LAB 11 - MAGNETIC FIELD MAPPING

Objectives:
- Investigate magnetic fields created by bar magnets
- Investigate components of magnetic field (x and y components) from bar magnets
- Investigate the Earth's magnetic field, and the field from "fridge" magnets

Preliminary activities

1. Prepare equipment. Make sure the magnetic field probe is plugged into the digital adapter cable and then into the Xplorer GLX, and then into the laptop, and set the probe to LOW (please follow the instruction in Blackboard). It would also be very helpful to look at the online help page for this lab. Start the DataStudio software.

2. Load the experiment file. Load the DataStudio file **Lab11_Magnetic_Field_Map.DS** from the **Univ2** folder.

Part 1 - Introduction

> **This lab deals with magnets - they are not strong magnets, but they can affect computer disks or flash drives!!! Make sure the computer disks are not put near the magnets, and the magnets are kept away from the computer itself!!!**

Bar Magnet: We have probably all seen the picture of the magnetic field around a bar magnet:
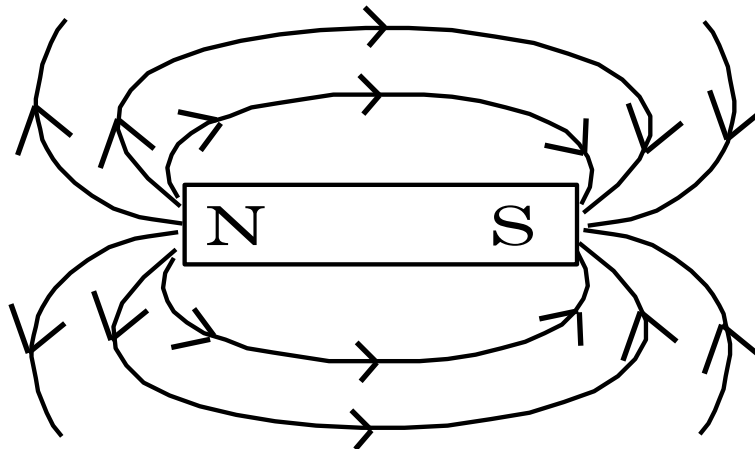
In this lab, we will have a chance to measure the field due to a bar magnet, and plot it in three dimensions in Excel. On the magnetic probe, there is a white dot on one side. ***The white dot points in the direction of the "positive" magnetic field.*** That is, if the probe is put on the North end of a magnet with the white dot outward from the pole, there will be a positive reading (indicating the magnetic field comes out from the North pole, through the probe. If the white dot is facing "outward" from a South pole, there will be a negative reading (meaning the field points *in* to a South pole). The magnitude also indicates how strong the field is. One standard unit of magnetic field is the Gauss - the readings for this lab are in milli-Gauss (10^{-3} G). [Note: the Experiment file might show "gauss", it is really milli-gauss.]

1. Setting the Zero for the Magnetic Probe. Hold the magnetic sensor up away from the table (and away from any magnets) and click the START button and record a few seconds, then click STOP. You should

get a nice horizontal line. Using the mouse, click and drag to highlight a section of that line, and then click on the "SUM" symbol ("Statistics") and click MEAN (to show the average reading). That reading will be mostly like in the 240 range. Double-click on the "Mag Field (zeroed)" data line in the DATA window (the mini-calculator). There should be a y=x function. You want to subtract your offset value from the end of that equation. For example, if the offset was 244, your equation would show y=x-244. Once you have edited the equation, click ACCEPT and then close the equation dialog box. From then on, the graphs would should be reasonably zeroed (at least from this LOW setting).

2. Magnet strengths. There are two magnets on the lab bench, labeled A and B. Using the magnetic probe (and the "meter" in DataStudio), find the strengths of the poles and record them on the Data/Question sheet below. Aim the "white dot" side **away** from the poles. (Also verify that the poles are correctly identified {North/South}, based on the probe-field convention listed above.) [You might find the opposite ends of the same magnet might have different strengths – that is not unusual … can you think of some reasons why?]

