Speaker in the House

OBJECTIVES

Children will:

- Develop an understanding of Lorentz Force and Faraday's Law of Induction in order to build a successful speaker that uses motion to create sound.
- Assess their understanding of the scientific concepts presented in this activity by responding to an array of scaffolded questions.

BACKGROUND KNOWLEDGE

Before this activity, which focuses on magnetism and sound, explain the concepts of *Lorentz Force* and *Faraday's Law of Induction*. First, point out that both Hendrik Lorentz and Michael Faraday were scientists who contributed discoveries related to electromagnetism. Then, have children read the "Lorentz Force" and "Faraday's Law of Induction" sections below to gain a better understanding of each of the scientists' developments in electromagnetism:

Lorentz Force

The Lorentz force is applied to an electric charge that moves through a magnetic field. The force is a combination of magnetic and electric force due to surrounding electromagnetic fields. A simple equation to help you understand Lorentz Force is: electricity + magnetism = motion. Lorentz Force is used in electric motors, electric generators, and loudspeakers. Since forces are difficult to visualize, it may be helpful to look online to find a few pictures or a video of how the Lorentz Force works.

Faraday's Law of Induction

Electromagnetic induction is the process by which a current can be induced to flow because of a changing magnetic field. Note that the term *induced* means to cause something to happen or exist. Faraday's Law of Induction is a law of electromagnetism that explains how a magnetic field will react with an electric current to cause electromagnetic induction.

Using Lorentz Force and Faraday's Law of Induction to Build a Loudspeaker

In this experiment, the motion that results from Lorentz Law will create sound. When a permanent magnet's magnetic field is reversed in direction, the result is sound. When the magnet is fixed to a flexible material, it creates sound via Faraday's Law of Induction. Both of these discoveries in the field of electromagnetism will be demonstrated in this activity.

What's with All the Noise?

Depending on their age, your children/students may or may not have heard of a speaker. If necessary, point out a speaker in the room (or in an area that you can easily access). Reiterate that speakers come in all shapes and sizes, which is how we're able to listen to music or talk on the phone. Have the children predict

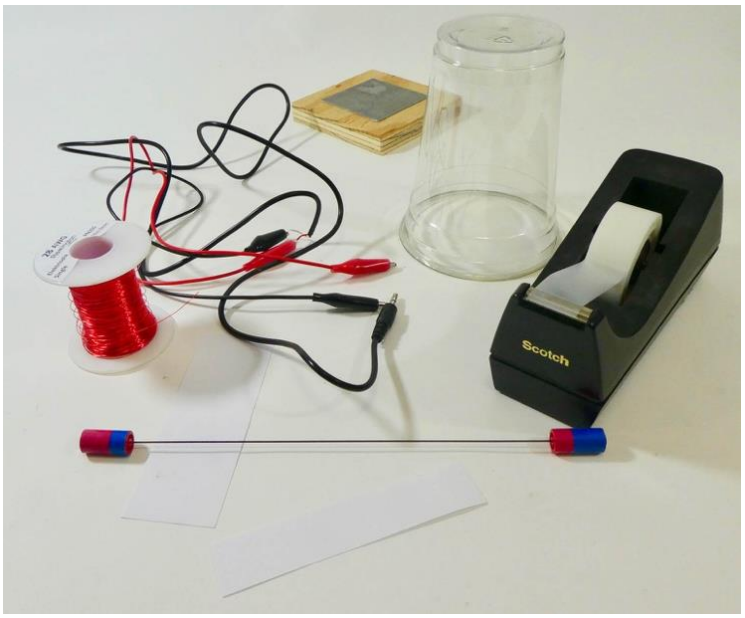
how a speaker works. Then, discuss its inner-workings once you've established their prior knowledge of speakers. Explain that an electromagnet is attached to a cone. These cones are made of flexible materials such as paper or plastic, which amplifies these vibrations. Then, sound waves are pumped into the surrounding air and gravitate towards your ears.

