Lab 8: Magnetic Fields

Name:

Group Members:

Date:

TA's Name:

Objectives:
To measure and understand the magnetic field of a bar magnet.
To measure and understand the magnetic field of an electromagnet, in particular, a solenoid.

Apparatus:
Bar magnet box, compass, PASCO magnetic field sensor, USB wire, PASCO interface, multimeter, power supply, red and black leads and alligator clips, rheostat.

Electric charges produce electric fields. Magnets and electromagnets produce magnetic fields. We used the electric field model to explain how a charge or a charge distribution exerts forces on other charges at a distance. Similarly we use the magnetic field model to explain how a magnet exerts forces on other magnets and charges moving relative to the field. Therefore magnetic field is a vector quantity. Magnetic field is measured in Tesla (T). "Tesla" is a large unit with one Tesla being a very strong magnetic field. Small magnetic fields like the magnetic field of a small bar magnet are measured in millitesla. The horizontal component of the earth magnetic field is about 50 microtesla on the surface of the earth.

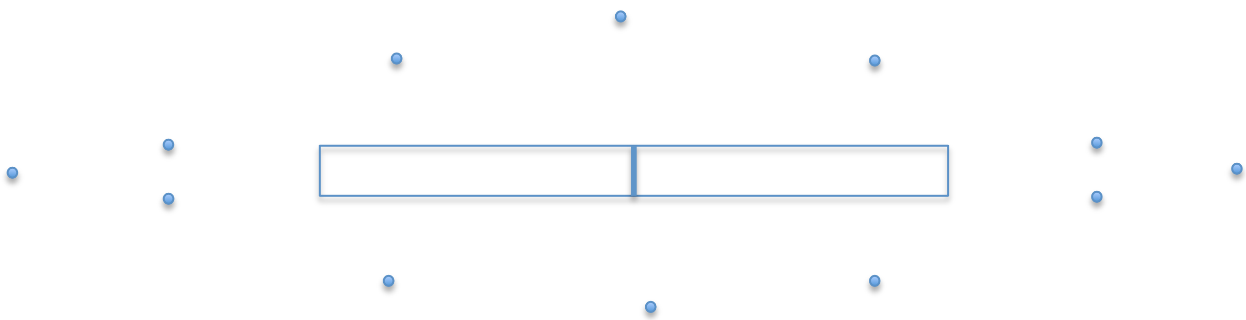
We learned that positive and negative electric charges can be separated and monopoles and dipoles occur naturally. However, in magnets we only find magnetic dipoles in nature where we always find a "north pole" and "south pole" together.

Here in this experiment we qualitatively investigate the magnetic field around a bar magnet (permanent magnet) and an electromagnet using a tiny test magnet called a "compass". Then we will measure the magnetic field of a bar magnet and an electromagnet using PASCO magnetic field sensor and study how the magnetic field depends on position, current, etc.

Part A: Permanent Magnets

1. Take the two bar magnets out of the box and investigate their interaction. Explain how the poles interact in terms of attraction and repulsion.

2. Now place one magnet on the marked space below and identify north and south poles of the magnet. The direction of the magnetic field at a point in space is indicated by the compass magnet. Then using the compass identify the direction of the magnetic field at the points shown. Then draw magnetic field lines connecting appropriate points to create a magnetic field line drawing.



3. Now connect the PASCO magnetic field sensor to the PASCO passport interface and the interface to the computer via USB cable. Open up the CAPSTONE software and select the graph and meter window. Select the vertical axis to be “magnetic field” and the horizontal axis to be “time.” Change the sampling rate to 10 samples per second. Press the record button and see if it records data on the graph. Move the sensor away from magnets and see if the value changes from position to position and in which direction the sensor is directed. Enlarge the scale of the magnetic field axis to read the value in minitesla. (1 mT = 0.001 T).

   Align the sensor as follows to measure the magnetic field.

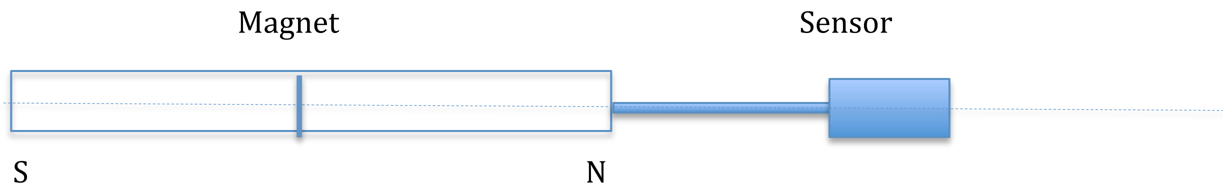
   Direction of the magnetic field 

   When you align the sensor as shown 

   Reading is positive.

   The sensor has to be perfectly aligned with the magnetic field to measure it accurately. Make sure that you keep the sensor as shown in the figure.

4. Keep the magnetic field sensor as shown below and measure the magnetic field at the edge of the magnet. It may be helpful to put something under the magnet so that the magnet and sensor are at the same height. Then move the sensor along the axis of the magnet to the right and measure the magnetic field at five different points. Keep the sensor at a fixed position and run the program to see the reading as a function of time. Get the average reading and record it below.



Position (cm)	Magnetic field strength (mT)
0.1	
0.5	
1.0	
1.5	
2.0	
2.5	

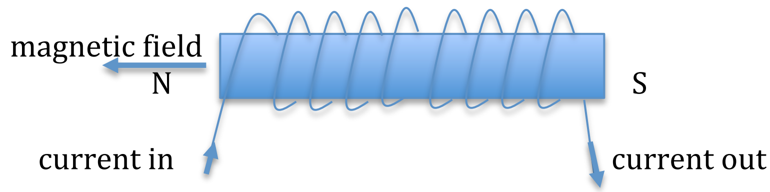
5. Transfer data to an Excel file and plot magnetic field vs. position. Draw an appropriate trend line and display the equation on the chart. Name the graph, label axes, and display units.