> Magnet A :   North = _____ mG   South = _____ mG
>
> Magnet B :   North = _____ mG   South = _____ mG

Part 2 - Mapping North Pole of Bar Magnet

There is a stiff paper sheet on the table with a grid marked on it, and a space for a magnet to be taped down. Tape one of the bar magnets in the location shown, with the North pole aligned in the place-mark near the grid.

1. Mapping the field. For this section of the lab, we will try to look for the maximum value of the field at the grid of points shown. Because of the symmetry of the field, we only have to map half the points, and the other half will be reasonably similar. Using the probe oriented so the white dot points away from the North pole of the magnet, find the maximum magnetic field strength at each point on the grid. This maximum can be found by rotating the probe (so that the plexiglas tube remains centered over each dot) until the maximum field value is shown in the DataStudio meter window. (Note: If you want to just monitor "live" data with the Meter, and don't need the graph – click the Experiment item in the menu, then MONITOR DATA – only the meter will show live. Once you are done, click Experiment, then STOP DATA, and it will go back to the regular collection mode of Start/Stop buttons.). Record that value in the chart on the Data/Question sheet.
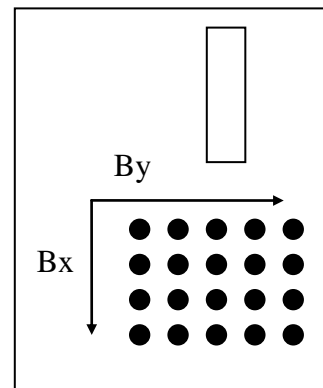
2. Multi-tasking with another laptop. To be more efficient, we can have DataStudio taking data on one computer, and the data being put into an Excel graph on another computer.

3. Load the Excel template. We will use Excel to make a graph based on the magnetic field measurements we will make. There is an Excel sheet, **U2Lab11_Magnet.XLS**, on the lab schedule webpage, load it into Excel. You might want to save it under a new name, as a working copy.

4. Graphing. Using the data you collect, fill in the cells on the first page of the spreadsheet file. You will only have to fill in the part of the cells (1,1 to 6,6 on the magnet paper), the other side is automatically "mirrored". Notice that the graph is "live" while you are doing that.

Part 3- Graphing X Component of B Field (One Pole)

Look at the diagram in Part 2 - we set up a convention for the two perpendicular components of the field (X to go from top to bottom of the page, Y to go from left to right on the page) If you want to look at the B_x component, the white dot should point in the direction shown for B_x - same for the B_y direction.

1. Graphing Bx field across the grid in DataStudio. Set the probe up so that it is near the 1,1 location in the grid with the white dot pointed outward (down the page) (in the Bx direction). (Turn the monitoring off if necessary.) Click START to start graphing. With the dot remaining in the Bx direction, slowly but smoothly move the probe laterally across the grid to location 11,1 (across the North pole). Sketch the resulting graph on the Data/Question sheet. [If the probe is moved smoothly, then this plot is a reasonable Field vs. Distance plot as well.]

Question   Answer on the Data/Question sheet:
Remember that the graph depicted is only the Bx component (as outlined in the convention). Does the graph seem reasonable for the Bx component? What features of the graph lead you to believe that? (Discuss this with your lab group before forming an answer.)

Part 4- Graphing Y Component of B Field

1. Graphing By field across the grid in DataStudio. Repeat the previous steps, but this time with the probe pointing in the B_y direction. Sketch the resulting graph on the Data/Question sheet.

Question   Answer on the Data/Question sheet:
Remember that the graph depicted is only the By component (as outlined in the convention). Does the graph seem reasonable for the By component? What features of the graph lead you to believe that? (Discuss this with your lab group before forming an answer.)
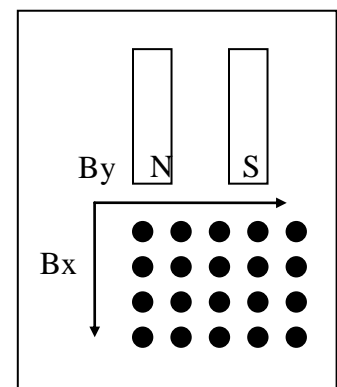
Prediction   Answer on the Data/Question sheet:
What if you had two adjacent poles (a North and a South) – What would the Bx graph look like (sliding the probe in front of the poles, as in Part 3)? What would the By graph look like (as in Part 4)?

