



# SCIENTIST IN RESIDENCE PROGRAM™

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**Science Unit:** *Concepts in Electricity*

**Lesson 2:** *Building Electromagnets*

**Summary:** Students **build** their own **electromagnets** using batteries, iron nails, magnets, wires, and switches. They learn about simple **circuits** and the relationship between **electricity** and **magnetism**.

**School Year:** 2013/2014

**Developed for:** Lord Selkirk Elementary School, Vancouver School District

**Developed by:** James Day (scientist); Marie-Christine Michel and Karina Houle (teachers)

**Grade level:** Presented to grade 6; appropriate for grades 5 – 7 with age appropriate modifications

**Duration of lesson:** 1 hour and 05 minutes

**Notes:** 1) See important **Safety Notes**.

2) The use of “PhETs” is strongly encouraged to support this lesson:

PhET is a suite of research-based interactive computer simulations for teaching and learning physics, chemistry, math, and other sciences. The PhETs can be “played with” by the students at home in advance of the lesson, or used to reinforce observations in the classroom. The relevant PhETs are listed in the reference section.

## Objectives

### Students will be able to:

1. Strengthen basic concepts related to electricity.
2. Develop a basic, conceptual understanding of electromagnetism.
3. Gain experience assembling basic electronic components; build an electromagnet.
4. Observe the interaction of electricity with magnetism.

## Background Information

Electromagnetism describes the relationship between electricity and magnetism. Electricity and magnetism are interdependent because a changing electric field generates a magnetic field, and a changing magnetic field produces an electric field.

## Vocabulary

<u>Charge</u>	A physical property of matter (just like mass is). There are two types of electric charges – positive and negative. Positively charged substances are repelled from other positively charged substances, but are attracted to negatively charged substances. Negatively charged substances are repelled from negative and attracted to positive. Matter may have no (i.e., zero) charge.
<u>Current</u>	A flow of electric charge—usually, electrons—through a medium.
<u>Voltage</u>	Most simply, voltage causes current. The voltage between two points is the electrical force that would drive an electric current between those points. Specifically, voltage is equal to energy per unit charge.



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<u>Circuit</u>	The flow of electric current in a closed and complete path, under the influence of a driving voltage.
<u>Energy</u>	The capacity for doing work.
<u>Work</u>	When a force acts upon an object to cause a displacement of the object, it is said that work was done upon the object. There are three key ingredients to work - force, displacement, and cause. In order for a force to qualify as having done work on an object, there must be a displacement and the force must cause the displacement.
<u>Power</u>	The rate at which electric energy is transferred by an electric circuit.

## Materials

<ul style="list-style-type: none"><li>• D-cell battery</li></ul>	<ul style="list-style-type: none"><li>• knife switch</li></ul>
<ul style="list-style-type: none"><li>• magnetic compass</li></ul>	<ul style="list-style-type: none"><li>• small permanent bar magnet, labeled North/South</li></ul>
<ul style="list-style-type: none"><li>• spool of 28 gauge magnet wire</li></ul>	<ul style="list-style-type: none"><li>• paper clips</li></ul>
<ul style="list-style-type: none"><li>• large bolt, nail, or steel rod</li></ul>	<ul style="list-style-type: none"><li>• electrical tape</li></ul>

## In the Classroom

### [30 minutes] Introductory Discussion

1. [10 minutes] Most electricity involves the flow of electric current in a closed path under the influence of a driving voltage. (This is analogous to the flow in a water circuit under the influence of a driving pressure.)

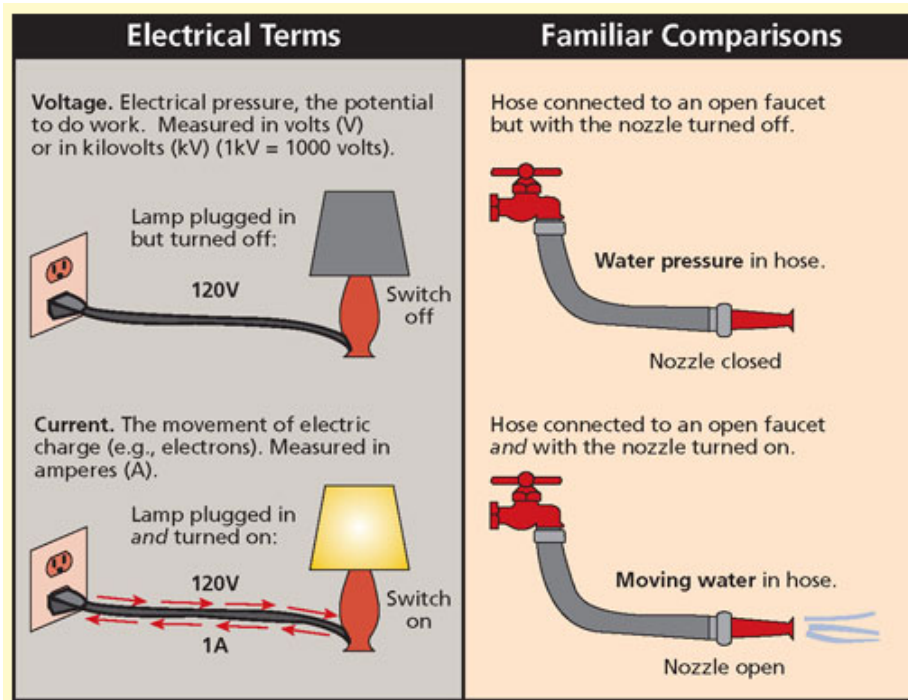
A complete path, typically flowing through conductors such as wires and through circuit elements, is called an electric circuit.

