UDL Teacher Guide: Intermediate Electricity

"I shall make electricity so cheap that only the rich will be able to afford to burn candles."
— Thomas A. Edison

Driving Question: What is electricity?

This unit explores how electricity is moved around and transformed into other forms of energy.

Introduction

Using the UDL approach, students explore electricity in multiple ways: from a fictional story to data collection with probes, and from hands-on inquiry experiments to testing variables using computer models. Data collection, which uses probeware, is displayed using smart graphs, allowing students to dissect elements of the graph for greater reflection and deeper understanding. Students are provided with scaffolded assistance to questions and offered choices for demonstrating what they have learned through text or drawings. Coaches offer prompts to engage students in the science content.

Each activity includes a discovery question to help students refine their understanding as they progress through the unit. They are:

- What are positive and negative numbers?
- How do electric charges behave?
- How do you design a circuit that will light up several bulbs?
- What kinds of energy does a bulb produce?
- How can you make and store electricity?

The discovery questions are located at the top of each page of the activity, so students can refer to them often. Point them out occasionally if students need reminding about the focus of the activity.

Technology

The technology used in the UDL approach is designed for students to discover the story told by the data as they investigate electricity. Using an inquiry approach, students use temperature and voltage probes in "Light and heat" and "Crank up the lights" to gather data on the temperature of a light bulb and monitor the voltage levels in batteries. Students use a Genecon, a hand-crank generator, to generate electricity and a capacitor for storage of the charge in "Crank up the lights."

The technology in UDL does not supplant the teacher. Instead, students are individually supported throughout the unit. One example of this support is that students can highlight the text and the computer will vocalize the words. Definitions for highlighted words (in blue) are also built into the program. A complete glossary for the unit can be found at the bottom each page using the book icon. In some of the units you will also find three robot helpers. These robots help the student understand the material by asking them to make predictions, asking guided questions, and by clarifying or predicting what will happen next.

The teacher can manage certain features of the units for both the class and individual students. Once a class is set up the teacher can go to the UDL Portal-Info page and click on the "View a report on this class" icon. At the top of the report page there are two options, one that allows you to configure the parameters for students. This allows you to control the font size and set the initial scaffolding level for students. The option on the class report page allows you to enable/disable activities within the units.

The default setting for lesson order when setting up your classes will be a sequenced order of lessons. When students enter the menu page they will complete the Pre-test. When they have submitted the Pre-test they will be able to access the next lesson in the sequence. If you want to allow students to choose their own sequence you can set up your class so that once they have completed the Pre-test and Introduction they can move between lessons in whatever order they like. (A more detailed explanation can be found at http://udl.concord.org/share/teacher-guides/Dashboard.pdf)

Scaffolding in UDL Units

Scaffolding in education has traditionally been done by the teacher as a way to assist students as they are learning new skills or content. The scaffolding is done not to provide answers or do the work for them but as a way for the students to gain confidence and develop understanding of skills and concepts. The goal of scaffolding is that over time the level of assistance that a student needs will gradually be reduced until the minimal amount of support is needed and used. To use a cooking analogy: a chef will use a recipe the first few times he makes a dish. After he has made it several times, he may have the recipe out for reference and then after more time, it becomes so natural he no longer needs the recipe.

In the UDL units different levels of support are offered to students when answering questions. As with the cooking analogy, the scaffolding is intended to provide support for those students who need it with the goal that with time they will be able to work with minimal scaffolding. When scaffolding prompts are available they are accessed by clicking on the green question mark icon. Students may answer the open-ended question as presented. Or, if they are unable to do so, they can click on the question mark and access the first level of support. At this level they are given a hint that may lead them to the correct response. If the student is still unable to answer the question, they can click the question mark again for the answer with key words left out and they can fill in the blanks. If they need additional help, they receive a multiple-choice list. The final level of scaffolding offers the student a model response; they are given the answer and asked to provide their own ideas about the response.

Standards/Benchmarks

NSES Content Standard A: Science as Inquiry (grades 5-8)

- Abilities necessary to do scientific inquiry.
    - Identify questions that can be answered through scientific investigation.
    - Design and conduct a scientific investigation.
    - Use appropriate tools and techniques to gather, analyze, and interpret data.
    - Develop descriptions, explanations, predictions, and models using evidence.
    - Think critically and logically to make the relationships between evidence and explanations.
- Understand about scientific inquiry.
    - Mathematics is important in all aspects of scientific inquiry.

- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.

