Yale National Initiative
to strengthen teaching in public schools®

Curriculum Units by Fellows of the National Initiative
2016 Volume IV: Energy Sciences

Get Charged Up: The Past, Present and Future of Electricity

Curriculum Unit 16.04.09, published September 2016
by Valerie Schwarz

> "Energy is the single most important challenge facing humanity today."
>
> Rick Smalley, Nobel Laureate to the U.S. Senate, April 2004

Overview

Based on Rick Smalley's testimony, it is vital that students understand that our varied sources of energy also come with costs to the environment. There are many environmental concerns regarding the future of energy. A huge concern is carbon emission leading to climate change and the rising sea level. This curriculum unit focuses on electricity and will include an overview of various types of energy, the value of historical contributions, fundamental principles of electricity, magnetism, and fuel cells. I want students to make the connection to their world and their future.

I teach at Mary Munford Elementary School in Richmond, Virginia. It serves students in grades K-5. Most of the students come from the west end of the city and are from middle-class families. However, students from all parts of the city are allowed to apply to attend if there is space. The demographics of Munford are about 20% minority students, mostly African-American with some Hispanic and Asian students. About 9% qualify for free and reduced lunch.

Objectives

Virginia State standard 4.6 requires that I teach my students about electricity. More specifically, the standard includes: historical contributions of Michael Faraday, Ben Franklin, and Thomas Edison; batteries; electric circuits; static electricity, electromagnets; and Faraday's Law, creating electricity by moving a magnetic field.

My students are highly engaged in this topic because it is new to them, it offers many hands-on opportunities, and the children just get excited when they can make a motor run. I plan to take my students not only deeper into the history of electricity, but also to develop a rich understanding of how electricity works. It is my goal to dig deeper into the biographies and inventions of Edison, Faraday, and Franklin, so my students can appreciate their humble beginnings, brilliance, and contribution to our modern society. The students will build batteries, a simple motor, a generator, and create a fuel cell and ignite their curiosity.

Rationale

Originally, I wanted to create a unit about electricity to deepen my knowledge about the content that I am required to teach to my students. However, my thoughts have changed after reading, researching, and participating in Gary Brudvig's seminar. Of course, I want to deepen my knowledge, but I now have a more in-depth understanding of energy science. I realize that teaching my students how to make circuits in isolation is a limited approach. I want my students to have a richer sense of this topic. They need to know where electricity comes from, and I do not mean the wall socket or a battery. They need to know electricity comes from fossil fuels and renewable energy sources. I want them to know that some forms of energy are better for the environment, and others are more harmful. Some forms of energy are more economic to produce, and some are more viable than others.

The curriculum unit I create will focus on electricity and magnetism, but it will provide a basic foundation to get my fourth grade students thinking about some of the issues surrounding the increasing demand for energy and the effects it has on the environment.

Historical Background

Michael Faraday

My students need to know that Michael Faraday is known as the Father of Electricity because he invented the electric motor. This simple fact about Faraday does not do him justice. In fact, on June 21, 2016, the Royal Institution's collection of Faraday's laboratory notebooks were inscribed into the UNESCO UK Memory of the World Register which gave special recognition and reminds us of Faraday's important work and its relevance to world culture.

Faraday hailed from a poor family and "grew up with much hardship and little schooling."[1] Faraday began experimenting with electricity and magnetism as a young boy. He had to save money to buy several jars, which he would use to make a Leyden jar and an electric generator. In 1813, he began working at the Royal Institution of Great Britain.

He worked for Sir Humphrey Davy, and helped to develop a lamp for coal miners that did not have a flame.[2] This was important because if there were gas in the coalmine, the flame would cause an explosion.

By 1819, just six years after beginning at the Royal Institution, "Faraday had a reputation as the leading chemist."[3] During the 1830's Faraday again began to focus his attention on electromagnetism, and in 1831 he discovered that magnetism could produce electricity. A few days after determining that ordinary magnets could create a permanent electric current, he invented the dynamo.[4] A dynamo, essentially, is a generator that uses DC current. Faraday's dynamo was the precursor to other dynamos and to the generator

In the late 1830's, Faraday's health began to decline. His illness affected his memory. He died in 1861. During his time, "he made the Royal Institution into one of the palaces for science."[5]

Benjamin Franklin

Benjamin Franklin was one of 17 children and had nine older brothers. He was born in 1706 in Boston, Massachusetts. Franklin only attended school for two years. Then he worked in his brother's soap-making shop. After two years he became an apprentice in his brother's printing shop. Ben Franklin worked here for nine years.[6]

Franklin is famous for flying a kite with a metal key attached during a lightning storm. However, most of my fourth grade students would not know that he was quite a scientist and also a politician. Franklin conducted many experiments. Additionally, he invented bifocal glasses, the lightning rod, and the Franklin stove, which put more heat into a room. He was the first person to speak of positive and negative with electricity. He studied oceans and currents.[7]

In 1748, Franklin took up science. He had some important ideas about science. One was that pure scientific research could be useful to gain knowledge. He took this to heart as he conducted many standard experiments to increase his knowledge.[8] Franklin also described what is known today as the "Principle of conservation of charge." He said, "You cannot create or make electrical fluid. You could only move or transfer it from place to place thereby producing electrical effects."[9] In 1751, Franklin published a book about his electricity experiments. He died on April 17, 1790.

Thomas Edison

Thomas Alva Edison was born on February 11, 1847 in Milan, Ohio. Edison's family moved to Port Huron on Lake Huron. He caught scarlet fever and, as a result, was hard of hearing. The following year, he attended school for the first time. He was a curious boy who also liked to play jokes. He got into a lot of trouble in school, and his teacher thought he was slow. Edison never returned to school and his mother taught him.[10] Edison became interested in chemistry and soon he had a laboratory in his basement.

