How an Electric Guitar Works Part I: The Naked Speaker

**Description of Activity**

* Students will build an electronic speaker from a magnet, wire, a paper plate and a paper bowl.
* The purpose is to allow students to build a simple device that employs Faraday’s Law.
* This activity is suitable for middle and high school physics and engineering classes.
* I would conduct this activity with one third of my class, while the other students participate in Parts II (The Naked Guitar) and III (The Naked Pickup) of this series. At the conclusion of the lesson, they would each share their products and see if they can link them to make a functioning Naked Electric Guitar.

**Learning Objectives:**

1. Students will successfully answer questions about Faraday’s Law
2. Students will build a working speaker.
3. Students will be able to explain how an electric speaker works.

**Standards:**

List The Common Core Math, Next Generation Science Standard and/or SME Competency Gaps. For example:

|  |  |
| --- | --- |
| **MS-PS3-5.** | Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. |
| **HS-PS4-5.** | Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. |

**Materials Required:**

Every student group will need the following.

* **A foam bowl** (for the speaker basket)
* **A paper plate** (that fits atop the bowl as the speaker cone)
* **Button magnets** (that can be staked into a cylinder)
* **A sheet of printer paper** (to form the voice coil support)
* **Magnet wire** (to form the actual voice coil)
* **Scissors, Hot Glue Gun, Pencil,**
* **The 3 Cs: Concentration,** **Communication, Common Sense**

**Safety:**

**safetys:**

* As with any school project, don’t do anything beyond the scope of the directions without first consulting with your teacher. Take care around the use of electricity, scissors, and the like. No one wants to get hurt doing something easy and fun.

**References:**

http://science.wonderhowto.com/how-to/make-paper-plate-speaker-actually-works-for-under-1-0141522/

<http://www.physics.org/article-questions.asp?id=54>

**Activity:**

This is for a 90 minute class. Please modify as necessary. This could easily be divided up into two consecutive class sessions.

* (5 minutes) Have students take the Pre-Test for this activity.
* (5 minutes) Ask students how a speaker works. I try to emphasize possibilities and good ideas, not just the one right answer. (Very few students will have any idea how this works. Those that do may be correct, but they probably won’t have a lot to say.) Give students 3 minutes to look it up online and then ask them again.
* (5 minutes) Explain to the class how a speaker works by taking one apart and showing each component.
* (10 minutes) Have students read the background information for this activity.
* (5 minutes) Allow a student to volunteer to use the disassembled speaker to explain to the class what everyone just read.
* (10 minutes) Tell students to preview the directions for building a paper plate speaker, which can be found at this website: http://science.wonderhowto.com/how-to/make-paper-plate-speaker-actually-works-for-under-1-0141522/
* Place students into groups of two (2) to three (3) and give them a set of supplies.
* (30 minutes) Ask students to follow the website directions and build a working speaker in the next 30 minutes. Having students divide some of the work will help save time. While circulating among my students, I try to catch time consuming errors early and catch the early finishes right away to evaluate their speaker and get them helping others.
* (10 minutes) Have students sign their speakers, place them in the designated storage area, clean up their areas and return their equipment.
* (10 minutes) Students should take their Post-Test on the same day if possible.

**Background Information for the Naked Speaker Activity**

Faraday's law of induction is a basic law of modern technology. All of our electronics function due to our understanding of electromagnetism, one of the Four Fundamental Forces in nature. Electricity and magnetism are related, sort of opposite sides of the same coin. Faraday’s Law predicts how a magnetic field will interact with an electric circuit to produce an electromotive force (EMF)—a phenomenon called electromagnetic induction. It is the basic operating principle of transformers, inductors, solenoids, many types of electrical motors, generators and the speaker you’re about to build.

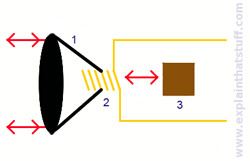
Electromagnetic induction was discovered independently by Michael Faraday in 1831 and by Joseph Henry in 1832, although Faraday published his results first. Faraday wrapped two wires around opposite sides of an iron ring. If he left one wire disconnected and then ran electricity through the second wire, he expected to see some electrical effect in the first (disconnected) wire. Indeed, he observed a secondary current (which he called a "wave of electricity") in the first wire when he connected the second wire to a battery, and another when he disconnected it. This is how modern transformers work.

Within two months, Faraday had found several other manifestations of electromagnetic induction. For example, he saw electric currents when he quickly slid a bar magnet in and out of a coil of wires; this is how we usually make alternating current (AC) electricity nowadays. This basic little known phenomenon is crucial to modern society. This is how we make electricity in electric generators and power plants. Something supplies the motion (or mechanical energy) to the magnet (this can be the pedals on a stationary bicycle, the crank on a no-battery flashlight, wind for wind power, water pouring over a turbine at a hydroelectric plant, or the rising steam from a coal fired power plant). The magnet then moves inside the coil of wires to produce electricity!

