SAVE THE SNAILS, SALAMANDERS, AND OTHER SLIMY CREATURES

STEM TEACHING KIT

An Introduction to Electrical Generation and Energy Transformations

Teacher's Guide

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

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UNIT OVERVIEW

Introduction and Background

Scientific literacy is generally described as what the general public should know about science (Durant, 1993). Coal fired power plants produce most of the electricity we use in this country, and the knowledge about how coal is actually converted into useful electricity should be considered part of being scientifically literate in every state in the nation. Since 2003, coal has been the top energy source for electric power generation in the US when compared with other petroleum products, natural gas, nuclear, hydroelectric, and renewable sources (US Department of Energy [ED], 2013). Indeed, 42% of the world's electricity is produced from coal (World Coal Association, 2013). Without an understanding of how coal is used to produce electricity, one cannot understand how wind or water could also generate electricity.

Energy literacy, a term used by the Department of Energy, encompasses understanding where energy comes from. The Department of Energy states that energy literacy is vital because it leads to informed decisions about energy use at home, consumer choices, and to national and international energy policies. "Current national and global issues such as the fossil fuel supply and climate change highlight the need for energy education (ED, 2012, p.4)." Energy literacy takes three forms, and involves cognitive constructs (knowledge about the science and technology), affective constructs (attitudes), and behavioral constructs; all three help citizens make informed decisions about energy use (Dewaters & Powers, 2010).

The National Research Council (NRC)'s *A Framework for K-12 Science Education* (2012) describes energy is a disciplinary core idea that spans all the grades, but is not fully developed until middle school. The NRC (2012) cautions teachers to be very careful about using the word energy inappropriately due to the ease with which it can be used incorrectly and plant the seeds of misconceptions.

The Framework (NRC, 2012) states that by the end of grade 5, students should understand that

> Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy (e.g., moving water driving a spinning turbine which generates electric currents). (p. 125)

This clearly implies that the middle school teachers should be able to understand and convey the cognitive construct of energy literacy, and that that motion can generate it in an electromagnetic field. The power plants that dot our landscape are black boxes to so many. Something like coal or water or uranium or natural gas goes in, and magically, electricity comes out. Black boxes can be dangerous items in science and technology if the privilege that comes with understanding the workings inside the box is held by only a few. If not taught in schools, how do citizens learn about energy issues from a scientific perspective?

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Teaching Strategies

Design-Based Science

This curriculum uses the teaching strategy of **engineering 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 and small group activities

While you may be tempted to jump into the design activity and skip over the demonstrations and small group activities, please do not. These activities provide the cognitive scaffolding necessary for students to link the design challenge with the complex science of electrical generation and transformation. They present students with cognitive dissonance through discrepant events; the opportunity for students to voice their conceptions and misconceptions of electricity is imperative for the success of this STEM Teaching Kit. Without the demonstrations, activities, and discussions that surround them, students will take away a fun design challenge that may or may not help them understand the science, or understand what engineers do. With the demonstrations and small group activities, students will gain increased conceptual understanding about electricity, electric circuits, and energy.

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, such as material collector or data collector. 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.

Safety considerations

Caution students not stand on tables in order to gain more height. Students will be using small hammers when necessary to tap gears into place. Caution them not to hit hard with the hammers. They are only for tapping when gears do not slide easily. Remind students to use the tools to get the gears on and off the wooden dowels because pushing by hand can result in splinters.

Technology

A computer with speakers, an LCD projector and screen will be needed to show PowerPoint presentations 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

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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

Save the Snails is based on standards derived from the Next Generation Science Standards, the National Science Education Standards, the Benchmarks for Science Literacy and Standards for Technological Literacy.

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. Define the Criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and 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.

Assessment

In *Save the Snails*, 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:

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- Whole-group discussions involving students' predictions of what will happen during demonstrations and feedback from students/groups following each demonstration.
- Measuring time and voltage and current—see what process skills your students still need practice with.
- 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. Ideally, the storyboard is on the wall for easy viewing.

Summative assessment – an evaluation of cumulative performance, given as written tests before and after the unit to determine students' content knowledge gains on electricity and energy transformation concepts. Teachers should have each student complete the electrical generation assessment (EGA) at the start of the unit; collect the assessments, score them, but do not return or discuss them with the students. The EGA instrument is based on misconceptions research. 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 electricity. For more information about this instrument and correct answers, contact Christine Schnittka at Schnittka@auburn.edu.

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Photo Credits:

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[Frog life cycle]
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UNIT SUMMARY

UNIT BIG IDEAS

- Electricity can be generated from motion of magnets relative to copper wires.
- Engineers follow a general process to design solutions to problems.

LESSON 1 – Learning Targets

An Introduction to Engineering, the Environment, and Snails

- One quarter of the world's population does not have access to electricity, which impacts progress and learning.
- Coal is the primary fuel source for electrical generation.
- Coal mining and use in power plants has an impact on the environment.
- Energy is the ability to make something happen or change
  Many amphibians and mollusks are indicator species
- There can be unintended consequences of any engineered or designed solution.
- Electrification is the greatest engineering achievement of the 20^{th} century.

LESSON 2 – Learning Targets

Electromagnetic Induction and Michael Faraday

- Electricity can be generated by moving a magnet in and out of a coil of wire.
- Coal fired power plants use burning coal to create motion.
- Engineers use scientific investigations to help them invent and design.

LESSON 3 – Learning Targets

Gear Trains , Generators, and LEDs

- Gears can be used to slow or speed up motion.
- Generators and motors both use magnets and coils of wire.
- Light Emitting Diodes work when electrical charges jump through space.
- Engineers use science experiments and scientific knowledge in order to invent and design.

LESSON 4 – Learning Targets

Gravity Light

- Electricity can be measured with units of voltage and current and power
- Voltage (volts) is a measure of the force on electric charges.

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- Current (amperes) is the measure of how many charges pass a point in a time period.
- Power (watts) is a measure of how much electricity is used in a time period.
- Engineers use scientific knowledge and creativity to design solutions to problems.
- Engineers work within constraints (time, materials, space, money…)
- Engineers use a process to design solutions to problems.

LESSON 5 – Learning Targets

Wind and Water Power

- Alternative energy sources such as wind and water work because the moving fluid turns a generator.
- Engineering is an iterative process of designing, testing and re-designing.
- There can be several solutions to one engineering 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.

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LESSON 1

Engineering, the Environment, and Snails

Overview

Learning Targets

1. One quarter of the world's population does not have access to electricity, which impacts progress and learning.
2. Coal is the primary fuel source for electrical generation.
3. Coal mining and use in power plants has an impact on the environment.
4. Energy is the ability to make something happen or change
5. Many amphibians and mollusks are indicator species.
6. There can be unintended consequences of any engineered or designed solution.
7. Electrification is the greatest engineering achievement of the 20th century.

Introductory Video

https://youtu.be/UfBTJm4vllY

Purpose of the Lesson

1. Get students to think about how electricity is used across the world, and think about how their lives would be different without electricity.
2. Discuss how coal is used to produce electricity and the destructiveness of modern strip mining processes, and pollution created by burning coal.
3. Demonstrate the ability to create electricity from motion.
4. Introduce students to storyboarding.