In 1859, as a boy, he found a job with the Grand Trunk Railroad. He sold newspapers and candy on the trains and at the stations. This was how he made money for his science equipment.

In 1861, he became the telegraph operator in Port Huron, as the regular one went off to fight in the Civil War. Edison became very involved with telegraph technology. In 1869, Edison was asked to repair the telegraph machine that showed gold prices at New York's gold exchange. Thomas fixed it and improved it. The Western Union Telegraph Company then asked him to work on a new idea, which led to the creation of the Edison Universal Stock Printer, or the stock ticker.

Edison opened his own workshop in Newark, N.J. in 1871. Thomas worked very hard, and preferred working late into the night. He expected his workers to do the same. Edison went on to hold more than 1,000 patents. After marrying his wife Mary, with whom he had several children (Marion (Dot), Thomas (Dash), and William), he moved his workshop to Menlo Park, N.J. in 1876. The first phonograph was built in 1877, by one of Edison's boys in Menlo Park.

Edison went on to develop a vacuum pump for building light bulbs. He showed off his longer burning bulbs. Edison and his Boys worked to develop a power station and electricity system. He modeled it on New Year's Eve in 1879 in Menlo Park, when the streets and houses were lit with his bulbs. By the 1880's several electric companies were trying to light up Manhattan. Edison lit up Pearl Street in September 1882. He had 49 subscribers, but by 1884, he had 555 subscribers and started to turn a profit.[11]

The competition to create a way to distribute electricity began between Nikola Tesla (with Westinghouse) and Thomas Edison. Tesla used alternating current, AC, and Edison used direct current, DC. Alternating current could be generated efficiently with a distant plant. Direct current couldn't be sent far. In 1889, Westinghouse and the AC current had five times as many customers as Edison. On October 27, 1893, Westinghouse and Tesla earned the contract to harness the power of the Niagara Falls.

Electricity

What is Electricity?

Electricity is the movement of electrons. It flows in a current like a river. It is measured in units called watts, which is power (energy per unit of time). The electrons flow through a circuit or path that creates power. The amount of electrical potential energy is measured in volts, which determines the amount of power that can be generated. The current is measured in amperes and the resistance is measured in ohms. The resistance can vary depending on the diameter or gauge of the wire and the length of the wire.

History of Electricity

Ancient civilizations were aware of electric shocks from fish. Later the ancient Greeks, Romans, and Arabs also mentioned knowledge of electric shocks. Early Mediterranean civilizations also described effects of static electricity and magnetism long before Benjamin Franklin would fly his kite. There were many important discoveries in the 18th century by Alessandro Volta and Michael Faraday to name a few scientists. The work of the 18th century and early 19th century really laid the groundwork for the discoveries of the 19th century. The work of Thomas Edison, Alexander Graham Bell, and Nikolai Tesla led to electricity becoming a necessary tool for life in the modern world. The discoveries that came out of the 19th century: the telegraph, the filament light bulb, and the distribution stations for electricity transformed the world and led to the Second Industrial Revolution.

As a result of Edison's light bulb and Tesla's AC power stations, businesses and homes could be lit up when it was dark outside. Once electricity could be delivered to factories, the opportunity for mass production began to take shape. The ability to distribute electricity led to many more inventions and modern conveniences. Today, technological advances such as the Internet, cell phones, and electronic devices continue to make our lives more convenient.

Sources of Energy

In 2005, the world used a vast amount, 16.3 TW of energy.[12] Over 80% of world energy is fueled by carbon-based fuels, or combustibles.[13] Electricity is generated from burning fossil fuels, running nuclear, hydroelectric, and geothermal power plants, and using solar and wind energy. 40% of the world's electricity comes from coal.[14] An important issue is that fossil fuels are readily available and are inexpensive. However, burning fossil fuels gives off carbon dioxide, a greenhouse gas that increases the average global temperature. "Most carbon dioxide emissions come from fossil-fuel burning."[15]

Electricity is generated by two different methods: 1) harnessing energy by boiling water to create steam processed through a turbine; 2) Using the kinetic energy to spin a turbine. Fossil fuels, biomass, nuclear, and geothermal all generate electricity by heating water, whereas wind, tidal, and hydroelectric use the kinetic force for generation. The exact way they are all generated is slightly different, but this process is essentially the same.

Conductors & Insulators

Conductors are materials that allow electricity to flow through them. Examples of conductors are metals, carbon, and saltwater. Copper and silver are good conductors. Pure water is not a good conductor, but pure water is rarely found in nature. Salt, sediments, and minerals are found in most water and these materials greatly improve the conductivity of water. Conduction occurs because the conducting materials have free electrons that can transfer from one atom to the next all the way across the material.

Insulators, on the contrary, are materials that impede the flow of electricity. If a free electron, hence a charge, is transferred to the insulating material, the charge will remain in that location and will not transfer. Some examples of insulators are plastic, wood, and Styrofoam.

Static Electricity

Static electricity is caused by an imbalance on an insulated material. It can result in crackling, a discharge, the attraction or repelling of materials. An example is if I rub a balloon on my head I can stick it to a wall. My head should have an equal number of protons and electrons so it is balanced. The balloon should as well. When the balloon rubs on my head, friction is created, and electrons jump from my head to the balloon. The balloon then is negatively charged. If it is positioned near a wall, the negative force of the balloon will push the negative electrons in the wall away. Thus the wall has a positive charge, and the negatively-charged balloon is attracted to the positively-charged wall. Therefore, the balloon will stick to a wall. Static electricity occurs in nature in the form of lightning. Benjamin Franklin's kite experiment determined that lightning was a form of static electricity. In the sky, clouds rub together creating friction, which leads to the discharge. Electricity does not only occur in a stationary form.