NSES Content Standard B: Physical Science

- Light, Heat, Electricity, and Magnetism (grades K-4)
  - Electricity in circuits can produce light, heat, sound, and magnetic effects. Electrical circuits require a complete loop through which an electrical current can pass.
- Transfer of Energy (grades 5-8)
  - Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.
  - Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

Benchmarks for Science Literacy (AAAS)

- The Physical Setting
  - Energy can be transferred from one system to another (or from a system to its environment) in different ways: 1) thermally, when a warmer object is in contact with a cooler one; 2) mechanically, when two objects push or pull on each other over a distance; 3) electrically, when an electrical source such as a battery or generator is connected in a complete circuit to an electrical device; or 4) by electromagnetic waves. 4E/M2
  - Electrical circuits require a complete loop through which an electrical current can pass. 4G/M4
- The Designed World
  - Electrical energy can be generated from a variety of energy resources and can be transformed into almost any other form of energy. Electric circuits are used to distribute energy quickly and conveniently to distant locations. 8C/M4
- The Mathematical World
  - A number line can be extended on the other side of zero to represent *negative numbers*. Negative numbers allow subtraction of a bigger number from a smaller number to make sense, and are often used when something can be measured on either side of some reference point (time, ground level, temperature, budget)

Alaska state standards (http://udl.concord.org/share/teacher-guides/TG_Electricity-Intermediate-AK-Standards.pdf)

California state standards (http://udl.concord.org/share/teacher-guides/TG_Electricity-Intermediate-CA-Standards.pdf)

Learning Goals

To work, electric devices need a **circuit**, which is a conducting loop that allows the electric charges to flow in a continuous circle. Electric **current** is the motion of charges (electrons) through a circuit.

Conductors (mostly metals) allow the flow of electric charge. **Insulators** (e.g., wood, paper, ceramics, plastics, stone) do not allow the flow of charges.

Batteries store electrical energy as chemical energy. Batteries can push electric charges through a circuit, transferring the electrical energy from the battery to the device in the circuit, such as a light bulb. **Voltage** measures the "push" of charges through a circuit.

Capacitors also store electrical energy. They collect positive and negative charges on two plates. When the capacitor is put into a circuit, the charges flow through the circuit, transferring energy.

A **generator** changes mechanical energy (e.g., turning a crank) into electrical energy.

When energy is transferred, there is always some loss of energy in the form of heat. For example, incandescent light bulbs make light by heating up a wire so much that it glows. More of the energy turns into heat than turns into light.

The wire in a light bulb, called a **filament**, is heated when electric charges (electrons) are pushed through the wire and bump into the atoms in the wire.

Voltage in batteries is added together when the batteries are lined up with the same orientation. If the orientation is reversed, the voltage is subtracted.

Rubbing certain things together, like a balloon and wool, transfers some charge from one to the other, so that they become oppositely charged. The charges are transferred, but not created.

Background Information and Misconceptions

Electricity is an abstract phenomenon that students interact with everyday. Many students do not fully understand the requirement of a complete circuit or even what electricity is in the first place. Common misconceptions abound. The following information is fundamental to understanding electricity and debunking misconceptions.

1. **What is electricity?**

   Electricity is a manufactured product. It is not something you pump out of the ground or mine or collect from the sun or wind. Electric power is manufactured from a rotating machine called an electrical generator. After it is generated or manufactured, electricity is delivered through copper wires to locations where it is utilized by various electronic gadgets (i.e., radios, light bulbs, etc).

   Electricity is a flow of electrons. These flowing electrons come from atoms, specifically the electron cloud that surrounds the nucleus of the atom. Usually the number of positive charges (the protons) equals the number of negative charges (the electrons). When the balancing force between protons and electrons is upset by an outside force, an atom may gain or lose an electron. When an atom “loses” an electron, the free movement of these “lost” electrons makes up an electric current.

2. **Do batteries have electricity inside them?**

   No. The electric current found in copper wires is not generated by the batteries connected to them. Batteries, like generators, do no create electrons – they merely pump the “lost” electrons from the metal wires through the circuit. In copper wire, copper atoms supply the “lost” electrons. These electrons were already there, even before the copper was mined and made into wires!

3. **Why do batteries "go dead"?**

   Batteries are chemically powered charged pumps. They contain "fuel" in the form of chemicals (these chemicals are usually metals in the form of metal plates). When the chemical fuel becomes exhausted, the battery has "gone dead." No chemicals ever leave the battery, so what happens to the fuel? It turns into waste products.

