Name: _____

Partners: _____

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PHYSICS 221 LAB #5: MAGNETIC FIELDS & INDUCTION

The enormous generators in the Hoover Dam are used to convert mechanical motion into electricity. Their operation relies on the principle of magnetic induction. Electric motors powered by these generators spin because of magnetic forces.

OBJECTIVES

1. To be able to identify the poles of a permanent magnet and know what the field near them looks like.
2. To understand the shape of the magnetic field due to the current in a loop of wire.
3. To understand the forces between permanent magnets and electromagnets.
4. To observe and understand the phenomena of magnetic induction.

OVERVIEW

The red end of a compass needle will point in the direction of an external magnetic field. Outside of a permanent magnet, the magnetic field points away from its north pole and toward its south pole. Magnetic field lines always form closed loops so they also pass through a permanent magnet - from the south pole, back to the north. A wire carrying a current will also produce a magnetic field that encircles it. If you place your right thumb in the direction of the current, the
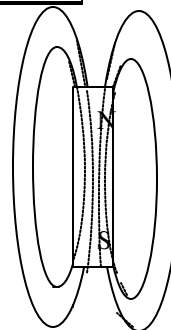
magnetic field line will wrap around the wire in the direction your fingers curl. The field lines come up, out of the current loop's "North" face, and enter the loop's "South" face, just as with a permanent magnet. Like poles of magnets repel and opposite poles attract.
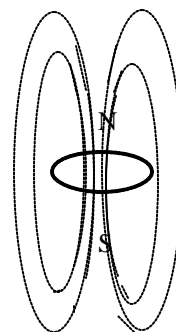
The size of the magnetic flux can be thought of as the number of magnetic field lines passing through an area or more exactly,
$$f_m = AB\cos q$$
where A is the area, B is the size of the magnetic field, and θ is the angle between the magnetic field line and a line perpendicular to the area. Magnetic flux is measured in units of webers, $Wb = T \cdot m^2$.

Magnetic induction results from a change in magnetic flux. According to Lenz's Law, the induced current will flow in the direction that will produce a magnetic fieldthat will somewhat oppose the change in magnetic flux. The average size of the current driving *emf* induced is related to the rate of change in the magnet flux by
$$\bar{e} = N\frac{\Delta f_m}{\Delta t}$$
where N is the number of loops. It is useful to know that $1 \, Wb/s = 1 \, V$.
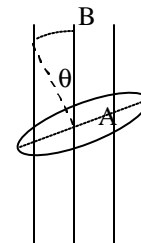
Field Code Changed

PART ONE: Permanent Magnets

1. Be sure to handle the magnets carefully. Do **not** bring them close to the computers since they are strong enough to do permanent damage! Also, keep the magnets at least a foot from the compass. The ceramic magnets are also somewhat fragile and may break if dropped.
2. Use a compass to determine where the poles of the "cow" and ceramic magnets are. Label the North poles of the magnets with stickers.
3. Test that the north pole of one of the magnets attracts the south pole of another group's magnet.

Question: Briefly explain how you decided which pole is which.

PART TWO: An Electromagnet

1. The coil that you make in this part of the lab will be used to make a motor in Part Three, so follow the directions carefully.

2. Get a 125-cm piece of 22 or 26 gauge magnet wire. Starting about 8 cm from the end of the wire, wrap it 7 and a half times around a paper tube. Cut the wire, leaving an 8-cm tail opposite the original starting point. Wrap each of the two tails around the wire coil twice so that the coil is held together and they extend perpendicular to the coil. (See illustration below.) Be sure to center the two tails on either side of the coil since balance is important for its use in a motor. Remove the paper tube and be careful not to bend the coil.

Tails are wrapped here to hold the coils together.
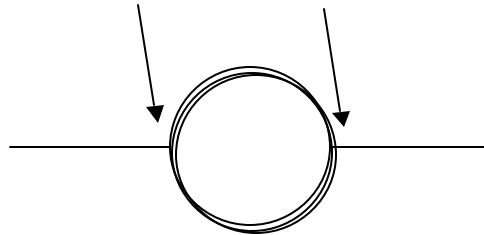
3. On one tail, use fine sandpaper to completely remove the insulation from the wire. Leave about 1 cm of insulation on the end and where the wire meets to coil. On the other tail, lay the coil down flat and lightly sand off the insulation from the **top** half of the wire only. Again, leave 1 cm of full insulation on the end and where the wire meets the coil.
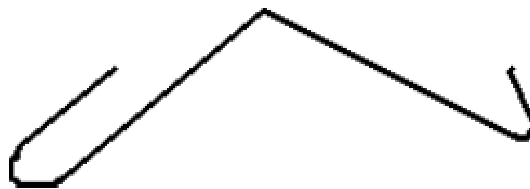
insulation