Lesson Objectives

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

- Explain why humans mine for coal
- Give examples of how coal mining impacts the environment
- Brainstorm other ways to make electricity to reduce fossil fuel consumption

Lesson in a Nutshell

1. Discussion about electricity use in the world.

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2. Pretest: "How does coal keep the lights on?" See Appendix B or http://www.auburn.edu/~cgs0013/ETK/coal_assessment.pdf
3. Electrical toy stations
4. Videos about ways developing countries are generating electricity without coal.
5. Discussion of how coal and batteries and affect snails, salamanders, and other slimy creatures.

Background

Energy: Energy is the ability to make something happen or change. There are many kinds of energy- kinetic, potential, thermal, electrical… but all those forms of energy share one thing. They all have the ability to make something happen or change.

Electricity: Electricity is the motion of electrons in a conductor. Since electrons are naturally present in any conductor, when a voltage is applied, these electrons will move. Moving electrons can create thermal and light energy in a light bulb, mechanical energy in a motor, thermal energy in an electric heater, etc.

The Harmful Effects of Burning Coal on our Slimy Friends

How can burning coal affect animals that live entirely or mostly in water? In order to find that out we have to look at what's in the emissions from burning coal, how what's in the air can get into the water, and lastly what that pollution does to the various kinds of animals that live in the water.

Coal's Role in Energy Production

In the United States and elsewhere in the world, it is common to produce electrical energy by burning coal. In 2012, 52% of all the energy that was consumed by Americans came from burning coal. Many states rely heavily on coal burning for energy, and even go to exhaustive lengths to obtain it. In 2008, ten states spent over $16 billion dollars on importing coal from other states to fulfill their energy needs. These states range from the Southeast (such as Texas, Alabama, and Georgia who spent the most) to the Great Lakes region (such as Michigan, Indiana, and Ohio). In that year, 38 states imported more coal than they used or exported.

Coal's Effect on the Environment

There are a lot of harmful chemicals in the smoke that rises up into the Earth's atmosphere from burning coal. The three big chemical players are: carbon dioxide, sulfur dioxide, and nitrogen oxide. **Carbon dioxide** is greenhouse gas known for its damaging effect on the atmosphere and adding to increasing the temperature on Earth's surface **(Global Warming)**. **Sulfur dioxide** is another common chemical found in coal smoke, and causes acid rain. In the U.S., coal burning is the number one producer of sulfur dioxide. Another harmful thing found in coal emissions is **nitrogen oxide**, which is harmful if it is inhaled and can combine with sulfur dioxide, oxygen and water to create sulfuric acid and nitric acid in acid rain. Read this latest news update for more information: http://abcnews.go.com/Health/wireStory/wva-spill-exposes-risk-water-coal-21583025

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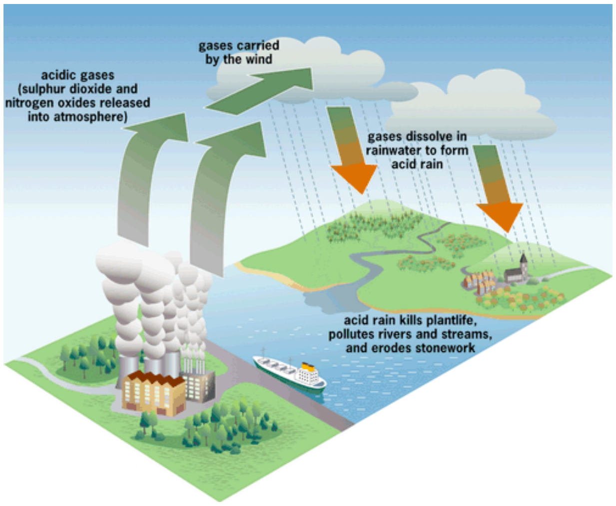
Acid Rain



When nitrogen dioxides and sulfur oxides are in the atmosphere, they condense into clouds just like water and oxygen do to form rain clouds. The addition of these chemicals to the rain clouds makes the cloud slightly or heavily acidic depending on how much nitrogen dioxides and sulfur oxides are in the atmosphere. As the molecules of oxygen, water, and pollutants are condensing and forming rainclouds, they are also moving. Acidic rain clouds can move hundreds or thousands of miles away from where the pollution occurred. It can also change to become snow, hail or fog. A dry particle mist can also occur and be carried by dry winds.

Acid rain becomes a big problem when it falls down to Earth from the atmosphere and comes in contact with the trees, soil, or waterways. The leaves of trees are harmed or killed by this acid making the tree vulnerable and unable to produce food during photosynthesis. When the acid comes in contact with the soil, it changes the nutrients available to the plants. The acid reacts with the nutrients and releases aluminum into the soils. This changes the ability of the trees to take up water, and leaves the soil with little nutrients available to trees. Acid rain that comes into direct contact with waterways makes the water toxic to aquatic animals that breathe through the water.

After a few weeks, amphibian tadpoles develop legs and lungs and move out of the water from which they were born. Frogs and toads go on land or different ponds, and salamanders and newts go onto the land or swim to new streams or rivers. One thing is always constant throughout their life: water.

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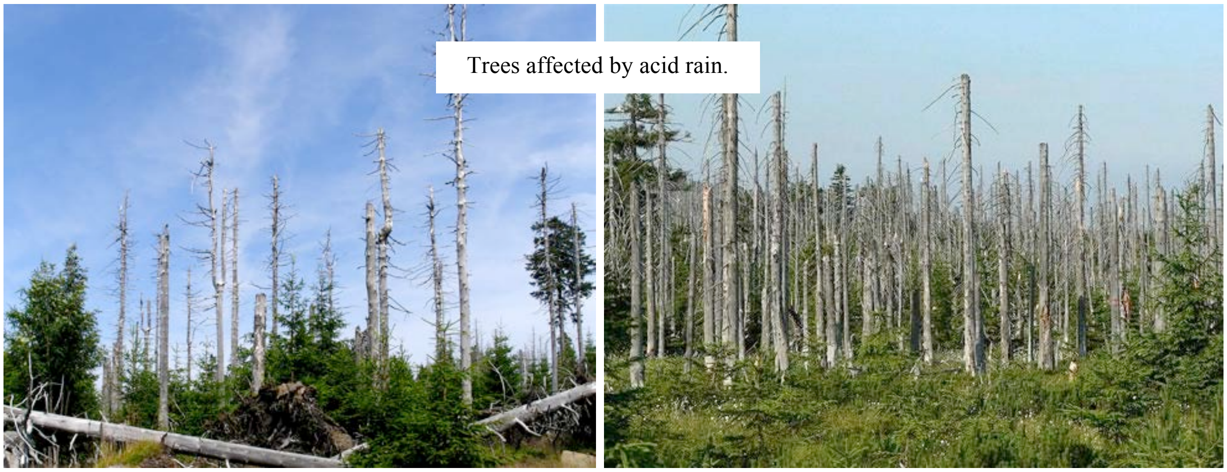
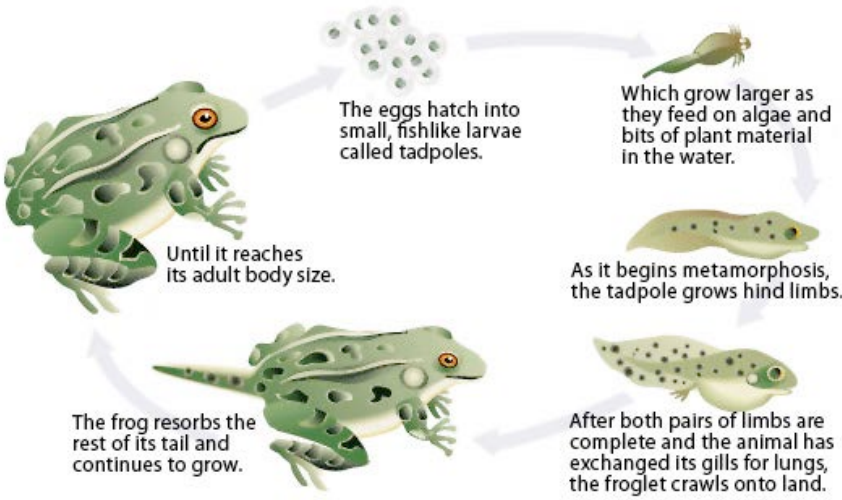


Trees affected by acid rain.

