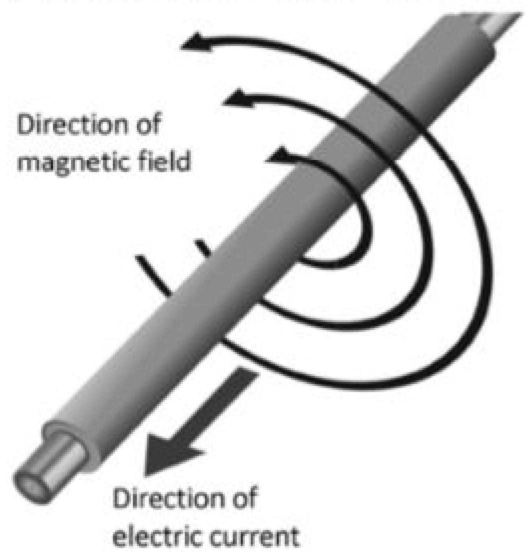
# Magnetic Force: How Is the Strength of an Electromagnet Affected by the Number of Turns of Wire in a Coil?

## Introduction

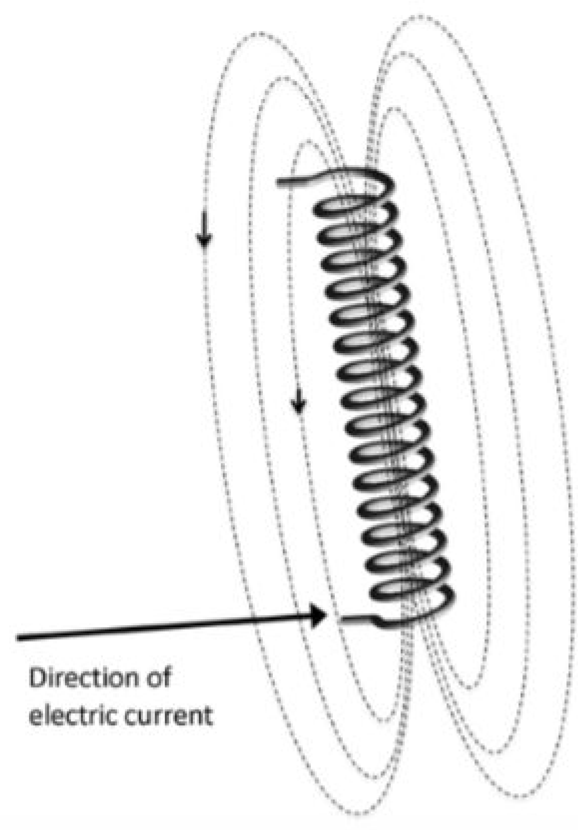
Magnets and magnetic fields are useful for many applications. For example, small permanent magnets and electromagnets are used in speakers that are found in cell phones or headphones used to listen to music. In a speaker, the changes in the magnetic field of the electromagnet cause parts of the speaker to vibrate, which produces the sounds we hear when we listen to music. The electromagnets in headphone speakers are small and fairly weak, but other electromagnets can be much larger and stronger, such as those used in junkyards to pick up and move old cars. Electromagnets are also used in the medical field in devices such as MRI (magnetic resonance imaging) machines. The powerful electromagnets in MRI machines influence the atoms in our bodies and allow doctors to create images that are useful in diagnosing injuries.

**Magnetic field surrounding a wire**




Permanent magnets, such as refrigerator magnets or those made from combinations of metals such as iron (Fe), nickel (Ni), or neodymium (Nd), always demonstrate magnetic properties. Permanent magnets are surrounded by a magnetic field. This magnetic field can influence other magnets or some materials (like some metals) and cause the objects to be pulled toward the magnet or pushed away from the magnet.

**Concentrated magnetic field in a coil of wire**




Magnetic fields can also be created when electricity passes through a wire. The electric current (moving electrical charges) in the wire creates a magnetic field surrounding the wire (see figure above). The magnetic field surrounding the wire is usually weak, but it can still have an effect on other magnets or materials. Coiling the wire will help concentrate the magnetic field on the inside of the coil (see figure to the right).

Turning a coil of wire into an electromagnet is as simple as wrapping the coil of wire around a piece of metal, such as an iron nail (see figure on the next page). When a wire is coiled around the nail, the magnetic field from the wire that is concentrated inside the coils magnetizes the iron nail and produces the electromagnet. Individual iron atoms can act like very small magnets, but inside a nail, the iron atoms point in random directions; therefore, the nail on its own does not act like a magnet. But when the iron atoms inside the nail are influenced by the magnetic field from the coil of wire, they change their alignment and point in similar directions. Only iron atoms inside the coil of wire will change their alignment, and the more atoms that point in the same direction, the greater the magnetic strength of the nail. The nail will only act like a magnet when the electric current is flowing through the wire; when the electric current stops, the iron atoms return to their original and random alignment and no longer act like a magnet.

**Your Task**
Build an electromagnet using a battery, some wire, and a nail. Then, use what you know about magnetic fields, tracking energy in a system, and structure and function to design and carry out an investigation that will allow you to determine how the number of turns of wire wrapped around the nail affects the strength of the electromagnet.

The guiding question of this investigation is: **How is the strength of an electromagnet affected by the number of turns of wire in a coil?**

**Materials**
You may use any of the following materials during your investigation:

- Size D battery
- Battery holder
- Copper wire
- Iron nail
- Paper clips
- Gauss meter (optional)
- Balance
- Ruler

**Electromagnet made from a D-cell battery, a copper wire, and an iron nail**

**Getting Started**
To answer the guiding question, you will need to design and conduct an investigation to measure the strength of your electromagnet. To accomplish this task, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it. The figure to the right shows how to construct a simple electromagnet from a battery, a copper wire, and a nail.

To determine *what type of data you need to collect,* think about the following questions:

- How will you determine the strength of the electromagnet?
- What information or measurements will you need to record?
- What parts of the electromagnet will you change and what parts will you keep consistent?

To determine *how you will collect your data,* think about the following questions:

- What equipment will you need to collect the data you need?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- Are there different ways you can measure the amount of coils you used?
- How will you keep track of the data you collect?
- How will you organize your data?

To determine *how you will analyze your data,* think about the following questions:

- How will you determine if the number of coils affects the strength of the electromagnet?
- What type of table or graph could you create to help make sense of your data?

**Report**

Once you have completed your research, you will need to prepare an investigation report that consists of four sections (be sure to have section headings):

1. Introduction: Give some background information on the topic. Explain what question were you trying to answer and include a hypothesis. (Background info, research question and hypothesis)
2. Procedure: What did you do during your investigation and why did you conduct your investigation in this way? (How you collected and analyzed data)
3. Data: Include a data table and/or graph to show your results. Be sure to include a title for your table or graph with labels for the variables.
4. Conclusion: What is your argument? (Claim - Evidence - Reasoning)

Your report should answer these questions in two pages or less. The report must be typed, and any diagrams, figures, or tables should be embedded into the document. Type your report on Google Docs (12 point font, double-spaced) and share it with your teacher. Your report will be graded based on the rubric in the class syllabus.