   If you have a rechargeable battery, then you can "recycle" the waste products. By pumping charges backwards through the battery, you force the chemical waste to turn back into fuel. This is a bit like pumping some exhaust into your car engine, and having gasoline come out the other end! The chemical reactions inside of rechargeable batteries are REVERSIBLE, while the burning of gasoline is not.

4. **What is the difference between voltage and current?**

   Voltage is sort of like electrical pressure. A current is a flow of electric charge.

   Think of it like this: voltage CAUSES electric current, just like water pressure causes water to flow. You can have a voltage without a current: a battery is sitting on a shelf, it is creating a voltage between its terminals, but there is no current. It's like a force without a motion. It's like an inflated balloon without any leaks.

   You can also have a current without a voltage: a ring of a "Superconductor" can contain a loop of flowing charge that flows inside it forever. It's like frictionless motion (with no force needed to keep it going). It's like a flywheel that keeps spinning forever.

   Whenever you have a voltage, you also have an electric field. Whenever you have an electric current, you also have a magnetic field.

5. **How do light bulbs light up?**

   The filament inside a light bulb is much thinner than the wires that lead up to the bulb. Electrical charges flow slowly in thick wires and faster in thin wires, like the filament. Charges experience a kind of "electrical friction," and when they flow faster, they create more heat. This friction heats up the filament. This same kind of "friction" heats up all wires, but the charges flow slowly in thick wires, so heating is usually not enough to even notice.

   This is even true for toasters and electric heaters. In these cases, heating isn't enough to make the wires glow WHITE HOT like a light bulb filament. Instead they just glow red or orange.

6. **Why do light bulbs go dead?**

   Electrical current flows quickly through the bulb's filament, a long, thin double-coiled tungsten wire. This "electrical friction" creates heat (about 4,000 degrees) and causes the tungsten atoms to release extra energy in the form of photons (light). At these temperatures, some tungsten atoms fly off and collect on the inside of the bulb's glass. This process is slowed, but not stopped, by adding argon or nitrogen to the inside of the bulb. In fact, some of the atoms rebound so vigorously off the glass wall that they hit the filament and are rejoined with the metal! However, eventually, as more and more atoms are lost, the filament disintegrates.

The filament is further damaged when the light bulb is turned on and off, due to the rapid heating and cooling of the tungsten wire. Eventually the stress, coupled with the loss of tungsten atoms, weakens the filament enough to cause it to break. And the bulb stops producing light.

Common Electricity Misconceptions: Operation Physics, American Institute of Physics: William J. Beaty, HV/Electrostatics specialist, lecturer, Sci. Exhibit Designer, Textbook Consultant, Amateur Physicist http://amasci.com/ele-edu.html

Concannon, James P., Brown, Patrick L. & Parejan, Enrique M. (2007). Tried and True: Making the connection—Addressing students' misconceptions of circuits. *Science Scope*, NSTA.

Unit Overview

Activity	Time	Materials	Overview
Pre-test	10-20 minutes	• Computer with Internet access	A short pre-test allows students to preview unit concepts. Prior knowledge can be identified.
Introduction	20 minutes	• Computer with Internet access	Students give two examples of forms of energy that can produce electrical energy and consider ways electricity moves.
Electrical Birthday Party	2 to 3 45-minute sessions	• Computer with Internet access • Printout of story (optional) (http://udl.concord.org/share/teacher-guides/Electricity_56_birthday-story_v3.pdf)	Students read and summarize a story. Margaret makes a discovery about static electricity. With the help of Elvira, a friend of Chen's family, she and Chen learn about static electricity and how it works.
Plus and Minus	60 minutes	• Computer with Internet access • Plus and Minus Game (http://udl.concord.org/artwork/elect_34/plus_minus_game/el_34_plus_minus_game.pdf)	Students explore the mathematics of combining positive and negative numbers.
Charged Balloons	40-60 minutes	• Two balloons • String • Scissors • Wool sweater or shirt • Computer with Internet access	Students use balloons, fabric, and a computer model to investigate static electricity.
Light It Up	1 to 2 45-minute sessions	• Computer with Internet access	Students use a computer model to investigate the flow of electricity through a wire (variables to manipulate: voltage and resistance) and basic circuits to light a bulb

