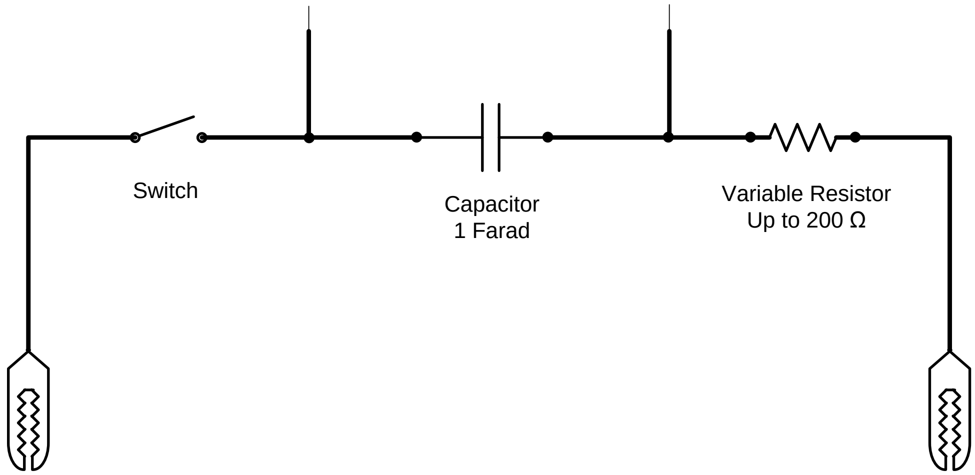
Preparation

1. Photocopy the Circuits Post-Test for students.

2. Prepare box lids with capacitors, variable resistors, and switches. Use push pins and a soldering iron to secure and wire everything. You can drill holes in the box lid for the black and red wires to extend.

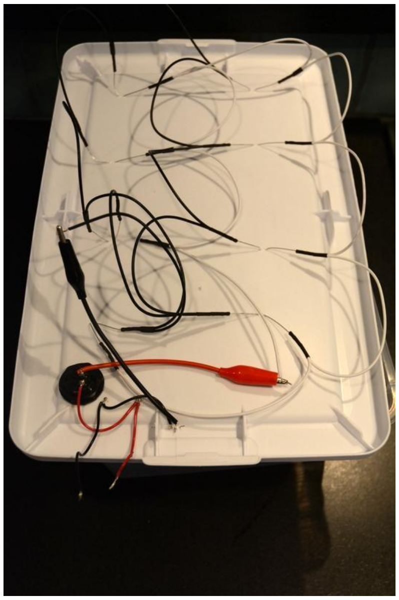


The circuit diagram for wiring these three components is as follows:

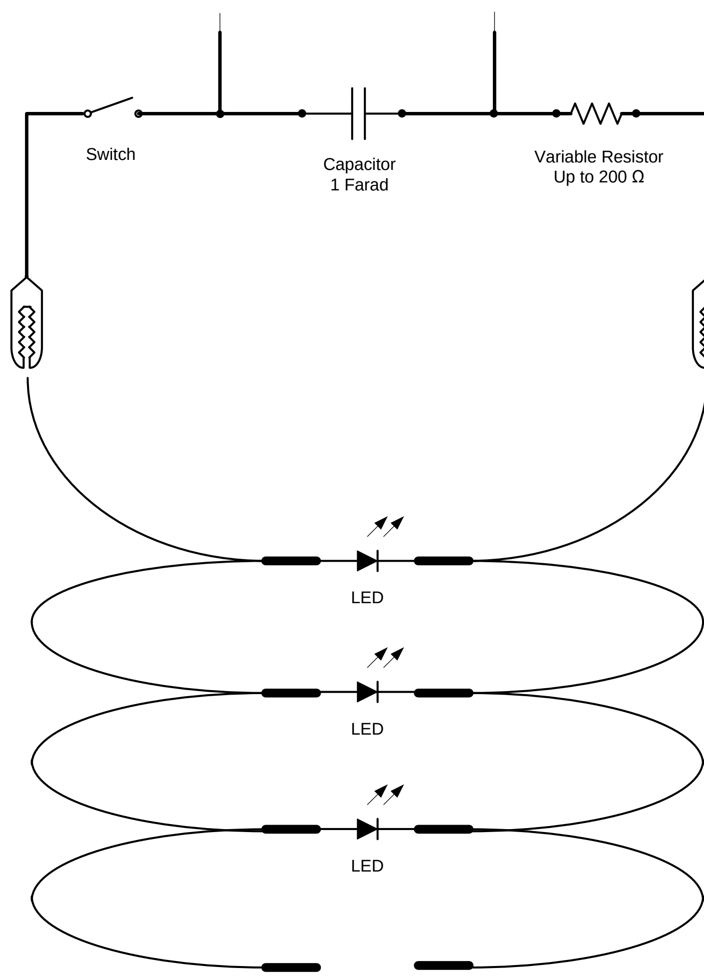


Procedures

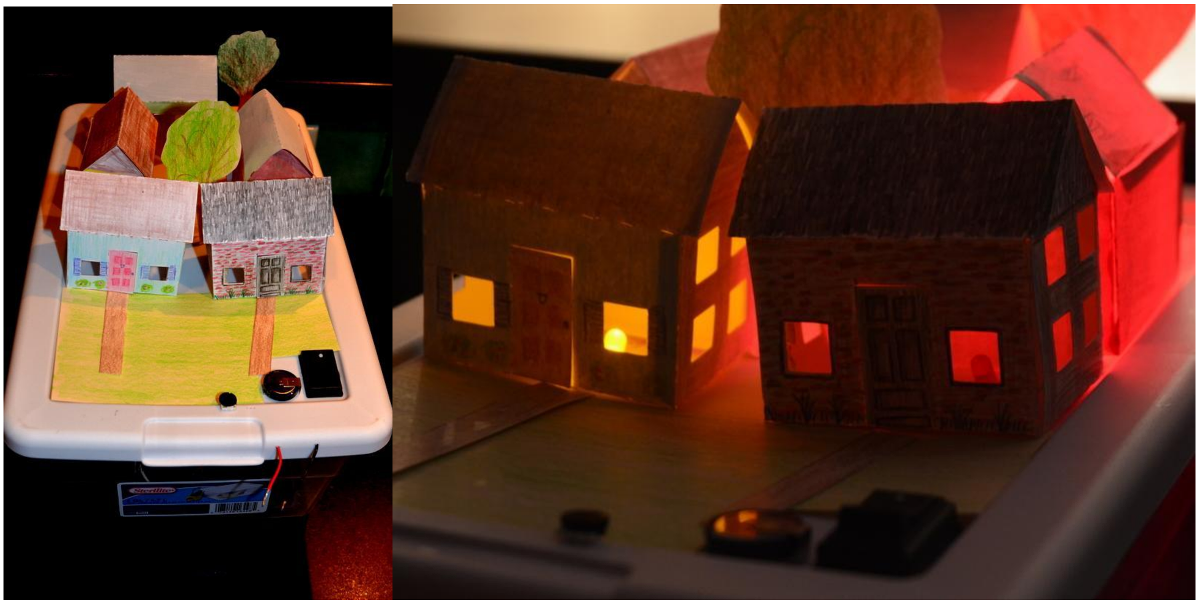
1. Pass out box lids and have students design the layout of their town.
2. Students use push pin to create holes for LED leads. Be sure to punch two holes per LED (one for each wire).
3. Students insert LEDs and then wire them in parallel on the underside of the box lid with the jumper cables that simply push on to the LED wires.



A possible schematic is as follows, with jumper cables connecting the LEDs in parallel.



4. Students tape their houses onto the LEDs on to top of the box lid so that the lights glow through windows in the house when lit.



5. Students charge their capacitor and **then disconnect the power source**. Disconnect the hand-crank generator RIGHT AWAY. Keeping it connected for a split second drains the capacitor! Since one minute in real life = one hour in Ferretville time, 2 minutes of solar cell use = 2 hours of sunshine, 2 minutes with the blowdryer = 2 hours of wind blowing, and 1 minute cranking the hand generator = 1 hour of riding a stationary bicycle . Decide how to parse out “time” to the students. Perhaps the sun shines for 3 hours, the wind blows for 2 hours, and the “power plant supervisor” rides a stationary bicycle for one hour.