Electric Current and Magnetism

An electric current occurs when electrons move or flow through a conductive material. In class, we will make a circuit and the current will flow through the wire. If a wire is wrapped around a rod or nail, and a magnet is moved over the top, electrons will move. This is because a moving magnetic field creates electricity. In this case, the magnet is moving the magnetic field.

Michael Faraday's work led to the discovery that electric current creates a magnetic field. Wrapping a wire around an iron nail or rod, and connecting it to a battery demonstrates this principle, and forms an electromagnet.

Early scientists came to this conclusion when a movement of a magnet caused a compass needle to jump. Wrapping an iron rod with wire, moving the magnet, and measuring the DC current with an ammeter is a method to demonstrate this idea.

Transformations of Electricity

Electrical energy is flexible because it can be turned into radiant, thermal, and mechanical energy. Radiant energy is light energy. With Thomas Edison's invention of the filament light bulb, radiant energy could light up homes and businesses. Electricity can also turn into thermal energy or heat energy. An example of heat energy is a toaster or a burner on an electric stove. Mechanical energy, or the energy of motion, is also the result of the transformation of electricity. Once electricity is turned into mechanical energy, the object has the ability to do work. When electricity creates a motor, which will be explained below, the result is a mechanism that turns. A motor can spin a turbine and run an engine or propel a fan.

Because electricity is so flexible, the modern world depends on it for so many of our everyday conveniences. Imagine our world without electricity: no lights, no household appliances, and no internet. In addition we would not have many of the products that we consume daily since many are made in factories that use electricity for mass production.

DC Current

Direct Current, also known as DC current, is current that flows in the same direction. It has a constant polarity. A battery is an example of DC current because the battery has definite positive and negative terminals.

AC Current

Alternating current is current that rapidly changes direction. It has both voltage that switches polarity and current that switches directions. Moving loops of wire on a turbine in a magnetic field generates alternating current. From the perspective of the electrons in the wire, the magnetic field is constantly changing its direction. To fight against this, the electrons move back and forth, causing the direction of the current to alternate.

Circuits

A circuit is a path for the electricity to follow. A simple circuit is made by connecting a battery, wire, and a light bulb to form a path extending from the negative terminal of the battery to the positive terminal. Circuits can be open or closed, but only closed circuits will conduct electricity. An open circuit has a gap, or break, and therefore the electricity is unable to complete the route. When a light switch is turned off, it creates a gap and the lights will not illuminate. When the switch is turned on, the gap is closed and the lights will work.

Circuits are characterized as either series or parallel. A series circuit has one path for the electricity to follow, but a parallel circuit has more than one path for the electricity to follow. If there is a break in a series circuit then no electricity will be conducted. In a parallel circuit, only the path with the break will not conduct electricity. For this reason, homes and buildings typically use parallel circuitry. An example of this is your electrical box at your house. If one fuse goes out, only the lights and appliances on that circuit will not work. The electrical devices on the other circuits will still work. Now that we have learned how to get electricity to flow through a circuit, the electricity can be transformed into different types of energy.

Batteries

Did you know that a *frog* led to the invention of the first battery? It is true. Luigi Galvani, a doctor and a professor of anatomy, was cleaning a frog, presumably for an experiment, and he noticed that frogs' legs twitched wildly when touched by wires made of two different metals. Galvani thought he discovered some type of "animal electricity." However, the work of Alessandro Volta showed differently. Volta thought it was some kind of reaction between two different kinds of metals and a fluid. Volta was correct and with further experimentation he invented the voltaic pile in 1800. It was the first electric battery and could produce an electric current when needed. The design was a stack of copper and zinc disks separated by a piece of cloth or cardboard soaked in brine or saltwater.[16]

Alessandro Volta did not understand the science behind his discovery. However, the science behind the voltaic pile is understood today. Two different metals, or electrodes are separated by a conducting fluid called the electrolyte. Charged atoms or molecules called ions move through the electrolyte to balance charges at the metal surfaces. Now, an electric current can flow through a wire from the metal electrode with the higher energy to the metal electrode with the lower energy in a similar way as water flows from a higher place to a lower place.

