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**Report Sheet for Experiment 10: Measuring the earths magnetic field**

Abstract

In this experiment, the concept of electromagnetic induction was investigated by rotating a coil and detect the induced electromotive force due to the changing of magnetic flux caused by the magnetic of the earth. The field’s magnitude and inclination can be calculated by measuring the amplitude and frequency of the induced emf, and subsequently, solve equations for each of the axes. The obtained results are 30.44 µT and 55.46 Degrees of inclination which is a -34% and -6% from the reference suggested by US-NGDC. The inaccuracy can be contributed from the instability of natural earth’s magnetic field and interruption from external electronic devices which will reduce the magnetic flux passed through the coil, leading to a negative error.

Introduction and Theoretical Background

When the earth rotates, their outer core that contains some metal liquid will generate the magnetic field from this rotation known as “earth’s magnetic field”. Its magnitude and angle of inclination can be determined by using the induction of rotating coil.

Considering a circular induction coil with N turns and radius R. The electromotive force will be induced if the coil rotates with angular velocity . If the coil has a uniform magnetic field pass through the oil with inner radius r1 and outer radius r2, the magnetic flux can be expressed as:

…(1)

According to Faraday’s law of induction, the induced EMF will be equal to:

…(2)

The amplitude will be equal to

Because of the symmetry between the x, y, z axes, the magnitude of magnetic field in each axis is

, , …(4)

given …(5)

The overall magnetic field is the square root of the sum of squared magnitude in each axis.

Finally, the inclination angle of earth’s magnetic field can be calculated via:

…(6)

Methods

1. Set the equipment as shown in the figure 1. Set the rotational axis to be z-axis
2. Rotate the coil around z-axis. And record the induced emf
3. Repeat 1-2 and change the rotational axis to be x and y axis, respectively

Diagram

Description automatically generated

Figure 1 depicts the experiment set-up

Results

|  |  |
| --- | --- |
| **object** | **value** |
| Turns of the coil | 320 |
| Inner radius of the coil (m) | 0.062 |
| Outer radius of the coil (m) | 0.072 |

Table 1 summarizes parameters used in the experiments

Chart, scatter chart

Description automatically generated

Figure 2 depicts the induced voltage in mV versus time for all x, y, and z axes. The variables for fitted sine curves are summarized in Table 2 below

|  |  |  |  |
| --- | --- | --- | --- |
|  | x-axis | y-axis | z-axis |
| Fitted equation |  | | |
| y0 | 0.006 | 0.006 | 0.008 |
| xc | 0.198 | 0.611 | 0.794 |
| w | 1.253 | 1.259 | 1.304 |
| A | 0.688 | 0.569 | 0.376 |

Table 2 summarizes parameters used to fit sine curves in Figure 2

|  |  |  |  |
| --- | --- | --- | --- |
|  | x-axis | y-axis | z-axis |
| amplitude (mV) | 0.688 | 0.569 | 0.376 |
| period (s) | 1.253 | 1.258 | 1.304 |
| angular velocity (rad/s) | 5.015 | 4.995 | 4.818 |
| a value | 22.672 | 22.582 | 21.785 |
| emf/a | 3.035E-05 | 2.520E-05 | 1.726E-05 |
| (emf/a)2 | 9.209E-10 | 6.349E-10 | 2.979E-10 |
| Magnetic field (T) | 2.441E-06 | 1.709E-05 | 2.508E-05 |
| Total magnetic field (T) | 30.444 | | |
| Angle of inclination () | 55.464 | | |

Table 3 summarize the parameters used to calculate the total Earth’s magnetic field and its inclination angle. The detailed calculation is shown below.

* a-value is as in eq.(5) in the Introduction = = 320turn x 5.015rad/s x x (0.0622 + 0.062x0.072 + 0.0722) / 3
* emf/a = 0.688/1000/22.672 represents the square root of sum of squared of magnetic field. In two other axes.
* magnetic field = sqrt { sum[(emf/a)2]/2 – 0.9209E-10 }
* Total magnetic field = x 106
* Angle of inclination = tan-1(

Discussion

According to the National centers of environmental information, the magnitude of the earth’s magnetic field at Daejeon is 46.12 µT and its inclination angle is 58.95 degree. This makes the error from the experiment result to be = -34% and that for the inclination angle to be = -5.92%. The huge error of the experimental value can be contributed from two reasons: uncertainty in the nature, and laboratory set-up. Since the Earth’s magnetic field is somewhat unstable, the variation in magnetic field can cause deviation to the induced emf in the coil. Furthermore, the external magnetic field caused by electronic devices such as computer that can debunk with the earth’s field. This makes the error in magnitude much worse than that of the inclination angle. To best solve this, wire with high resistance can be used to minimize the occurred electric current.

Graphical user interface, application, table

Description automatically generated

Figure 3 depicts the inclination angle and total magnetic field in Daejeon with latitude and longitude obtained from ref.3

Conclusion

In conclusion, the concept of electromagnetic induction was introduced in this experiment by rotating a coil and detect the induced electromotive force due to the changing of magnetic flux caused by the magnetic of the earth. The field’s magnitude and inclination can be calculated by measuring the amplitude and frequency of the induced emf, and subsequently, solve equations for each of the axes. The obtained results are 30.44 µT and 55.46 Degrees of inclination which is a -34% and -6% from the reference suggested by US-NGDC. The inaccuracy can be contributed from the instability of natural earth’s magnetic field and interruption from external electronic devices which will reduce the magnetic flux passed through the coil, leading to a negative error.

Reference

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