6. Students light up their towns and see how long the town stays lit up. The potentiometer (variable resistor) can be used to dim the lights and allow them to last longer. The goal is to light up the town for six hours at night in Ferretville, so six minutes in the classroom.

Extension

Math Connection:

Which method of charging the capacitor takes the least amount of time? Which uses the most energy from our own electrical grid (the hair dryer, the lamp)? A 500W hair dryer uses 500 Joules of energy each second and a 100W light bulb uses 100 Joules of energy each second. The mechanical energy required to turn the generator = Force (N) x Distance (m), so if you calculate the circumference of the circle your hand pushes through, and use a spring scale to determine the force necessary to move the handle, you can determine how much energy was used because a Joule = 1 Newton x 1 meter.

Wrap-Up

Wrap up the lesson with a review of the learning targets. Ask students:

- Do you think cities can truly go “off the grid”? Can one single house? Can a school?
- What is the most effective way to accomplish the goal of producing electricity locally and without pollution?
- What does any of this have to do with ferrets?

APPENDIX A

MATERIALS AND SUPPLIES

The materials listed below will supply one teacher with four classes of students- approximately 112 students. Some materials will be left over for future classes. Most materials can be purchased from a grocery store, hardware store, craft store, or large shopping mart. The entire kit can also be purchased from www.stemteachingkits.com
Suggested sites are provided below.

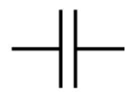
Item	Amount per class	Amount for 4 classes	Where to buy
Posterboard	One per group, so 7	28	Office Supply Store
Conductive Dough	One 3 oz. container per group, so 7 per class	7 (can be re-used for each class)	Super Store
9V Batteries	One per group in a class, so 7	7 (can be reused for each class)	Office Supply Store
9V Battery connectors	One per group in a class, so 7	7 (can be reused for each class)	Radio Shack
Low current LEDs (rated at 1mA)	10 per group, so 70 per class	280 for four classes	Radio Shack
Heavy Duty Aluminum	6x6" sheets (2 per group, so 14)	56	Grocery Store
Plastic plate	1 per group, so 7	28	Hardware Store
Neon bulbs	One per group in a class, so 7	7 (can be reused for each class)	scientificsonline.com Item #3081446
Copper nails	2 per group, 14 per class	14 (can be re-used for each class)	Hardware Store
Zinc-plated (galvanized) nails	2 per group, 14 per class	14 (can be re-used for each class)	Hardware Store
Citrus fruit	7	7 (can be re-used for each class)	Grocery store
Cardstock	60 per class	250 sheets	Office Supply Store
10" long 0.75 OD PVC pipe	One per group in a class, so 7	7 (can be reused for each class)	Hardware store
Wool socks or Wool fabric swatch	One per group in a class, so 7	7 (can be reused for each class)	Fabric store

1 Farad Capacitor with 30 ohms ESR	One for a teacher demo and 28 for the box lids.	29	arborsci.com Part # P6-8012
Hand crank generator	2 per teacher	2	arborsci.com Part # P6-2631
Wire with alligator clips at each end	1 per group, so 7 per class	7 (can be re-used for each class)	Radio Shack
Clear tape	One per group in a class, so 7	7 (can be reused for each class)	Office Supply Store
Big Push Pins	One per group in a class, so 7	7 (can be reused for each class)	Office Supply Store
Clear plastic shoe boxes	7 per class	28 for four classes	Hardware Store
Switches	7 per class	28 for four classes	Radio Shack
Variable resistors	7 per class	28 for four classes	Radio Shack
Eight-node jumper chain cables	2 per group, 14 per class	56 for four classes	Amazon.com Part # OSEPP CONT-01 (cut into 3x 8-node jumper chains)
Blow dryer	1 per teacher	1	Super store
5V solar panels (need to solder wires to them)	2 per teacher	2	dx.com Part # 17441
Wind generator	1 per teacher	1	mount a model airplane propeller to a motor with wires
Clamp light with 150W bulb	1 per teacher	1	Hardware store
LCD Clocks	One per group in a class, so 7	7 (can be reused for each class)	Remove from a potato/lemon clock kit
Mineral oil	One small bottle	One small bottle	Drug Store
Q-tips	7 per class	28 per teacher	Drug Store

Appendix B

ASSESSMENT ON ELECTRICAL CIRCUITS

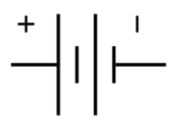
- This questionnaire is about your understandings of electricity.
- For each question, circle the answer that is closest to your understanding.
- Be sure to read all the choices before selecting one.

