Magnetic Field

Safety and Equipment

- Paper and pen/pencil
- Computer with PASCO 850 Universal Interface and PASCO Capstone
- PASCO 2-Axis Magnetic Field Sensor
- Two Banana-to-Alligator Wires (for Signal Generator)
- Solenoid Coil
- Set of small compasses
- Horseshoe magnet, bar magnet, iron rod

Introduction

The gravitational field a point mass or electric field of a point charge is radial, meaning it points outward or inward from the point source. The magnetic field of a magnet consists of complete loops that surround and go through the magnet. Magnetic fields always form looped patterns. Each loop goes through the object causing the magnetic field. Any point on the object where the field emerges (points outward) is called a "North" pole, while a spot where it points toward the object is a "South" pole.

A compass needle is a magnet that is free to rotate. It tends to rotate so that its poles are aligned with the direction of an external magnetic field. Because of this, magnetic compasses are helpful in finding the direction of the magnetic field.

The strength of a magnetic field decreases with the distance from the magnet. The strength of the magnetic field ***could*** vary inversely as the square of distance, as with the strength of a gravitational field or an electrical field. However, it is not always the case and the strength of the magnetic field could vary in a different way relative to distance.

We expect that the magnetic field inside a solenoid coil will be found by the equation:

$$B = \frac{\mu_0 N I}{l}$$

where $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}$ and is a magnetic permittivity of a vacuum, N is the number of loops of wire, and ℓ is the length of the coil. Outside the solenoid, the field should be weaker than inside.

Objective:

- *Investigate the direction and the magnitude of the magnetic field around two permanent magnets and a solenoid.*

Part #1: Permanent "Horseshoe" magnet.

1. Place a "horseshoe" permanent magnet flat in the middle of a blank sheet of paper.
2. Use a pencil to trace the shape of the magnet on the paper.
3. Place small compasses evenly around the magnet in such way that that the ***arrows*** (not compasses) form one ***continuous line (head-to-toe)***. See Figure 1.

Figure 1. Horseshoe magnet with compasses measuring the magnetic field direction.

4. Trace out the magnetic field line formed by the compasses. To do this, remove the compasses one by one, while drawing the exact direction of the arrow on the paper.
5. Repeat 3−4 for two more different lines starting at different point of the magnet. See Figure 1
6. Determine and label the poles of the magnet on each sketch. (Note: Sometimes the compasses get "reversed" due to re-magnetization. Use an agreement among several compasses to determine the direction of a magnetic field line.)
7. Take a picture of the final drawing for the report. (If you took pictures along the way in Step 4, assemble your multiple pictures into a figure like we did in Figure 1.)
8. Hold the magnet vertically with its poles down on another blank sheet of paper and repeat steps 2–7 for three different lines connecting the poles.

Part #2: Permanent "Bar" magnet

1. Repeat steps 2-7 from Part #1 for the permanent "bar" magnet laid flat on a blank sheet of paper.
2. Repeat steps 2-7 from Part #1 for the permanent "bar" magnet standing vertically by either pole on a blank sheet of paper. Be aware that all lines in this case will be open (either beginning or end).
3. Take a picture of the final drawing for the report.

Part #3: Solenoid Coil

1. Place the solenoid on a blank sheet of white paper and mark the ends and the sides of the solenoid.
2. Connect banana plugs to corresponding Red/Black terminals of the 850 Universal Interface; and then connect banana plugs or alligator clips (depending on what your coil needs) to the terminals of the solenoid. See Figure 2.
3. Open "Magnetic Field Sensor Set Up" file.
4. Press Record to turn on the power supply.
5. Repeat steps 2–7 from Part #1 for the solenoid. (Include the solenoid standing on its end.)
6. Investigate how the orientation of the compasses' arrows changes if the current through the solenoid is reversed (switch the terminals). State your findings in the abstract.
7. Compare the shapes of the magnetic fields of the horseshoe magnet, bar magnet, and solenoid coil. Which permanent magnet does the solenoid most resemble? State your findings in the abstract.

