EXPERIMENT 9: MEASURING B FIELDS

In lecture we discuss magnetic fields, B fields, theoretically, and describe how to calculate them. By using a Hall's effect device, B fields can be measured with some degree of accuracy, which allows us to check the precision of our theories. There are, however, limits to the accuracy of the sensor we use, which will be good to keep in mind for the procedures to come.

ADVANCED STUDY ASSIGNMENT

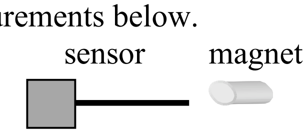
1. Refer to your first experiment (or to your textbook) and draw the magnetic field in the vicinity of a bar magnet. Next, draw the B field for a short cylindrical magnet. Include labels of North and South poles and the direction of the magnetic field in your sketches.
2. If a magnetic field sensor reads 250 gauss when held close to the North end of a magnet, what would you expect the reading to be when the sensor is held close to the South end of the same magnet? Explain. (If you need a hint, consider that the magnetic field sensor is a Hall's effect device, and it is measuring magnetic field by measuring a voltage. Then think what reversing the magnetic field should do.)

BACKGROUND

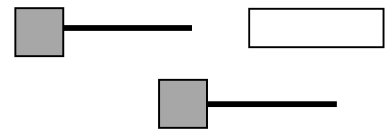
Magnetic fields originate from currents and from magnetic materials and from at least one other source. In all cases the field should be understood as a dipole field, with magnetic field lines always forming loops, not ending or starting at any fixed points. Recall our derived formula for the magnetic field of a solenoid as $B = \mu_o n i$, with n being the number of turns of wire wrapped around the solenoid per unit length (meter, in SI units). Remember also that in the ideal case, B inside a solenoid is axial (that is, parallel to the axis), uniform, and has zero magnitude outside the solenoid. Finally, the ideal case is approached for $L >> d$, where L is the length of the solenoid and d is the diameter.

PROCEDURE A

1. Turn on the Pasco interface box, and then the computer. Open Data Studio, and on Experiment Setup window, select Magnetic Field Sensor (for Analog Channel A). Drag the table icon (from Displays window) onto the Magnetic Field Sensor icon on Experiment Setup window.
2. In the Experiment Window, click on Options and enter a check on the first box ("Keep data values…") and remove checks from other boxes; then click OK.
3. Now plug the magnetic field sensor into Analog Channel A on the Pasco Interface box, and check that the buttons on the sensor are set to 1X and Axial.
4. Click Start on the Experiment Window, and push and release the tare button on the Magnetic Field Sensor now and also before each series of readings. Be careful not to accidentally push this tare button again during any series of measurements below.
5. Hold the strong, small cylindrical magnet close to the sensor, in the position sketched at right, and click the Keep button on the Data Studio Experiment Window. Record the value displayed in Data Table A.



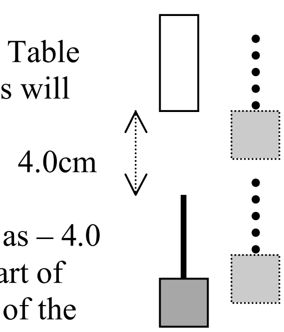
6. Now turn and hold the opposite pole of the magnet close to the sensor, and record again the value from the Table on Data Table A.
7. Hold the North pole of a bar magnet close to the sensor, as shown at right, and record. Then hold the South pole in the same position and record the reading from the table.
8. Now hold the sensor and magnet in the lower orientation at right, and again record the value on Data Table A.



9. Now, as a test of the sensitivity of the Magnetic Field Sensor, place the sensor on the table, with no magnetic materials or currents nearby, and point the sensor towards North. (The wall with the clock on it is in the North direction.) Click the red square button (next to the Keep button), and then click Start again, to start a new data table. Now click Keep, then rotate the sensor to point approximately 30° East of North, click Keep again, and repeat in steps of 30° until you have returned to the Sensor pointing North, and click Keep one last time. You should now have 13 readings on the computer data table. Enter these values on Data Table A.
10. Examine the pattern of readings you took in attempting to measure the earth's magnetic field. Compare the pattern when reversing the magnets earlier in Procedure A. What do you conclude about the ability of the Magnetic Field Sensor to measure the earth's magnetic field? Place comments in the section provided in Data Table A.

PROCEDURE B

11. Now connect a Power Amplifier to the Pasco Interface box (both virtually and physically), and connect it to a solenoid. In the procedures which follow, be sure to watch the overload indicator (it glows red) on the Power Amplifier, and immediately turn off the amplifier if the light glows, and then check with the instructor.
12. Connect the Power Amplifier to a solenoid (the inside of the nested solenoid pair). Count the number of turns in two centimeters, and enter this as n (number of turns per unit length) on Data Table B. (To count accurately, it may help to use your thumbnail to count, since some solenoids are covered in thin plastic.) We don't divide by 2 because there are two sets of windings on the solenoid.
13. Set the voltage to 0.25 V. Click on the DC icon. Drag the icon for Table onto the Analog Channel the Power Amplifier is plugged into. This will display the current supplied by the Power Amplifier. Set up the sensor on top of a half-meter stick, with the axis of the sensor parallel to the axis of the solenoid, and 4 cm away from the solenoid, as indicated by the meter stick. This data will be entered as – 4.0 cm in Data Table B, for 4.0 cm away from the solenoid. See left part of the sketch at right, with the solid heavy line indicating the location of the sensor, outside the solenoid. Periodically feel the solenoid, and if it feels more than a little warm, turn off the power to the solenoid and check with the instructor.