BUILD IT

MATERIALS

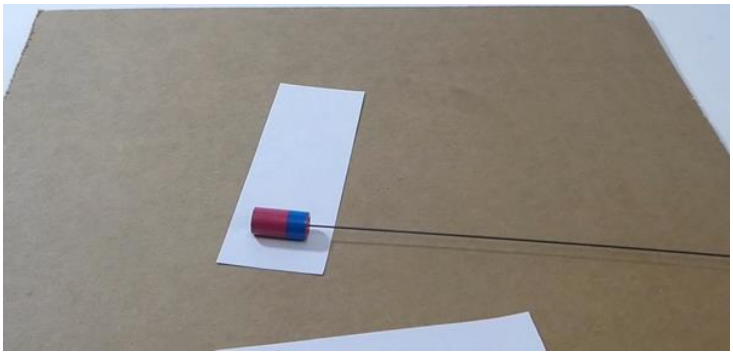
- Small plastic or paper cup (maximum of 4"L x 3" diameter at the top opening)
- Sound source with a headphones output (computer, smart phone, MP3 player, or tablet)
- Auxiliary audio cord (3'L)
- 2 Alligator clip wires
- 1 Red/Blue Wave Wire/magnet wire (8mm)
- Enameled copper wire (6'L)
- Wire strippers (with a cutter)
- Hot glue gun (with a low-temp setting) and low-temp glue sticks (caution: hot)
- Double-stick tape
- Plain copy paper
- Sandpaper
- Clear, thin packing tape
- Scissors
- Ruler

**Note: this activity is meant to demonstrate Lorentz Force and not meant to be a quality speaker. It will provide children with a glimpse into how audio sound is produced, but just as with any experiment, it may take multiple attempts to reach the desired result. You can experiment with small paper plates, or in contrast, you could use a small Styrofoam cup, which will deaden sound.*



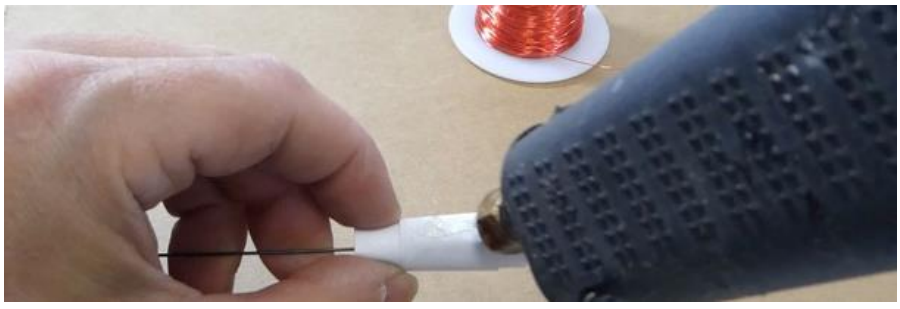
Voice coil assembly

1. Cut a strip of plain paper, roll it around the Wave Wires magnet, and tape the paper roll.

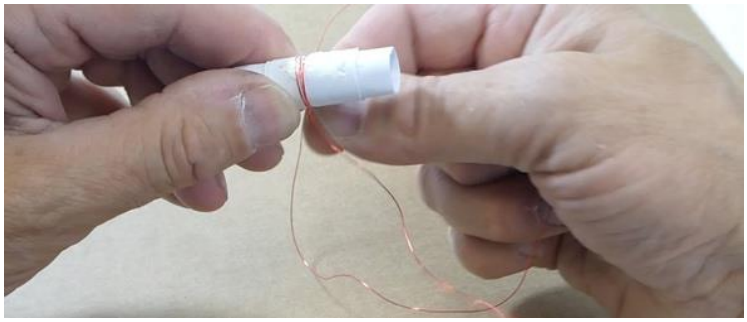


2. Repeat **step 1** but make the next roll of paper a little shorter.

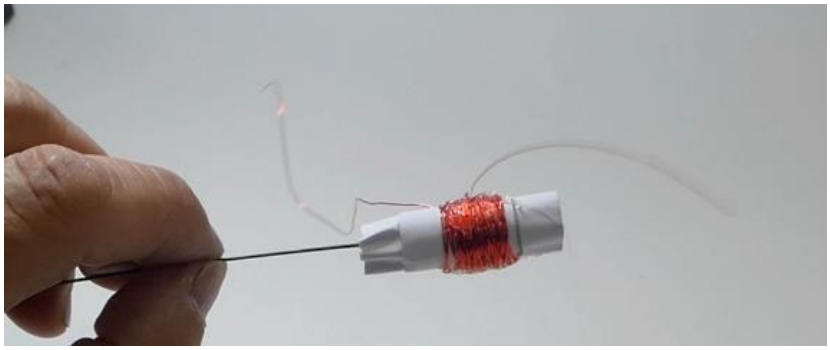
3. Run a bead of hot glue along the side of the second (shorter) paper roll. Be sure not to get glue on the first paper roll.



4. Making sure to leave a long, loose lead wire (4”–6”L), begin wrapping the wire around the paper roll (through the hot glue). Wrap 50 turns of wire around the roll. The wraps do not have to be really tight but should be firm.