About amphibians and other slimy creatures

So how are amphibians and other slimy creatures affected by acid rain? Can't they just hop out of the water and live on land if the water is not safe? Let's first look at the life cycle of an amphibian. Frogs, toads, salamanders and newts start their lives as soft, small eggs in the water. They then develop into tadpoles and stay in the water. When they are tadpoles, they cannot breathe air and do not even have lungs yet as well as other important structures like legs. They have gills and tails and rely on the water for survival. They feed on aquatic algae and insects that live in the water are also affected by the chemicals in it.



Amphibian Slimy Skin

Amphibians need moist areas to keep their skin healthy. They do a lot with their skin; using it not only for protection and camouflage, but for gas exchange with the environment. The

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slimy or moist feel to their skin protects them from predators, making it easy to escape a foe's grasp. Amphibians can also breathe and gain water through their skin. In order to stay protected in a coat of slimy mucous, they need to inhabit wet areas. This is why we commonly find frogs, toads, or salamanders close to bodies of water or underground in moist soils.

This coating of mucous is also very sensitive. It highly depends on clean water and moist soils that have no harmful chemicals in them. If the water becomes polluted, the amphibians living in the habitat will likely die or try to leave to find a cleaner habitat.

Amphibians as Indicator Species

When scientists are studying the environment, they can look at many things to see if it is healthy. They can test many things like the soil or trees, but the best way to get a quick yes or no answer is to look at what the animals living there say. **An indicator species** is basically a specific animal that shows the condition of the surrounding environment based on how many individuals are in that environment. Amphibians are an indicator species for water quality. For example, if there are a lot of healthy frogs, toads, and salamanders in a waterway we know the quality of the water is very good because if it was polluted the amphibians would not be able to exchange water and oxygen through their skin.

Who Cares?

So why do the amphibians and aquatic life matter? What would happen if we didn't have anything living in the water? Well, without amphibians and aquatic animals we would be overwhelmed with bugs. Frogs, toads, salamanders and even fish love to eat mosquitos and other water bugs that can give us illnesses like West Nile Virus. They also like to eat algae, and if you like to swim in clear water with little algae, we need the animals that live there to eat it! Too much algae in a waterway can eventually deplete the oxygen, because as algae dies and decays, bacteria consume it and use up all the oxygen the fish need. We also like to eat fish and sometimes even frogs, and how could we do that with no fish and frogs? Amphibians are an essential part of the food web and essential for environmental health.

For more information, see Disappearing Frogs – KQED Quest Watch from 3:24-5:14 – for a good explanation of amphibian importance as an indicator species.
http://www.youtube.com/watch?v=b3V04D3C4Lg

Teacher Materials

- Pretest: "*How does coal keep the lights on?*"
  http://www.auburn.edu/~cgs0013/ETK/coal_assessment.pdf
- *What is Engineering* PowerPoint
  http://www.auburn.edu/~cgs0013/ETK/Engineering.ppt
- *Coal Keeps the Lights On* Power Point
  http://www.auburn.edu/~cgs0013/ETK/Coal.ppt
- *Save the Snails* webquest
  http://savetheslimycreatures.weebly.com/
- Lump of coal

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- Computer connected to LCD projector and speaker system
- Tube filled with marbles or balls
- One electrical toy for each student group.

Stations

1. **Hand-held generator with bell.**
- A hand-held generator is connected to a doorbell that works because of an electromagnet and a metal hammer clanging on the bell. Students are asked to crank the generator forwards and backwards and observe the action at the bell. They are asked to use their prior knowledge about electric circuits and sound to discuss how they think energy transforms from the cranking hand to the electricity entering the bell, to the sound made by the bell. They have to make close observations to notice the electromagnet, and make inferences based on their knowledge of electricity and magnetism.

2. **Hand-crank flashlight.**
- A flashlight that operates when a crank is turned is present at this station. Students are asked to make a light come on and observe carefully what is inside the generator. They are to use their prior knowledge of electric circuits and light bulbs to make inferences about how the energy is transformed.

3. **Dissected motor.**
- At this station, students are presented with a dissected electric motor. The magnetic pieces are colored red and blue, and the magnet wire coils are very easy to see. The students are asked to use their prior experiences with motors to draw, examine, and determine how an electric motor uses electrical energy to produce kinetic energy. They are asked to compare this motor to the hand-crank generators they have experienced, and make a comparison between motors and generators. You can glue the dissected motor to a small board for easy use and re-use.

4. **Wind turbine model.**
- A small wind turbine is wired to an LED light bulb. When you blow on it, the bulb glows. Students are asked to use their prior knowledge about hand-cranked generators to determine how kinetic energy from wind is transformed into light energy.

5. **Energy balls**
- Energy balls have nothing to do with electromagnetism, but they provide an interesting problem solving activity, and lead students to create circuits and see that a complete circuit is necessary for the sound and lights to work. Many students will think that their body heat creates the energy needed for the sound and light. After trial and error they will see that a battery must be inside, and that the two metal pieces simply need to be connected. Encourage students to hold hands in a circle and complete the circuit that way to make the energy balls "go."

6. **Shake tube**
- A shake flashlight could be used for this station. Alternatively, you can encase a neodymium magnet inside a clear plastic tube with stoppers in each end. Wrap magnet wire around the tube and attach an LED. Shake and glow!

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7. **Hand-held generator with two-way LED**

- Students are asked to crank the generator forwards and backwards and observe the LED. They are asked to discuss how they an LED works, and why two colors shine from it. They have to make close observations and make inferences based on their knowledge of electricity and magnetism and light .

Student Materials (for each group)

- ½ sheet poster board
- 1 box colored markers or pencils

Preparation

1. Photocopy the pre-assessment "*How Does Coal Keep the Lights On?*"
2. Examine the links in the PowerPoint. The links are simply gathered there for you to use as you see fit with your students. Alternatively, set up an Edmodo site so that students can access the same information on their own or in small groups. Use the *Save the Snails Webquest* either as a presentation or let students investigate the issues on their own.
3. Prepare the electricity toys, including the dissected motor.
4. Set up a projector and screen with speakers attached to your computer
5. Purchase large poster sheets. Make sure there is one for each student group, plus markers.

