Lab 6: The Biot-Savart Law

Introduction: The Biot-Savart law predicts that a current will generate a magnetic field and current generated magnetic fields were first discovered in 1820 by Hans Christian Oersted. "Electromagnets" opened the door to many possibilities since magnets could be created when desired and materials could be magnetized through induction. Today the use of electromagnets is widespread. Scrap yards use large electromagnets to move junk metal around, relays in electronic circuits open and close using an electromagnet, and electric motors are possible because of the Biot-Savart law. This lab will show the principles behind the electromagnet, and how they are applied in everyday devices. By the end of this lab, you should:

- Know the strength and direction of a magnetic field generated by a current-carrying wire
- Understand forces between magnets
- Apply magnetic fields to audio speakers

Materials:

- Solenoid
- Current Supply
- Speaker with banana and mini-jack
- Musical signal (e.g. from a computer audio card)
- Audio Driver
- Oscilloscope
- B Field Probe

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Experiment 1- The Electromagnet

An electromagnet is made simply by running current through a wire, but its strength can vary widely depending on the orientation of wire. According to the Biot-Savart law, the magnetic field is proportional not only to the current in the wire but also to the distance from the wire.

For this experiment you should attach the current source and run 100mA of current through a coil of wire (see figure). Now, using the magnetic field sensor, measure the magnetic field generated in and about the coil at various locations. Your goal should be to produce a graph of the field by measuring the field in a plane (e.g. see the figure.) Since the magnetic field is a vector, you should measure its axial (z) and radial (s) component in, for example, a plane perpendicular to the solenoid axis and 10 cm from the center of the solenoid.

- What is the maximum value you measured? At what point(s) was this maximum value located?
- How could you increase the strength of the magnetic field from the wire without changing the current? What is the maximum value you think you could attain? Would this be located at the same place as the maximum value was before?

Figure: Measurement of the radial magnetic field component at the center of the coil (s=0), in a plane 10cm from the center of the coil (Z=10cm).

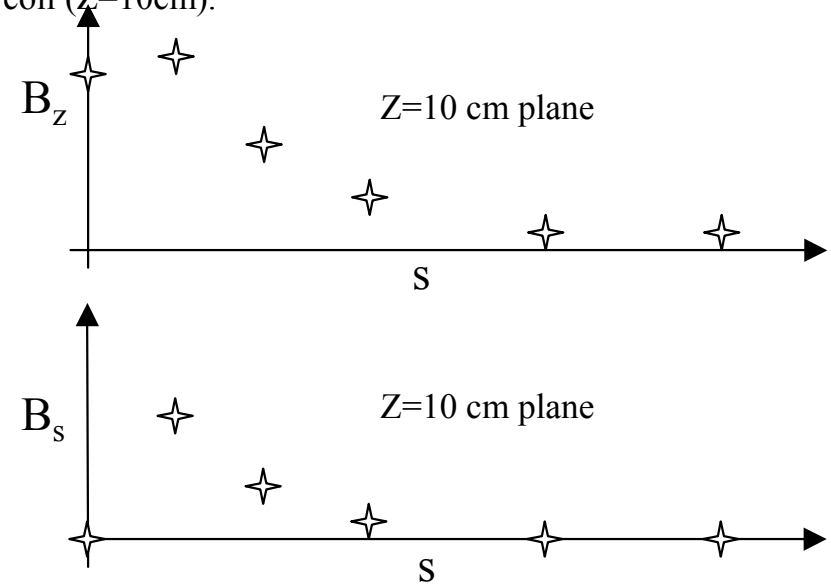


Figure: Magnetic fields are 3-D so to quantify a field, you must carefully choose your measurements. Two suggested measurements are given above, the Bz and Bs components of the field measured at z=10cm from the coil center. What about Bϕ?

Experiment 2- The Speaker

A speaker uses the magnetic field from a wire coil to convert electrical current into sound. A speaker usually contains a permanent dipole magnet aligned with the magnetic field from an electromagnet called the voice coil – essentially a short solenoid. Clearly, if you run current through the voice coil of wire a magnetic field is generated. Okay, so try it: connect a 9V battery to the speaker. What happens and why? Also connect it with the opposite polarization and see what happens then. The battery supplies a constant "DC" current. Why does the speaker move?

Next, consider alternating currents. For the measurement, attach the audio driver to the speaker and the oscilloscope as shown in the figure. Does the frequency you measure from the oscilloscope match the frequency given on the audio driver? How is the speaker generating the sound wave? What are the highest frequencies you can hear?

Connect the speakers to a musical audio driver such as the one in the back of the computer. Play a *.wav or *.mp3 file. Can you measure any frequencies from any of the songs? (You should be able to measure some from Mozart's Moonlight Sonata, if nothing else). How do these correspond to notes on the musical scale?

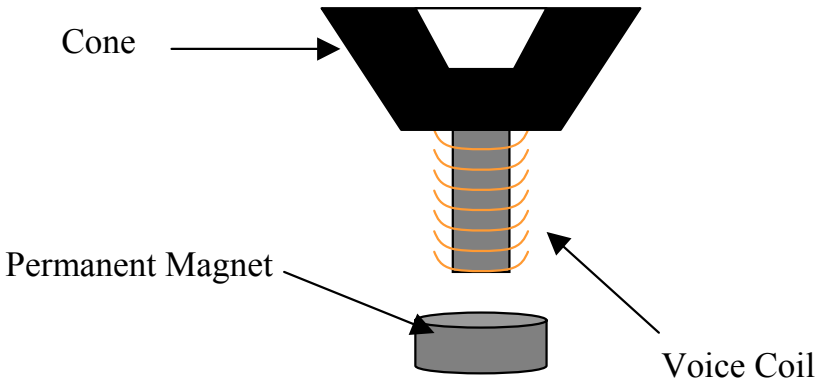


Figure: Cut-away diagram of a speaker. The voice coil is the wire through which current flows, creating an electromagnet.