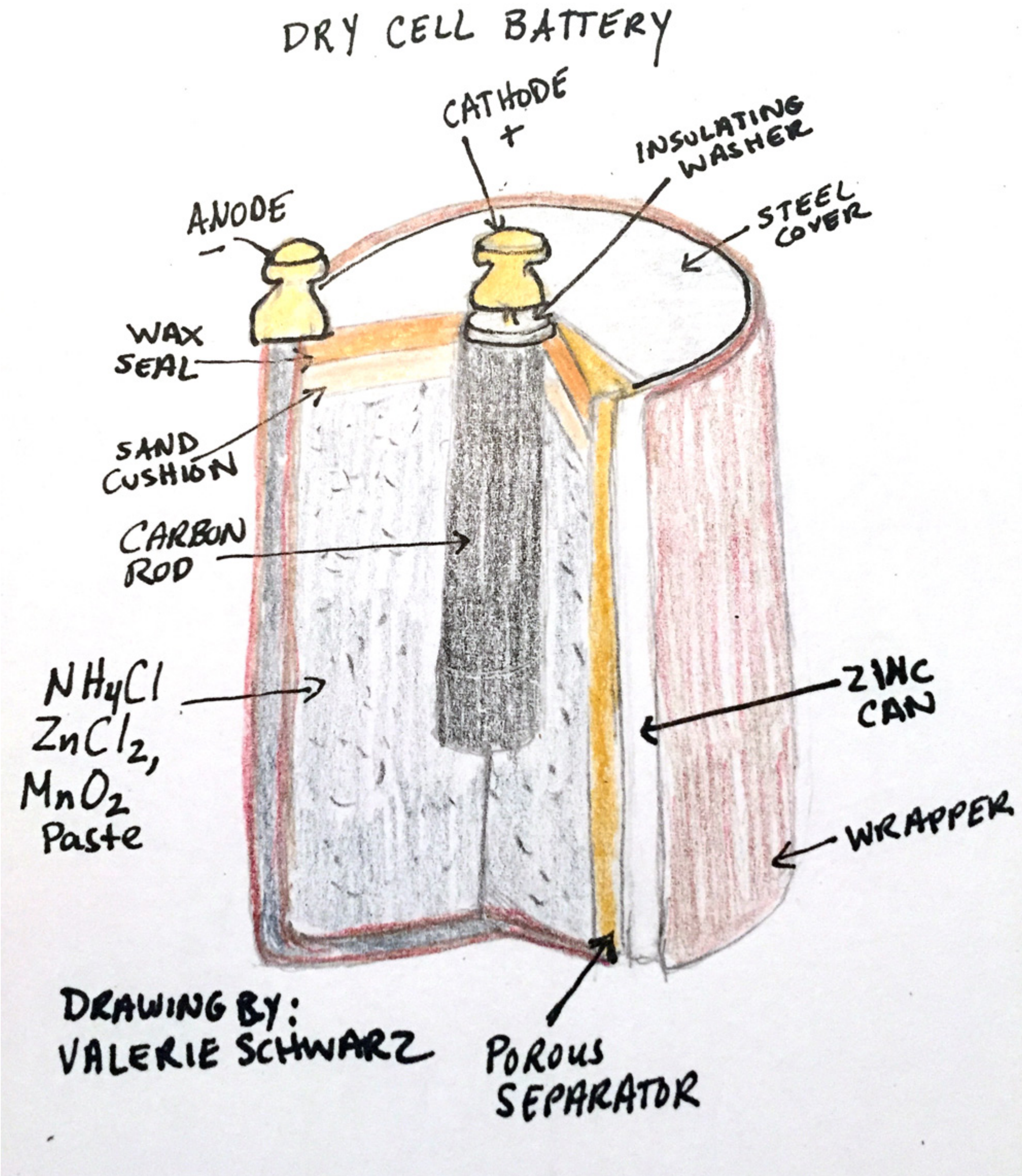

Figure 1: Dry cell battery.

Electricity is generated when wires are attached to the voltaic pile and the circuit is closed. Batteries then evolved into various forms of wet cells, which used the same general principle of moving charged particles, or ions, to generate electricity. As the name implies, wet cells use chemicals in liquid form.

In 1812, the first dry-cell battery was invented called the Zamboni pile. In the late 1800's, improvements were made to dry cell batteries. Despite the name, dry cells do not use dry chemicals, but chemicals in a paste-like form. Zinc and carbon were used in Zamboni's pile. The batteries became known as zinc-carbon batteries and are still produced today.

Motors and Generators

A motor is a machine that turns electricity into mechanical energy. When electricity runs through a coil it becomes an electromagnet. So if the coil is suspended and placed in a magnetic field the forces of the poles will cause the coil to spin. The spinning action is mechanical energy.

Michael Faraday created the first motor, which is now called a homopolar motor. Faraday also determined that if a moving electric current creates magnetism, then the opposite must also be true. So Faraday used moving magnetic fields to generate electricity, thus inventing the Dynamo, or a generator. Faraday's discoveries really could not do any mechanical work for industrial purposes, but laid the groundwork for the future.

Important discoveries were made when Thomas Edison, using DC current, and Nikolai Tesla, using AC current, were competing to find a way to bring light to houses and the workplace. Both men were trying to generate electricity in order to light up an area. In the end, Tesla won out with his AC current because AC current can travel further without losing much current. The high voltage used to transmit AC current's power is reduced as it enters homes and buildings for safety reasons. With Edison's DC current, the electricity could only travel about a mile without a voltage drop. So a power station would be needed in the center of every square mile.[17]

Electrolysis

William Nicholson and Anthony Carlisle built the first Voltaic Pile in England, and began conducting experiments with it. While experimenting, Nicholson and Carlisle noticed the production of bubbles when two wires attached to the battery were put in water. Intrigued, they conducted further experiments with a larger amount of water. Then they took a tube full of water and inserted the two wires. They were surprised when bubbles emerged from both wires. Nicholson and Carlisle discovered electrolysis, or the decomposition of water into hydrogen and oxygen. They also embarked on a new field: electrochemistry, which would change the field of chemistry.

Fuel Cells

William Grove, a friend of Faraday and a professor of experimental philosophy, experimented with electrolysis and thought that process could be reversed. He reasoned that by reversing the process, he could create electricity. He was correct and, in 1839, he built the first fuel cell.

Francis T. Bacon developed modern-day fuel cell technology. Bacon's technological improvements paved the way for the use of fuel cells on space shuttles. One big improvement was using nickel instead of platinum as a catalyst to remove the electrons from the hydrogen atoms. Platinum was prohibitive because of its cost. Bacon pressurized the cell to keep the liquid from boiling, but the pressurization also improved the efficiency of the cell. Bacon made single- cell, six-cell, and forty-cell models. In 1959, Allis-Chalmers, a tractor manufacturer "demonstrated the first fuel-cell powered vehicle."[18]

Fuel cells are similar to batteries in some ways. A fuel cell uses two different gases, hydrogen and oxygen, to create electricity. Hydrogen enters one side of a panel and electrons are stripped away, turning the hydrogen into a positively-charged ion. The electrons flow, creating electricity. Oxygen is pumped into the fuel cell, the opposite side and through another panel. The hydrogen ions flow through a membrane and bond with the oxygen to produce water as exhaust. Fuel cells are a clean source of energy, but it is difficult to build practical ones.