Procedures

1. Begin this unit by telling students that 1/4th of the world's population does not have access to electricity. Have students discuss this in groups, focusing on the following questions:
    a. How does this impact people?
    b. How does it impact children in particular?
    c. Does it matter?
    d. If you were a child who grew up without electricity when 75% of everyone else did, how would that change you?
2. Show students a lump of coal but do not tell them what it is. Ask students to observe and guess what it is. They may guess graphite, lead, iron, plastic. When students figure out if is coal, assess their prior knowledge about how coal is used to produce electricity using the included "*How Does Coal Keep the Lights On?*" assessment. Collect all of the assessments and score them but do not return to or discuss with the students. The assessment is intended to gauge the students' understanding of how the nation's leading source of energy is utilized.

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How does this happen?

Coal ⟶ Electricity

Assess these with the following rubric, by giving one point for each component mentioned:

coal was burned	1 point
water is involved	1 point
water is boiled	1 point
steam is produced	1 point
something is turned or moved	1 point
a turbine is involved	1 point
magnets are involved	1 point
coils of wire are involved	1 point
a generator is involved	1 point
energy is involved	1 point

3. Pass out the electricity toys with one for each group of students. Give students a few minutes with each toy to examine it and try to figure out how it works.
4. Either set this up as stations that students move through, or have student groups pass the toys from group to group. EDMODO SUGGESTION: Have students log onto the social networking site, Edmodo, and write about the toy they are playing with. How do they think it works? What do they notice?
5. Through discussion ask students what types of energy were involved in the toys. Ask students, what is electricity? Ask students, what is energy? Most will have trouble defining energy and reassure them that it's ok because scientists only know what energy can do, not what it is. The following simplified definition works well:

Energy is the ability to make something change or happen.

6. What happened or changed in the toys? Most students will also have difficulty explaining what electricity is. They may conceive it to be the flow of electrons, but not the flow of electrons that are already present in the conductor.

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7. After the toy activity, use the marble and tube demonstration to show students that electricity is just the motion of electrons already present in a wire or other conductor. The tube and marbles demonstration is used to show that electrons are part of the wire or the conductor, and are pushed by the energy source. Directions: Fill a tube with marbles. Hold the marbles in at both ends. When one marble is pushed into the left side, a marble pops out of the right side. Ping pong balls and a cardboard tube would work also. Ask students, "What pushes the marbles? What pushes the electrons in a wire?" Magnets push the electrons in the wire. Move a magnet near wire, and you get electricity!
8. Show some of the videos in the *Coal Keeps the Lights On* PowerPoint that explain how some people in the world create energy without coal. The goal of these videos is to get the students to understand that electricity is created by spinning a generator by various methods, as well as identifying some of the methods commonly used today such as fossil-fuel fired boilers, wind/water plants, etc. Throughout the videos are various prompts intended to promote a continuous discussion by the students. EDMODO SUGGESTION: Instead of delivering a PowerPoint presentation, post the links on Edmodo or have students go to the *Save the Snails Webquest* and investigate on their own. Post questions on Edmodo for students to respond to.
9. Introduce the concept of the storyboard. A storyboard is like a comic strip in that it tells a story through drawings and words divided up into sections that flow on into another. Each time students learn a new concept, do an experiment, create a design, or test a design, it should be recorded on the story board for teachers and students to see and comment on. You might want to show students a sample storyboard.

10. Show some videos from the *Save the Snails* PowerPoint that show how coal mining and burning impacts the environment. Get students to understand how coal mining affects all living creatures around the world, and begin brainstorming other forms of energy that can be used for electricity generation. Alternatively, use the EDMODO SUGGESTION: Instead of delivering a PowerPoint presentation, post the links on Edmodo or have

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students use the *Save the Snails Webquest* to investigate and learn on their own. Post questions on Edmodo for students to respond to. Remember that the focus of the discussion should be directed towards the use of wind turbines, hydroelectric dams, wave turbines, and other sources of natural motion to produce electricity.

Wrap-Up

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

- **What did you learn about electricity today?**
- **How does chemical energy in coal become electric energy? (accept all responses, but do not give answers. Find out what students learned at this point.)**
- **What are the environmental impacts of coal mining and use in power plants?**
- **How does coal mining and burning hurt snails, salamanders, and other slimy creatures?**
- **What are some alternative ways to create electricity?**
- **What parts or components are needed to make electricity?**

In lesson 2 we will explore the components and parts needed to make electricity

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LESSON 2

Electromagnetic Induction and Michael Faraday

Learning Targets

1. Electricity can be generated by moving a magnet in and out of a coil of wire.
2. Coal fired power plants use burning coal to create motion.
3. Engineers use scientific investigations to help them invent and design.

Purpose of the Lesson

1. Introduce students to the concept of motion-generated electricity.
2. Provide a series of activities that allow students to understand:
    a. What is inside a motor
    b. A motor is a generator, just used differently
    c. Electricity and magnetism are related
    d. How motors and generators were invented

Lesson Objectives

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

- Explain how electricity and magnetism are inter-connected.
- Explain how motors and generators work

Lesson in a Nutshell

1. Have students investigate magnets and coils of wire with multimeters
2. Discussion on electromagnetism and Michael Faraday
3. Explanation of how motors and generators work

Background

Electromagnetism: Electricity creates magnetic fields, magnetic fields create electricity. Both phenomena are related and called electromagnetism.

Basic review of magnetism:

Magnetism is the phenomena associated with a magnetic field.

http://www.explainthatstuff.com/magnetism.html

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Materials

Teacher Materials

Computer connected to LCD projector and speaker system
Save the Snails Webquest (Innovations Section)
Lump of coal

Student Materials (for each group)

- ½ sheet posterboard and markers
- Magnet wire
- Sand paper
- Multimeters
- Magnets (If your magnets are very strong, I recommend putting them in a tube as shown below).
- Tape

Preparation

1. Cut magnet wire into 1-meter lengths—one piece per student group.
2. Prepare small squares of sand paper.

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Procedures

1. One of the first concepts that students should try to understand is that electricity and **magnetism** are connected. This was shown with the miniature wind turbine demonstration and many of the other toys in the previous lesson. This principle can also be shown with simple coils of wire and a magnet.

2. Pass out magnet wire (1 meter per student group) and magnets.

3. Pass out multimeters and demonstrate how to find current in mA. This handy sheet illustrates how to use a multimeter. Multimeter Directions
http://www.auburn.edu/~cgs0013/ETK/Multimeter_Directions.doc

4. Challenge students to figure out a way to use their wire and magnet to make electricity they can measure on the multimeter. Give them time to think and struggle. If necessary, pass out the toys from Lesson 1 to remind students what they saw

5. Tell students the story of Michael Faraday, and how he discovered that he could make electricity from magnets and wire while working for Humphry Davy. See
http://www.bbc.co.uk/history/historic_figures/faraday_michael.shtml

At that time, Davy had to use crude batteries to create electricity. Davy used the electricity to separate compounds into elements. The Faraday story is very remarkable. Several videos illustrate his life. Consider showing one:

- http://youtu.be/TEVEBzNSwTU
- http://youtu.be/yVDHKKTC4tA
- Then show this one: http://youtu.be/NqdOyxJZj0U

6. Eventually show students how to sand the covering off the ends of the wire and make a coil. Have them experiment with the diameter of the coil and the number of windings, and the proximity of each coil to the other. Provide tape to students who want to bind their coil.