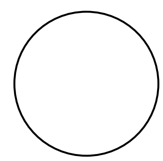


14. Click Start, push the tare button, and then turn on the Power Amplifier (both virtually and physically). Record the current on Data Table B at the top. Click Keep on the monitor screen, and you should have the first reading on the data table. Move the sensor so the tip of the sensor is 3.0 cm away from the solenoid, and again click Keep. This will be data for – 3.0 cm. Continue and fill Data Table B, with 0 cm when the tip of the sensor is just at the open end of the solenoid, and continuing until the sensor tip is 6.0 cm inside the solenoid.

15. Next, repeat procedure 13 and 14 twice, once with the sensor parallel to its original position, but two to three cm outside the solenoid, in the dotted positions in the sketch above. After these readings check that the current readings is still the same as you recorded. The second repetition is again lined up axial and going inside the solenoid, but this time with the current in the solenoid turned off.
16. Comment on the behavior of the magnetic field in the vicinity inside and outside of the solenoid, and compare with the theory as expressed in Chapter 30 of the text. Place your comments in the space provided with Data Table B.

PROCEDURE C

17. The narrow solenoid used above does not allow examination of the field at different, off-axis points inside the solenoid. For this purpose, we will use the two large coils we have used previously. Line these up, and connect them in series, being careful to make symmetrical positioning and connections, so the magnetic fields will be aligned and will add. In essence, you are constructing a large solenoid (although L>>d does not apply).
18. Set up the half-meter stick on books or blocks of wood, so it can extend into the middle of the coils, as near the middle of the circle of coils as possible.
19. Set the voltage to 10 V (still DC), tare the Magnetic Field Sensor, and turn on the Power Amplifier. Immediately check the current and the overload indicator light, to be sure the current is not too large. Now position the sensor as in procedure 13, and take another series of readings, and enter in Data Table C.
20. Next, remove the meter sticks and take 8 readings of B with the sensor at L/2 inside the first coil, and held at ± 1/4 d, ± 7/16 d (that is, one half the radius from the center, and just inside the interior wall) in both the x- and y- directions. See points on sketch at right. Record the readings in Data Table C. Also make 4 measurements just outside the coil, with the sensor held parallel to the axis as before.



21. Comment on how nearly the two coils approximate an ideal solenoid.

PROCEDURE D

22. Calculate the value of B for the solenoid used in Procedure B and for the two coils considered as a solenoid used in Procedure C. From the Data Tables B and C take the experimental reading you estimate to be the best value of B for each of the two cases. Enter these two theoretical and two experimental values in Data Table D. (To avoid frustration, note that the attempt made by the instructor in this experiment produced a difference by nearly exactly one order of magnitude between the theoretical and experimental values.)
23. There are no questions for this experiment, but be sure to write a conclusion addressing the concerns raised in the procedures. (For example, do either or both of the solenoid or coil act like an ideal solenoid, what are the limitations of the Magnetic Field Sensor, can you say anything about the earth's magnetic field.) Make use of the various readings made by the sensor when there were no magnet or currents nearby.

DATA TABLE A

B near pole of cyl. mag.___________________
B near opposite pole ___________________
B near N pole of bar mag.________________
B near S pole of bar mag.________________
B near middle of bar mag.________________
(parallel to mag.)
Comments:

N (0°)	
30°	
60°	
E 90°	
120°	
150°	
S 180°	
210°	
240°	
W 270°	
300°	
330°	
N 360°	

DATA TABLE B

n______________ /cm
i ______________

	B (magnetic field intensity)		
d	Inside	Outside	i = 0
-4.0 cm			
-3.0 cm			
-2.0 cm			
-1.0 cm			
1.0 cm			
2.0 cm			
3.0 cm			
4.0 cm			
5.0 cm			
6.0 cm			
7.0 cm			
8.0 cm			

Comments:

Data table C

d	B
-4.0 cm	
-3.0 cm	
-2.0 cm	
-1.0 cm	
1.0 cm	
2.0 cm	
3.0 cm	
4.0 cm	
5.0 cm	
6.0 cm	
7.0 cm	
8.0 cm	

x = 0	B
y = 1/4d	
y = -1/4d	
y = 7/16d	
y = -7/16d	
y = 0	B
x = 1/4d	
x = -1/4d	
x = 7/16d	
x = -7/16d	

Four points outside	B

Comments:

i = _____________
N = _____________
L = _____________

DATA TABLE D

	EXP	THEO.
$B_{solenoid}$		

B_{coil}		