			(parallel and series).
Light and Heat **Safety goggles should be worn.**	1 to 2 45-minute sessions	• Computer with Internet access • Temperature sensor, fast response • Holiday light • Battery (AA or AAA 1.5V) • Clear tape • Aluminum foil (a small piece – 2 to 3 cm square) • Paper binder clip • Extra wire	Students investigate the energy (heat and light) given off by a burning light bulb. Efficiency and resistance are addressed as students design a circuit to light the bulb.
Crank up the Lights **Safety goggles should be worn.**	1 to 2 45-minute sessions	• Computer with Internet access • Genecon hand generator • Voltage sensor • Tokin capacitor • AA 1.5 volt battery • Holiday light	Students use hand generators and capacitors to make and store electricity. They test their generation of electricity by timing how long a light bulb will remain lit.
Wrapping Up	Ongoing	• Computer with Internet access	Students can visit and revisit "Wrapping Up" during their completion of the unit activities. In Wrapping Up they have the opportunity to review and clarify their thinking.
Post-test	20 minutes	• Computer with Internet access	Students complete the post-test, which contains the same set of question as the pre-test, as well as student feedback questions.

Unit Activities

Pre-test

Time: 20 minutes

Materials: computer with Internet access

This unit begins with a short pre-test. The pre-test allows students to share what they already know about the learning goals. Students must complete the pre-test and press "Submit" button before proceeding to any of the activities. The post-test at the end of the unit contains the same set of questions.

Once the pre-test is submitted, students cannot go back to change their responses.

Introduction

Time: 30-40 minutes

Materials: computer with Internet access

The driving question, “What is electricity?” is introduced. Students explore how energy is moved and transformed into other forms of energy.

Electrical Birthday Party — *Story*

In this activity students read and summarize a story that introduces static electric charges and how they can change.

Time: two to three 45-minute sessions

Standards/Benchmarks:

NSES Content Standard A: Science as Inquiry (grades 5-8)

- Abilities necessary to do scientific inquiry.
  - Identify questions that can be answered through scientific investigation.
  - Design and conduct a scientific investigation.
  - Use appropriate tools and techniques to gather, analyze, and interpret data.
  - Develop descriptions, explanations, predictions, and models using evidence.
  - Think critically and logically to make the relationships between evidence and explanations.

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California state standards (http://udl.concord.org/share/teacher-guides/TG_Electricity-Intermediate-CA-Standards.pdf)

Materials: computer with Internet access (or you can print a PDF version)

Student Activity:

While reading the story of Chen’s birthday party students are introduced to some initial concepts and vocabulary they will use in the unit. The story tells how Margaret discovers static electricity and some of the properties of electricity. She rubs some of the party balloons on her wool sweater and discovers that they are then **attracted** to the sweaters, but that they **repel** each other. Elvira uses a special magnifying glass that allows the children to see the charges on the balloons and sweater and explains that electrical charges can be positive or negative. When the charges are the same on an object, they repel each other; when they are different, they attract each other. At the end of Chapters 1, 6, and 7, students are asked to respond to a question about the story.

Scaffolding is available using the “robot” helpers, which provide prompts to help students understand the story.

Plus and Minus — *Math*

Discovery Question: What are positive and negative numbers?

In this activity students explore the mathematics of combining positive and negative numbers.

Time: 60 minutes plus additional time to reinforce concepts

Standards/Benchmarks:

NSES Content Standard A: Science as Inquiry (grades 5-8)

- Understand about scientific inquiry.
    - Mathematics is important in all aspects of scientific inquiry.

Benchmarks for Science Literacy (AAAS)

- The Mathematical World
    - A number line can be extended on the other side of zero to represent *negative numbers*. Negative numbers allow subtraction of a bigger number from a smaller number to make sense, and are often used when something can be measured on either side of some reference point (time, ground level, temperature, budget)

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Materials:

- copy of “Plus and Minus” game sheet (PDF)
- scissors
- computer with Internet access

Student Activity:

Teacher Notes:

In this activity students look at positive and negative charges. All materials have charges and when the number of positive or negative charges is out of balance, these charges will move so that the overall charge of the material is balanced for a net charge of zero. Sometimes, though, materials will have either extra positive or negative charges, in which case their net charge will be either positive (> 0) or negative (< 0).

When thinking about combining positive and negative numbers it is important to help students understand a couple of key ideas. The first is that when you add negative numbers (charges), these charges will latch on to any extra positive charges in the material. If there are more negative charges being added than there are positive, the result will be a net negative result.
Example:
3 + (-2) = 1
3 + (-5) = -2

If the material starts with a net negative charge and you subtract some of those negative charges you move closer to zero.

Example:
-5 – (-3) = -2

Or if you subtract more negative charges than you started with, you will end up with a net positive charge.

Example:
-5 – (-7) = 2

It is important prior to, during, and after doing this activity to help students visualize what is happening. The concepts may come easily to some students while others will need more support to understand them.