7. After the activity, ask students to think of different ways they could create motion in the magnet in order to produce electricity. What are some natural sources of motion? (wind, water, rain falling)

8. Hold up the lump of coal and ask: Does anyone know how this lump of coal is used to create electricity?

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Based on what you know about magnets and coils of wire, what can this lump of coal do? Talk students through the process—that coal is used to make fire, that fire is used to boil water, and that water turns to steam to turn coils of wire or turn magnets near coils of wire. Consider showing this video:

- https://www.youtube.com/watch?v=20Vb6hlLQSg

9. Have students update their storyboards with some of the ideas that they have learned.

Wrap-Up

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

- **How can motion create electricity?**
- **How are magnetism and electricity related?**
- **How can electricity create motion?**
- **What are some ways to create motion needed to create electricity?**

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LESSON 3

Gear Trains, Generators, and LEDs

Learning Targets

1. Gears can be used to slow or speed up motion.
2. Generators and motors both use magnets and coils of wires.
3. Light Emitting Diodes work when electrical charges jump a gap.
4. Engineers use science experiments and scientific knowledge in order to invent and design.

Purpose of the Lesson

1. Students see that simply turning a motor hooked up to an LED creates light.
2. Introduce students to the idea that gears are important components of machines in that they change the speed or direction of motion.
3. Challenge students to use gears to keep the light on longer.
4. Have students experiment with gears and learn that multiple sets of gears can be meshed together to make a gear train.
5. Have students calculate gear ratios of a single pair of gears, and of gear trains.
6. Have students design and build a simple gear train meshed with a motor.
7. Ask students to think of ways to keep the gear train moving without human intervention.

Lesson Objectives

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

Create a simple gear train hooked to a LED, which when turned, makes the light come on.

Lesson in a Nutshell

1. See that turning a motor makes electricity
2. Understand how gears are used in machinery
3. Play with the www.gearsket.ch simulation online
4. Understand the relationship between gear ratios and gear speed
5. Design and build a gear train that lights an LED or series of LEDs

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Background

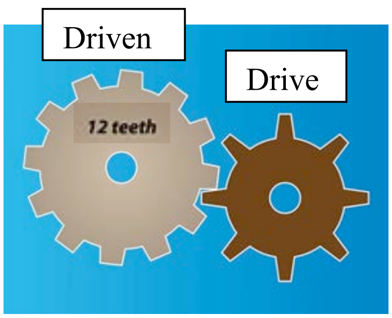
Light Emitting Diode: The LED is a light source created when photons are released when electrons jump a gap between a cathode and an anode. LEDs come in all sorts of colors. See http://www.howstuffworks.com/led.htm

Gear: A gear is a wheel with teeth. The teeth from one gear mesh with the teeth from another gear, transmitting rotational motion.

Gear Train: A gear train is made when gear pairs are joined to create more mechanical advantage or a higher gear ratio.

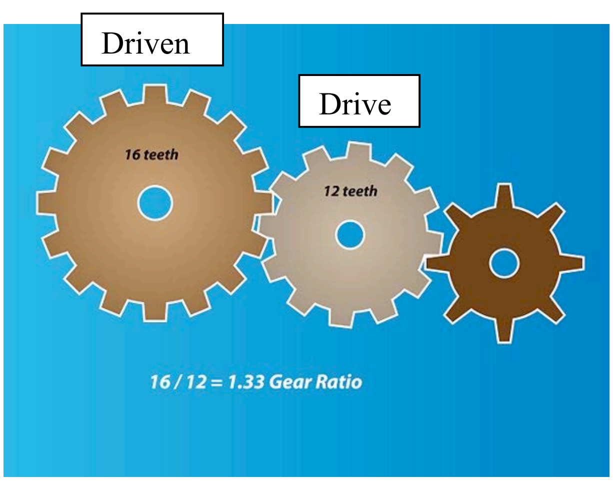
Motor: A motor is a device that converts electricity to motion. This is not to be confused with an engine, which converts a fuel like gasoline into motion.

Generator: A generator is a device that converts motion to electricity. Inside a generator are magnets and coils of wire. Motion of the magnets relative to the coils induces an electric current.



This is a gear train. A gear train consists of a drive gear that is connected to a motor and a driven gear that is being moved by the drive gear. In this picture, the small brown gear is the drive gear; it has 8 teeth. The gray gear is the driven gear; it has 12 teeth. To determine the **gear ratio** of this system we divide the number of teeth of the driven gear by the number of teeth of the drive gear. **Driven/Drive**.

This results in $\frac{12}{8}$ or simplified to $\frac{3}{2}$. This is then written as 3:2. Since $3 \div 2 = 1.5$, the drive gear turns 1.5 times faster that the driven gear and the driven gear turns 1.5 times slower than the drive gear. Not only are the speeds different, but the directions are different too. If the drive gear turns in a clockwise direction, the driven gear will go counter clockwise and vice versa (see pictures at the right).



Now, what happens if you add a gear? Calculating the gear ratio becomes a little bit of a longer process and the new driven gear is the 16 tooth one. Since the brown and gray gears are still connected, we keep that ratio handy $\left(\frac{3}{2}\right)$, but to add the tan 16- tooth gear we now establish the gray gear as the drive gear and the tan gear (16 teeth) as the driven gear. This setup creates a ratio of $\frac{16}{12}$ or $\frac{4}{3}$. Since $4 \div 3 = 1.33$, the drive gear turns 1.33 times faster that the driven gear and the driven gear turns 1.33 times slower than the drive gear. To determine the gear ratio for the train,

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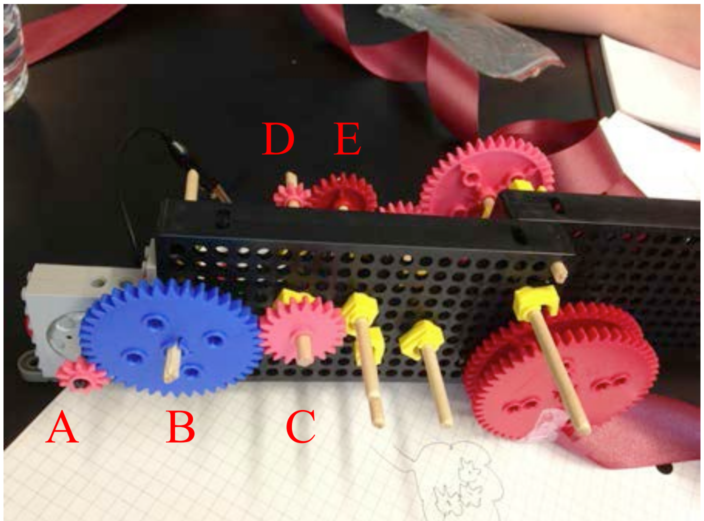
we then multiple our two calculated gear ratios: $\frac{3}{2} \times \frac{4}{3} = 2$. The middle gear, which is called the idle gear, serves only one purpose: to change the direction of the driven gear. In conclusion, we can say that the brown drive gear spins 2 times faster than the tan driven gear or that the tan driven gear turns 2 times slower, or half the speed, of the brown drive gear.

Think about how two gears work when they are connected by the same axle, for example, on opposite sides of a board. Let's say your motor has a gear with 10 teeth attached to its shaft, like the one pictured below. What will be the speed of the red gear E, on the other side of the board?