- Make analogy to the flow in a water circuit under the influence of a driving pressure. Be certain to make this real-world connection, and emphasize that this is a helpful conceptual model.
- Ask students to name examples of things that rely on electric circuits.
- Review the particle model of the atom, in which electrons “orbit” the nucleus. (Use the “Build An Atom” PhET here.) Emphasize that this, too, is a helpful conceptual model.



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2. [15 minutes] Introduce electromagnetism:

- Electricity and magnetism are intimately related (two faces of the same coin, really).
- Magnetic fields are produced by electric currents.
- Electric currents can be:
  - > Macroscopic currents in wires, or
  - > Microscopic currents associated with the electrons in atomic orbits.
- Magnetic fields are essentially dipolar in nature, having a north and south magnetic pole. (Use the “Magnets and Electromagnets” PhET here.)

3. Explain that in today’s lesson, students will be constructing their own electromagnets.

4. Briefly describe the processes of science that the students will focus on: prediction/hypothesis, observations, recording results, conclusions.

## Safety Notes

You might notice a significant spark whenever the battery is disconnected from the electromagnet coil: much greater than the spark produced if the battery is simply short-circuited.

This spark is the result of a high-voltage surge created whenever current is suddenly interrupted through the coil. The effect is known as inductive “kickback” and is capable of delivering a small but harmless electric shock!

**To avoid receiving this shock, do not place your body across the break in the circuit when de-energizing! Use one hand at a time when un-powering the coil and you’ll be perfectly safe.**



## [30 minutes] Science Activity/Experiment

### **Activity Title:** Build Your Own Electromagnet

**Purpose of Activity:** To give the students experience with very basic circuit construction, and to demonstrate the close relationship between electricity and magnetism.

**Experimental Observations:** Students will explore the interacting effects of electricity and magnetism. (This is not an experiment with controls and treatments.)

**Prediction or Hypothesis:** Before making your prediction (or hypothesis), it helps to start with a question, or make observations and then ask a question. Use your prior experience with electricity and magnetism, if any, to predict what you think will happen when the nail is wrapped with wire and current is allowed to flow through the wire. Record your prediction based on the following question: What do you think will happen to the nail when current is made to flow along the wire.

### **Methods and Instructions:**

Students will work in groups or pairs to build an electromagnet:

1. Wrap a single layer of electrical tape around the steel nail to protect the wire from abrasion.
2. [5 minutes] Proceed to wrap many (up to several hundred!) turns of wire around the steel bar, making the coil as even as possible.
  - It is okay to overlap wire.
  - It is okay to wrap in the same style that a fishing reel wraps line around the spool.
  - The only rule you must follow is that all turns must be wrapped around the bar in the same direction (no reversing from clockwise to counter-clockwise!).
3. [10 minutes] After you've wrapped several hundred turns of wire around the rod, wrap a layer or two of electrical tape over the wire coil to secure the wire in place.
4. Scrape the enamel insulation (cover) off the ends of the coil wires (to connect wire to jumper leads).
5. Connect the coil to a battery (through a switch, and using the wires from the battery holder). The electromagnet should look like that in Figure 1, below.

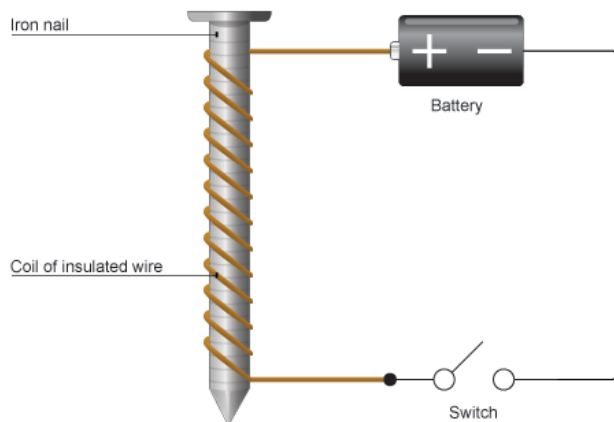


Figure 1: Diagram of the electromagnet.



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6. [5 minutes] Close the switch (i.e., turn the switch “on”) to complete the circuit and start the flow of electrons through the coil (“energize the electromagnet”). As the electric current goes through the coil, it will produce a strong magnetic field. The magnetic field will produce one “pole” at each end of the rod. This phenomenon is known as electromagnetism.
7. Use the magnetic compass to identify the “North” and “South” poles of the electromagnet.
8. [5 minutes] With the electromagnet energized (connected to the battery):
  - Place a permanent magnet near one pole. Note whether there is an attractive or repulsive force.
  - Reverse the orientation of the permanent magnet and note the difference in force.
  - See how many paper clips your electromagnet can pick up.
9. Ask students to record their observations and draw a schematic of their electromagnet into their science notebook (similar to Figure 1).

## **[10 minutes] Closure Discussion**

1. [5 minutes] What do you think might make your electromagnet stronger/weaker?
2. [5 minutes] What advantages do electromagnets have over permanent magnets?

## **References**

1. [http://www.allaboutcircuits.com/vol\\_6/chpt\\_2/9.html](http://www.allaboutcircuits.com/vol_6/chpt_2/9.html)
2. <http://www.physicsforidiots.com/em.html>
3. <http://hyperphysics.phy-astr.gsu.edu/hbase/emcon.html>
4. <http://phet.colorado.edu/en/simulation/magnet-and-compass>
5. <http://phet.colorado.edu/en/simulation/magnets-and-electromagnets>
6. <http://phet.colorado.edu/en/simulation/faraday>

## **Extension of Lesson Plan**

1. Test hypotheses about making the electromagnet stronger (e.g., use multiple batteries in series).
2. Explore the importance of the “core” of the electromagnet (the steel nail). Try removing it completely. Try replacing it with a different material (e.g., a pencil).