Lab 7
Electromagnetism Applications

Relevant SOLs: PS.1a, PS.1h, PS.1j, PS.1k, PS.8c, PS.8d, PS.11a, PS.11b, PS.11c, 3.1a, 3.1g, 3.1j, 4.1a, 4.1f, 4.1h, 4.3b, 4.3e, 5.1e, 5.1f, 5.2c, 6.1c, 6.1i

Overview
Electromagnets are used widely in many applications that we use every day. A small sample of applications includes motors, generators, headphones, and ear-buds, microphones, and doorbells. In this investigation, you will continue to study the properties of electromagnets and you will build your own speaker.

Fig 7.0.1 Headphones are one of many applications of electromagnets.
Activity 7 - 1: Solenoid

Objectives: Observe the behavior of a magnetic compass in the presence of an electrical current in a coil of wire.

SOLs: PS.1a, PS.1k, PS.11a, PS.11b, 3.1a, 3.1j, 4.1a, 4.3b, 4.3e, 5.1e, 5.1f, 6.1c

Materials:
- Compass
- Enameled Wire 1.0 m (26 gauge enamel-covered copper wire)
- Iron nail
- 1.5-Volt cell (from home)
- Pencil (from home)
- Duct tape (from home)

Prediction:

In this activity, you will be testing the magnetic field around a solenoid. See Fig 7.1.1. Use the coil of wire from Lab06 without the iron nail.

Fig 7.1.1 The wire is fashioned into a solenoid. Note that since the positive terminal of the battery is not connected to the solenoid, there should be no current in the wire.

1. In Fig 7.1.1, which direction is the compass pointing; North, South, East, or West. Explain your answer. The coil is not supposed to be connected to the battery.
2. If you connect the top of the solenoid to the positive terminal of the battery and if you connect the bottom end of the coil to the negative end of the battery, what direction do you predict the compass will point? Explain your answer.

Observation and Procedure

1. Place the compass flat on a surface with no nearby sources of electricity or magnetism. Turn the compass until the red end of the pointer is pointed $0^\circ$. Describe the direction that the compass needle points in the space provided.

2. You make use the coil from Lab06. Take the iron nail out of the coil. Place the coil so that one end is at the $90^\circ$ heading on the compass (as in Fig 7.1.1). Connect one end of the coil to the positive terminal of the 1.5-Volt cell. Briefly (!) connect the other end of the coil to the negative terminal of the 1.5-Volt cell. (!) Warning: The wire will get hot very fast because the cell is essentially shorted, which means there will be a large current through the wire. This will also drain the cell rapidly. Do not keep the wire connected to the cell for too long. It will only take less than 3 seconds to see the deflection. Describe the direction that the compass needle points.

3. Without moving the coil, turn the 1.5-volt cell around and connect the other end of the coil to the positive terminal of the 1.5-Volt cell. Briefly (!) connect the first end of the coil to the negative terminal of the 1.5-Volt cell. Describe the direction that the compass needle points in the space provided.
4. Place the iron nail in the middle of the coil. Repeat steps #2 and #3. Describe the direction that the compass needle points in the space provided.

Fig 7.1.2 A nail is now inserted into the solenoid.

Explanation

1. Use your observations from Steps 2 and 3 to conclude how you can tell the direction of the magnetic field generated by the current in a solenoid. T

2. State whether the magnetic field produced by the current was stronger or weaker with the nail inserted. Explain how you made your determination.
Activity 7 – 2: Semi Quantitative Paperclip Pickup II

Objectives: Investigate the effect of changing the number of coils on the strength of an electromagnet.

Materials:
- Wires with alligator clips
- Iron nails (7.5 cm long and 0.95 cm in diameter)
- Enameled Wire 3.0 m (26 gauge enamel-covered copper wire)
- 1.5-Volt cells x3 (from home)
- Steel wool or a blade to scrape the ends of the magnet wire (from home)
- Transparent adhesive tape (from home)
- Small paper plates or bowls x2 (to hold paperclips, from home)
- About 100 Paper clips (from home)

SOLs: PS.1h, PS.1j, PS.1k, PS.11a, PS.11b, 3.1a, 3.1g, 3.1j, 4.1a, 4.1f, 4.1h, 4.3b, 4.3e, 5.1e, 5.1f, 6.1c, 6.1i

Prediction:
During Investigation 4, Activity 3, you built an electromagnet that was able to pick up a large number of paperclips. In this activity, you will keep the current going through the wire constant but you will vary the number of coils of your electromagnet. How do you think the number of coils of wire in your electromagnet will affect the number of paperclips that your magnet can pick up? Explain.