We are going to estimate the number of teeth for the gears A, B, C, D, and E respectively to be, 10, 40, 22, 10, and 20. Since we know that gear ratios can tell us how fast a gear is turning relative to another one, we will start our calculations with that. Fortunately for us, the first gear that gear A is connected to is an idle gear, so it can be ignored. This makes our first calculation to be the gear ratio between gears A and C. Gear A is obviously our drive gear, while gear C is our driven gear. **Driven/Drive**. So, $\frac{22}{10} = 2.2$, which means that gear A turns 2.2 times faster than gear C. Since gear D is connected to gear C by the same axle, they will share the same speed. Now, to determine how fast gear E is turning, we will need to find the gear ratio between gears D and E. Gear D is the new drive gear and Gear E is driven, so the calculation looks like this: $\frac{20}{10} = 2$. Gear D goes 2 times faster than gear E. Finally, we have to put all of this together. For the first gear ratio, **Driven/Drive** = 2.2 and for the second gear ration, **Driven/Drive** = 2. Therefore from Drive Gear A to Driven Gear E, the ratio is 2.2 x 2 = 4.4. Gear E spins 4.4 times slower than gear A.

Now, to elaborate, what direction will Gear E be turning if gear A is turning clockwise? If you said counter clockwise you are correct! If gear A is being turned clockwise by the motor then gear B will turn counter clockwise, making gear C turn clockwise. Gear C and D will turn the same direction, in respect to your view of the gears, making gear E turn in the counter clockwise direction.

Some good websites about gears:

http://science.howstuffworks.com/transport/engines-equipment/gear-ratio4.htm

http://m.wikihow.com/Determine-Gear-Ratio

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http://www.eng.iastate.edu/twt/Courses/Undergrad/packet/info/gears.htm

Some good videos about gears:

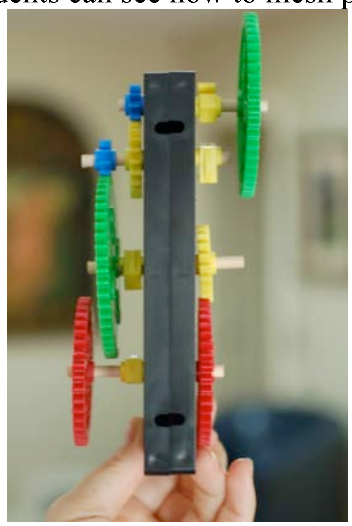
http://www.sciencekids.co.nz/videos/physics/gears.html

http://vimeo.com/30206625

http://www.youtube.com/watch?v=D_i3PJIYtuY

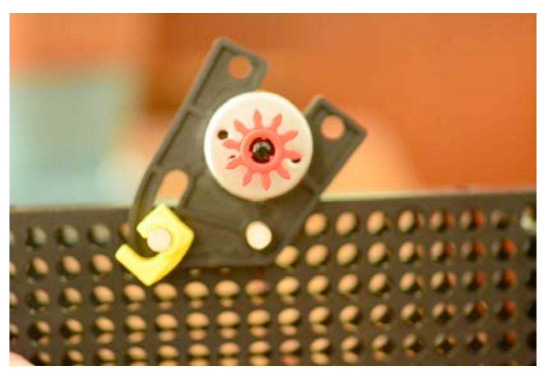
Teacher Materials

Provide some gear trains pre-built so students can see how to mesh pairs together



Student Materials (for each group)

- ½ sheet of poster board
- Gear assortment (See Teacher Geek)
- Boards with holes and a way to mount a motor on one end (Suggest two TeacherGeek plates glued together)
- Wooden dowels that go through holes in boards
- Motor with gear mounted on shaft
- Motor holder (see image)
- LED assortment
- Multimeter
- Small hammer (Crab mallet will do)
- Wooden board to protect counter/table
- ½ inch plastic pipe to help tap gears into place



Preparation

1. Prepare some gear trains to demonstrate how two gears on one shaft can be used effectively to create gear trains.

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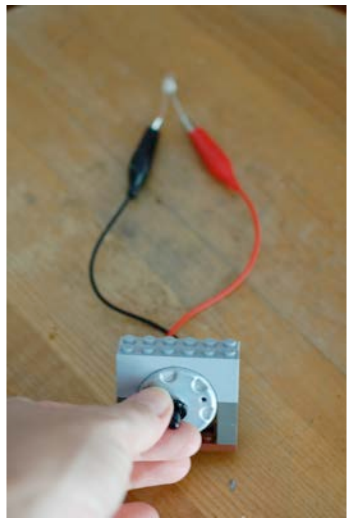
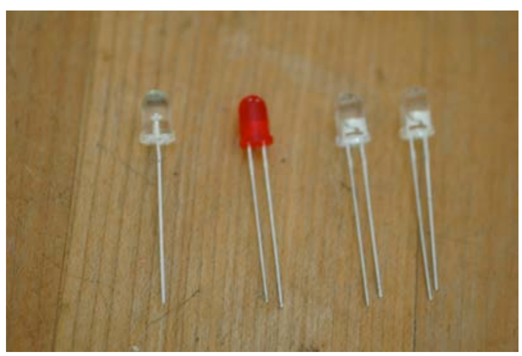
2. Cut the wood dowels to 6" and smaller lengths
3. Prepare motor mounts and a method of securing motors to boards with holes. See image.

Procedures

1. Give students a motor with wires, and an LED. Challenge students to use the motor to make the light come on. Students see that simply turning a motor hooked up to an LED creates light.



2. Have students examine the LED closely and notice that two metal pieces are separated by a slight gap. Explain that when electrons jump this gap, light shines.



3. Ask students what they could do to make the motor spin faster. Would that make the light brighter? Would it cause more electrons to jump the gap in a second? Introduce students to the idea that gears are important components of machines in that they change the speed or direction of motion.
4. Demonstrate how gears mesh together, and how two sizes can be used to change motion. Provide a board with holes, dowels, and gears. Encourage students to play with these to figure out how gears change speed and direction of motion. See image below.

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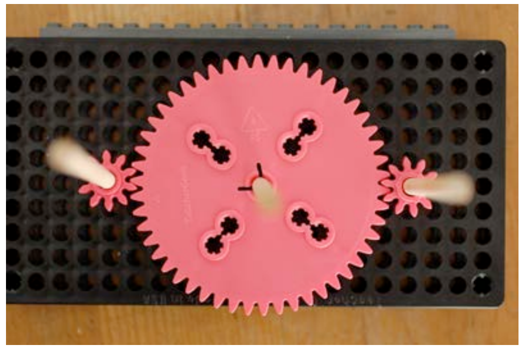
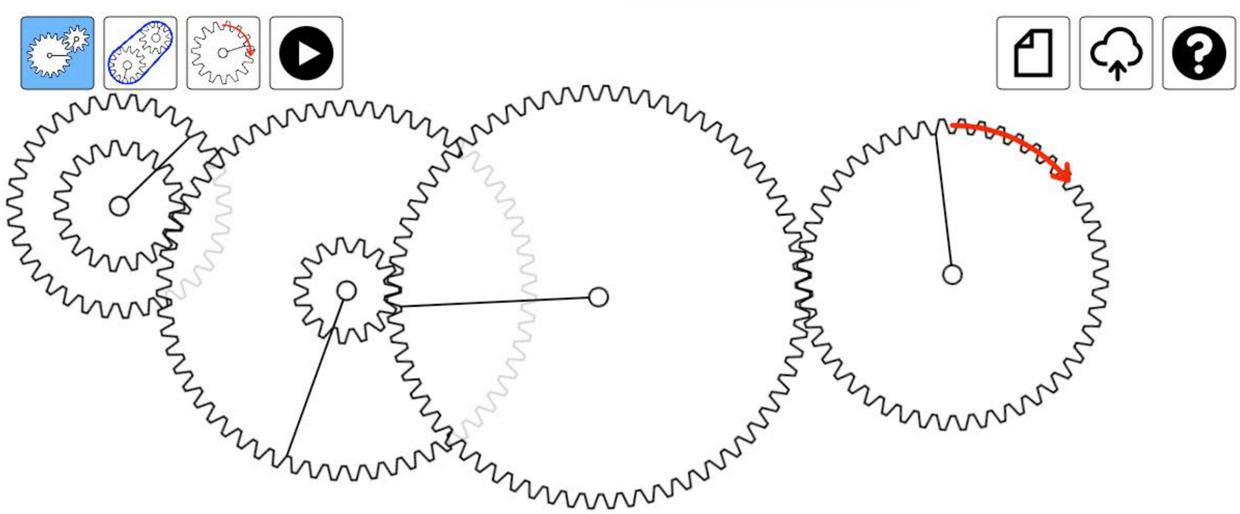