Engage:
Chen and Maria are arguing about which is greater: -6 or -3. An introduction to the number line with both positive and negative numbers allows them to begin visualizing how the numbers are arranged.

Explore:
Students use the "Plus and Minus" game sheet to explore combining positive and negative numbers. Students will need various amounts of support while working through this investigation.

Explain:
Students make connections by explaining how subtracting a positive number will result in the same result as adding a negative number. Again students will need various amounts of support during this part of the investigation.

Elaborate:
Students are given an example of a charged piece of metal and are asked to use what they discovered about charges to find the total charge of the piece of metal.

Charged Balloons ***Hands-on & Computer model***

Discovery Question: How do electric charges behave?

Students use a balloon and a piece of wool, plus a computer simulation to explore static electric charges.

Time: 40-60 minutes

Standards/Benchmarks:

NSES Content Standard A: Science as Inquiry (grades 5-8)

- Abilities necessary to do scientific inquiry.
    - Ask a question about objects, organisms, and events in the environment.
    - Plan and conduct a simple investigation.
    - Employ simple equipment and tools to gather data and extend the senses.
    - Use data to construct a reasonable explanation.
    - Communicate investigations and explanations.
- Understandings about scientific inquiry.

Benchmarks for Science Literacy (AAAS)

- 4G Forces of Nature
    - Without touching them, material that has been electrically charged pulls on all other materials and may either push (repel) or pull (attract) other charged materials. (3-5)
    - A charged object can be charged in one of two ways, which we call either positively charged or negatively charged. Two objects that are charged in the same manner exert a force of repulsion (repel) on each other, while oppositely charged objects exert a force of attraction on each other. (6-8) (Atlas of Science Literacy; Volume 2)

Materials:

- Two balloons
- String
- Scissors
- Wool sweater or shirt
- Computer with Internet access

Student Activity:

Engage:
All materials have electric charges; students begin to explore these charges. Students read a short explanation of how these charges can be moved from one material to another. Students then use a computer simulation to model these charges by placing charges on a sweater and balloon in a computer simulation. Several questions ask students to think about how charges impact the overall charge of a material.

Explore:
Students change the overall charge of each balloon and investigate what happens. They begin by blowing up the balloon and tying each to a length of string. They then rub the balloons on their hair and record their observations. They also try rubbing the balloons on a piece of wool and record how the balloons react to each other.

Explain:
Having observed what happens to the balloons students answer a series of questions to help them solidify their understanding of the static charges they observed.

Elaborate:
Students use the results from rubbing balloons on wool and the behavior that changing the overall charges causes and a computer simulation to model the movement of charges. First with one balloon and then two, students move the charges on the models and observe how the balloons react.

Elaborate:
Now that students have explored static charges, they are asked to use their understanding in a new situation. They must explain what happens when they rub their feet on the carpet or get out of a car with cloth seats. Then they are asked to model their balloon-hair investigation.

Teacher Notes:
In the investigation "Plus and Minus" the math that is involved in finding the net charge produced is introduced. Students learn about adding and subtracting negative numbers.

Discussion:
Lead the whole class in a discussion using the questions below to start the conversation. Allow students time to clarify their ideas and encourage them to explain their thinking.

"When you touch someone and they get a shock what is causing that to happen?"

"What can you do to create a charge so that you can shock someone? Do some materials give up their charges better than others?"

Light It Up — *Computer model*

Discovery Question: How do you design a circuit that will light up several bulbs?

In this activity, students use a computer model to build a circuit to light two holiday lights with a battery, learning the difference between parallel and series circuits.

Time: one to two 45-minute sessions

Standards:

NSES Content Standard B: Physical Science

- Light, Heat, Electricity, and Magnetism (grades K-4)
    - Electricity in circuits can produce light, heat, sound, and magnetic effects. Electrical circuits require a complete loop through which an electrical current can pass.

- Transfer of Energy (grades 5-8)
    - Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

Benchmarks for Science Literacy (AAAS)

- Electrical circuits require a complete loop through which an electrical current can pass. 4G/M4

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Materials: computer with Internet access

Student Activity:

Engage:
Students use the drawing tools to create a circuit using a single battery that would light a bulb. They take a snapshot for their lab book. Encourage students to use the text feature to label their diagram.

