CE CLEAN ENERGY BRIGHT FUTURES

LESSON PLAN

The 50 Year Energy Plan Project

Lesson 2: Diving into the Physics of Motors and Generators

AUTHOR
Bradford Hill

CONTACT

Teacher Contact: Bradford_hill@beaverton.k12.or.us
CE Editor Contact: CEbrightfutures@b-e-f.org, 503-553-395

DESCRIPTION

Using energy analysis and some tinkering students hand wind speakers to play music from a phone. This acts as a phenomenon to engage students in the exploration of electromagnetism. At this point, they have created a motor, which utilizes electric current to perform work (the speaker itself creating noise). They can then explore the reversal of this process in the next lesson. Next, we disassemble the speakers and connect them to simple, student-made $3 guitars to make them electric guitars. This process reversal of the speaker system above, and students are given insight into how generators work. They can spend time optimizing different parts of their guitar design for as long as they choose in order to make it more effective or clear.

ACTIVITY LENGTH

3 x 90 minute periods.

LEARNING GOAL(S)

1. Through hands-on exploration, create a working speaker for a cellphone.

2. Use the creation of a speaker to observe as a model for the process of generating electrical current in a simple generator/motor.

CONTENT BACKGROUND

STUDENT BACKGROUND

This unit attempts to meet students where they are at with understanding of motors and generators, which varies from high interest and knowledge to relatively uninformed.

EDUCATOR BACKGROUND

Educators wanting to be prepared to teach this lesson should read a basic physics textbook or online resource that explains motors and generators. A few clear explanations can be found online here ("https://www.explainthatstuff.com/electricmotors.html") and here ("http://www.edisontechcenter.org/generators.html").

Also, reading the Framework for K-12 Science Education ("https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts") from the National Academies Press is a great resource for learning about inquiry-based education and taking a new approach to hands-on, engaging science education.

Activity-Specific Background Resources:

GENERATOR PHENOMENON:

- Review background and assembly notes for the Magnetic Phenomenon Presented in Part 3 of the Lesson Progression from Exploratorium.edu (https://www.exploratorium.edu/snacks/motor-effect)

BUILDING DIY SPEAKERS:

- Review instructions created by the Exploratorium, found online here https://www.exploratorium.edu/snacks/cup-speaker
- How Speakers Work: https://animagraffs.com/loudspeaker/

BUILDING MOTORS: https://www.exploratorium.edu/snacks/stripped-down-motor
From the Exploratorium: "A coil of wire becomes an electromagnet when current passes through it. The electromagnet interacts with a permanent magnet, causing the coil to spin."

MATERIALS NEEDED

HANDOUTS/PAPER MATERIALS

- EMPP Unit Packet

CLASSROOM SUPPLIES (PER CLASS OF 24 IN GROUPS OF 3 - 4)

- Audio Visual Equipment
- Masking Tape
- 1 Clear, reusable cup for each student
- 2 Clear buckets
- Water
- 2 Food Coloring – Blue and Yellow or any two primary colors
- 3 Light Bulbs (1.5 V)
- 3 Alligator Clips
- 1 Bar Magnets
- 2 magnetic compasses (to react to electromagnets)
- 2 Multimeters
- 2 Spools Enameled Wire – 1lbs 24 AWG (for building speakers)
- 1 Easy to work with 20 AWG wire (for electrical connections)
- 8 Hand Held Generators
- 16 Cylindrical Magnets made of Neodynium (1/2 in diameter x 1/2 in tall)

LESSON PROGRESSION

PLANNING AND PREP

Review the Unit Slides. Students will work on various small hands-on activities during these dates, requiring several material stations to be set up. Make sure to read through the instructions for making both the speakers and electric guitars before dividing materials into groups of 3 to 4 students.

Review embedded videos from EMPP Unit Slides.

