Measure Your Magnetism

Difficulty	
Time Required	Average (about one week)
Prerequisites	None
Material Availability	Specialty items
Cost	Low ($20 - $50)
Safety	No issues

Abstract

Do you know how to find the north and the south poles of a magnet? What materials are more magnetic than others? Is there a way to measure how strong a magnet is? Is there a way to measure the strength of an electromagnet? How much does the material that is in the core of the electromagnet affect its magnetic strength? With this project, you'll be able to answer these questions and many others. You will learn how to build and use a simple meter for measuring magnetic field intensity.

Objective

The goal of this project is to build a sensor for measuring magnetic field strength and to use it for measuring the strength of different types of magnets.

Credits

By Akram Salman AMD

Edited by Andrew Olson, Ph.D., Science Buddies

Last edit date: 2011-11-07

Introduction

Magnets and magnetic fields are used in everyday electrical equipment such as motors and refrigerators. You will also find them in electronic equipment like cell phones and radios. A magnetic field can be produced by a permanent magnet, or by electrical current flowing through a wire. You can make an electromagnet by wrapping a coil of wire around a magnetic material (e.g., iron, magnesium, or cobalt). When current flows through the coil, a magnetic field is produced. This type of magnet is an *electromagnet*.

Magnetic fields are also important in communication systems. The waves used to transfer information for television and radio broadcasts or cell phone calls are electromagnetic waves. Light, x-rays, and radio waves are all examples of electromagnetic waves.

The strength of a magnetic field can be measured. Magnetic field strength is measured in units of *gauss* (abbreviated G).

The device that is used to measure the magnetic field strength is called the gaussmeter.

The gaussmeter that you will build for this project is based on the Hall effect, discovered by Dr. Edwin Hall in 1879. Hall discovered that when a current is passing through a thin sheet and a magnetic field is applied perpendicular to the sheet, a voltage (called the Hall voltage) is generated across the third dimension, perpendicular to the direction of the original current. The magnitude of the Hall voltage is proportional to magnetic field strength. The Hall effect is used in different applications including making an electric motor.

Your gaussmeter will be based on an integrated circuit that allows you to measure the Hall voltage generated by a magnetic field. You'll learn how to build the gaussmeter, and how to use it to measure magnetic field strength. You'll also learn how to use your gaussmeter to identify the north and south poles of a magnet.

Terms and Concepts

To do this project, you should do research that enables you to understand the following terms and concepts:

- electrical current,
- electric voltage,
- magnetic field,
- electromagnet,
- gauss,
- gaussmeter,
- Hall effect,
- multimeter.

Bibliography

- For learning about magnetism and magnetic fields, check out these webpages:
  - Stern, D.P. and M. Peredo, 2004. "Magnetic Fields," The Exploration of the Earth's Magnetosphere [accessed May 10, 2006] http://www.phy6.org/Education/wmfield.html (http://www.phy6.org/Education/wmfield.html).
  - Wikipedia contributors, 2006. "Magnetic Field," Wikipedia, The Free Encyclopedia [accessed May 10, 2006] http://en.wikipedia.org/w/index.php?title=Magnetic_field&oldid=52459775 (http://en.wikipedia.org/w/index.php?title=Magnetic_field&oldid=52459775).
- For learning about the Hall effect, this website is a good start:
  Nave, C.R., 2006. "Hall Effect," HyperPhysics, Department of Physics and Astronomy, Georgia State University [accessed May 10, 2006] http://hyperphysics.phy-astr.gsu.edu/HBASE/magnetic/hall.html#c3 (http://hyperphysics.phy-astr.gsu.edu/HBASE/magnetic/hall.html#c3).
- To learn about the Hall effect sensor used in this project, see this website:
  Allegro Microsystems, 2006. "Linear Hall Effect Sensors for High-Temperature Operation," Allegro Microsystems, Inc. [accessed May 10, 2006] http://www.allegromicro.com/sf/1321/ (http://www.allegromicro.com/sf/1321/).
- This Science Buddies project has information on making your own electromagnets: The Strength of an Electromagnet (http://www.sciencebuddies.org/mentoring/project_ideas/Elec_p001.shtml).