Explore:
The Circuit Construction Kit (PhET) is introduced. Students are first challenged to design and test a one bulb/one battery circuit and measure the voltage between any two points in the circuit. Remind students to take snapshots of their circuit by using the “take a snapshot” button. This puts the snapshot in their lab book. Students are asked to describe how they made their circuit work. This inquiry continues as students are challenged to construct a circuit that will light two bulbs with one battery


Quick Check for Understanding:

- How did students complete the challenge?
- How did they find the voltage of the battery – and could they get the value to change?
- Did anyone use a switch or a resistor – what did they find out when they used these devices?

Note: Students will often find a way to design the circuit to not only light the bulb, but that also ignites the batteries.

Explain:
Students are given information on two kinds of circuits, series and parallel, and are asked to discuss what kind of circuit they used in the last computer model.

Elaborate:
Using the Circuit Construction Kit (the PhET model), students are asked to construct parallel and series circuits to light two bulbs with one battery. They test each circuit to see if they had

correctly identified the circuits by removing one light. Using evidence, students predict the circuitry in their homes.

Quick Check for Understanding: How can students turn on the microwave, recharge their phone and turn off the bathroom room light – without having the microwave stop heating their nachos – while all the time their refrigerator is running?

Teacher Notes:

Once students begin the inquiry, they will come up with a variety of creative solutions to the challenge. Showing others their solutions – and their creativity – adds to the excitement. Students enjoy using the model to make their bulb shine the brightest or to ignite batteries. This is a great opportunity to discuss lab safety with students. Battery and bulb labs usually end with hot wires and scorched fingers – this is a safe and fun way to explore these concepts.

Encourage students to include a switch in their models. This allows the student to "turn on" their circuit. The voltage of the battery can be displayed in the model by right-clicking on the battery. The student can change voltage by right-clicking on the battery and selecting "Change Voltage." This is also true for the resistor. To split the junction and redesign the circuit, students simply right-click on the connection and tap the "delete" key on the keyboard.

Light and Heat — *Hands-on (temperature sensor)*

Discovery Question: What kinds of energy does a bulb produce?

In this activity, students measure the temperature of a holiday light using a temperature sensor.

Time: one to two 45-minute sessions

Standards:

NSES Content Standard B: Physical Science

- Transfer of Energy (grades 5-8)
  - Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.
  - Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

Benchmarks for Science Literacy (AAAS)

- Electrical energy can be generated from a variety of energy resources and can be transformed into almost any other form of energy. Electric circuits are used to distribute energy quickly and conveniently to distant locations. 8C/M4

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Advance Preparation:
If necessary, use a wire cutter to evenly separate the holiday lights. Students use the wire to create their circuit (bulb, battery and wire) and the longer the wire, the easier it is to work with. Make sure to strip the very end of the wire to expose the copper wiring of the holiday lights. If a light has a third wire, the ground wire, it is easily untwisted it and removed.

Any holiday light set (small twinkle lights) will work for this unit. The color of the bulb appears not to influence the temperature readings. However, this would be a great extension for students to investigate.

Batteries (AA or AAA) can be reclaimed from disposable cameras that are sent in for developing. These cameras are usually free for the taking and still contain a useful battery. Use caution when removing the battery. Safety goggles, screwdriver and work gloves are suggested. Use care – an electric shock can be generated when trying to remove the battery.

The foil will need to be cut to a useable size. A square, approximately 1”x1” works fine. It does not have to be exact, just big enough for wrapping around the light. A quick foil twist at the top of the holiday light allows the foil to keep its shape, while allowing for easy removal and clean up.

Safety: Safety goggles should always be worn when working with glass and heat.

Materials:

- Temperature sensor, fast response
- Holiday light
- Battery (AA or AAA 1.5V)
- Clear tape
- Aluminum foil (a small piece, approximately 1 inch square)
- Paper binder clip
- Extra wire (The leads on the holiday light may not be long enough to connect to two batteries.)
- Computer with Internet access

Student Activity:

Engage:
Students are asked to make a prediction about the energy given off by a light bulb, and its efficiency.

Explore:
Given materials, students record the temperature of a lit holiday light using a temperature sensor. The setup for the experimental is detailed step-by-step for the student. Caution the students to use a minimal amount of tape – just enough to hold the sensor in place. Data is automatically recorded in the temperature sensor graph. Students need to record data for 10

and 30 seconds; however, they do not need access to a clock with a second hand. Instead students could use the graph's x-axis as a timer, watching the graph as the sensor records data.

Quick Check for Understanding:

- On chart paper, have students record the amount (in degrees) the bulb heated up in 10 and 30 seconds.
    - Was there much variation in the class data? If so, what could account for the variation?
    - How could we change the protocol to get more standardized results?