Part 5- Graphing/ Mapping Two opposite poles

Set up both magnets as shown to the right. Try to pick a north/south pair of different strengths (use the numbers from Part 1 to help you with that decision).

Before we map the grid, we will again use DataStudio to get a rough idea of what we will find.

1. Graph the Bx field in DataStudio. Repeat Part 3.1 for the double-pole configuration (but, you don't have to sketch).

Question   Answer on the Data/Question sheet:
            Remember that the graph depicted is only the Bx component (as outlined in the convention).
            Does the graph seem reasonable for the Bx component? What features of the graph lead you to
            believe that? (Discuss this with your lab group before forming an answer.)

2. Graph the By field in DataStudio. Repeat Part 4.1 for the double-pole configuration (but, you don't have to sketch).

Question   Answer on the Data/Question sheet:
            Remember that the graph depicted is only the By component (as outlined in the convention).
            Does the graph seem reasonable for the By component? What features of the graph lead you to
            believe that? (Discuss this with your lab group before forming an answer.)

Why are taking "grid" data? We want to create a three-dimensional graph of the magnetic field for two poles, but we have to do it in each of the two directions (Bx and By). There is no way to have DataStudio automatically do this for us, so we will have to take data at each grid point, and input that to Excel. It may be tedious, but we will obtain very useful graphs to help us understand the nature of these fields.

Speeding up the data-taking/graphing: Assuming you have at least three people in the group, and two laptops … one person sets the probe at each grid point (Bx, and then By) – one person records it on the Data Question sheet (easy to copy down an number by hand) – one person starts inputting those numbers into Excel.

3. Mapping Bx and By for the grid. In a similar fashion to Part 2 (and using MONITOR), map the Bx and By field values for the double-pole system. Record the values on the Data Question sheet.

Question   Answer on the Data/Question sheet:
            Remember that the graph depicted is only the By component (as outlined in the convention).
            Does the graph seem reasonable for the By component? What features of the graph lead you to
            believe that? (Discuss this with your lab group before forming an answer.)

~~4. Print graph. When finished, you will print the second page in the Excel spreadsheet (the double-pole system). You should enlarge the two graphs so that each graph will take up about ½ of the single printed page (one above, one below) (you can cover up the data – the graphs are more important). The template should be pre-set for the print area, use Print Preview to check your placements.~~ *Lab handed in during class – thus we don't print the Excel sheets.*

Part 6- Observation of the Earth's Magnetic Field

1. Hide data and switch sensor setting. Hide any current data runs (rename them also if necessary). Switch the magnetic sensor to the HIGH setting (more sensitive reading). Note: our "zero" will now be off, but that doesn't matter too much for our purpose.

Prediction   Answer on the Data/Question sheet:

The Earth's magnetic field has a direction that points roughly toward the North, but also into the ground (about 70 degree angle with respect to the ground). If you were to hold the magnetic sensor vertically (the long axis of the Plexiglas cylinder is vertical), and if you rotated the sensor, what might you expect to see on the graph? (Discuss this with your lab group before forming an answer.)

2. Start DataStudio and rotate the sensor. Click on the START button, and then slowly rotate the magnetic sensor around that long axis, with the long axis held vertically.

Question   Answer on the Data/Question sheet:
            Did your prediction match what you saw? How can you explain the shape of the curve that you measured?

3. Find best "horizontal" direction – then rotate end over end. Click on the START button, and then rotate the sensor as before until you locate a local maximum or minimum. At that point, start rotating the sensor "end over end" (around an axis at the middle of the sensor, perpendicular to the long axis). This should give a similar (but larger amplitude) curve to what you saw before.

