Earth’s Magnetic Field

Purpose

The purpose of this activity is to measure the local properties, both magnitude and direction, of the Earth’s Magnetic Field.

Theory

The Earth’s magnetic field is rather complex and dynamic, however a decent first order approximation of it can be obtained by modeling it as a bar magnetic. The South magnetic pole of this theoretical bar magnet would be located near (but not at) the Earth’s North geographical pole, and the North Pole of this theoretical bar magnet would be located near (but not at) the Earth’s South geographical pole. Since when it comes to magnetic fields the opposite ends attract each other this is why the North Pole of a compass points North, because that is the direction towards Earth’s magnetic South pole!

A magnetic field is a vector field, in that it has both a local magnitude and local direction, and as you change locations the magnitude and direction of the magnetic field changes. The magnitude, and direction of the Earth’s Field varies over the surface of the Earth, and like any vector it can be broken up into component form. One way to break it up is into...
its local horizontal and vertical components. The Horizontal component is the part of the magnetic field that points parallel with the local surface of the Earth, and the vertical component is the part of the magnetic field that points perpendicular to the local surface of the Earth. The direction of a magnetic field is defined to be pointing from the North Pole to the South Pole, and this results in the vertical component of Earth’s magnetic field pointing downwards into the ground (in the Northern Hemisphere). The angle \( \theta \) that is formed between the horizontal component of the Earth’s magnetic field and the direction of the Earth’s total magnetic field is called the Dip Angle, and from the properties of the right triangle we can see that it is given by;

\[
\theta = \cos^{-1}\left(\frac{B_H}{B_T}\right)
\]

Where \( B_H \) is the magnetic field’s horizontal component, and \( B_T \) is the total magnetic field.

**Setup**

NOTE: During this experiment, keep the apparatus away of all sources of magnetic fields, such as electronics, computers, bar magnets, and so on. Also keep away from all ferromagnetic materials: iron, nickel, and cobalt. Best results will be obtained if preformed on a wooden, or hard plastic table.

1. Using the listed equipment construct the hardware setup as shown in the pictures.
2. Make sure the PASCO 850 Interface is turned on.
3. Double click the Capstone software icon to open the Capstone software.
4. In the Tool Bar, on the left side of the screen click on Hardware Setup to open the Hardware Setup window.
   - An image of the PASCO 850 Interface should be in the Hardware Setup window. If it is skip to step 5. If it is not then click on Choose Interface to open the Choose Interface window. In the Choose Interface window select PASPORT, then Automatically Detect, and then click OK.
5. On the image of the PASCO 850 Interface click on Digital Inputs Ch (1) to open up the digital sensors list.
   - Scroll down and select Rotary Motion Sensor.
   - The Rotary Motion Sensor icon should now appear in the Hardware Setup window with lines indicating that it is selected for Ch (1) and Ch (2)
   - Plug the Rotary Motion Sensor into the Digital Inputs. Yellow to Ch (1), and black to Ch(2).
6. On the image of the PASCO 850 interface click on the Analog Inputs Ch (A) to open up the analog sensors list.
   - Scroll down and select Magnetic Field Sensor.
   - The Magnetic Field Sensor icon should now appear in the Hardware Setup window with a line indicating that is selected for Ch (A).
7. The Gain switch, which is physically on the Magnetic Field Sensor, set it to 100X
8. Make sure orientation switch, which is also physically on the magnetic field Sensor, is set to Axial.
9. In the Tool Bar click on the Data Summary icon to open the Data Summary window.
   - In the Data Summary window click on Magnetic Field Strength (100X) (T) to cause a properties icon to appear to its right.
   - Click on the properties icon to open the property window.
   - In the properties window click on Numerical Format.
   - Set Number of Decimal Places to 3.
   - Click ok to close the properties window.
10. Close the Tool Bar.
11. Near the bottom center of the screen select Common Rate for the instrument, and then set the sample rate to 20.0 Hz.
12. In the Display Bar, on the right side of the screen, double click the graph icon to make a graph appear on Page #1.
   - Click on Select Measurement for the y-axis, and select Magnetic Field Strength (100X) (T).
   - The computer will automatically change the x-axis to time, we need to change the x-axis to Angle.
   - Along the x-axis click on Time, then select Angle (rad). Now click on the units (rad), then change the units to (°).
**Procedure: Horizontal Component**

1. Arrange the Dip Needle into its horizontal position, and then move it to be underneath the rotary motion sensor.
   - Allow the dip needle to settle and find magnetic north.
   - Then tilt the rotary motion sensor such that the angle indicator reads 90°.
   - Then rotate the magnetic field sensor till its probe is oriented in the same direction (North) as the dip needle.

2. Remove the dip needle so its magnetic field won't interfere with your measurements, but note the orientation of the magnetic field sensor.

3. Slip the zero gauss chamber over the magnetic field sensor probe, press the tare button on the top of the magnetic field sensor, and then remove the zero gauss chamber. (This isolates the sensor from the Earth’s magnetic field while calibrating it.)

4. Near the bottom left of the screen click on record to start collecting data.
   - Slowly start to rotate the magnetic field sensor through one complete 360° rotation. Click Stop once you have rotated through 360°.
   - Repeat this process to try to get a nice smooth curve. Be careful to not let the cords get tangled up.
   - Pick your smoothest graph, and then using the click on the arrow next to the Apply Smoothing to Active Data icon at the top of your graph, and then smooth out the graph as best you can.

5. Click on the Add Coordinate Tool icon at the top of the graph to add a coordinate tool to your graph.
   - Use the coordinate tool to determine the value of the measured horizontal component of the local magnetic field, when the magnetic field sensor was pointing north, and record this value in the provided Table.
Procedure: Vertical Component

1. Rotate the setup till the angle indicator reads an angle of 0°.
2. Near the bottom left of the screen click on record to start collecting data.
   - Slowly start to rotate the magnetic field sensor through one complete 360° rotation. Click Stop once you have rotated through 360°.
   - Repeat this process to try to get a nice smooth curve. Be careful to not let the cords get tangled up.
   - Pick your smoothest graph, and then using the click on the arrow next to the Apply Smoothing to Active Data icon at the top of your graph, and then smooth out the graph as best you can.
3. Click on the Add Coordinate Tool icon at the top of the graph to add a coordinate tool to your graph.
   - Use the coordinate tool to determine the value of the measured vertical component of the local magnetic field, when the magnetic field sensor was pointing downwards, and record this value in the provided Table.
Table (40 points)

<table>
<thead>
<tr>
<th>Horizontal Component of Magnetic Field (T)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Component of Magnetic Field (T)</td>
<td></td>
</tr>
</tbody>
</table>

1. Using your two measured components calculate the magnitude of the local Earth’s magnetic field. (10 points)

2. The current accepted value of the magnitude of the Earth’s magnetic field in the San Antonio area is $4.68 \cdot 10^{-6} \, T$. Calculate the % error between this and your measured value. (10 points)

3. Calculate the Dip Angle of the local Earth’s magnetic field. (10 points)

4. The current accepted value of the Dip Angle of the local Earth’s magnetic field in the San Antonio area is $58.2^\circ$ (downwards). Calculate the % error between this and your measured value. (10 points)