Observation and Procedure

1. Use the electromagnet that was prepared in Lab 6, Activity 3. Record the number of coils present in the electromagnet. Start with 50 coils.

2. Place ~100 paper clips on a paper plate. Connect one alligator clamp lead to each end of the electromagnet wire. You may try connecting the ends of the electromagnet directly to the 3 cells but the connection may be erratic and intermittent depending on how well the ends were cleaned of enamel.

3. Place the end of the electromagnet directly over and touching the pile of paper clips. Connect the leads, picking up a number of paper clips. Transfer the magnetically attracted paper clips to the other plate and disconnect the leads. Count the number of paper clips transferred and enter your data in Table 7.2.1. Do this for a total of 4 trials.
<table>
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<th># of turns</th>
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<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
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Table 7.2.1

4. Remove 10 coils from the wire by unraveling 10 coils and reconnect the ends to the battery. You now have 40 coils.

5. Remove the number of turns of wire that you calculated in Step 4 from the electromagnet by unraveling the wire from the iron nail. The unwrapped wire will just hang loose from the nail. Repeat Steps 2 and 3 above capturing paper clips and counting them. After four trials, unwind again 10 coils. Now, you have 30 coils. Continue until Table 7.2.1 is completely filled in. Since the length of the wire has not changed, the current through the wire should remain the same.

6. Use Excel to plot the average number of paper clips picked up vs. the number of turns in the electromagnet coil. Include your graph here.

Explain

1. What happens to the strength of the electromagnet as you decrease the number of coils of wire? How can you tell?

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_______________________________________________________________________

2. Describe the relationship shown on the graph. Why do you think this relationship exists?

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3. Do you think this relationship would be valid all of the way down to 0 coils of wire? Explain.

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University of Virginia Physics Department
Activity 7 – 3: Loudspeaker

Objectives: Build a simple loudspeaker from magnets and a coil of wire.

SOLs: PS.8c, PS.8d, PS.11a, PS.11b, PS.11c, 3.1a, 4.1a, 4.3b, 4.3e, 5.2c

Introduction

A simple loudspeaker consists of a magnetic, a coil of wire, and a membrane that can vibrate back and forth to produce sound. See Fig 7.3.1. A solenoid (coil) will produce a magnetic field that will attract another magnet when the current flows one way and will repel the same magnet when the current flows the other way. If a flexible membrane is attached to the coil then the membrane will move back and forth with the changes in the current. If the current changes are rapid enough, the membrane will produce sounds audible to the human ear.

Fig 7.3.1 A speaker

Materials:

- Enameled Wire 1.0 m (26 gauge enamel-covered copper wire)
- Neodymium Magnet
- 3.5 mm Audio Jack Plug
- Disposable Clear Cups x2 (from home)
- Needle or pin (from home)
- Steel wool or a blade to scrape the ends of the magnet wire (from home)
- Cell phone, computer or mp3 player (from home)
Prediction

In this activity, you will be building a speaker out of two plastic cups, a magnet, and a coil of wire. You will play music or some other audio file from a phone, Ipad, computer or mp3 player. **Predict what you think you will hear when you play the file. Will you be able to tell what song it is? How loud will it be?**

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Observation and Procedure

1. Wrap the wire between your two fingers to make a coil of about 3 cm in diameter. It should be just slightly larger than the neodymium magnet. Secure the coil by winding the ends around the coil on opposite sides of the coil. Leave at least 10 cm of wire free for connection to the cell(s). Scrape the end of the wire so that the copper core is exposed.

2. Flip a clear cup upside-down. Place the coil at the center of the bottom of the cup. Draw a line on the bottom of the cup to mark the diameter of the coil. Then use a needle or a pin to poke a small hole through the cup on each end of the line. See **Fig 7.3.2**.

3. Pick up the cup. Put the coil inside. Thread the two ends of the coil through the two holes. On the outside of the cup, tie a knot with the wire ends that stick out...
of the holes on the cup. Pull on the two ends until the knot is tight and the coil is secured against the inside bottom of the cup.

4. Tape the neodymium magnet at the center of the bottom of the other cup. Push the second cup into the first cup. Tape the rim of the second cup to the rim of the first cup in order to make sure they fit snugly to each other. See Fig 7.3.3.

5. See Fig 7.3.4 for an illustration of the 3.5 mm audio jack plug. Hook one end of the wire to Terminal C. Hook the other end of the wire to Terminal A. Make sure the copper core of the wire is exposed to the terminals.

6. Connect the plug to an audio jack from your phone, iPad, computer or an mp3 player. Turn up the volume to the maximum. Describe what you hear from the clear cups?
Explain

1. **Compare the sound you heard to your prediction.**

2. **Why isn’t your sound system as good as the one in Fig 7.3.5?**