Materials and Equipment

To do this experiment you will need the following materials and equipment:

- Multimeter, such as the Equus 3320 Auto-Ranging Digital Multimeter; available online from Amazon.com (http://www.amazon.com/gp/product/B000EVYGZA/ref=as_li_ss_tl?ie=UTF8&tag=sciencebuddie-20&linkCode=as2&camp=217145&creative=399369&creativeASIN=B000EVYGZA),
- 9 V battery,
- 9 V battery clip connector (e.g. Radio Shack 270-325),
- +5 V voltage regulator (7805 or NTE1934, e.g. Radio Shack 276-1770),
- solderless breadboard (e.g., Radio Shack 276-175),

- jumper wires for breadboard (e.g., Radio Shack 276-173),
- alligator clip leads (e.g., Radio Shack 278-1156),
- Hall effect linear IC (A1321EUA), available from http://www.newarkinone.com (http://www.newarkinone.com),
- magnets with different shapes.

If you want to build and measure the strength of simple electromagnets, you will also need:

- one or more iron nails,
- insulated hook-up wire,
- a battery,
- wire cutters.

Experimental Procedure

Note Before Beginning: This science fair project requires you to hook up one or more devices in an electrical circuit. Basic help can be found in the Electronics Primer (http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_primer-intro.shtml). However, if you do not have experience in putting together electrical circuits you may find it helpful to have someone who can answer questions and help you troubleshoot if your project is not working. A science teacher or parent may be a good resource. If you need to find another mentor, try asking a local electrician, electrical engineer, or person whose hobbies involve building things like model airplanes, trains, or cars. You may also need to work your way up to this project by starting with an electronics project that has a lower level of difficulty.

The Experimental Procedure for this project has four sections, which are described briefly below.

1. **Using a Solderless Breadboard.** You will be building your gaussmeter on a solderless breadboard. The first section explains how breadboards work.
2. **Building the Gaussmeter.** This section has the step-by-step instructions for assembling the gaussmeter circuit.
3. **Measuring Magnetic Fields.** This section shows you how to use the gaussmeter to measure magnetic fields.
4. **Analyzing Your Results.** This section shows you how to calculate magnetic field strength from your measurements, and also how to identify the north and south poles of a magnet.

Using a Solderless Breadboard

Figure 1, below shows a small solderless breadboard, used for quick assembly of a circuit for testing or experimentation. The breadboard has a series of holes, each containing an electrical contact. Holes in the same column (examples highlighted in yellow and green) are electrically connected. When you insert wires or component leads into holes in the same column, the wires and leads are electrically connected. The two single rows of holes at the top and bottom (highlighted in red and blue) are power buses. All of the red holes are electrically connected and all of the blue holes are electrically connected. Connect the red (+) wire from the battery connector to one power bus, and the black (– or common) wire to the other power bus. Then you can use jumper wires to connect components to the buses.

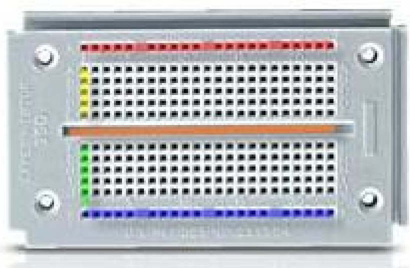


Figure 1. An example of a solderless breadboard. The highlighting shows how the sets of holes are electrically connected. The red and blue rows are power buses. The yellow and green columns are for making connections between components. Integrated circuits are inserted to span the gap (orange) so that the two rows of pins are not connected to each other.

One more note about the breadboard, for future projects you might build: the gap (highlighted in orange) marks a boundary between the electrical connections. A wire inserted in one of the green holes would *not* be connected to a wire inserted in one of the yellow holes. Integrated circuits with two rows of pins should be inserted so that they span the gap in the breadboard. That way, the top row of pins is connected to one set of holes, and the bottom row of pins is connected to another set of holes. If the integrated circuit was not spanning a gap in the breadboard, the pins from the two rows would be connected together (shorted), and the integrated circuit wouldn't work. There are no integrated circuits with two rows of pins in this project, but if you continue your interest in building circuits you'll run across them soon enough.