5. Show some of the YouTube videos about gears. (see above in Background Information)
6. Challenge students to calculate the gear ratio when one set of gears is meshed with another. Discuss Driven and Drive gears, and introduce the ratio $\frac{Driven}{Drive}$.
7. Go to the www.gearsket.ch website and draw gear trains. You can change the drive and driven gears, change the direction of rotation, change the speed of the Drive gear, and even put gears on top of each other on the same axle. It is super cool on a Smartboard and students can draw their own gear trains. You can even save gear trains as websites. See the one I created below, but also on this website. (Use the cloud icon to make a website). http://www.gearsket.ch/#90dbd2fee2c7b836



8. Have students design and build a simple gear train meshed with a motor.
9. Ask students to think of ways to keep the gear train moving without human intervention. Let them brainstorm ways that would keep the gears in motion. They may think of wind or

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water, but may not think of a falling object like a bucket over a well or a Grandfather clock weight falling and moving the gears of the clock over time.

10. Have students storyboard about what they learned and accomplished in this lesson.

Wrap-Up

1. Gears can be used to slow or speed up motion or reverse motion.
2. Generators and motors both use magnets and coils of wires.
3. Light Emitting Diodes work when electrical charges jump a gap.
4. Engineers use science experiments and scientific knowledge in order to invent and design.

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

- **What is the purpose of using gears in a machine?**
- **How is a generator different from a motor?**
- **What is inside an LED, and how do you think they make light?**

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LESSON 4

Gravity Light

Learning Targets

1. Electricity can be measured with units of voltage and current and power
2. Voltage (volts) is a measure of the force on electric charges.
3. Current (amperes) is the measure of how many charges pass a point in a time period.
4. Power (watts) is a measure of how much electricity is used in a time period.
5. Engineers use scientific knowledge and creativity to design solutions to problems.
6. Engineers work within constraints (time, materials, space, money…)
7. Engineers use a process to design solutions to problems.

Purpose of the Lesson

The purpose of this lesson is for students to design a way to keep a gear train moving for the longest period of time, thus keeping the lights on.

Lesson Objectives

At the end of this lesson, students will be able to measure the amount of electricity they can create in a period of time and calculate the power output of their gravity light.

Lesson in a Nutshell

1. Perfect the gravity light by using ribbon tied to a weight to keep the gears in motion.
2. Measure the amount of electricity generated.

Background

Voltage: Technically, voltage is potential energy per unit charge. I like to describe it as the force pushing electrons in a circuit, but that is not really accurate.

Current: Technically, current is the flow of unit charges. It is a measure of the quantity of charges that pass by in a circuit each second.

Energy: Energy is the ability to do work, or make something happen or change. It is measured in joules.

Power: Power is the ability to do work quickly. In electricity, power is calculated by multiplying voltage (J/charge) x current (charge/sec) to result in Joules per second.

A review of the physics:
http://electricalengineeringforbeginners.blogspot.com/2009/07/voltage-current-power-and-energy.html

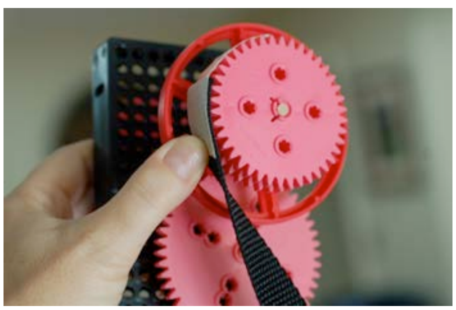
Materials

Student Materials (for each group)

- ½ sheet poster board
- 2 meters of ½" – ¾" ribbon
- Scissors
- Tape
- Gear materials from lesson 3
- Hollow tube for tapping gears into place
- Wooden mallet for tapping gears into place
- Timer
- Multimeter
- Bottle of water as the weight tied to the ribbon

Preparation

- Cut ribbon into 2-meter lengths so that the ribbon can wrap around a couple of gears put together to make a spool.



- Assemble kits of materials for each group (gears, dowels, plates with holes, LEDs, etc.)

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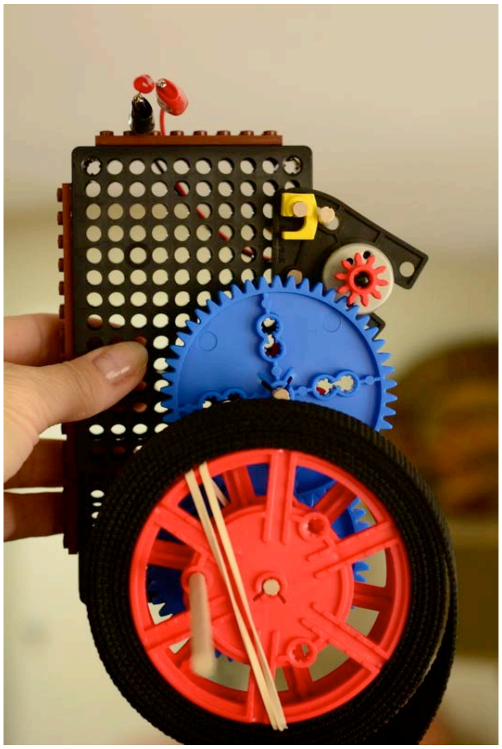
This is what a simple, functioning gravity light looks like.



