Electromagnets

Name:	Teammates:

Introduction

Mankind's knowledge of magnetism is nothing new; people have known of its existence for millennia. The term "magnet" comes from the ancient Greece word "Magnesia", which is the place in Thessaly where the naturally occurring magnetic rock lodestone was found in the BCE era. However, the ability to create magnetism is a much more recent phenomenon. In 1820, Hans Oersted discovered that he could deflect the needle of a compass by running a current through a nearby wire. He deduced that the reason for this was because the current was producing its own magnetic field. This led to the discovery of electromagnets. A typical electromagnet is made by coiling conducting wire around a ferromagnetic core. One typical coiling method is what is often referred to as the solenoid.

Solenoids

Fig 1: Massive Solenoid (*LBL*)

The magnetic field created by a single wire is given by: $B = \frac{\mu_o I}{2\pi \cdot r}$

where μ_o is the permittivity of free space ($4\pi \times 10^{-7}$ Tm/A) and r is the distance for the wire. The equation shows that currents on the order of 1-100 amps produce fairly weak fields outside of a few millimeters from the wire.

One way to boost the field from a wire is to add together the effect of many wires that are all carrying current in the same direction. This is the basis behind a solenoid, a wire that is coiled into a series of loops that are all laid on top and next to one another. In the middle of the solenoid, the magnetic fields from all of the wire loops add vectorally to provide a very strong field that is parallel to the axis of the solenoid. When the wires are close together, and the solenoid diameter is not too large, the magnetic field within the solenoid can be approximated by a uniform field given by

$$B = \mu\, nI$$

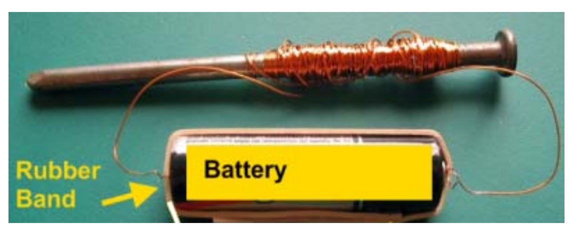
where μ is the permitivity of the material contained in the solenoid (if there is something other than air in it), n is the number of wire loops per unit length, and I is the current running through the solenoid. If a vacuum (or air) exists within the solenoid, then the permitivity is that of free space, i.e. $\mu = \mu_o .= 4\pi \times 10^{-7}$ Tm/A

From this equation, we see that we can change the magnetic field by varying the number of turns per unit length, the current running through the solenoid, or by placing a different type of material, like iron core, in the solenoid.

In part 1 of this week's experiment, we will qualitatively test this equation by building a simple electromagnet and testing its effectiveness on picking up paper clips. In part 2 of the lab, we will quantitatively test this equation by varying the current in two different solenoid configurations. In part 3 of the lab, we will use the right hand rule to help explain the operation of a homopolar motor.

Procedure

Part 1: Electromagnet:



Acquire about two-meters of copper wire. Scrape the insulation off about 1 cm of the wire at each end. Wrap the copper wire around the nail and leave at least 10 cm free at each end. Connect the ends of the wire to the battery.

WARNING: Do not leave the battery connected for more than one half minute at a time. Disconnect one end of the wire between parts of the experiment to avoid draining the battery and causing the wire to heat up excessively.

1. Try, without powering the coil (no battery) to pick up paper clips with the wire and nail electromagnet. What did you observe?

2. Now connect the battery (to connect the battery, attach the stripped end of the wire with a rubber band to the ends of the battery, or use the battery holder and alligator clip wires) and try to pick up paper clips with the wire and nail electromagnet. What happens now? Where is the electromagnet the strongest the side or the tip?

3. Use the compass to identify the poles of the electromagnet.

4. Reverse the direction of flow of current by reversing the battery connections. Use the compass to identify the poles. How does the direction of current flow affect the polarity of the electromagnet? Can you use the right hand rule to predict the poles?

5. Add another battery in series with the first so that you can increase the current through the coil. Does the increase in current affect the strength of the electromagnet? **Be careful not to keep the coil connected to the batter for longer then 30 seconds.**

6. Remove the additional battery, then remove the nail from the coil. Does the coil still act as an electromagnet? Use the compass to test it. What is the role of the nail then?

Part 2: Magnetic Field Within a Solenoid:

For this activity, you will need a solenoid, the Vernier Labpro Interface, a magnetic probe and the "magnet3.cmbl" logger pro settings file.

1. Download the settings file from http://physics.kennesaw.edu/magnet3.zip
2. Make sure to expand the zip archive.
3. Connect the solenoid as shown in Fig. 2 (2400-coil configuration: voltage leads connected to green and yellow leads on the solenoid) to the power supply output. The magnetic probe should be connected to Port 1 of the Vernier Labpro Interface.
4. Make sure that both the LabPro interface is powered.