Strategies

Blended Learning

My students really enjoy science because there are a lot of hands-on activities. My students are nine and ten years old, and science seems to be more relaxed and fun. The students are very curious about the world around them. My students also love to work with technology. Recently I learned about "smashing apps," which basically means using two different applications or software in conjunction with each other. I want my students to explore using Glogster and Thinglink together. Glogster is a site to create multimedia posters. Thinglink is a site to make images interactive. Students can add sound, video, or text to an image. These two graphical design tools are compatible and work well together. The idea is that we will use Glogster to create exciting interactive posters to showcase the student learning. Video clips of our experiments and work in class may also be included. As the teacher, I can also add resources or showcase student work as well. The idea is to engage the students with the content of the electricity curriculum unit, and have them apply higher level thinking skills as they create the Glogster posters. The creation of the posters will require the students to create, apply, and synthesize their knowledge. By blending the learning, my students will develop their technology skills while delving into science content.

Throughout the unit, there are days set aside to work on Glogster and Thinglink. I think in order to be efficient with time, some of the creation of materials and content will take place as part of their homework. Then more class time will be preserved for actually working on the technology piece. I also can utilize some language arts time for students to develop explanatory essays about ideas learned throughout the unit.

Read Aloud

Read aloud is a strategy I will use to introduce the historical figures. There are many great picture books to showcase the lives of Benjamin Franklin, Michael Faraday, and Thomas Edison.

Center-based Learning

My students enjoy learning in centers. The plan is to set up four centers for static electricity, so my students can rotate through them to explore static electricity in several different ways. The four centers I plan to use are: 1) making an electroscope; 2) moving a ping-pong ball with static electricity; 3) testing charged plastic wrap with other objects; 4) having the students rub a comb more times to see how many pieces of puffed rice are attracted to the comb.

Scientific Investigation

I enjoy having my students discover science concepts through an investigation. Electricity really lends itself to experimentation. The students will conduct an experiment to see which kinds of fruit can be turned into a battery. We will experiment with a lemon, a grapefruit, a pear and an apple.

Another experiment will be implemented to make discoveries about an electromagnet. The students can wrap the wire more times, whether the wire is wrapped neatly or sloppily, the diameter of the metal rod, or core can vary, and the gauge of the wire can also be altered. I would like to allow the students to choose a variable that interests them. Several experiments will be conducted simultaneously and the information shared. Video clips and write-ups about the results will become a part of our Glogster and Thinglink presentation.

Scientific investigation will also be used to conduct an experiment about circuits. The students will work on different experiments to illuminate lights. Wire length and wire gauge will be the independent variables in the respective experiments.

Hands-on Collaborative Groups

My students will work in collaborative groups to explore whether a material is an insulator or a conductor, series and parallel circuits, electromagnets, motors, generators, electrolysis and fuel cells. Many of these concepts are new to my fourth graders. They need time to explore, play, and collaborate with their peers in order to deepen their knowledge.

Energy Showcase

As a celebration of my students' hard work, we will celebrate and showcase our work by inviting the parents to come in for an Energy Showcase. Students will share aspects of our Glogs through the Thinglink application and demonstrate some of the hands-on learning that we did in class.

Explanation of the sequence

It seems logical to begin with an overview of energy to lay out its importance as well as the challenges facing the world in regards to energy. After an initial overview, our unit will start with Benjamin Franklin, since his discovery came earlier than the other scientists. Since his famous kite experiment involved lightning, it seems logical to focus on static electricity for the subsequent days. Then the students will have a technology day to produce the portion of the Glogster presentation dedicated to static electricity.

Once the students understand static electricity, and that in this form the electricity is stationary, we will then look to electric current, or electricity that is moving. Michael Faraday, who is known as the "Father of Electricity," really laid the groundwork for understanding electric current. We will do a read aloud about Faraday and then look at some of his experiments. As we explore electrical current, it is important for the students to understand that materials are conductors and insulators. Then the students will be ready to make various types of circuits. At the end of this section, the students will again have time to work on Glogster to develop the section about Michael Faraday and Thomas Edison.

The students learn how to make batteries. We will make some batteries with fruit, and also with water and salt. Since it is fourth grade, we will not construct dry cell batteries as the chemicals are more dangerous. Then we will examine DC and AC current. Once the students understand batteries and current, we will make circuits. Following the completion of this section, students will add to their Glogs.

The students will examine and build electromagnets, motors, and generators. These are probably the most complicated applications. So by working on it later in the curriculum unit, the students should have a stronger understanding of electricity. Again, upon completion of this section, the students will add to their Glogs.

