

Teacher's Guide

ACTIVITY 3:

Shake it up!

Intro

In Activity 2 students learned that moving charges in the form of current create a magnetic field. In this activity students will learn that a moving magnet will cause charges to move. They will also learn that the direction in which the charges move depends on the direction in which the magnet is dropped. These two activities together do a good job illustrating the connections between electricity and magnetism.

Key Question

When a magnet is dropped through a coil of wire what happens in the wire? Does it depend on the direction and speed of the magnet?

Key Terms

Magnetic field: A field that is produced by either moving charges or a permanent magnet.

Current: Movement of positive charges

Diode: A diode only allows current to flow in one direction. It's like a one way street for current.

LED: *Light Emitting Diode.* This is a type of diode that lights up when current goes through it.

Induction: When current is created from a changing magnetic field it is an induced current. The process of changing the magnetic field to create the current is called induction.

Direct Current (DC): In this type of power the current never changes direction. Batteries have this type of power. Edison's power system was DC.

Alternating Current (AC): In this type of power, current constantly changes direction, like water in a washing machine. Wall sockets give this type of power. Tesla invented a way to power cities, including Chicago, with this type of power.

Materials

- Cardboard tube
- Long copper wire
- Green LED
- Red LED
- 4 disk neodymium magnets
- Steel slug
- Scissors
- Tape
- Ruler
- Permanent marker

Before the activity students should know ...

For current to flow, there must be a source of electrical energy, like a battery or a wall socket.

For a light to light, there must be current.

Magnets have a north and a south pole.

After the activity students should know...

Moving a magnet through a coil of wire quickly enough will cause a current to flow.

The direction of the current depends on which pole of the magnet goes through the coil first.

The amount of current depends on how fast the magnet falls.

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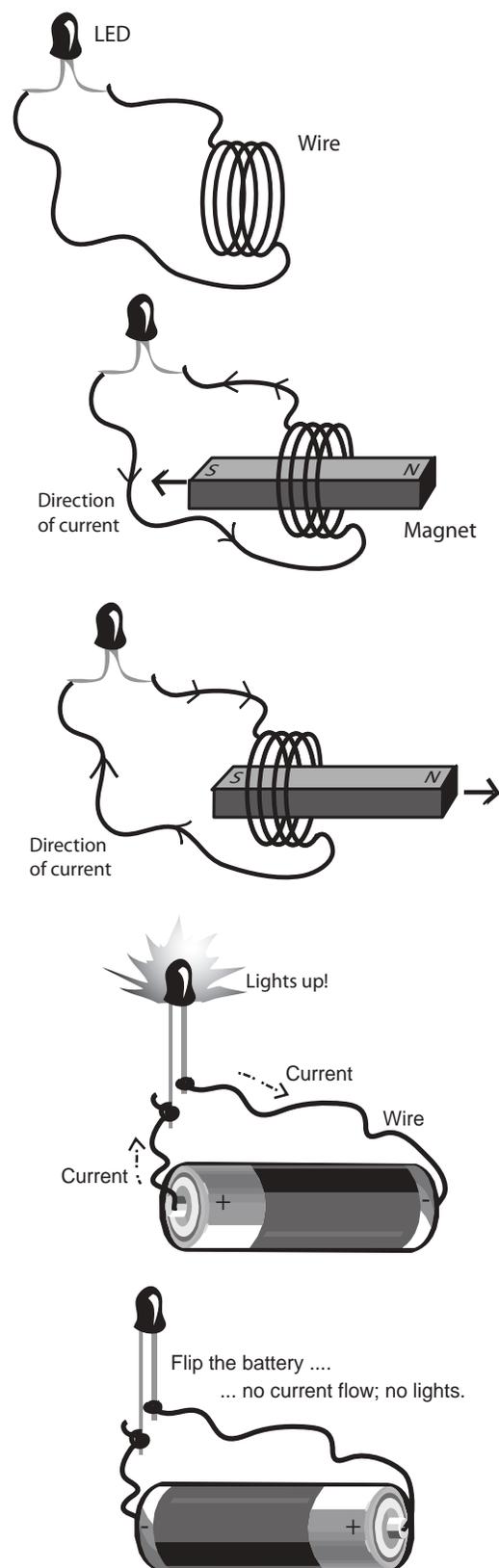
The science behind induction

Usually we think of a battery or wall power as the only way to make current flow. Just connecting wire to a light bulb won't cause it to light up; there must be a power source, something to push the charges. It turns out that batteries and sockets are not the only way to push positive charges and create a current. When a magnet is moved through a loop of wire the magnetic field the wire sees is changing and this change causes the charges to move. This is a fantastic and rare example of energy of motion, moving the magnet, being changed into electrical energy. When current is created by moving a magnet through a coil it is said to be an "induced current." Faraday's Law is also called the law of induction.