Review hands-on activity instructions and materials →

a. ELECTRONS AS WATER ANALOGY:

   Materials (for an entire class):

   - 2 clear buckets

- Yellow and Blue food coloring
- Water
- Tape for creating a path for students to follow on the floor
- Clear, reusable cups

b. LIGHTING LIGHTBULBS:

Materials (per each group of 3-4 students):

- 1 AA 1.5 volt battery
- 1 D battery
- 1 9V battery
- Light bulb

c. GENERATOR PHENOMENON:
Review background and assembly notes for the Magnetic Phenomenon Presented in Part 3 of the Lesson Progression from Exploratorium.edu (https://www.exploratorium.edu/snacks/motor-effect)

Materials (for one teacher to demo in front of class):

- Two to four small disk magnets
- One or two 1.5-volt flashlight batteries
- Two to three feet (60 cm to 1 meter) of flexible wire, such as solid or multistranded hookup wire or magnet wire
- Masking tape
- Sandpaper
- A table
- A partner

d. BUILD DIY SPEAKERS: Review instructions created by the Exploratorium, found online here https://www.exploratorium.edu/snacks/cup-speaker

Materials (per each group of 3-4 students):

- Eight feet (2.5 meters) or more of magnet wire that is 24-gauge or higher (thinner)
- Piece of sandpaper, a few inches (5–8 centimeters) square
- C- or D-cell battery (it can be dead; it's just used to wind the coil)
- A 1/8-inch (3.5-millimeter) mono phone plug (if you don't want to buy one, you can cut the head gear off a pair of old headphones, but leave the cable intact; any plug that fits into a radio, phone, or other amplified audio device will work)

- Two alligator clip leads
- Scotch tape or masking tape
- Wire cutter/strippers or scissors
- One or two donut magnets about 1 inch (2.5 centimeters) in diameter and 1/4 inch (6.4 millimeters) thick
- Paper cup
- A working audio device (such as a radio or phone) with headphone plug

e. BUILDING MOTORS: https://www.exploratorium.edu/snacks/stripped-down-motor From the Exploratorium: "A coil of wire becomes an electromagnet when current passes through it. The electromagnet interacts with a permanent magnet, causing the coil to spin."

Materials (per each group of 3-4 students)

- About 2 feet (60 cm) of solid (not stranded) enameled or insulated copper wire, 20–24 gauge
- Wire strippers (if you're using insulated wire) or sandpaper (if you're using enameled wire)
- A black permanent marking pen
- Plain paper, plastic foam, or plastic cup
- At least 2 disk or rectangular ceramic magnets
- Two large paper clips
- Masking tape
- Aluminum foil
- One or two batteries, C or D size

LESSON SEQUENCE

DAY 1

This lesson corresponds to slides 37-139 of the EMPP Unit Slides and also follow activity sheets and guided notes in the Unit Packet on pages 7-8.

1. Engage students in a video about large scale power production.
   - *Before* watching, ask: **"What are the three big ideas of the following?**
   - *After* watching, connect students to their Lesson 1 K-W-L chart and compare/contrast findings

2. Lighting a small LED
    - Thinking about lighting a light bulb, “Walk the Triangle” as a class → What is the Experience (or Phenomenon occurring)? How can we Graph this Experience (or create a diagrammatic example)? Can we develop a Mathematical Representation of the Experience?
    - MOVING WATER AS AN ELECTRICAL CIRCUIT ANALOGY → in this simple activity students visualize and engage with the three major parts of a circuit:
        - First Water Container = AA Battery or Electron Source
        - Dyed Blue Water = Flowing Electrons
        - Rate of Students Moving with Cups = Voltage
        - Path of Students Walking = Current
        - Second Container Holding Yellow Food Coloring = Load/Light Bulb
        - Color Change from Yellow/Blue to Green = Energy Transformation
        - Empty Cups = Electrons Returning to Positive end of Battery
    - Go through the Water Bucket Analogy and repeat the exercise for different amounts of time and different battery voltages – ex. 1.5 V vs 9 V
    - Go through analytical questions, formulas, circuit symbology, graphs, and mathematical representations of the water as electron analogy as represented in Lesson 2 EMPP Unit Slides
    - Have student teams connect light bulbs to batteries and complete a circuit
    - Introduce Power = Current * Voltage
    - Students change their circuit designs, adding more batteries or power loads, and use PhET Interactive Simulations (https://phet.colorado.edu/sims/html/circuit-construction-kit-dc-virtual-lab/latest/circuit-construction-kit-dc-virtual-lab_en.html) to draw conclusions about the effects of these changes on their circuits
    - Introduce the concepts of Series and Parallel Circuits

3. Present a Phenomenon: What is a Generator?
    - In the next section or day of this lesson, students begin to explore the fundamental inner workings of generators and motors.
    - Begin by observing a teacher demonstration involving a current flowing through a simple circuit that visibly exerts force on a magnet.
    - From Exploritorium.edu:
        - *WHATS HAPPENING: "The magnetic field of the disk magnets exerts a force on the electric current flowing in the wire. The wire will move up or down or forward or backward, depending on the direction of the current and the direction of the disks' magnetic field."*
        - *ASSEMBLY:*

          Remove insulation from ends of the wire.

