NATIONAL UNIVERSITY OF TECHNOLOGY

COMPUTER ENGINEERING DEPARTMENT

Applied physics Lab (PHY13002)

Experiment No:4

Title: Experiment to measure the magnitude and direction of the Earth's magnetic field

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Objectives:

1. To calculate the horizontal and total magnetic fields strengths from the amplitude values and access their symmetry around zero.

2.To compare sinusoidal curves to experimental data by using curve fit tool to determine amplitudes and angles variations.

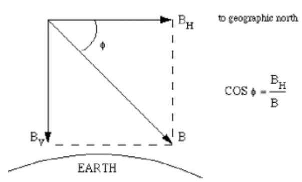
3.To determine the dip angle(θ)by determining the relationship between horizontal and total magnetic fields.

Apparatus:

1. 850 Universal Interface
2. 2-Axis Magnetic Field Sensor
3. Zero Gauss Chamber
4. Rotary Motion Sensor
5. Dip Needle
6. Aluminum Table Clamp
7. 25 cm Stainless Steel Rod (threaded)
8. Adjustable Angle Clamp
9. Angle Indicator

Theoretical explanation:

Across the Earth's surface, the magnetic field varies in both magnitude and direction, forming a vector quantity. It is composed of two main components the horizontal component ($B_{Horizontal}$) and the total magnetic field (B_{Total}). The angle between these components, called the dip angle (θ), represents how inclined the magnetic field lines are relative to the horizontal plane.



A Magnetic Field Sensor is used to measure these components by rotating it in specific planes. In the horizontal plane,it detects B_{90}=$B_{Horizontal}$ cos α where alpha is the angle from magnetic north. In a vertical plane aligned with B_{Total} it detects B_{00}= B_{total}*cosβ. The dip angle (θ) occurs when β=0. The dip angle θ is the angle at which the magnetic field lines are inclined relative to the horizontal plane as shown in the figure above.To calculate the Dip we use:

$$\cos\theta = B_{Horizontal} \backslash B_{Total}$$

Procedure for $B_{Horizontal}$:

a) **Setup for Horizontal Rotation**: Adjust the Rotary Motion Sensor so its angle indicator reads 90° with the Magnetic Field Sensor placed on top.
b) **Align the Compass**: Place the Dip Needle horizontally against the Rotary Motion Sensor case. Rotate the Rotary Motion Sensor until the compass needle aligns with its holding fork and points to 270°. Remove the Dip Needle to avoid interference.
c) **Level the Sensor**: Ensure the top of the Rotary Motion Sensor case is level. A slight tilt (less than 10°) won't significantly affect results but could impact the dip angle measurement.
d) **Zero the Sensor**: Rotate the Magnetic Field Sensor probe perpendicular to the Earth's magnetic field. Cover it with the Zero Gauss Chamber, press the Tare button to zero the sensor, then remove the chamber.
e) **Collect Horizontal Data**: Align the Magnetic Field Sensor with the Rotary Motion Sensor's long axis pointing north. Click RECORD and rotate the Rotary Motion Sensor steadily through two full revolutions. Click STOP when complete.
f) **Verify Alignment**: Ensure the magnetic field readings are at their most negative (or positive if aligned south) at 0°, 360°, and 720°. If not, adjust the setup and repeat.
g) **Save the Run**: Label the recorded data as "Horizontal 1."
h) **Repeat**: Perform two more runs following steps 5–7, labeling them "Horizontal 2" and "Horizontal 3."

Procedure for B_{Total}:

a) **Setup for Vertical Rotation**: Adjust the Rotary Motion Sensor so the angle indicator reads 0°, keeping it aligned with the Earth's magnetic field as shown by the compass needle (Dip Needle).
b) **Position the Sensor**: Point the Magnetic Field Sensor probe horizontally.
c) **Record Vertical Data**: With the probe still horizontal, click RECORD. Rotate the Rotary Motion Sensor slowly through two full revolutions, turning the probe downward first. Click STOP when done.
d) **Save the Run**: In Data Summary, double-click the run and label it "Vertical 1."
e) **Repeat**: Repeat steps 2–4 two more times, labeling the runs "Vertical 2" and "Vertical 3."
f) **Measure Dip Needle**: Hold the Dip Needle horizontally on top of the Rotary Motion Sensor case, level it, and align it with 270 mark. Rotate the fork 90° to pivot the needle in a vertical plane. Let it rest and measure the angle it is below horizontal (270°).