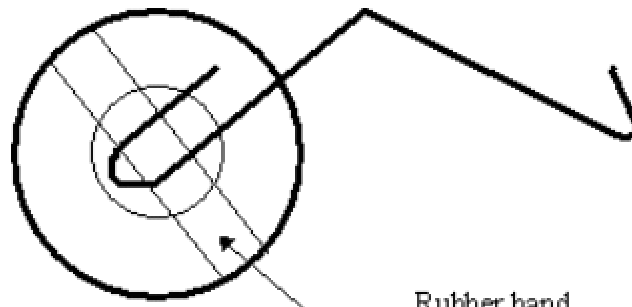Left tail   Right tail

4. Bend the two paper clips into the shape shown below. They should match each other well.

5. Use a rubber band or tape to hold the paperclips to the terminals of the "D" Cell battery as shown below.


Rubber band
may need to be
looped a few
times for a snug
fit.

6. Set the tails of the coil on the cradle formed by the paperclips and hold it at an orientation so that current flows through it. Use a compass to determine magnetic field near the center of the coil. Label the North pole of the electromagnet with a sticker.
7. Sketch the direction of the current flow through the loops of wires (it flows from the positive terminal of the battery to the negative terminal) and indicate the direction of the magnetic field measured near the middle of the loop.

Question: Is the direction of the magnetic field given by the Right Hand Rule? Explain. (A sketch would be very helpful!)

PART THREE: Magnetic Forces and a Simple Motor[*]

1. Temporarily remove the coil. Stick the ceramic magnet on the side of the battery as shown below. Place the assembly on the slotted wooden block so that it is in the orientation pictured when viewed from the side.
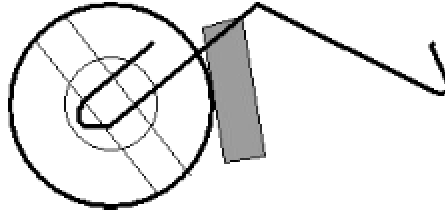
2. Place the coil on the paperclips so that the sanded strips touch the paper clips. You may have to give it a gentle push to get it started, but it should begin to spin rapidly. If it doesn't spin, check to make sure that the insulation has been removed from the wire ends correctly (see step 3 of Part Two). If it spins erratically, make sure that the tails on the coil are centered on the sides of the coil.

Question: Briefly explain how the motor works. Why is the insulation removed so that current only flows half the time? (Sketches will probably be helpful!)

Question: Does the motor still work if the ceramic magnet is flipped over? Explain.

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[*] The design for the electric motor is from Chris Palmer's web page (http://fly.hiwaay.net/~palmer/motor.html).

1. You have at your table a 30-gauge spool of wire connected to two light emitting diodes (LEDs) which are connected in parallel. Each LED only allows current to flow through it in one direction. If the red LED lights up, the current is flowing in the direction of the red arrow and if the clear LED lights the current is flowing in the direction of the green arrow.
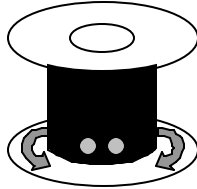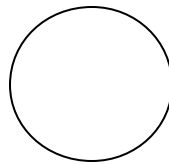

2. Put the cow magnet into the coil so that its north pole is pointing downward. Drop the magnet and observe which direction the current flows as viewed from above (circle one).

<div align="center">clockwise / counterclockwise</div>

3. Draw the magnetic field *due to the cow magnet* inside the coil <u>as viewed from above</u> before and after the magnet is dropped. (Note: there are field lines *within* the magnet.)
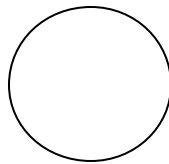
Before   After

Question: Use Lenz's Law to explain the direction of the current observed in step 2.

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4. Put the cow magnet into the coil so that its north pole is pointing downward. Pull the magnet upward quickly and observe which direction the current flows as viewed from above (circle one).

clockwise / counterclockwise

Question: Explain the direction of the current flow. (Sketches will be very helpful!)

5. Put the cow magnet into the coil so that its south pole is pointing downward. Drop the magnet and observe which direction the current flows as viewed from above (circle one).

clockwise / counterclockwise

Question: Explain the direction of the current flow. (Sketches will be very helpful!)

6. Hold the magnet a short distance above the coil with the north pole pointing downward and drop it through the coil. Carefully describe the current that flows.

Question: Explain your observation in step 4. (3 sketches will be very helpful!)

Question: There are approximately 750 loops on the spool. A voltage difference of about 1.2 V is required to light up an LED. Use this information to make a rough estimate of the size of the magnetic field inside the magnet.