Building the Gaussmeter

Using the solderless breadboard, connect the components as shown in the schematic diagram (Figure 2, below).

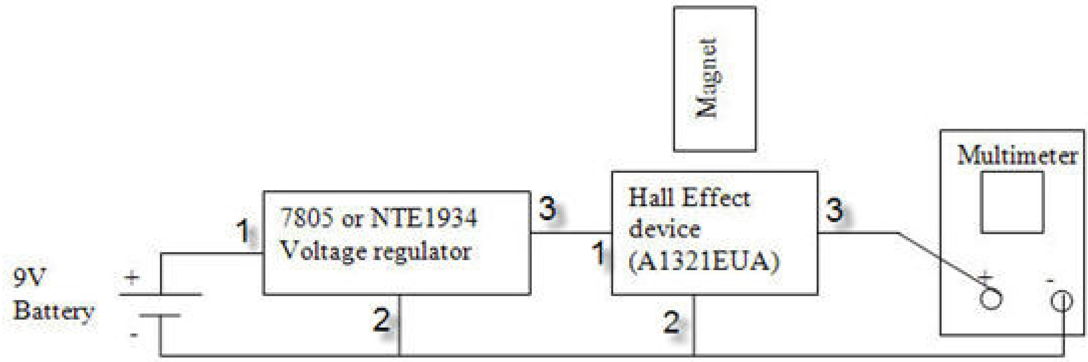


Figure 2. Schematic diagram of the gaussmeter circuit.

1. Connect the red (+) wire of the battery clip to the upper power bus (single row) of the breadboard. (Do not connect the battery yet. Wait until the circuit is complete, and you have double-checked your wiring.)
2. Connect the black (– or common) wire of the battery clip to the lower power bus (single row) of the breadboard.
3. Carefully spread the two outer pins (pins 1 and 3) of the 7805 voltage regulator, so that all three pins can be inserted into neighboring columns on the breadboard. Carefully insert all three pins into the breadboard.
4. Use a jumper wire to connect the input (pin 1) of the 7805 voltage regulator to the +9 V power bus.
5. Use a jumper wire to connect the common (pin 2) of the 7805 voltage regulator to the common power bus.
6. Carefully insert the Hall sensor IC into the breadboard.
7. Use a jumper to make a connection from the output of the 7805 voltage regulator (pin 3) to the +5 V input of the Hall sensor IC (pin 1).
8. Connect the common of the Hall device (pin 2) to the common power bus.
9. Set the multimeter to DC Volts.
10. Attach the + input of the multimeter to the output of the Hall device (pin 3). You can use the alligator jumpers.
11. Attach the - input of the multimeter to the common power bus.
12. Double-check all of your connections.
13. You are now ready to snap a battery onto the battery clip.

Figure 3. Example photo of the gaussmeter circuit on a solderless breadboard.

Measuring Magnetic Fields

Follow these steps to use the gaussmeter to measure the electric field

1. Observe the value read by the multimeter. With no magnet near the sensor, you should see a reading of approximately 2.5 V (it may be a little higher). This value is considered the zero level of the gaussmeter. We will call this level V_0.
2. To measure the strength of a magnet, touch it to the front of the Hall sensor. (The front side of the IC has the brand name on it and angled sides. The Hall sensor element is right in the center of the chip.) Experiment with different orientations of the magnet to see where you get the maximal response.
3. If the Hall voltage decreases, you are measuring the north pole of the magnetic field; if the Hall voltage increases, you are measuring the south pole.
4. Observe the new voltage on the multimeter and record it in your lab notebook. We will call this level V_1.
5. Repeat steps 1–3 for each magnet you want to test.
6. Check your understanding of how the Hall-effect sensor works by answering the following questions:
   a. What happens to the readout voltage if you touch the same side of the magnet to the back side of the Hall sensor IC?
   b. Why?