1. Why do you think the symbol for a capacitor looks like this? 

A. It's a signal like the Morse code, but with a series of dashes and spikes of electricity
B. It's a symbol for a cup with no bottom, which holds an infinite capacity
C. A capacitor contains markings, lines which run around the circumference
D. A capacitor contains two metal plates separated by something

2. If all the houses in a town were wired in series and your neighbor turned off all his lights, what would happen to your lights?

A. They would glow brighter
B. They would go dimmer
C. They would turn off
D. Nothing would happen to my lights

3. Why do you think the symbol for a battery looks like this? 

A. It produces a signal with alternating spikes of high voltage and low voltage
B. It's the universal symbol for a weapon, which can result in the crime of "battery"
C. A battery can be made from layers of different types of metal
D. A battery contains four parallel plates separated by air

4. What do capacitors store?

A. Protons
B. Electrons
C. Neutrons
D. Neutrinos

5. What is the primary difference between capacitors and batteries?

A. Capacitors store energy but batteries transform energy
B. Capacitors generate energy but batteries transform energy
C. Capacitors hold more energy than batteries do
D. Capacitors hold less energy than batteries do

6. Why does a battery have an electrical charge?

A. It was charged up at the battery manufacturing plant
B. It creates electrons which can move
C. It creates protons which can move
D. A chemical reaction inside it can push electrons in a circuit

7. Why do batteries eventually stop working?

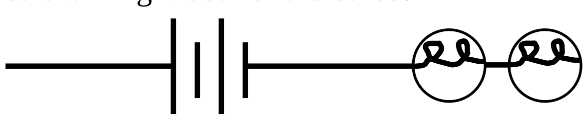
A. They run out of electricity
B. The chemical reaction stops happening
C. They have emitted all of their electrons
D. They have passed their expiration date

8. Electricity happens when electrons ____________.

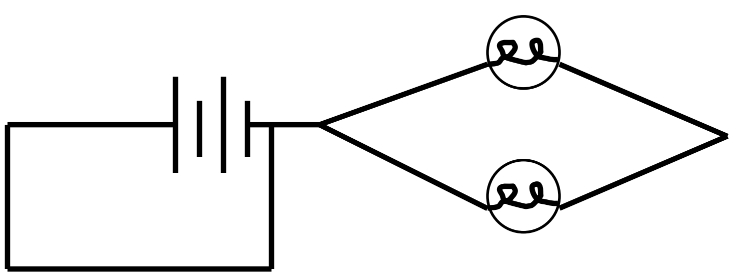
A. disappear
B. are attracted to each other
C. change form
D. move

9. Which circuit will light both of the bulbs?

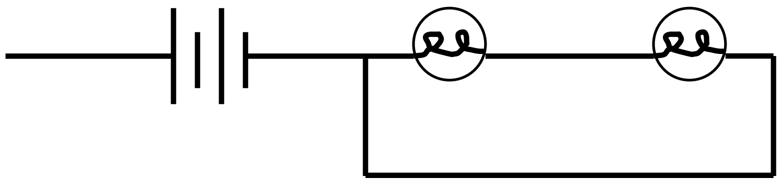
A.



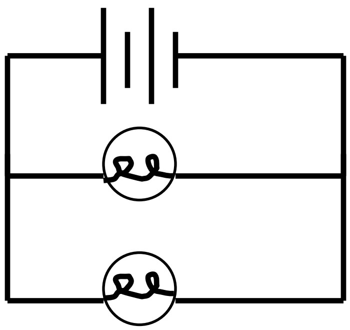
B.



C.



D.



10. What makes a capacitor able to store more energy?

A. More surface area on each plate
B. More distance between each plate
C. A longer series of dashes and electrical spikes
D. A better conductor separating the critical parts