This phenomenon was discovered by both Michael Faraday and Joseph Henry in 1831 but is called Faraday's Law because Faraday published his work first. In science it is important to quickly publish your discoveries! Faraday also discovered that the direction in which the magnet is moved will change the direction of the current. So if you drop a magnet south end first through a coil the direction of the current will be different than if you dropped in north end first.

Another important point is that the amount of current depends on how fast the magnetic field is changing. If the field is changing quickly the current will be stronger than if the field is changing more slowly. For this experiment it is the moving magnet that makes the magnetic field near the wire change so if the magnet is dropped quickly there is a bigger current than if it is dropped slowly. The LED must have a minimum current to make it light up. Even if there is some current produced from a slowly falling magnet it may not be enough for the LED to light. Your students will investigate this and find that the magnet must be dropped straight through the coil and not slid down the side of the tube to make the LED light up.

If changing the direction of the magnet changes the direction of the current, what happens if you shake the magnet back and forth through the coil of wire? The current will



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be changing direction constantly like a washing machine. This type of current is called alternating current, or AC. This is the type of current that comes from our wall sockets. Tesla designed a type of generator that moves magnets through coils of wire to create current and because it was so efficient, this is the type of power we use.

DC, or direct current is the type of current that comes from a battery. The current is always flowing in the same direction, like a stream. Edison designed all his systems based on this type of current even though it was less efficient than an AC system and in the end it was beaten by Tesla's AC system. Interestingly, though AC comes into our homes, most of our electronics are designed to run on DC power. This first thing the current passes through is a device that converts the AC power to DC power.

It is possible to see Faraday's law of induction using a very strong magnet, a coil of wire and two LEDs. LED stands for "Light Emitting Diode." When current tries to flow in one direction it will pass through the diode and make it light up. However, if it tries to pass through in the other direction it gets blocked and the light won't light. By attaching 2 LEDs to a coil of wire it is possible to drop a magnet through the coil and watch the LED light up. If the LEDs are attached so that one lets current through in one direction while one lets current through in the other it is possible to see which direction the current is flowing. Manufacturers of LEDs let us know which way current can flow by making one leg of the LED longer than the other. Current is allowed to flow from the long leg, through the LED and then through the short leg. It is not allowed to flow from the short leg to the long leg. Remember, current flows from positive to negative so if the long leg of the LED were put against the positive end of the battery and the short leg against the negative end, current would flow and the LED would light. However, if the LED were flipped, with the short leg on the positive end, current would not flow and the LED would not light.

Safety

The magnets used are quite strong. It is very important to be careful when handling them. If two are brought close together and part of a finger is in the way it will be pinched. Do not swallow the magnets. Do not bring them near cell phones, computers, iPods or credit cards.

Corresponding extension activities

- **Homemade battery** – Use common household products to build a battery
- **Mechanical flashlight** – Use mechanical energy to light a flashlight
- **Wearable LED** – Make a little light for your shirt or backpack.

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Bibliography/Suggested resources

National Academy of Sciences. *Joseph Henry*

<http://www.nationalacademies.org/history/members/henry.html>

University of Colorado at Boulder. *PhET program*

http://phet.colorado.edu/simulations/sims.php?sim=Faradays_Electromagnetic_Lab

Wolfram Research. *Faraday, Michael*

<http://scienceworld.wolfram.com/biography/Faraday.html>

University of Virginia Physics Department. *LED coil*

<http://demolab.phys.virginia.edu/demos/demos.asp?Demos=K&Subject=5&Demo=5K10.81#subtopic>

Key Question

When a magnet is dropped through a coil of wire what happens in the wire? Does it depend on the direction and speed of the magnet?

Student's Guide

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Intro

You've seen that current can create a magnetic field but is there a way that a magnetic field can create current? In fact there is! It is this idea that is the basis for Tesla's powerful AC generators.

Materials

- Cardboard tube
- Long copper wire
- Green LED
- Red LED
- 4 disk neodymium magnets
- Steel slug
- Compass
- Scissors
- Tape (electrical)
- Ruler
- Permanent marker