- Is there any relationship between the amount of heat gained and the time spent recording the data? (Did the 30 second test result in 3x the amount of heat energy produced?) Explain your thinking.

Explain:
After wrapping a holiday light with foil, students attach the temperature sensor with tape. Temperature data is recorded during a 30-second test of a lit bulb and 30-second test of an unlit bulb. Attention is focused on the filament of the holiday light. (If a colored bulb is used, it could be difficult to see the color of the filament as it incandesces.)

Quick Check for Understanding:

- How did your test results vary?
    - Can any pattern be seen?
    - How can you explain your results?
- During the long summer days in Alaska, newcomers often put foil on their windows to block out the midnight sun. (It's hard to sleep when it's 11 pm and the sun hasn't yet set!) In addition to blocking the sunlight, how else might the room be affected by the foiled window?
- Do you think it would matter if the foil was put on shiny side out or shiny side in?

Elaborate:
Students are asked to think about the light bulb in terms of efficiency – as both a light emitter and a heat source. They set up the investigation again this time using two batteries. Using this new data they are asked to discuss the level of light production as it compares to heat production?

Quick Check for Understanding: Before students run the test, predict and explain which experimental design will yield the greater increase in heat production.

Quick Check for Understanding: Realizing the difference in efficiency between fluorescent and incandescent bulbs, under what circumstances might an incandescent bulb be a good choice? (When would you want the heat as well as the light?)

Teacher Notes:
For easier cleanup, remind students to use minimal foil and tape. Used tape, foil and burned out holiday lights can be disposed of in the trash. Spent batteries should always be disposed of in a hazardous materials container. If in doubt, consult your school administration or waste management provider.

Crank Up the Lights — *Hands-on (voltage sensor)*

Discovery Question: How can you make and store electricity?

Working in teams of two, students use hand generators and capacitors to make and store electricity.

Time: one to two 45-minute sessions

Standards:

NSES Content Standard A: Science as Inquiry (grades 5-8)

- Abilities necessary to do scientific inquiry.
  - Design and conduct a scientific investigation.
  - Use appropriate tools and techniques to gather, analyze, and interpret data.
  - Develop descriptions, explanations, predictions, and models using evidence.
  - Think critically and logically to make the relationships between evidence and explanations.

NSES Content Standard B: Physical Science

- Transfer of Energy (grades 5-8)
  - Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

Benchmarks for Science Literacy (AAAS)

- Electrical energy can be generated from a variety of energy resources and can be transformed into almost any other form of energy. Electric circuits are used to distribute energy quickly and conveniently to distant locations. 8C/M4

Alaska state standards (http://udl.concord.org/share/teacher-guides/TG_Electricity-Intermediate-AK-Standards.pdf)

California state standards (http://udl.concord.org/share/teacher-guides/TG_Electricity-Intermediate-CA-Standards.pdf)

Materials:

- Computer with Internet access
- Genecon hand generator
- Voltage sensor
- Tokin capacitor
- AA 1.5 volt battery
- Holiday light

Safety: Safety goggles should always be worn when working with glass.

Advance Preparation:
This activity works best in two-person teams. Remind students to switch off jobs – cranking the Genecon and materials/design management.

The handheld generator, a Genecon, is an engaging tool for the students. However, remind students to crank the generator slowly or they will burn out the light bulb. (See Background Information question #6.) Test that each light bulb works before handing it out; just construct a simple battery/wire/bulb circuit. In fact, students could test the light themselves! Make sure you have enough holiday lights separated from the string, with wire ends striped, ready for use.

Engage:
Students are asked to think about the impact of electrical power in their lives and its sources. Students are asked to list as many sources of electrical power as they can. Remind students to think carefully; this question isn't asking what items use electrical power.

Explore:
Students investigate the Genecon using simple systems. First, the Genecon/light bulb system is explored by connecting it to a holiday light. Students are asked if it was easier to crank the generator when it was/wasn't connected to the holiday light. Exploration continues as students change the system by connecting two Genecons together and removing the bulb, creating a generator/motor system. Adding a capacitor allows students to investigate storing electrical charges. Finally, students disconnect the Genecon and investigate the capacitor/light bulb system.

Quick Check for Understanding:

- How is a battery like/unlike a capacitor?
- Did anyone burn out their bulb? How did they do this – and what could they do to not have this happen again? (Add a resistor to the circuit. See Background Information question #6.)
- In any of the Genecon systems investigated, what was an "ah-ha" moment?

Explain:
Using a computer model for drawing, students graphically communicate their understandings of how a capacitor stores electrical energy. Remind students to label their drawings by adding text boxes.