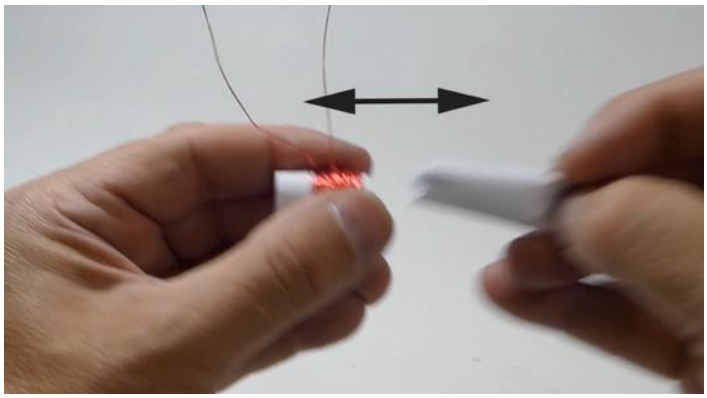
5. The area of wound wire should measure about .50”–.75” (long enough to cover the length of the magnet inside the paper roll).



6. Secure the wound wire in place with hot glue.

7. Carefully pull the Wave Wires magnet out of wrapped paper roll. You should now have a hollow roll with a wound wire around it. This wound wire is your voice coil.

8. Remove the inner paper roll, leaving the outer paper roll with the wire coil intact.



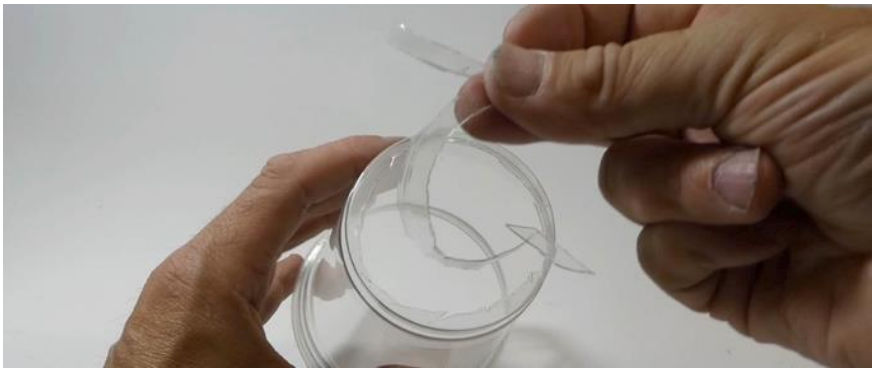
9. Carefully cut the voice coil paper roll to a length that will slide over the Wave Wires magnet. The wire coil needs to completely cover .50” of the end of the Wave Wires magnet.

10. Using sandpaper, sand the ends of the loose wires (the lead and end wires of the wire coil) to remove the enamel coating.

Speaker assembly

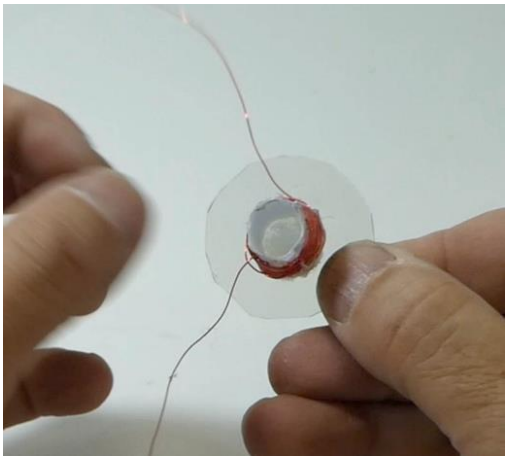
11. Being careful to leave .25” still attached around the edge of the cup’s base, cut out the circular base on the bottom of your plastic cup.

12. Cut and discard a thin ring (about .13”W) from around the inside of the base of the cup. (In **step 16** we will be placing the circular base piece—that you cut out before—back in the area where the original base of the cup was, so **step 12** ensures that there will be a gap between that circular base piece and the outer rim of the base of the cup.)



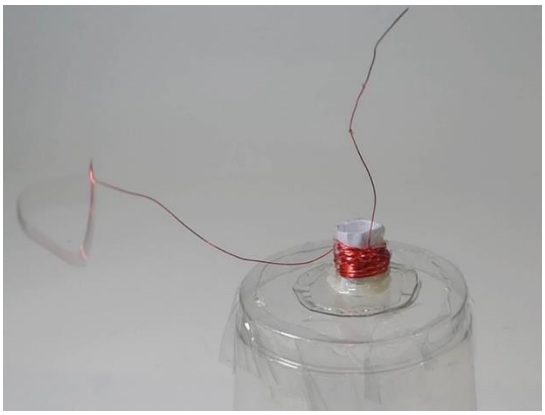
13. Place a piece of clear, thin packing tape over the hole in the base of the cup. Try to make the tape as taut as possible.