Getting started

What is a "complete circuit"? _____

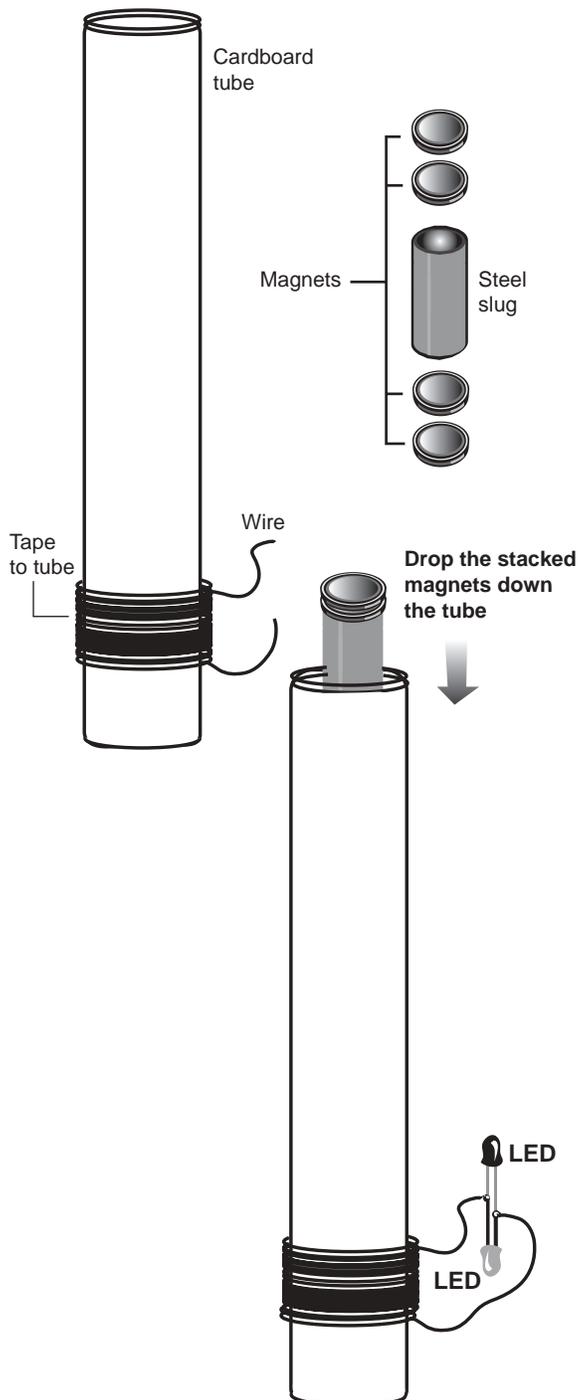
What type of things can make current flow in a circuit?

How might you be able to tell if current is flowing?

Can you think of a way you could tell which direction current is flowing? _____

Setting up the experiment

1. Use the scissors to scrape the coating off of each end of the copper wire.
2. Put a piece of tape 0.5-inch from one end of the tube.
3. Tape one end of your wire 1.5-inch from the same end of the tube. Leave the scraped off end free from the tape.
4. Wrap the rest of the wire around the tube making sure to keep your coils between the two tape marks.



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5. Use tape to secure the coil.
6. Twist the longer leg of the red LED around the shorter leg of the green LED and mark this side with a permanent marker.
7. Now twist the short leg of the red LED around the long leg of the green LED and leave unmarked.
8. Twist the end of the copper wire that is taped to the tube around the marked end of your LED set up.
9. Twist the unmarked end around the other end of the copper wire.
10. Put two magnets on either end of the steel slug (you need all four magnets)
11. Use your compass to figure out which end of the magnet and slug combination is north and mark it with an “N”. Mark the other end with an “S” for south.

Collecting data

Hold the tube at a 45 degree angle and slide the magnet down the tube north end first.

What happened to the LEDs?

Now hold the tube at a 70 degree angle and slide the magnet down the tube north end first. What happened to the LEDs?

Now hold the tube completely vertical and drop the magnet north end first down the tube. What happened to the LEDs?

Repeat these three steps but this time drop the magnet south end first.

What happened to the LEDs at each step?

Trial	Red lit	Green lit
45 degrees, north first	_____	_____
70 degrees, north first	_____	_____
Vertical, north first	_____	_____
45 degrees, south first	_____	_____
70 degrees, south first	_____	_____
Vertical, south first	_____	_____

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Analyzing your results

What types of energy do you see in each step of the experiment?

How is energy being changed from one form to another? _____

Sometimes the green LED lit up, sometimes the red LED lit up and sometimes neither did. What is the pattern you saw? _____

When did the red LED light and when did the green LED light? _____

What is flowing in the wire? Can you tell the direction? _____

What things do you need to make the LEDs light up? _____

Could you ever make them light at the same time? _____

How would the current behave if you dropped a magnet north end first and then very quickly dropped a magnet south end first? _____

Using your results to help Tesla

You have almost done it faithful sidekick. You have found 2 of Tesla's tools and you are about to chase yet another pigeon to find the third Those pigeons are fast, but you are faster. Now you need to find which one has Tesla's tool. When you dropped the magnet north side first when the tube was held vertically, which LED lit up?

Green Chase the white pigeon

Red Chase the gray pigeon

Both Chase the pigeon with stripes

Neither Chase the pigeon with a white body and gray head