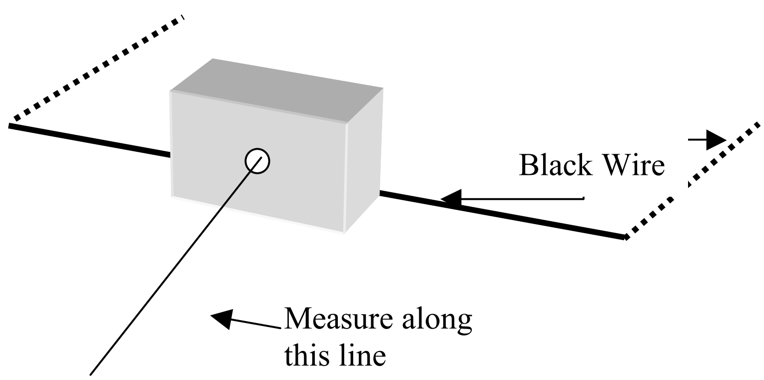
Magnetic Fields Due To Current Carrying Wires and Permanent Magnets

Determining Direction of Field with the Sensor

1. Place the small magnet on the graph paper standing upright. Place the magnet so that the bottom edge is aligned against the front of the wire taped to the paper. Use the compass to determine the direction of the magnetic field due to the small magnet along the straight line that runs perpendicular to the magnet and through the its center (shown below). Remember, the end of the compass needle that points to the geographic north is actually a north magnetic pole. (The geographic North Pole-where Santa lives- is a magnetic south pole).

What is the direction of the magnetic field associated with the magnet along this line? Toward the wire or away from it?



2. Measure the magnetic field at a point about 3 cm from the magnet along this line using the sensor. To do this, <u>check that the switch on the magnetic field sensor box is in the "high" position.</u> Align the sensor so that the face with the white dot is parallel to the face of the magnet. Have the white dot facing TOWARD the magnet. Then put your computer cursor over the "collect" button at the top of the page and click. The computer will begin to collect data. Hold the sensor still. After a few seconds, you can click on the "Stop" button at the top of the screen.
   A) Is the value you measured for the magnetic field positive or negative?
   B) Based on your answer to #1 above, would you say that the magnetic field pointed into or out of the sensor face with the white dot?

3. Again, align the sensor so that the face with the white dot is parallel to the face of the magnet at a point about 3 cm from the magnet. However, this time orient the sensor so that the white dot is facing AWAY from the magnet. Measure the magnetic field again as you did in the question above. The sign on your measurement of the magnetic field should have reversed.

A) Is the value you measure for the magnetic field now positive or negative? (Note, the actual direction of the field did not change, since the magnet was not moved. It is only the sign on the measured value that changes.)
B) Based on your answer to # 1 above, would you say that the magnetic field now points into or out of the sensor face with the white dot?
C) Using your answers to all the questions above, come up with a rule you can use to tell the general direction of the magnetic field relative to the white dot based on whether the field reading is positive or negative. State that rule clearly on your lab write-up. Check with your lab instructor to make sure you are correct before you continue working.

4. Use your rule for determining the direction of the magnetic field based on the sign of the sensor's field reading from #3 above to determine the direction the current is flowing in a coil. To do this, turn on the power supply to the coil on your table. Turn up the current to about 0.05 A. Use the sensor to measure the field due to the coil along the line perpendicular to the coil and passing through its center. Hold the sensor as close to the coil as possible.
   A) Is the field due to the coil along this line directed perpendicular to the coil face, parallel to the coil face or in some other direction? (You should know from last week's lab).
   B) Describe how you can verify your answer to A) above using the sensor.
   C) Based on your sensor reading, would you say the field due to the coils is directed toward or away from the side of the coil with the electrical connectors? Explain your reasoning.
   D) Based on your answer to C) above, and your understanding of the "right hand rule" from last week's lab and lecture, would you say that the current in the coil is running clockwise or counterclockwise? (Answer based on looking at the face of the coil on the same side as the electrical connectors).