Analyzing Your Results

1. The sensitivity of the Hall sensor IC (A1321EUA) described in this experiment is 5 mV/G. Therefore, to calculate the magnetic field strength, B, in gauss, you can use this equation:

$$B = 1000 \times (V_0 - V_1) / 5.$$

   Your measurements, V_0 and V_1, are in volts. The factor of 1000 converts your measurement to millivolts, in which the Hall sensor is calibrated.
2. Use the equation to calculate the magnetic field strength for each magnet. (If you are using a different Hall sensor IC, substitute its sensitivity in the equation above.)

3. Check your understanding of the field strength calculation by answering the following questions:
    a. The Hall sensor IC used in this project is supposed to have a linear response throughout the supply voltage range (0–5 V). Assuming a V_0 of exactly 2.5 V, what is the maximum magnetic field strength that can be measured with this device?
    b. Is the value the same for both north- and south-pole magnetic fields?

Variations

- An interesting variation is to use your gaussmeter to measure the strength of electromagnets with different number of turns. Here are the steps:
    - Create several electromagnets with different number of turns (e.g., 50, 100, 150, 200).
    - Allow current to pass through the electromagnet. Use the same battery for each electromagnet.
    - Measure the magnetic field for each electromagnet using steps 1–3 from the previous section. Try to power the electromagnets as briefly as possible, since they tend to drain the battery quickly.
    - On graph paper (or using a computer graphing program), plot the value of the magnetic field strength on the y-axis versus the number of turns used for the electromagnet on the x-axis.
    - What is the relationship between number of turns and magnetic field strength?
- The core material of the electromagnet also affects its strength, so another interesting experiment would be to vary the core of the electromagnet and see how much it affects the measured magnetic field. For example, you could use more nails, you could try steel bolts, you could try different shapes.
- Another idea would be to map the magnetic field distribution around the magnet. You would need to measure the magnetic field strength at many points around the magnet, and then use the data to draw a map of the field strength. One way to do this would be to pick several constant values of field strength, then vary the distance of the magnet from the sensor until the multimeter reading matches that value. Record the distance and orientation of the magnet for each measurement. This way you will be measuring the points at which the magnetic field strength is equal, making it easier to draw a contour-line map.

Ask an Expert

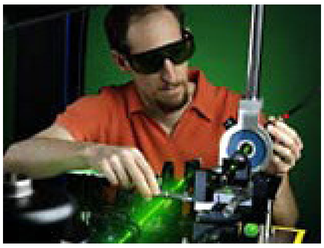
The Ask an Expert Forum is intended to be a place where students can go to find answers to science questions that they have been unable to find using other resources. If you have specific questions about your science fair project or science fair, our team of volunteer scientists can help. Our Experts won't do the work for you, but they will make suggestions, offer guidance, and help you troubleshoot.

Ask an Expert (http://www.sciencebuddies.org/science-fair-projects/ask_an_expert_intro.shtml)

Related Links

- Science Fair Project Guide (http://www.sciencebuddies.org/science-fair-projects/project_guide_index.shtml)
- Other Ideas Like This (http://www.sciencebuddies.org/science-fair-projects/recommender_results.php?solt=Elec_p030.shtml)
- Electricity & Electronics Project Ideas (http://www.sciencebuddies.org/science-fair-projects/recommender_interest_area.php?ia=Elec)
- My Favorites (http://www.sciencebuddies.org/science-fair-projects/recommender_show_favorites.php)

If you like this project, you might enjoy exploring these related careers:



Electrical & Electronics Engineer

Just as a potter forms clay, or a steel worker molds molten steel, electrical and electronics engineers gather and shape electricity and use it to make products that transmit power or transmit information. Electrical and electronics engineers may specialize in one of the millions of products that make or use electricity, like cell phones, electric motors, microwaves, medical instruments, airline navigation system, or handheld games. Read more (http://www.sciencebuddies.org/science-fair-projects/science-engineering-careers