14. Glue the voice coil roll to the center of the circular cup base piece (plastic disc) that you cut out earlier.

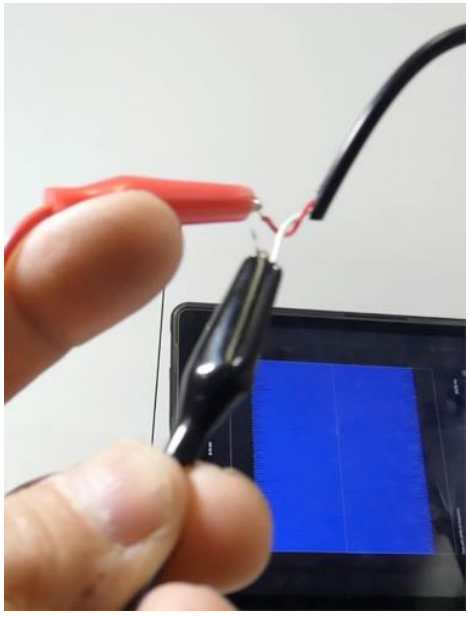


15. Apply a thin bead of hot glue around the edge of the underside of the plastic disc (on the opposite side of the disc from where the voice coil roll is glued).

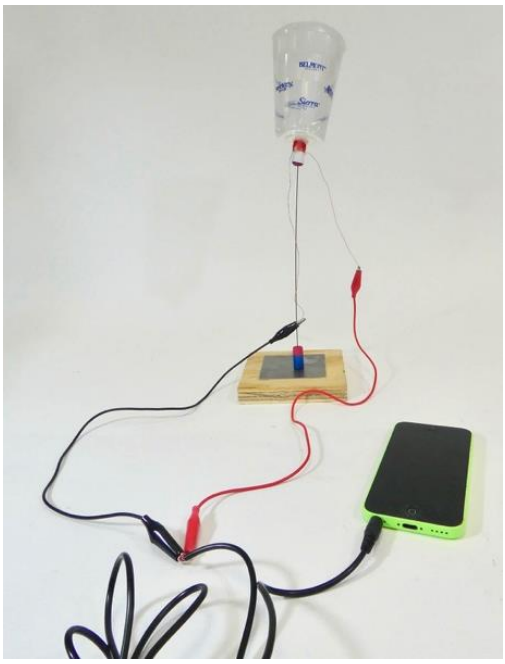
16. With the voice coil roll positioned *outside* of the cup, center the plastic disc on the tape that is on the base of the cup, and glue the plastic disc in place. (A ring of tape should remain around the outside of the plastic disc.) You have just built the sound diaphragm of the speaker!



17. Cut one end of the auxiliary audio cord. Use wire strippers to strip the wires. Using two alligator clip wires, connect the lead wires of the coil to the auxiliary cord.



18. Plug in the jack of the cord to your sound source (a computer, smart phone, MP3 player, or tablet).



19. Turn on your sound source, adjust the volume to the highest level, and press play on a song or app with sound/music. You should hear your music playing out of the cup!

Note: the cup is directional and can be heard best when the cup's opening directly faces you. You also can experiment with and compare your results using different numbers of coil windings and different materials of cups.

Troubleshooting Notes

- *If you do not hear anything, double check your connections. The two wires from the voice coil should connect to the positive and negative terminals of one channel of your system. It does not matter which wire goes where, as both will work.*
- *Your stereo will also need to have a built-in audio amplifier to push a higher wattage to the plate. If you're trying to run this from your iPhone or MP3 player, you might hear a faint noise, but your results will be much better if you first amplify the power output.*
- *If you still don't hear anything, either your voice coil is damaged (shorting out or broken), or your wires do not have a good connection to your sound source.*

ANALYZE

Encourage children to reflect on this experiment by answering the scaffolded questions below. Have them discuss their responses with an adult or peer, or they can write the responses in their science journals. Reiterate the importance of reflection as a tool to help scientists and engineers evaluate their designs. Scientists combine their evidence, analysis, and evaluations from an experiment to make improvements on future ones.

1. What were some of the challenges you encountered during this experiment?
2. Were the challenges due to user error or obstacles not in your control?
3. How would you avoid these challenges in the future if you were to conduct this experiment again?
4. How did this activity demonstrate Lorentz Force and Faraday's Law of Induction? *Note: if a child has difficulty with this question, review these two laws (see BACKGROUND INFORMATION above).*
5. If you worked on this activity in a group of other children, compare the results of your setup and speaker design. Record the similarities and differences between your designs. If you worked on this activity by yourself, explain how you would teach a younger child about the laws of electromagnetism and how speakers demonstrate Lorentz Force and Faraday's Law of Induction?