Question   Answer on the Data/Question sheet:
            Does this second curve support the idea of the Magnetic field pointing about 70 degrees from vertical?

            (Our sensor is picking up other magnetic fields, and there is a slight calibration problem with respect to this Vernier sensor used with the Pasco software .. but in principle, we could use graphs similar to these to find a value for the local magnetic field strength. With our current setup, we can at least conceptually verify the ideas.)

Part 7- Magnetic field from a "fridge" magnet

1. "New" experiment file for zeroing. We now need to rezero the magnetic sensor using the HIGH switch setting. Ideally, we would have a new experiment file (because if we rezero – it will "throw off" all the other graphs). So, if you didn't save over top of the original experiment file, you could just save this current set and then open the original experiment file (which starts with y=x in the equation box) and follow the zeroing process down in part 7.3.   … Or …

2. Re-doing the current file for zeroing. If you saved on top of the original, then you can just save the current version (to a new file name), and then delete all the current data runs. Double-click on the Mag Field (zeroed) Data line (the mini-calculator) and remove your old offset (so it is back to y=x). Then follow the zeroing steps in part 7.3.

3. Re-zeroing the magnetic sensor. We are going to follow the steps from Part 1.1, but we need a certain orientation of the sensor (thus we want to zero it how we will use it). Hold the sensor horizontally, close to the table surface (maybe 1 cm from the surface), away from any of the bar magnets or fridge magnets, with the white dot facing the table. Ideally, you would align the long axis parallel to one of the edges of the table (and then remember this orientation for when we make the measurements) – this way that pesky Earth's magnetic field won't affect our readings. At this point, you follow the steps in Part 1.1 .. click START then STOP – highlight some of the horizontal line – click SUM – find the MEAN, subtract it from the X in the equation. This should give us a zeroed sensor on the HIGH setting.

4. Two "axes" of the fridge magnets. There should be some of those flexible square or rectangular "fridge" magnets available in the lab. Most of them should have some sort of writing on them – let's call that axis the "side to side" axis (as if you were reading the words), and then the other direction is the "top to bottom" axis.

5. Slide a strip of a magnet along both of the axes of the fridge magnet. There should be a thin strip of magnetic material (cut from the same kind of fridge magnet that you are using). Imagine that the strip also has the two axes (side to side, and top to bottom). Try sliding the strip along the main magnet (magnetic sides facing each other) – with the side axes aligned. Then try sliding it so the side axis of the strip is perpendicular to the side axis of the main magnet (thus slide the strip along the top to bottom axis of the main magnet). Sheesh, that seems really complicated to write … slide the strip along one axis, and then try sliding it along the other axis of the main magnet.

Question   Answer on the Data/Question sheet:
            In one of those two directions .. you should find some very strange behavior .. there should be a "shuddering" or a "hopping" of the thin strip along the main magnet. The other direction from that should involve some smooth sliding. Do you have any ideas as to why you might get that very different behavior from the magnets?

6. Try flipping the strip and the main magnet around to slide the printed faces together. If you slide the printed faces of the magnetic pieces along each other .. you shouldn't notice very much of that behavior .. in fact, the printed faces probably don't even attract each other very much! It appears that the magnetic field strength does NOT extend very far in distance .. and the thickness of the printed layer is enough for the field strength to drop off. (You notice that even with the strong side .. it can't hold up too many pieces of paper on the fridge – there is a severe distance limitation to the magnets .. I wonder why … maybe we should measure the field!)

7. Slowly scan along each of those axes. Hide/delete any data runs you don't need (so it is a blank graph). Start with the magnetic sensor in the "zeroing" position (close to the table, oriented with the long axis aligned with whichever edge of the table you chose, and white dot facing down). Put the fridge magnet, with magnetic side up, on the table. Click START and then slide the magnetic sensor slowly but smoothly along the "side to side" axis – right down the middle. (Start your sliding when the sensor is a short distance off the end of the fridge magnet, then down the axis, then off the other end .. so that we can see any "edge" effects.) Name that data run "Side to Side" and hide it. Repeat the process to scan the "top to bottom" direction.