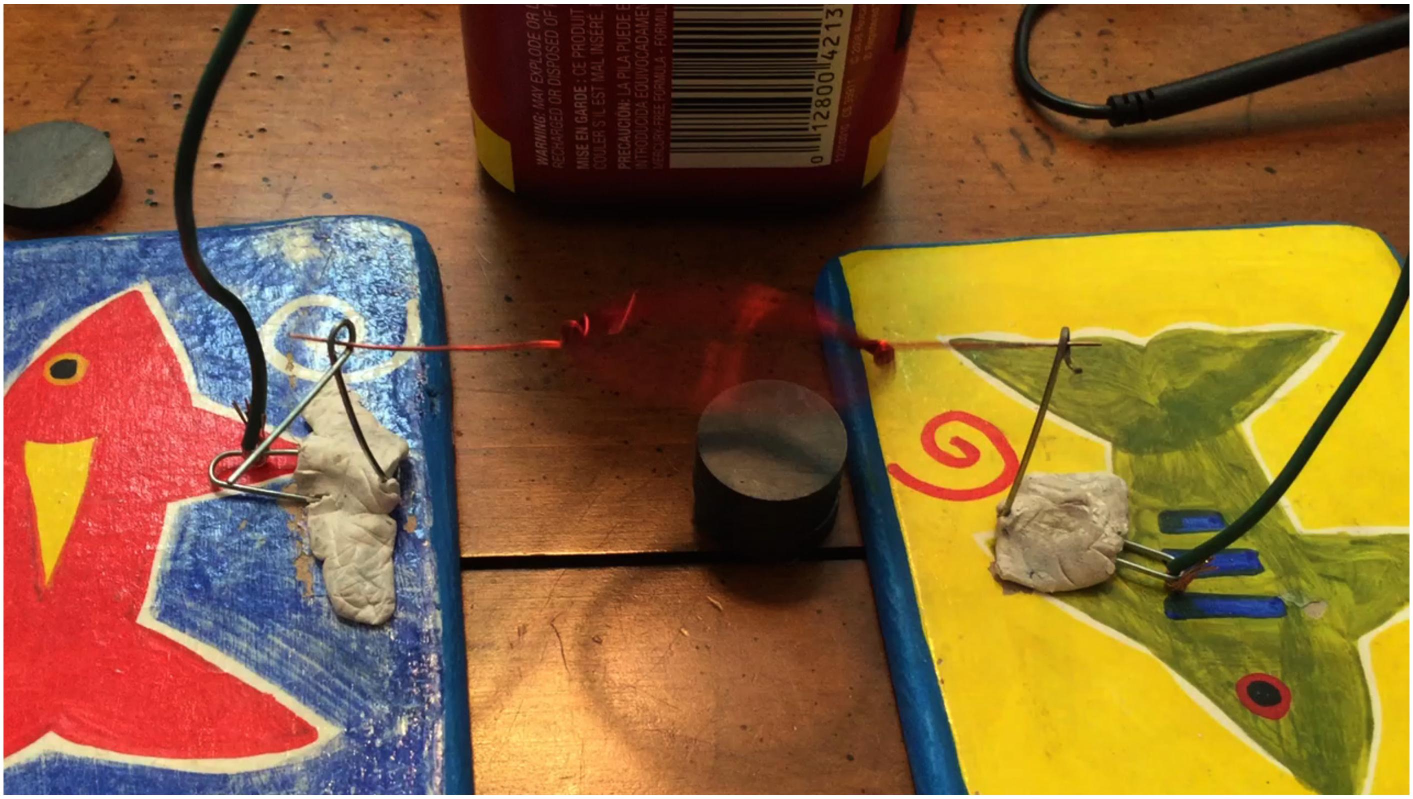

Figure 2: A Simple Motor.

The final section is learning about electrolysis and fuel cells. I put electrolysis into the curriculum unit because it seems as if it is a natural step to help the students understand the fuel cell. The students will have time to make final additions the class Glog. The culminating activity is inviting the parents to class for a grand presentation of the students' Glogster and Thinglink efforts where students can showcase their work. I also plan to have several demonstration tables set up, where the students can show off their batteries, circuits, and fuel cells.

Activities

Activity 1

I will read aloud Electrical Wizard: How Nikola Tesla Lit Up the World by Elizabeth Rusch. I will also share the biographical information about Thomas Edison. The students will know their task and will take notes during the instruction and read aloud. Then the students will complete a graphic organizer to compare and contrast Thomas Edison and Nikola Tesla.

Activity 2

For the second featured activity the students will construct batteries from various fruits. The students will use a lemon, a grapefruit, an apple, and a pear. The students will identify the independent and dependent variables and predict which will make the best battery. Then the students will connect a current detector to the fruits to see if an electric current is being generated. The students will record the electric current. Upon completion, the students will be given a snack of the various fruits used. Based on the taste of the fruit, the students will draw a conclusion related to the taste and ability to generate a current.