          Tape a battery (or two) near the edge of the table. If using two batteries, tape them so that they are in series, with the positive terminal of one battery touching the negative terminal of the other.

          Near each battery's terminal, tape the ends of the wire to the table. Allow the remainder of the wire to dangle over the table edge in a loop.

          Group the disk magnets into a single cylindrical pile.
        - *TO DO AND NOTICE:*

          Over the side of the table, have one person hold the grouped magnets next to the bottom of the loop of wire.

          On top of the table, have the other person touch one end of the wire to the positive side of the battery (or batteries) and simultaneously touch the other end of the wire to the negative side. (See photos at top.) The wire loop will jump one direction or another.

          If you reverse the direction of the current's flow, the wire will jump in the opposite direction. To reverse the current, attach the lead that was connected to the positive end of the battery to the negative end and vice versa.

          See what else happens if you flip the orientation of the magnets or hold them somewhere else near the wire."
    - Use questions within the EMPP Unit Slides to think, pair, share ideas about the observed phenomenon

DAY 2

NOTE – this activity may take more than one day or class period, returning to projects in following work time ask:

Warm Up Question:

What will happen if we hold this electromagnet up to a compass?

How do we get it to attract the south end of the compass?

4. DIY SPEAKERS:
   - Deliver a brief introduction to sound waves as a form of energy and how stereo speakers work before moving to students constructing their own
   - DIY Speaker using instructions created by the Exploratorium, found online here https://www.exploratorium.edu/snacks/cup-speaker
   - Have students build in teams, test, and collect evidence to explain how they work referencing what the class learned previously
   - On their own or in teams, students use devices to conduct online background research about how Speakers Work: https://animagraffs.com/loudspeaker/
   - Use that information to inform team redesign of speakers
   - Have groups carry out their tests and build arguments from evidence they collect to explain *how* this small machine works and *why*
   - Following project completion, students are given additional background on electric fields, observing the effect of an electromagnet on a compass

5. BUILDING MOTORS:
   - Students are given instructions to build a motor, essentially reversing the process observed in their creation of a speaker. This is related to the design of an electric guitar, providing students with visual models and background content information.
   - To Start this section, present:

     "Electric Currents producing Magnetic Fields, the basis for electric motors, is definitely a Big Idea in Science."

   - Then ask:

     "Playing with this idea, what are ideas that come to mind?
     Can we **brainstorm** applications of this big idea in science?
     How might we want to modify our motor for other applications?"

- Present instructions for making a simple mini motor: https://www.exploratorium.edu/snacks/stripped-down-motor'

- Have students build in teams, test, and collect evidence to explain how they work referencing what the class learned previously

6. (LESSON EXTENSION) Going Electric – Build an Electric Guitar
   - Use this added activity to connect all parts of this lesson into a fun, hands-on engaging activity involving primitive electric guitars made of approximately $3.00 of materials. This document includes a brief introductory activity to introduce the topics to students.
   - See guitar instructions in unit materials.
   - Present phenomenon – show video embedded within EMPP Unit Slides for Lesson 2.
   - A few questions to Ask thinking about how they generate (Kinetic) energy and this kinetic energy can be converted into electricity:
     - "How do electric guitars work?"
     - "What is the most basic physics of Guitars?"
   - Explore Faraday's Law 1.1.10 -PhET (https://phet.colorado.edu/sims/html/faradays-law/latest/faradays-law_en.html)

ASSESSMENT AND EXTENSIONS

FORMATIVE ASSESSMENT

Students should be tracking their data and findings in various methods throughout this unit, whether it be in worksheets provided along with the curriculum or through their own engineering notebooks. Teachers are encouraged to determine as many open-ended methods for observing student understanding formatively as they engage with content in an exploratory manner.

SUMMATIVE ASSESSMENT

Note the Key for EMPP Unit Packet. This guide contains sample answers for each day's activities, which vary between usability as formative or summative assessments. In addition, there is a quiz for students to complete focusing on the basics of motors and generators, attached in the materials for this section.

LESSON EXTENSION

Student DIY speakers, as a linear motor, can be extended to be used as a simple cyclical motor as well.