Question   Answer on the Data/Question sheet:
            In one of the directions (each style of magnet is a little different as to the "preferred direction") – you should notice some very strong edge effects, and some "oscillations" of the magnetic field strength along the main part of the magnet. Can you correlate your findings with the observed "jumping" of the strip and come up with a theory?

DATA/QUESTION SHEET FOR LAB 10 - MAGNETIC FIELD MAPPING

Part 1 - Introduction

<u>2. Magnet strengths.</u> There are two magnets on the lab bench, labeled A and B. Using the magnetic probe (and the "meter" in DataStudio), find the strengths of the poles and record them on the Data/Question sheet below. Aim the "white dot" side **away** from the poles.

Magnet A: North = _____ mG   South = _____ mG
Magnet B: North = _____ mG   South = _____ mG

Part 2 - Mapping North Pole of Bar Magnet

<u>1. Mapping the field.</u>

	1	2	3	4	5	6
1						
2						
3						
4						
5						
6						

Part 3- Graphing X Component of B Field (One Pole)

<u>1. Bx field across the grid.</u>   (This is the DataStudio graph.)

Bx

time

("distance")

(Since our velocity is supposed to be constant as we move the probe .. the time axis on DS is similar to distance.)

Question   Answer below:
Remember that the graph depicted is only the Bx component (as outlined in the convention). Does the graph seem reasonable for the Bx component? What features of the graph lead you to believe that? (Discuss this with your lab group before forming an answer.)

_____
_____
_____

Part 4 - Graphing Y Component of B Field (One Pole)

1. By field across the grid.   (This is the DataStudio graph.)

By

time

("distance")

Question   Remember that the graph depicted is only the By component (as outlined in the convention).
Does the graph seem reasonable for the By component? What features of the graph lead you to
believe that? (Discuss this with your lab group before forming an answer.)
_____
_____
_____

Prediction   Answer on the Data/Question sheet:
What if you had two adjacent poles (a North and a South) – What would the Bx graph look like
(sliding the probe in front of the poles, as in Part 3)? What would the By graph look like (as in
Part 4)?
_____
_____

Part 5- Graphing/ Mapping Two opposite poles

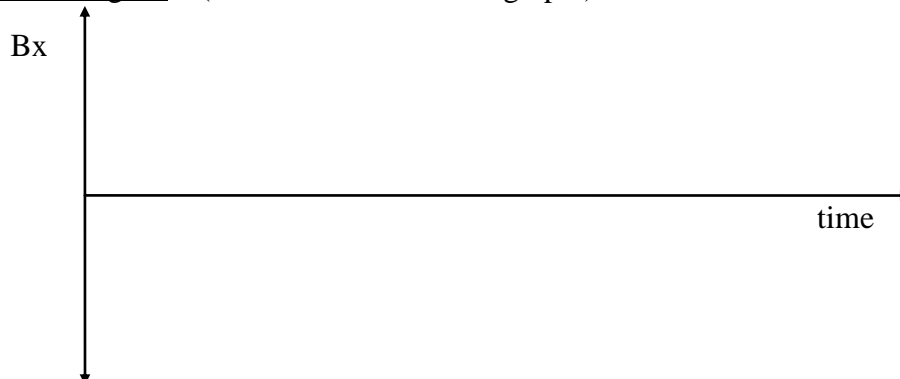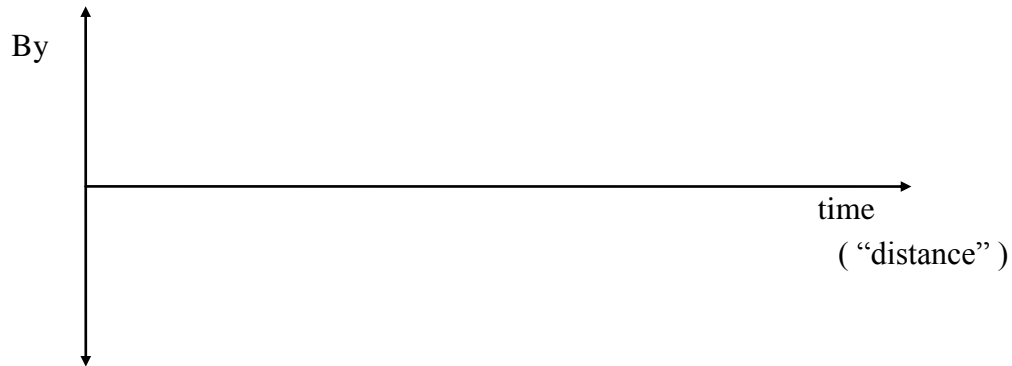1. Bx field across the grid.   (This is the DataStudio graph.)