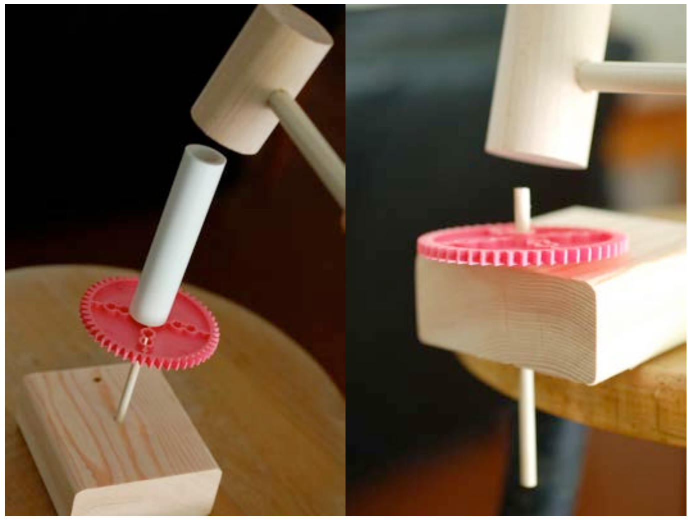
Procedures

- Ask student to think of ways they can keep their gear train moving without human intervention.
- Remind them of the gravity light from the video in Lesson 1.
- Pass out water bottles and ribbon and challenge students to design a way to make a gravity light. The objective is to keep the light on for the longest time.
- When student groups have successfully made a gravity light, have them time the number of seconds that the light is on, and then hook up the multimeter instead of the light measure the voltage and current generated. Multiply V x A and divide by time to get Watts.
- Ask students to think of more ways they could keep their gear trains moving.

  This video shows a functional gravity light I made. http://youtu.be/ZfiC-1pUHyc
  This video shows the original gravity light:
  https://www.youtube.com/watch?v=f_OLgLgy_wE

  These videos shows a man who created a gravity light in his home.
  https://www.youtube.com/watch?v=iJUM4pCi71Q
  https://www.youtube.com/watch?v=foqqxqW8aBg

- Some gears can be stubborn and not slide easily on the dowels. We suggest a small hammer and a hollow tube with a wood block. The wood block has two holes- one that goes all the way through, and another that only partway goes through. See below. Hammering the tube pushes the gear down on the dowel. If the dowel is put through the entire hole, the dowel itself can be hammered.



Wrap-Up

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

How do we measure electricity?
What is voltage?
What is current?
What is power?
What other devices use gravity to keep moving? (a grandfather clock, a watermill that grinds corn)
How would a gravity light help save the snails, salamanders, and other slimy creatures?

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LESSON 5

Wind and Water Power

Learning Targets

1. Alternative energy sources such as wind and water work because the moving fluid turns a generator.

2. Engineering is an iterative process of designing, testing and re-designing.

3. There can be several solutions to one engineering problem.

Purpose of the Lesson

1. The purpose of this lesson is to have students design and construct a device that turns when air blows across it, or when water falls on it.
2. Students measure the amount of power generated in the same amount of time their water bottle was falling in order to compare designs.

Lesson Objectives

At the end of this lesson, students will be able to design and construct a wind or water powered device that is capable of generating electricity. The second goal is to connect the turbine to a series of LED lights and see how much light can be produced, and for how long. The third goal is to measure the amount of power produced by the wind and the water-powered device and compare that to the gravity powered device. Finally students will analyze their designs to determine which features worked best and which did not.

By the end of day 5 students should be able to:

- ➢ Connect their gear train to a series of LEDs to test the light production of their designs
- ➢ Evaluate the effectiveness of their designs

Lesson in a Nutshell

1. **Students will modify their gravity light so that it turns from wind or water.**
2. **Students will see how many lights they can turn on.**
3. **Students will measure the amount of electricity produced and compare it to the gravity-powered light.**

Background

Wind Turbine: A wind turbine is a device that converts wind to motion of blades to electricity in a generator.

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Hydroelectric Generator: A hydroelectric generator is a device that converts moving water to motion of turbine blades to electricity in a generator.

Teacher Materials

- Hairdryer for wind generation. Set hairdryer to the COLD setting.
- Bucket or sink for catching water, and pitcher for pouring water.

Student Materials (for each group)

- ½ sheet posterboard for storyboard
- Dixie cups (plastic or paper)
- Tape
- Scissors
- A device to collect water, and another to pour water
- Multimeter

Preparation

➢ Prepare a chart with the results from Lesson 4 to use as a reference for today's redesigns

Procedures

Step 1: Allow students to make changes to their designs so that wind and water turn the generator. Below is one suggestion of many possibilities.

Step 2: Once a group has made their desired changes allow them to retest their design. Have students compare their results with the previous results. Have them measure voltage and current, and see how many lights can turn on. See this video of a wind turbine I made for an example. Wind Light http://youtu.be/q02GgvOEskc

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Step 3: Conduct a final discussion with students about the use of the gravity, wind, and water. Do they think that these are viable alternatives to fossil fuels? Why would gravity lights or wind generators or water turbines be used more in certain areas of the world more than others?

Be sure to share the story of William Kamkwamba with your students. He is the author of the book, *The Boy Who Harnessed the Wind*, which would be a great English Language Arts component to this curriculum. There are several videos about him and his work. Watch here:

This first video is more recent, and William has better English skills. I'd show it first.

https://www.youtube.com/watch?v=arD374MFk4w

These next two videos are older, and show William as a teenager. I think in some ways they are more inspiring because you see his youth and his struggles more directly.

https://www.youtube.com/watch?v=6QkNxt7MpWM

http://www.ted.com/talks/william_kamkwamba_on_building_a_windmill?language=en

Step 4: Ask students what they liked and disliked with this unit. This information can be used to plan how to utilize future units that combine science and engineering.

Step 5: Distribute awards for fun. Award categories can include best improved, highest output, as well as any others you may find fitting.

Step 6: Have students update their storyboards.

Step 7: Distribute the post tests (How does Coal Keep the Lights On)
http://www.auburn.edu/~cgs0013/ETK/coal_assessment.pdf

Wrap-Up

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

- **Describe some ways you can make electricity from motion.**
- **How does coal turn into electricity?**
- **How do alternative ways of making electricity help the environment, especially slimy creatures like salamanders, frogs, and snails?**

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APPENDIX

MATERIALS AND SUPPLIES

Appendix A: Materials

The materials listed below will supply one teacher with one class of students- approximately 28 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. Also try science supply websites like http://www.scientificsonline.com/ and http://www.teachersource.com/
The entire kit can also be purchased from www.stemteachingkits.com

Lump of coal

1 miniature wind turbine. See http://www.instructables.com/id/Small-Wind-Turbine-With-LED/

1 shake light. See http://www.shake-flashlights.com/how-they-work.html

2 hand crank generators

1 energy ball. See http://www.teachersource.com/product/energy-ball/electricity-magnetism

Assortment of LEDS, including one bi-color LED

Doorbell with open gong

Sand paper

Paper or plastic small cups

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Marbles that fit in a clear tube

Digital timer

7 small motors that fit into the Teacher Geek motor holder.

One dissected or open-frame motor

Ample supply of magnet wire

7 neodymium magnets (consider placing them in clear tubes with rubber stoppers on ends for protection)

7 multimeters

1 hair dryer with a cold setting.

14 black holed bricks (28 black plates) from Teacher Geek

Gears- at least 3 big, 3 medium, 3 small for each of 7 groups

7 small hammers

7 small wood cutting boards or blocks of 2x4 for hammering on

7 small pieces of PVC pipe

Ten 4” dowels and ten 2.5” dowels per group

14 dowel clips per group (see Teacher Geek)

Flat ribbon or fabric tape for pulling the water bottle

Order gears and bricks from Teacher Geek. www.teachergeek.com

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Appendix B: How does Coal Keep the Lights on?

Name ____________________   Date _______________

How does this happen?

Coal ⟶ Electricity

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