6. Qualitatively explain how the strength of the magnetic field changes with distance from the edge of the magnet based on your graph.

7. Your data might indicate a magnetic field even when the sensor is far away from the magnet. What are the possible reasons for this situation? (Slowly move the probe around other wires, computers etc. and see if they indicate any magnetic field)

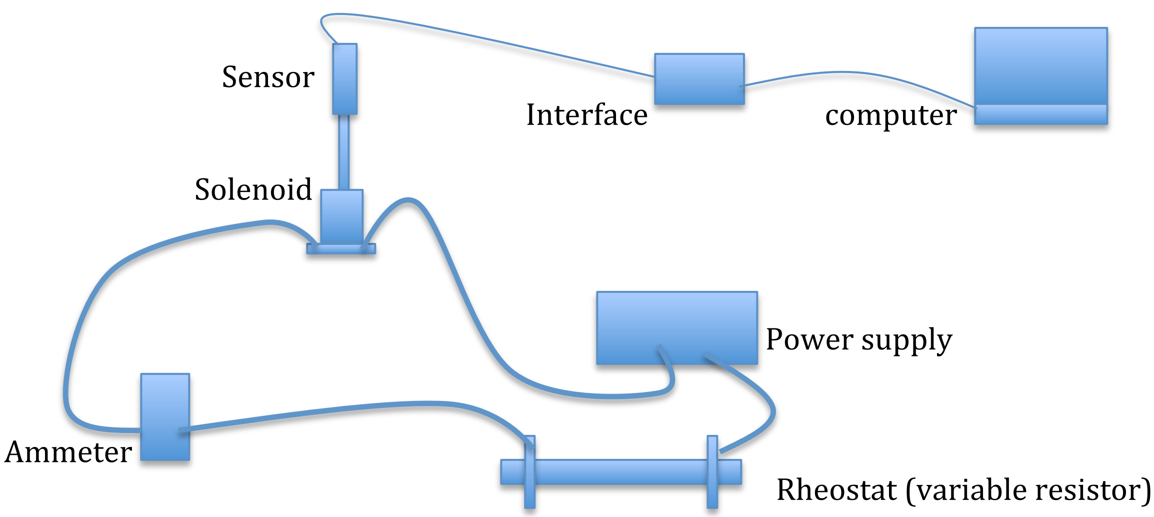
Part B: Electromagnets

The figure below shows a schematic diagram of a solenoid. The direction of the magnetic field created by the solenoid depends on how the wire is wrapped and the direction of the current flow (which end it enters). The strength of the magnetic field depends on the number turns per unit length of the solenoid, the current in the wire, and the magnetic permeability in the medium.



You are given a solenoid and it is an electromagnet. Carefully observe how it is made. An insulated wire is wrapped around a hollow metallic cylinder. When a current flows through the wire the solenoid becomes an electromagnet. In this experiment you want to investigate the strength of the magnetic field inside the solenoid as the current is varied.

We need to send a known current through the solenoid wire and measure magnetic field. Connect the circuit as shown below for the experiment.



8. Power supply is set around 5.0V for you and adjust the rheostat until the current indicated by the ammeter is 0.25 A. Place the magnetic sensor as shown above and make sure that aligns with the axis of the solenoid. Insert the probe about one inch into the solenoid and read the measurement. With trial and error find out the maximum reading for recording. Record the reading below with units.

   Magnetic field = ______________________________

9. Switch off the power supply. Then switch the direction of the current by switching the wires connected to the power supply. Switch on the power supply. Record the reading below with units. Make sure the current is still 0.25 A.

   Magnetic field = ______________________________

10. Why does the magnetic field have a different sign now? Explain.

11. Now repeat the same measurement as in Question #8 with a range of values for the current flowing through the wires of the solenoid. Record your data in the table.

Current (A)	Magnetic field (mT)
0.25	
0.50	
1.25	
1.50	
1.75	
2.00	

The magnetic field inside a solenoid is expected to be given by the equation

$$B = \frac{\mu_0 N I}{L} = \mu_0 n I$$

where $n = \frac{N}{L} = \frac{Number\ of\ turns}{Length}$, $\mu_0 = 1.257 \times 10^{-6}\ \mathrm{Tm/A}$

So this suggests that the magnetic field is linearly dependent on the current. Plot the magnetic field vs. current graph in Excel. Draw a linear trend line and display equation on chart.

12. Are your measurements of magnetic field vs. current consistent with a linear relationship? Explain why you come to that conclusion.

13. Use the slope of your linear fitting to determine the number of turns per unit length, n, for this solenoid. Show your work. Remember to watch exponents since you measured the field in mT.

$n =$ ______________________________

Part C: Conclusions and Reflection

14. Summarize what you learned about the magnetic field from a bar magnet.

15. Summarize what you learned about the magnetic field from a solenoid.

16. We did not consider the effect of earth's magnetic field when doing our experiment. Would your results be effectively different if we considered the effect of earth's magnetic field? You need to pay attention to the earth's magnetic field vector (magnitude and direction) when making your arguments.

Instructions on how to submit the graphs:

1. Open a word document and type the names of all present group members.
2. If you need help finding slopes using Excel, please talk to your TA.
3. Copy your Excel graph (with title and axis labels) to your Word document.
4. Print the document and attach it to the lab.