Bx

time

Question   Remember that the graph depicted is only the Bx component (as outlined in the convention).
Does the graph seem reasonable for the Bx component? What features of the graph lead you to
believe that? (Discuss this with your lab group before forming an answer.)

_____
_____

2. By field across the grid.   (This is the DataStudio graph.)

By

time

("distance")

Question   Remember that the graph depicted is only the By component (as outlined in the convention). Does the graph seem reasonable for the By component? What features of the graph lead you to believe that? (Discuss this with your lab group before forming an answer.)

_____

_____

3. Map the Bx component for the graph.

	1	2	3	4	5	6	7	8	9	10	11
1											
2											
3											
4											
5											
6											

Map the By component for the graph.

	1	2	3	4	5	6	7	8	9	10	11
1											
2											
3											
4											
5											
6											

Part 6- Observation of the Earth's Magnetic Field

1. Hide data and switch sensor setting. Hide any current data runs (rename them also if necessary). Switch the magnetic sensor to the HIGH setting (more sensitive reading). Note: our "zero" will now be off, but that doesn't matter too much for our purpose.

Prediction   Answer below:
             The Earth's magnetic field has a direction that points roughly toward the North, but also into the
             ground (about 70 degree angle with respect to the ground). If you were to hold the magnetic
             sensor vertically (the long axis of the Plexiglas cylinder is vertical), and if you rotated the sensor,
             what might you expect to see on the graph? (Discuss this with your lab group before forming an
             answer.)

             _____

             _____

             _____

   2. Start DataStudio and rotate the sensor. Click on the START button, and then slowly rotate the
   magnetic sensor around that long axis, with the long axis held vertically.

Question   Answer below:
           Did your prediction match what you saw? How can you explain the shape of the curve that you
           measured?

           _____

           _____

           _____

   3. Find best "horizontal" direction – then rotate end over end.

Question   Answer below:
           Does this second curve support the idea of the Magnetic field pointing about 70 degrees from
           vertical?

           _____

           _____

Part 7- Magnetic field from a "fridge" magnet

   5. Slide a strip of a magnet along both of the axes of the fridge magnet.

Question   Answer on the Data/Question sheet:
           In one of those two directions .. you should find some very strange behavior .. there should be a
           "shuddering" or a "hopping" of the thin strip along the main magnet. The other direction from that
           should involve some smooth sliding. Do you have any ideas as to why you might get that very
           different behavior from the magnets?

           _____

_____

7. Slowly scan along each of those axes.

Question   Answer below:
             In one of the directions (each style of magnet is a little different as to the "preferred direction") –
             you should notice some very strong edge effects, and some "oscillations" of the magnetic field
             strength along the main part of the magnet. Can you correlate your findings with the observed
             "jumping" of the strip and come up with a theory?

_____

_____

_____

_____

How do I write up this lab? … What is required for this lab report?
Consult the Rubric for this experiment and the "Lab Report Instructions" document
(both found on the Lab Schedule page).

Questions/Suggestions -> Dr. Scott Schneider - S_SCHNEIDER@LTU.EDU

*Portions of this laboratory manual have been adapted from materials originally developed by Priscilla Laws,
David Sokoloff and Ronald Thornton for the Tools for Scientific Thinking, RealTime Physics and Workshop
Physics curricula. You are free to use (and modify) this laboratory manual only for non-commercial educational
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