

# Electromagnets

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**Subject:** Physics

**Grade Level:** Middle & High School

**Standards:** Next Generation Science Standards ([www.nextgenscience.org](http://www.nextgenscience.org))

**MS-PS2-3** Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

**MS-PS2-5.** Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

**HS-PS2-5** Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

**Schedule:** 4-5 45 minute classes

**CCMR Lending Library Connected Activities:**  
 Marvelous Magnets  
 Batteries



<p><b><u>Objectives:</u></b></p> <p>Students will understand what an electromagnet is and how it works. They will be able to explain the relationship between electricity and magnetism.</p>	<p><b><u>Vocabulary:</u></b></p> <p>Magnet                  Electricity                  Electromagnet                  Charge                  Current                  Magnetic Field</p>
<p><b><u>Students Will:</u></b></p> <ul style="list-style-type: none"> <li>● Understand that when you run a current through a wire, you create a magnetic field.</li> <li>● Understand that when you move a magnet through a coil of wire, you create an electric current.</li> <li>● Experimentally discover how to strengthen electromagnets.</li> <li>● Establish a definition for magnetism that incorporates its relationship to electricity.</li> <li>● Present/share results</li> <li>● Design and conduct their own experiments.</li> </ul>	<p><b><u>Materials:</u></b></p> <p><b>For Each Group (3-4 students)</b></p> <ul style="list-style-type: none"> <li>___ D Cell Battery</li> <li>___ Battery Holder</li> <li>___ 30 cm of wire</li> <li>___ Compass</li> <li>___ Tube w/coiled wire</li> <li>___ 2 Wire leads w/alligator clips</li> <li>___ Multimeter</li> <li>___ Magnet</li> <li>___ Steel Bolt</li> </ul> <p><b>For Class</b></p> <ul style="list-style-type: none"> <li>___ Paperclips</li> <li>___ Different gauge wires</li> <li>___ Different size steel bolts (magnetic)</li> <li>___ Brass bolts</li> <li>___ Stainless steel bolts (non-magnetic)</li> </ul> <p><b>Teacher Will Need to Provide</b></p> <ul style="list-style-type: none"> <li>___ Scissors</li> </ul>
<p><b>Safety</b></p>	<p>Do not hold wires to battery terminals with fingers, they get hot.</p>

### **Science Content for the Teacher:**

Students should be familiar with magnets and magnetic fields. Here is a good resource on this:

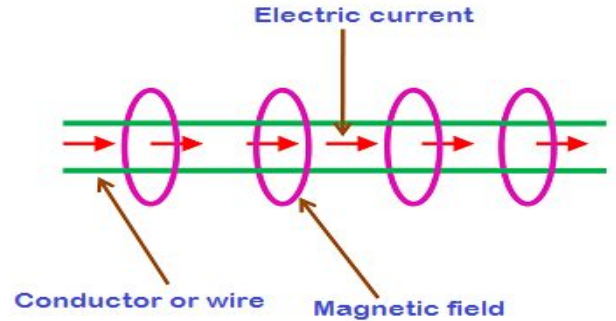
Physics4Kids.com: Electricity & Magnetism: Magnetic Fields." 2006. 14 Sep. 2016  
 <[http://www.physics4kids.com/files/elec\\_magneticfield.html](http://www.physics4kids.com/files/elec_magneticfield.html)>



### Relationship between Electricity and Magnetism

Two experiments that you will have your students do led to the development of electrical generators and motors:

1) Oersted's experiment showed that when an electric current is passed through a conducting wire, a magnetic field is produced around it. The presence of magnetic field at a point around a current carrying wire can be detected with the help of a compass needle.

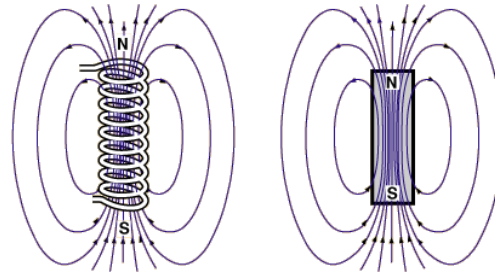


[www.physics-and-radio-electronics.com](http://www.physics-and-radio-electronics.com)

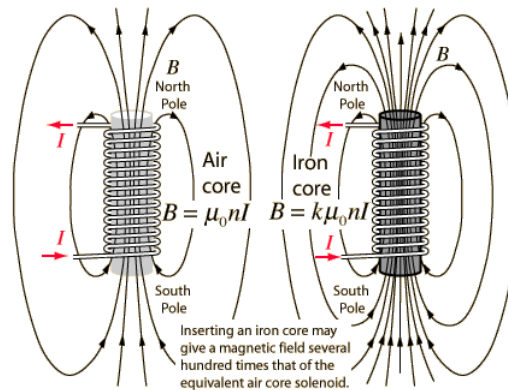
2) Michael Faraday's Law of Electromagnetic Induction showed that when you move a magnet through a coil of wire, it creates an electric current. This was actually discovered by Joseph Henry, but he failed to publish this.

A wire, with a current running through it, will produce a magnetic field. This is very weak.