Observations and Calculations:

Runs	$B_{Horizontal}$	B_{Total}
Run 1	0.0219	0.0470
Run 2	0.0216	0.0473
Run 3	0.0220	0.0468
Average	0.022	0.047

To calculate the dip angle we used the formula:

$$\mathrm{Cos}(\theta) = B_{Horizontal}/B_{Vertical}$$

Using Average values of $B_{Horizontal}$ and B_{Total} we calculate Dip angle:

$$\theta=\cos^{-1}(B_{Horizontal}/B_{Vertical})$$

$$\theta=\cos^{-1}(0.022/0.047)$$

$$\theta=62^{\circ}$$

Result and Analysis:

The experiment successfully measured the horizontal $B_{Horizontal}$ and total B_{total} components of Earth's magnetic field. By analyzing the data, the dip angle (θ) was calculated using the formula $\cos\theta=B_{Horizontal}/B_{total}$. Sine curves from the horizontal rotations were used to determine $B_{Horizontal}$, and vertical rotations provided B_{Total}. Averaging data from three runs improved accuracy, and the calculated dip angle was consistent with direct measurements.

The sine curves showed periodic behavior, with maximum amplitudes representing the horizontal and total magnetic fields. Repeating the experiment minimized errors caused by noise or misalignment. The calculated dip angle matched direct measurements, confirming reliability. Minor discrepancies were likely due to environmental magnetic noise or alignment issues. Averaging runs and minimizing interference helped reduce uncertainties, ensuring the experiment accurately demonstrated how Earth's magnetic field can be analyzed through simple measurements. Additionally, careful alignment, consistent motion, and avoiding nearby interference were essential to obtaining precise and reliable results throughout the experiment. The experiment also demonstrated how even small changes in the sensor's orientation can significantly affect the results, emphasizing the importance of precision and consistent setup.

Precaution:

- Keep the setup away from electronic devices, computers, magnets, and ferromagnetic materials to avoid interference and distortions.
- Properly zero the Magnetic Field Sensor using the Zero Gauss Chamber before starting.
- Align the Rotary Motion Sensor accurately with the Earth's magnetic field using a compass needle.
- Handle equipment gently, especially the Magnetic Field Sensor and Dip Needle, to prevent damage or inaccurate readings.
- Take multiple measurements and recheck connections and settings to minimize errors and interference.

Comments:

- After calculating $B_{horizontal}$, I had to adjust the setup to ensure proper measurement in the vertical plane.
- Rotating the sensor smoothly and consistently was challenging; keeping it in constant motion without jerks took some practice.
- For B_{total}, I made sure the sensor was positioned at an appropriate angle to capture the combined magnetic field from both the horizontal and vertical planes.
- I had to use the compass needle repeatedly to ensure the sensor's axis was correctly aligned with the Earth's magnetic field, keeping the setup accurate.
- The setup changes were essential to obtaining consistent and reliable results, ensuring that the experiment accurately reflected the Earth's magnetic field in both planes.

Conclusion:

The experiment effectively measured Earth's magnetic field components and calculated the dip angle (θ). By rotating the sensor in both horizontal and vertical planes, the horizontal and total magnetic fields were determined, and their ratio provided the dip angle. Averaging multiple runs reduced errors from noise and misalignment, enhancing accuracy. The calculated dip angle aligned with direct measurements, confirming the reliability of the results. The experiment highlighted the importance of careful sensor alignment and minimizing interference to ensure precise measurements. Overall, the experiment demonstrated how Earth's magnetic field can be broken into components, providing valuable insight into field analysis and reinforcing the importance of consistency and accuracy in scientific experiments.