Part #4: Strength of the magnetic field.

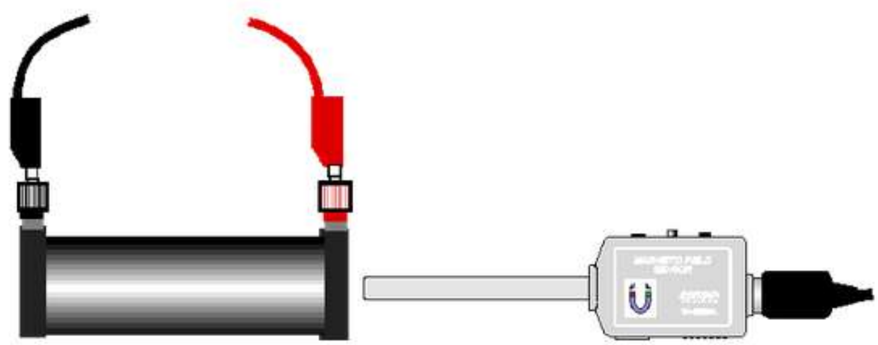

Figure 2. Measuring the magnitude of the magnetic field inside of the solenoid

1. Connect the PASPort 2-Axis Magnetic Field Sensor into PASPort 1.
2. Switch to the Magnetic Field Components page in Capstone.
3. Press Record and Tare the sensor while holding it as far as possible from any magnet. Press Stop.
4. Insert Magnetic Field Sensor all the way into the coil as shown in Figure 2.
5. Press Record to measure the current through the coil and the magnitude of the magnetic field in the center of the solenoid.
6. Move the sensor out 1 cm from where the previous measurement was. Record the magnetic field.
7. Repeat Step 6 until the field gets to zero (about 11 cm).
8. Graph your measurements of ***B* vs. *x*** (***x*** is the distance from the initial point). Briefly describe it.
9. Record the length of the solenoid (inside the end caps) use the maximum ***B*** to calculate the number of loops *N* in the coil. Organize this calculation into a Table.

Part #5: Effect of an iron rod in the Solenoid.

1. Insert the Magnetic Field Sensor back into the coil as in Part #4.
2. From the other side of the coil, insert the iron rod until it touches the sensor end-to-end inside the coil. Move them out together to find the max magnetic field magnitude inside the coil.
3. Find and record the maximum magnetic field ***B*** with the iron rod. Describe how much stronger the field is with the iron core vs. without the iron rod (max field from Part #4). Why is the field stronger?

Requirements for the Report:

The report must contain a **Header** at the top (Title of Lab, Authors, and Date)

Abstract Section must contain the following in paragraph form:

- Brief Introduction that includes objectives and basic theory of the lab. Include:
  - A statement about sources of magnetic field.
  - What distinguish permanent sources from temporary?
  - What is a magnetic field line and why a compass is useful to find it?
- Methodology describing broadly what was done, using what tools, and what was measured/recorded.
- Data Summary including quantities worked into sentences.
  - Describe shape and strength of magnetic field surrounding each permanent magnetic and the solenoid. Describe similarities and differences in magnetic fields of three magnets. How might shape of the field impact usefulness of each type of magnet? Which permanent magnet does solenoid resemble?
  - How does magnetic field strength change as you move further from center of solenoid? (Be specific. Don't just say that it increases or decreases). Use the graph to make conclusions about the solenoid. What happens to the solenoid's magnetic field when the current is reversed? What effect does the iron rod have on the strength of the magnetic field inside the solenoid?
- The lab manual contains questions and/or imperatives throughout that will guide you with the conclusions. **Always incorporate the questions and/or imperatives from the lab manual**.

Data Section must contain the following:
[Each table, figure, and graph should be labeled and descriptively captioned]

- 6 Photo Figures (6 magnet configurations, showing 3 field lines each)
- 2 Tables
  - Part 4: Position & Magnitude of field w/o iron bar
  - Part 4: Measurements and result about the number of turns in the solenoid.
- 1 Graph Figure (magnitude of field vs position w/o iron bar)