Faraday described electromagnetic induction as invisible lines of force. Scientists at the time rejected his theoretical ideas, mainly because they were based in observation and not math. An exception was James Clerk Maxwell, who used Faraday's ideas as the basis of his quantitative electromagnetic theory, creating Maxwell’s Equations. These became the basis of Einstein’s Theory of Special Relativity. We’re pretty lucky Michael Faraday saw what he saw and wrote down what he thought about it, otherwise there would be no lights, no internet and no cell phones.

Faraday’s Law of Induction also allows us to build electronic speakers. Speakers come in all shapes and sizes, so you can listen to music on your iPod, enjoy a movie at the theater or talk to a friend the phone.

There are two basic concepts at play. First, live electrical wires have magnetic fields, so a coil of live electrical wire is called an electromagnet. Second, a moving a magnet near a wire produces electricity (an electrical current)!   
  
In order to translate an electrical signal into sound, speakers contain an electromagnet: a metal coil which creates a magnetic field when an electric current flows through it. This coil behaves much like a normal (permanent) magnet, with one particularly handy property: reversing the direction of the electric current in the coil…flips the poles (or the direction) of the magnet.  
  
Inside a speaker, an electromagnet is placed in front of a permanent magnet. The permanent magnet is fixed firmly into position whereas the electromagnet is mobile. As pulses of electricity pass through the coil of the electromagnet, the direction of its magnetic field is rapidly changed. This means that it is in turn attracted to and repelled from the permanent magnet, vibrating back and forth.  
  
The electromagnet is attached to a cone made of a flexible material such as paper or plastic which amplifies these vibrations, pumping sound waves into the surrounding air and towards your ears.



Inside a speaker:  
1. Cone  
2. Electromagnet (coil)  
3. Permanent magnet

The frequency of the vibrations governs the pitch of the sound produced, and their amplitude affects the volume – turn your stereo up high enough and you might even be able to see the diaphragm covering the cone move.  
  
To reproduce all the different frequencies of sound in a piece of music faithfully, top quality speakers typically use different sized cones dedicated to high, medium and low frequencies.   
  
Finally, here is another little known phenomenon: most electronic devices can be run backwards to make the opposite effect. For example, an electric motor is just an electric generator in reverse. In this way, you can think of a microphone as a speaker running backwards. By using the same mechanism as a speaker (but in reverse) a microphone converts sound into an electrical signal. In fact, you can even use a headphone speaker as a small microphone!

**Quiz:**

**Pre/Post Test for The Naked Speaker Activity**

**1 The following electronic components and device(s) work due to electromagnetic inductance.**

A speakers

B electric motors

C transformers

D electric generators

E All of these answers

**2 Electromagnetic induction is…**

A The fact that a magnetic field will interact with an electric circuit to produce an electromotive force.

B The force that slows down a magnet as it drops through a copper pipe.

C A phenomenon whereby hot substances expand, decrease their density and rise.

D The Fundamental Force that allows some protons to become neutrons and vice versa.

**3 An electric field can be induced into a wire by a**

A stationary magnetic field

B a moving gravitational field

C static gravitational field

D changing magnetic field

**4 An electric generator is a device that**

A converts the energy of light directly into electricity

B changes voltages from one value to another

C converts mechanical energy to electrical energy

D converts electrical energy into mechanical energy

**5 An electric power plant is basically like a (an)…**

A large motorcycle

B electric generator

C combustion engine

D small ant farm

**6 True or False**

A wire with electric current running through it will have a magnetic field.

**7 True or False**

A coil of wire with an electric current running through it is called an electromagnet.

**8 True or False**

A You can make an electrical current by moving a magnet near a wire.

**9 How does a speaker work?**

A No one knows.

B After fuel is mixed with air, drawn into the cylinder and compressed by the piston, the spark ignites it, causing combustion.

C A speaker works by converting mechanical energy into electrical energy.

D An electromagnet is attached to a flexible cone and placed in front of a permanent magnet. Pulses of electricity pass through the coil (of the electromagnet), making it vibrate, which creates sound.

**10 The microphone also uses induction; guess how it works.**

A The vibrating membrane is attached to a magnet and induces an electromotive force in a coil, creating electrical impulses, which can be sent to a speaker.

B Areas of concentrated gravity induce laser signals in the internal wires.

C An electromotive leak is induced when an electrical short is created.

D An electromagnet is attached to a flexible cone and placed in front of a permanent magnet. Pulses of electricity pass through the coil (of the electromagnet), making it vibrate, which creates sound.

**Answer Key:**

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