Elaborate:
Students continue to investigate the Genecon/light bulb system by adding the voltage sensor. Technical hints regarding how to set up this system are given. A graphical comparison showing the voltages used by the light bulb from the capacitor and a battery help students to deepen their understanding of a capacitor and a battery. Given a drawing of a Genecon hand generator attached to a capacitor, students identify where mechanical energy is created and where electrical energy is transported and stored. Students are asked to identify where chemical energy is stored, where electrical energy is transported, and where heat and light are produced in a battery/bulb system.

Quick Check for Understanding:

- How did the light bulb respond when connected to the capacitor, the generator and the battery?
- What was similar and what was different?
- How can these be explained?
- Why is the term mechanical energy used in the Genecon system and not in the battery system?
- What is the same/different in how each system operates?
- How would the comparison of the systems change if the Genecon were attached to a light bulb instead of a capacitor?

Wrapping Up

Driving Question: What is electricity?

Time: Ongoing

Materials: computer with Internet access

Having completed the activities in this unit, students review what they have learned about electricity and respond to the discovery question for each activity with text, drawings, snapshots, or data they have collected. Students can revisit any activity except the pre-test. When students are ready, they need to input a password to unlock the test.

The password is: **electricity**

Post-test

Time: 20 minutes


Materials: computer with Internet access

In the post-test students have an opportunity to rethink their answers to the same set of questions as the pre-test. Once the post-test has been unlocked, students will not be able to revisit any previous activities.

Note: When the students finish the post-test, a box comes up saying they have finished and should tell the teacher. At that moment, their data is *not yet saved*. They must close the unit for the data to be saved. The student cannot just walk away. Students can close the unit by going to the File menu and selecting Exit or by simply clicking the red circle (upper left).

Additional Resources

Vocabulary

Atom: the smallest bit a piece of matter that can still retain its properties. Several atoms joined together are called molecules.

Battery: a device that produces electrical energy to provide power for cars, radios, etc. by converting chemical energy into electrical energy.

Bulb or light bulb: a rounded glass container with a thin thread of metal inside that produces light (and heat) when an electric current goes through it.

Capacitor: a device that collects and stores electricity, and is an important part of electronic equipment such as televisions and radios.

Charge: a basic property of the tiny particles that make up matter. Particles can have positive, negative, or no charge.

Circuit: a conducting loop that allows the electric charges to flow in a continuous circle.

Computer model: a computer program that attempts to simulate an abstract model of a particular system.

Conductor: a material or object that allows an electrical current to flow easily through it.

Device: a piece of equipment that is designed to perform a specific function.

Electricity: a form of energy, produced in various ways, which provides power to devices that create light, heat, sound, etc.

Fluorescent bulb: an electric bulb that is coated with a fluorescent material on the interior surface and contains mercury vapor. When bombarded by electrical current the mercury vapor provides ultraviolet light, causing the material to emit visible light.

Filament: a thin flexible threadlike object. In a bulb, the material is usually tungsten, a conductor, and is made to glow when an electrical current is passed through it.

Heat: the energy associated with the random motions of the molecules or atoms that make up all matter.

Incandescent bulb (also called a light bulb)**:** an electric bulb, one in which a filament gives off light when heated to incandescence by an electric charge. An incandescent bulb is based on a glowing metallic filament (often tungsten) that is enclosed within a thin glass shell filled with an inert gas, such as nitrogen.

Junction: where something is joined to something else. In circuits, a junction is a place where dissimilar metals make contact.

Ohms: a unit of electrical resistance.

Parallel circuit: a circuit in which charges can flow through each bulb along a separate path. Parallel means “side by side.”

Resistor: a device that slows the flow of electrical current in a circuit. A resistor is used in an electric circuit for protection, operation, or current control.

Series circuit: a circuit in which charges flow through first one and then the other bulb along the same path. Series means “one after another.”

Snapshot: a casual photograph typically made by an amateur with a small camera. A snapshot can also be an impression of something brief or transitory.

Switch: a device for making, breaking, or changing the connections in an electrical circuit.

Voltage: electric potential or potential difference expressed in volts. An electromotive force or potential difference expressed in volts. Voltage should be more correctly called “potential difference.” It is actually the electron-moving force in electricity, called electromotive force and the potential difference is responsible for the pushing and pulling of electrons or electric current through a circuit.

Watts: a unit of power.

Wire: metal in the form of a usually very flexible thread or slender rod. A single, usually cylindrical, elongated string of drawn metal, used to carry electricity and telecommunications signals.