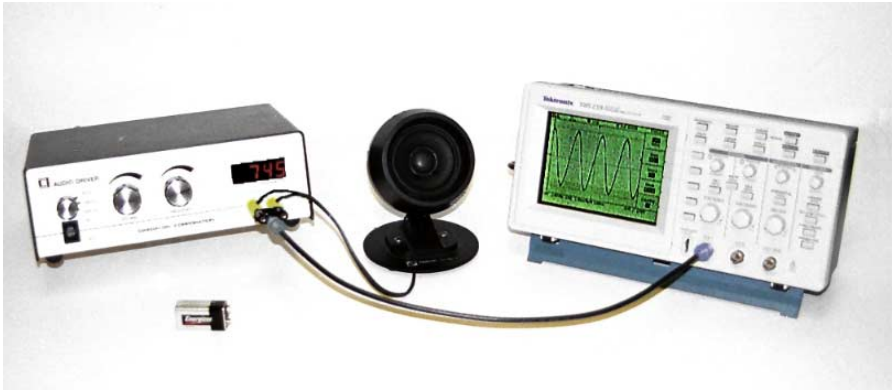
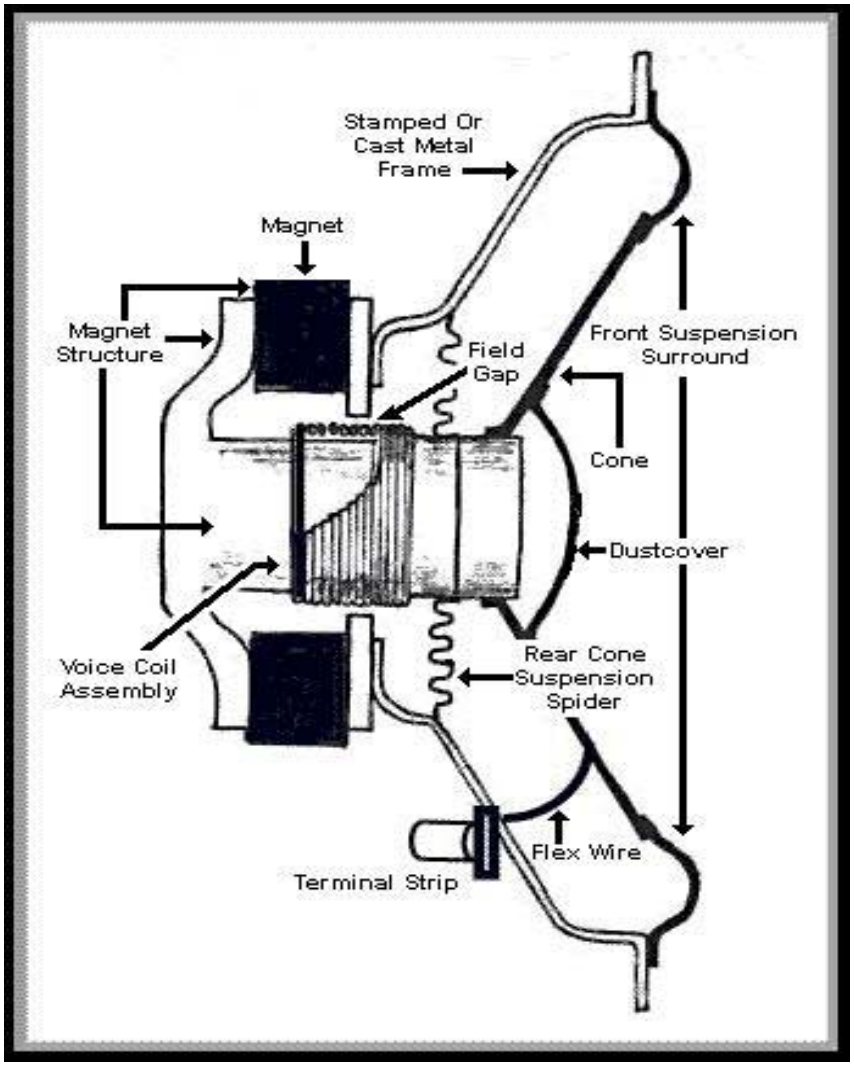


Figure: The scope can measure the voltage from the audio driver across the speaker while the speaker is operating.

Real World Problem– Speaker Design

You work for a speaker company whose main product is a speaker utilizing a ceramic dipole magnet with a strength of 100 gauss at the surface and 3000 wraps of 42 gauge copper wire. Eighty percent of the energy is lost in the resistance of the wire. Sales of this speaker have been steadily declining, and you have been put in charge of creating a new speaker to get the company back in the market. Your boss would like a forty percent increase in speaker efficiency any way possible– the people in marketing have determined that this amount will be enough to begin outselling the competition.



• Knowing the facts behind the operation of a speaker, begin to think about areas modifications could be made to increase the efficiency of the speaker. How much energy is there in the original system, and how would your changes improve the use of this energy to give 40% more sound for the same energy?

• What materials would be needed to make these changes and how much of a percentage increase in cost might this incur?

• Design your new speaker and show exactly how it will achieve the increased efficiency. Are there other ways you could have modified the design to achieve the same results?

Internet Resources

http://www.howstuffworks.com/speaker.htm	Speaker physics
http://www.webervst.com/sptalk.html	Q/A about speakers
http://www.eatel.net/~amptech/elecdisc/speaker.htm	Speaker introduction