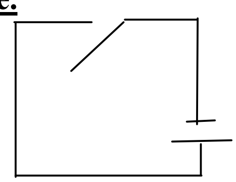
<u>Turn off the power supply!!!</u>

5. Use the sensor to measure the Earth's magnetic field. To do this, recall the direction of the Earth's field from last week's lab. Then orient the sensor correctly and collect data as you have above. Then, when you are done collecting data, select a region of the data that you think is accurate and fairly constant by placing the cursor over the graphed data and holding down the left mouse button as you move the cursor across the region. Then release the left mouse button. (This is just the same technique used to select text in Microsoft Word for copying or deleting). Once you have selected your region of interest, click on the icon that says "1 2 Stat", located at the top of the page. The average and other statistics for the data in your range will be displayed.
   A) What value do you get for the Earth's magnetic field (the textbook value is about 0.06 mT)?
   B) According to your measurement and your rule for determining the direction of magnetic field based on the sensor reading, does the magnetic field of the earth point from the geographic north pole to the geographic south pole or the other way around? Explain how you came up with your answer.

Measuring the Magnetic Field of a Current Carrying Wire

We will now measure the magnetic field associated with a current carrying wire along a line perpendicular to the wire and through its center.

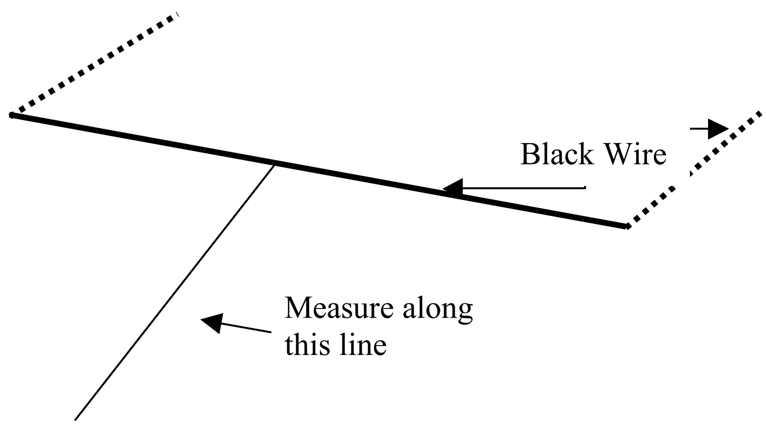
6. Remove the small magnet from the graph paper and attach the black wire to a battery and switch as shown below. **<u>MAKE SURE THAT THE SWITCH IS OPEN! No current should be running through the wire.</u>**



A) Based on your knowledge of the right hand rule, in order to measure the field associated with this current carrying wire, should the sensor be oriented with the white dot perpendicular to the paper? Or should the sensor be oriented so that it is lying flat on the desk with the white dot parallel to the desk top? Check your answer with your lab instructor.

B) Draw a diagram that justifies your answer to the question above.

7. Measure the magnetic field due to the current carrying wire at a point 2 cm from the wire along the line perpendicular to the wire and through its center as shown below. The procedure for this follow.



A) Make sure that you have the sensor oriented correctly. Start to collect data, with no current running through the wire. You will notice that there is a "background" magnetic field present. We want to measure ONLY the field due to current in the wire, so we must subtract this background field from our measurements. The software will do this for us if we click on the "zero" button. So, orient the sensor correctly, with NO current in the wire, and then click on the "zero" button at the top of the screen. Then click the "collect" button again. You should now have a zero field reading.

B) Again, click the “collect” button and start to collect data. Close the switch in the circuit so that current starts to flow through the wire. You should see the field measurement change when you close the switch. Be sure to hold the sensor still while collecting data. You only need to collect data for 5-10 seconds, then you can hit the “stop” button at the top of the screen. The batteries will go dead within about 5 minutes of being connected to the wire. So, **OPEN THE SWITCH AS SOON AS YOU ARE DONE TAKING A MEASUREMENT. IF YOU DON’T, YOU WILL BE SENT TO HOMEDEPOT TO BUY NEW BATTERIES FOR EVERYONE!!!**

C) Use the same procedure that you used to measure the magnetic field due to the earth in #5 above. Make a data table with the distance from the wire and average magnetic field reading.