Activity 3

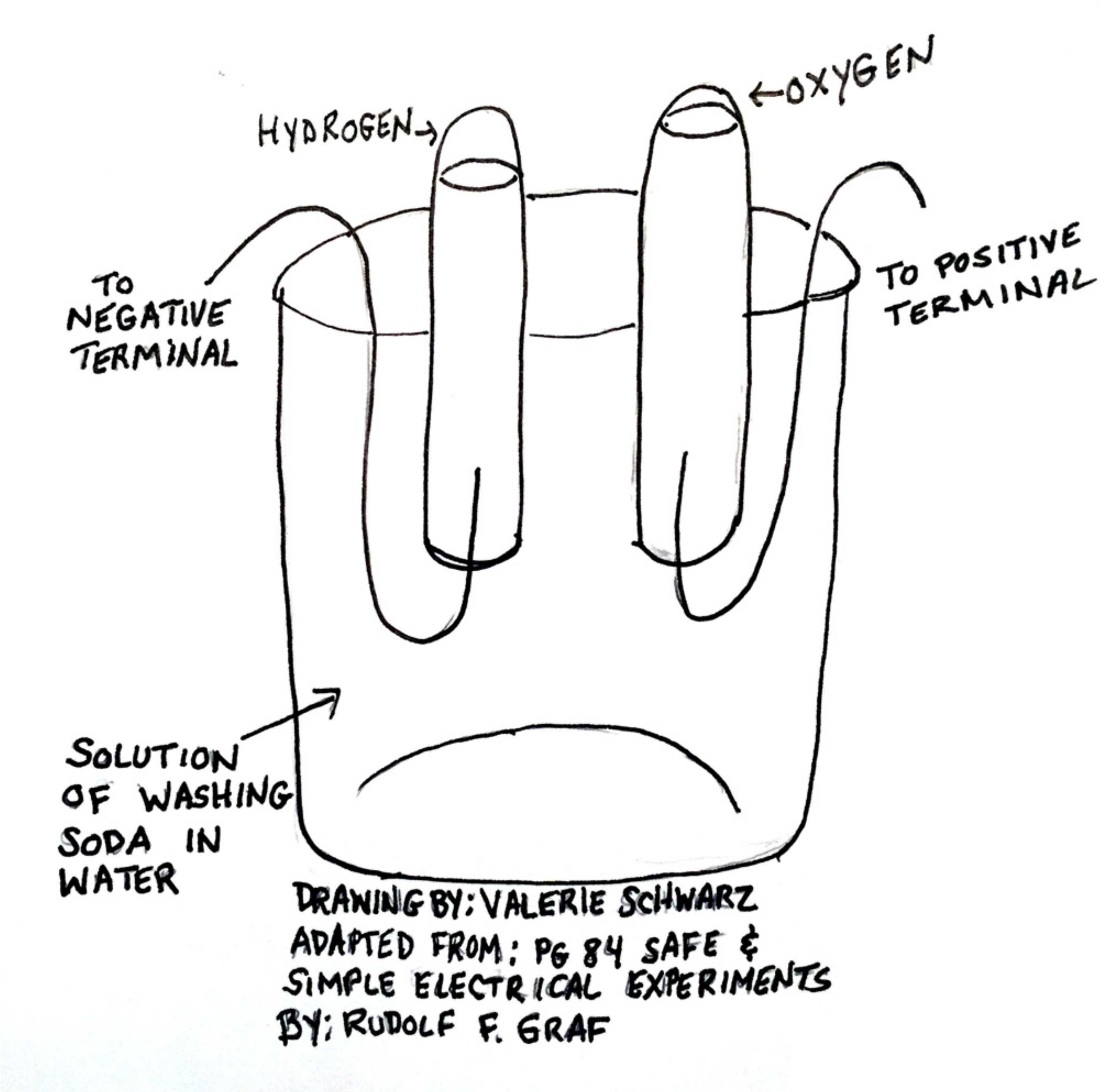

Figure 3: Electrolysis set-up

The students will create a simple motor based on the model provided by Aims *Electrical Connections*. The materials needed to make the motor are thin wire (not coated), clay, paper clips, a film canister or small cylinder, alligator clips, and a 6 V battery. Using the uncoated wire, wrap it about 5-8 times around the film canister, leaving about 1 inch of excess wire at each end. Now taking a paper clip, pull the innermost loop toward you until the two metal loops of paper clip form a right angle. The paper clip should be able to stand upright. Now take the vertical part and bend the loose end up to make a small circular loop. The paper clip will no longer stand. Do the same with the second paper clip. Now press a small amount of clay on top of the base of each of the paper clips. The small circular loops should be up at the top of the paper clips. Using the wire that you previously wrapped around the film canister, set one end of the excess wire in each loop. Attach wires from the base of each paper clip to the battery. You may need to fiddle with or sand the wire to get a better connection. The set up can be seen in the video embedded in the unit.

Activity 4

The students will make a wet battery using a small Rubbermaid container, a zinc electrode and a copper electrode. The students will add salt to the container, fill it with water, and attach alligator clips from the electrodes to a 6 V battery. The zinc electrode will make bubbles and the copper side will oxidize. This salt bridge battery will lay the groundwork for the next step: electrolysis. The materials for each group are a wide-mouthed jar, two test tubes, a 6 V battery, copper wire, and washing soda (which can be purchased or made by heating baking soda in a baking pan with a lip or a glass baking dish. Spread 2-3 cups of baking soda in the pan. Heat at 400 degrees for about an hour. The finished product should be a fluffy powder.

The set-up is similar. Fill a wide jar or beaker about half way with water. Attach copper wires to each terminal of the battery. Put the free end of the copper wires into the water, being careful not to touch them. Bubbles should appear around the wires. Remove the wires. Add a tablespoon of soda ash and stir the solution. Bend the wires so they form a U. Put the wires back in the solution and add a test tube on top of each wire. The test tube will collect the gases that are being emitted. The gas bubbles are a result of the water molecules being split. The students should notice that there is twice as much gas in one test tube (hydrogen) as compared to the other (oxygen). This is because water is made up of H_2O, or two molecules of hydrogen and one of oxygen.

Day 1 Overview of the energy problem

Day 2 Benjamin Franklin- read aloud – PhET – balloons and static electricity

Day 3 Static Electricity – centers – What is attracted? Rubbing a comb to pick up puffed rice.

Day 4 Static Electricity – centers – electroscope – moving ping-pong ball

Day 5 The class will have time to work on Glogster and Thinglink.

Day 6 Michael Faraday – read aloud

Day 7 Faraday’s inventions –video and demonstrations

Day 8 Thomas Edison & Tesla -

Day 9 Experiments with circuits to light lights – longer wire, thicker wire

Day 10 Computer Time – work on Glogster and Thinglink

Day 11 Conductors and Insulators

Day 12 Batteries

Day 13 Batteries

Day 14 Experiment with batteries (different types of fruit)

Day 15 DC and AC current

Day 16 Circuits - series

Day 17 Circuits - parallel

Day 18 Extra time building circuits/ Venn diagram

Day 19 Electromagnets - overview

Day 20 Electromagnet experiments – wrapping wire more – various gauges (thickness) – various core diameters of bolts – various lengths