You can increase the magnetic field produced by electric current by coiling the wire. This is called a solenoid coil and is similar to that of a bar magnet:



An iron core has the effect of multiplying greatly the magnetic field of a solenoid compared to the air core solenoid on the left.

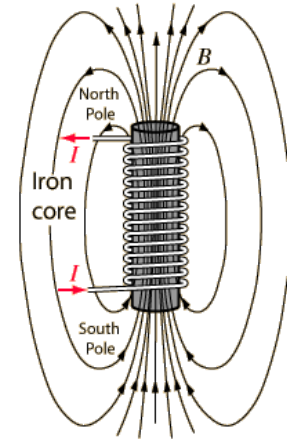


## Electromagnet

Electromagnets are usually in the form of iron core solenoids. The ferromagnetic property of the iron core causes the internal magnetic domains of the iron to line up with the smaller driving magnetic field produced by the current in the solenoid. The effect is the multiplication of the magnetic field by factors of tens to even thousands. The magnetic field (B) at the center of the solenoid is:

$$B = \mu n I, \text{ where } \mu = k \mu_0$$

Where n is the number of coils in the wire, I is the current in the wire,  $\mu_0$  is the magnetic permeability constant ( $4\pi \times 10^{-7} \text{ N/A}^2$ ), k is the relative permeability of the core (for iron ~200).



The magnifying effect is proportional to k, so for a solenoid with an iron core you would expect a magnification of about 200 compared to a solenoid with an air core.

## Austenitic Stainless Steel

There are two types of stainless steel bolts in the kit: **Ferritic** and **Austenitic**. Ferritic steel has more iron and less chromium in it, which makes it more magnetic. Austenitic steel has more chromium and nickel added to it. This makes it less likely to corrode and also non-magnetic.<sup>1</sup>

Class	Non/Magnetic
Ferritic	Magnetic
Austenitic	Nonmagnetic
Martensitic	Magnetic
Duplex	Magnetic
Precipitate-Hardened	Magnetic

<sup>1</sup> "Stainless Steel and its Families - Stainless Steel World." 2006. 20 Sep. 2016  
 <<http://www.stainless-steel-world.net/basicfacts/ShowPage.aspx?pageID=485>>



## Preparation:

Organize and lay out materials.

## Classroom Procedure:

### **Engage (Time: 20mins)**

Game: Are you smarter than a 19th century scientist?

Have students, in small groups, use a wire, battery, and compass to simulate Osted's experiment. They will make observations and try to infer what it shows.

Have groups, use a wire, toilet paper roll, ammeter, and magnet to simulate Faraday and Henry's experiment. They will make observations and try to infer what it shows.

As a class, discuss the classes findings and what groups came up with. Ask them, "What is the relationship between *electric current and magnetic fields*?"

### **Explore (Time: 20 mins)**

Have the students get the materials listed below and build an electromagnet. See how many staples/paper clips they can pick up with it.

- 30 cm of wire      - Nail      - Battery      - 2 wires with alligator clips

Ask the students to think of what **variables** might affect the strength of an electromagnet.

Some variables to test are:

Number of coils	Wire thickness	Type of metal core	Size (thickness or length) of core
Voltage*	Current*	spacing between coils	

\* Will need to provide variable resistors or voltage power supply to do these.

Discuss the different variables as a class



**Experiment (60 mins)**

Students will design their own experiment to **test how a variable affects the strength of an electromagnet**. They will need to come up with a plan that includes an aim, hypothesis, list of materials, method, and results table.

Teacher will approve plans before students begin their experiments.

**Explain (Time: 20 mins)**

Each group should share their experiment design and its results with the larger group. Students should be encouraged to ask questions about their classmates' experiments.

**Challenge (45 minutes)**

Using all of the results from the different groups, students will try to build an electromagnet that can pick up the most paperclips.

Before each group goes, they will explain what variables they chose to use and why.



## **Assessment:**

The following rubric can be used to assess students during each part of the activity. The term “expectations” here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

- 1= exceeds expectations
- 2= meets expectations consistently
- 3= meets expectations occasionally
- 4= not meeting expectations

	<b>Engage</b>	<b>Explore</b>	<b>Explain</b>
<b>1</b>	Shows leadership in the discussion and offers creative ideas reflecting a good understanding of magnetism and electricity.	Designs and conducts experiment creatively and scientifically while providing an explanation for what is observed. Works very well with group.	Provides an in-depth explanation of findings, makes excellent use of vocabulary and examples.
<b>2</b>	Participates in the discussion and shows an understanding of electricity and magnetism.	Designs and conducts experiment creatively and scientifically. Works cooperatively with group.	Provides clear explanation of findings. Makes good use of vocabulary, provides some examples.
<b>3</b>	Contributes to the discussion, but shows little understanding of electricity or magnetism.	Works cooperatively with group, but makes some mistakes with the procedure.	Provides a limited explanation of findings. Uses a few vocabulary words or examples.
<b>4</b>	Does not participate in discussion. Shows no understanding of electricity or magnetism.	Has trouble working with group. Does little to complete the procedure.	Is not clear in explanation of findings. Does not make use of vocabulary or examples.

## **Extra Activities:**

Included in the packet is an activity to build a simple electric motor. Teacher will need to provide circular magnets.