D) Repeat this measurement for points 3 cm, 4 cm, 5 cm and 6 cm from the wire. Be sure to keep the same orientation of the sensor for each measurement. Fill in your data table. (Each heavy line on the graph paper is ½ cm from the next line, so two lines is one cm).

8. Use excel to plot the magnetic field strength versus distance from the wire for your data. Is the graph of field strength vs. distance a line or a curve?

9. Use excel to plot the magnetic field strength versus one over the distance from the wire (1/r). Is the graph a line or a curve?

10. Based on your answers to #8 and #9 above, is the magnetic field proportional to distance from the wire? If not, what is it proportional to?

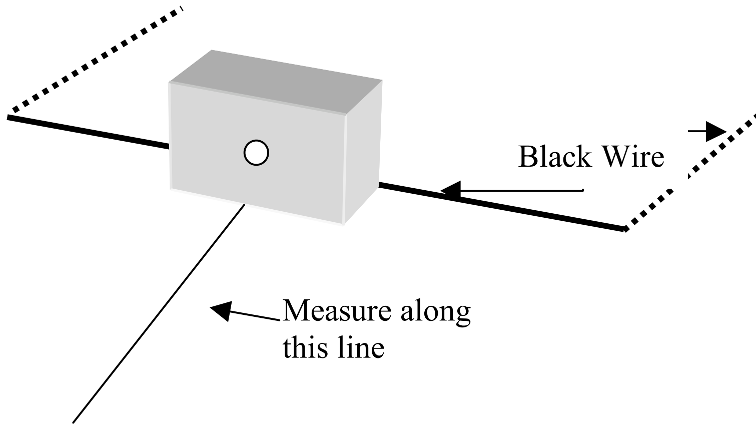
11. The formula for magnetic field due to a current carrying wire that is cited in your textbook is *B*=u_o*i*/(2□*r*) where *r* is the perpendicular distance from the wire, *i* is current and u_o is 4□ x 10^{-7} T•m/A. Based on this formula, what was the approximate value of the current flowing through the wire? Show your calculation in your lab write-up.

12. Use an ammeter, connected in series with the wire to measure the current. What value did you measure? If the value is within 15-20% of your calculated value from above, great. If not, talk to your lab instructor. REMEMBER TO OPEN THE SWITCH WHEN NOT MAKING MEASUREMENTS!!!

Measuring the Magnetic Field Due to a Permanent Magnet

13. Disconnect the wire from the switch and battery. Find the box on your table labeled “Magnetic Field Sensor” and flip the amplification switch to the “low” position. Place the small magnet on the graph paper standing upright. Align the magnet so that the bottom edge is aligned with the wire taped to the paper. Measure the magnetic field due to the small magnet at a point 2 cm from the

magnet along the line perpendicular to the wire and through its center as shown below.



(Each heavy line on the graph paper is ½ cm from the next line, so two lines in one cm). To do this, make sure that you have the sensor oriented correctly (not the same orientation as for the wire). Be sure to hold the sensor still while collecting data. Use the same procedure that you used to measure the magnetic field due the current carrying wire in # 7 above. Make a data table with the distance from the magnet and average magnetic field reading. Repeat this measurement for points 3 cm, 4cm, 5 cm and 6cm from the magnet. Be sure to keep the orientation of the sensor the same for all measurements and stay on the line through the center of the magnet as shown in the figure above. Fill in your data table.

14. Use excel to plot the magnetic field strength versus distance from the magnet for your data. Is the graph of field strength vs. distance a line or a curve?

15. Use excel to plot the magnetic field strength versus one over the distance from the magnet (1/r). Is the graph a line or a curve?

16. Use excel to plot the magnetic field strength versus one over the distance from the magnet square ($1/r^2$) for your data. Is the graph of field strength vs. distance a line or a curve?

17. Based on your answers to #14,#15 and #16 above, is the magnetic field proportional to distance from the magnet? If not, what is it proportional to?