Day 21 Motors

Day 22 Generators

Day 23 Types of Energy

Day 24 Computer Time – Work on Glogster and Thinglink

Day 25 Computer Time – Work on Glogster and Thinglink

Day 26 Electrolysis

Day 27 Fuel Cells

Day 28 Fuel Cells

Day 29 Computer Time – Work on Glogster and Thinglink

Day 30 Closing

Day 31 Invite Parents and share presentations and our Thinglink page

Endnotes

1. Russell, Colin A. *Michael Faraday Physics and Faith*, 12. Oxford University Press, New York: 2000.
2. *IBID*, 43
3. *IBID*, 54.
4. *IBID*, 89.
5. *IBID*, 11.
6. Giblin, James Cross. *The Amazing Life of Benjamin Franklin,* 9. Scholastic Press, New York: 2006.
7. Parker, Steve. *Benjamin Franklin and Electricity,* 4. Chelsea House Publishers: Philadelphia: 1995.
8. *IBID,* 11.
9. *IBID,* 19.
10. Parker, Steve. *Thomas Edison and Electricity,* pg 5. Belitha Press Limited: Great Britain, 1992.
11. Adkins, Jan. *DK Biography Thomas Edison,* pg. 89. DK Publishers, New York: 2009.
12. *Science*, New Series, Vol. 315, No. 5813 (Feb. 9 2007)
13. Yergin, Daniel. *The Quest,* pg 720. Penguin Books, New York: 2012.
14. *IBID*, 720-721.
15. MacKay, David. *Sustainable Energy – without the hot air,* pg 5. UIT, Cambridge: 2009.
16. Graf, Rudolf F. *Safe and Simple Electrical Experiments,* pg77. Dover Publications, Inc., New York: 1964.
17. Yergin, 350.
18. Hoffmann, Peter. *Tomorrow's Energy: Hydrogen Fuel Cells and the Prospects for a Cleaner Planet,* pg 147. The MIT Press, London: 2001

Resources

Bibliography for Teachers

Adkins, Jan. *Thomas Edison*. New York: DK, 2009.

Allen, Maureen, et al. *Electrical Connections*. Fresno: Aims Educational Foundation, 1991.

Giblin, James, and Michael Dooling. *The Amazing Life of Benjamin Franklin*. New York: Scholastic Paperback Nonfiction, 2006.

Graf, Rudolf F. *Safe and Simple Electrical Experiments*. New York: Dover Publications, 1973.

Hoffmann, Peter. *Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet*. Cambridge, MA: MIT Press, 2001.

MacKay, David J. C. *Sustainable Energy--without the Hot Air*. Cambridge, England: UIT, 2009.

Parker, Steve. *Thomas Edison and Electricity*. New York: Chelsea House Publishers, 1995.

Russell, Colin Archibald. *Michael Faraday: Physics and Faith*. Oxford: Oxford University Press, 2000.

Yergin, Daniel. *The Quest: Energy, Security and the Remaking of the Modern World*. New York: Penguin Press, 2011.

Bibliography for Students

Dooling, Michael. *Young Thomas Edison*. New York: Holiday House, 2005.

Fritz, Jean, and Margot Tomes. *What's the Big Idea, Ben Franklin?* New York: Coward, McCann & Geoghegan, 1976.

Glover, David. *Batteries, Bulbs, and Wires*. New York: Kingfisher Books, 1993.

Midthun, Joseph, and Samuel Hiti. *Electricity*. Chicago, IL: World Book, 2012.

Rusch, Elizabeth, and Oliver Dominguez. *Electrical Wizard: How Nikola Tesla Lit up the World*.

List of Materials

The materials for this unit are extensive, and this list is my best effort to name all of the necessary materials. Computers with and internet connection are necessary for the technology piece of this unit. You will need books for the read aloud. For the hands on electrical explorations you will need: wire (various lengths and gauges), wire cutters, motors, batteries (1.5 V and 6 V), alligator clips, test tubes, beakers, magnets, Christmas lights, iron rod, zinc nail, copper nail, Rubbermaid containers, clay, paper clips, combs, puffed rice, ping-pong balls, plastic wrap, small jars, aluminum foil, Styrofoam, salt, thread, small pieces of paper, pennies, dimes, paper towel, salt, lemons, pears, apples, grapefruits, ammeter, bolts (various sizes), and a fuel cell car (for demonstration), and a Venn diagram. For testing conductors and insulators have a variety of materials. Here are some suggestions: popsicle sticks, sponges, plastic chip, grommet, foil, piece of copper, nails of various metals.

Appendix 1: State Standards, Next Generation Science Standards(NGSS), and Common Core

---

Virginia has not adopted the Common Core Standards, but I am including the related NGSS and Common Core Standards for educators outside of Virginia.

Virginia Standards of Learning

4.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) distinctions are made among observations, conclusions, inferences, and predictions; b) objects or events are classified and arranged according to characteristics or properties; c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units; d) appropriate instruments are selected and used to measure elapsed time; e) predictions and inferences are made, and conclusions are drawn based on data from a variety of sources; f) independent and dependent variables are identified; g) constants in an experimental situation are identified; h) hypotheses are developed as cause and effect relationships; i) data are collected, recorded, analyzed, and displayed using bar and basic line graphs; j) numerical data that are contradictory or unusual in experimental results are recognized; k) data are communicated with simple graphs, pictures, written statements, and numbers; l) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and m) current applications are used to reinforce science concepts.

4.3 The student will investigate and understand the characteristics of electricity. Key concepts include a) conductors and insulators; b) basic circuits; c) static electricity; d) the ability of electrical energy to be transformed into light and motion, and to produce heat; e) simple electromagnets and magnetism; and f) historical contributions in understanding electricity.

NGSS

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-P3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

4-ESS3-1. Obtain and combine information to describe that energy and fuels derived from natural resources and their uses affect the environment.

Common Core

4.P.1.1 – Explain how various forces affect the motion of an object. Explain how magnets interact with all things made of iron and with other magnets to produce motion without touching them.

4.P.1.2 – Explain how electrically charged objects push or pull on other electrically charged objects and produce motion.

4.P.3.1 – Recognize that energy takes various forms that may be grouped based on their interaction with matter. Students will recognize the basic forms of energy (light, sound, heat, electrical, and magnetic) as the ability to cause motion or create change.