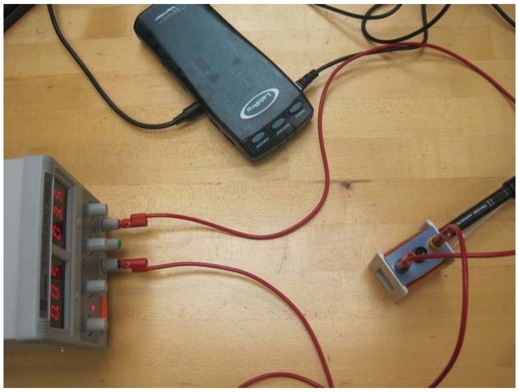
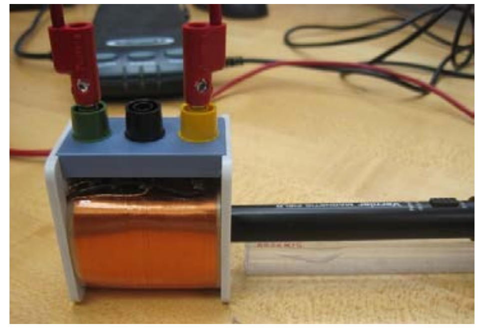


Fig. 2: Set up



5. Place the measuring part of the magnetic probe in the center of the solenoid. Check image for guidance.
6. Make sure that the magnetic probe is set to the higher setting (6.3 mT)
7. Start the “magnet3.cmbl” settings file.
8. With the power supply still off, turn both voltage knobs fully clockwise.
9. Turn both current knobs of the power supply counterclockwise.
10. Turn the power supply on.
11. Select “Zero” from the “Experiment” menu of LabPro (or click the combination CTRL+0), check next to “Magnetic Field” then press OK.
12. The values of the current through the solenoid can be read in Amps from the Power supply current display.
13. Labpro provides a reading of the magnetic field (in Gauss)
14. Press the “Collect” button to start the process.
15. Press the “keep” button to collect the initial data point. Type the value of the current then press “enter”.
16. Slowly manipulate the coarse and fine adjustment current knobs of the power supply to increase the current by 0.01 Amps. (note that for small current values, it is hard to adjust the power to a constant current value, just get an approximate value.)
17. Press the “keep” button to collect the second data point. Type the value of the current then press “enter”.
18. Slowly manipulate the coarse and fine adjustment current knobs of the power supply to increase the current by another 0.01 Amps. Press the “keep” button to collect the third data point.
19. Repeat the process until you collect 10 data points. Press the stop button
20. Now press the “curve fit icon” (it is the one that has “R= “ in it) and record the slope value.

800-turn slope = _______ 2400-turn slope = _______

21. Change the solenoid configuration to the N=800 one
22. Select “New Data Set” from the “Data” menu, and close the “linear fit” box
23. Repeat steps 11-20 for the 800-turn configuration.
24. Shut off the power supply, log off the computer and replace all equipment where it was found.

A. How close do your plots come to being linear? What possible sources of error can account for any nonlinear data points?

B. What should the slopes be equal to?

C. What should the ration of the slopes be equal to?

D. What is the ratio of the slopes from the two solenoids? Does this fit with what you expected? What possible reasons could account for deviations from your expectations?

E. From this experiment and the previous part, what are the factors that might affect the strength of the magnetic field within a solenoids?

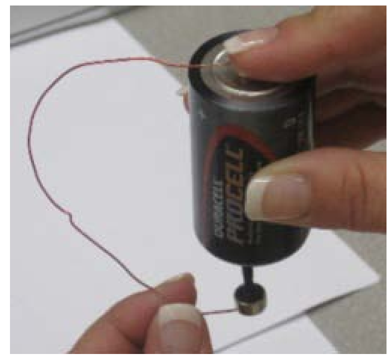
Part 3: Homopolar Motor:

Directions and graphics in this activity were adapted from: http://sci-toys.com/scitoys/scitoys/electro/homopolar/homopolar.html

Secure the following: a battery, a disc magnet, about 10 cm of wire, a sharp pointed screw (it must be magnetic, it must conduct electricity, and it must have a flat end.)

1. Set the screw in the center of the disk magnet.
2. Strip the insulation from the ends of the 10 cm electrical wire.
3. Hold one end of the wire against the flat end of the battery.
4. Bring the button end of the battery to touch the point of the screw, and lift the screw and magnet off the table.
5. Gently hold the other end of the wire against the edge of the magnet.
6. That is it! It should start spinning.

Why does the screw stick to the battery?



In what direction does the magnet and screw rotate?

Flip the direction of the battery, in what direction does the magnet and screw rotate now?

Flip the magnet instead, in what direction does the magnet and screw rotate now?

Add a small piece of plastic between the screw and the magnet. How did that affect the operation of the homopolar motor?

Remove the plastic but now connect the wire to the bottom of the magnet instead of the side. What do you observe?

Touch the wire to the side of the screw instead of the magnet. What do you observe?

Can you use the right hand rule to explain what makes the magnet rotate? Use the right hand rules for each of the suggested configurations.

Why would they continue to rotate for a long time even after you remove the electrical connection?