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Real-Time Measurement and Analysis of Magnetic Fields Using Data Logger

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Abstract. This study aims to perform real-time measurement and analysis of magnetic fields using a data logger. The experimental setup consisted of a data logger, magnetic field sensor, permanent magnet, straight current-carrying conductor, power supply, probe cables, and distance measuring instrument. Magnetic field measurements on a permanent magnet were conducted by varying the distance between the sensor and the magnet from 0.5 cm to 10 cm. The results showed that the magnetic field strength decreased significantly from 31.470 G at 0.5 cm to 0.098 G at 10 cm, indicating that magnetic field intensity weakens with increasing distance from the magnetic source. Measurements were also performed on a straight current-carrying conductor carrying approximately 5 A. The magnetic field strength decreased from 0.317 G at 0.5 cm to −0.073 G at 2.5 cm, reflecting variations in both magnetic field magnitude and direction around the conductor. The data logger provided stable real-time acquisition, automatic data recording, and graphical visualization of magnetic field variations throughout the experiments. These findings demonstrate that a data logger can be effectively utilized for real-time measurement and analysis of magnetic fields, supporting reliable magnetic field characterization in applied physics experiments.

1 Introduction

Magnetic fields are fundamental physical phenomena that play an important role in electrical engineering, electromagnetic instrumentation, industrial monitoring systems, and modern sensing technology. An accurate magnetic field measurement is essential because magnetic induction directly affects the performance of electrical devices, current detection systems, electromagnetic actuators, and sensor-based technologies [1]. Recent developments in magnetic sensing technology have enabled the use of compact digital magnetic sensors capable of performing real-time magnetic field measurements with high sensitivity and stable signal acquisition [2]. Magnetic field measurement systems based on Hall-effect sensors and digital acquisition modules are increasingly used because they offer practical implementation, low-cost operation, and continuous magnetic flux density monitoring [3]. Modern magnetic sensing systems also enable and direct graphical visualization of magnetic

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field variations, allowing more effective analysis of magnetic induction characteristics under experimental conditions [4].

Electromagnetic theory explains that an electric currents flowing through conductors generate magnetic fields surrounding the conductor. The magnetic field strength around a long straight current-carrying conductor can be calculated using the equation (1).

$$B = \frac{\mu_0 I}{2\pi r} \quad (1)$$

where B is the magnetic field strength (T), $\mu_0 = 4\pi \times 10^{-7}$ Wb/Am is the permeability of free space, I is the electric current (A), and r is the distance between the conductor and the observation point (m) [5]. This equation indicates that magnetic field intensity is directly proportional to electric current and inversely proportional to the distance from the conductor [6]. Experimental measurement of magnetic fields around current-carrying conductors is important because it provides direct verification of electromagnetic interaction and magnetic induction theory [7]. Permanent magnets also produce magnetic fields whose strength decreases significantly as the observation point moves farther from the magnet surface due to spatial reduction of magnetic flux density [8]. Measurements of magnetic field distributions around permanent magnets and conductors therefore, is essential for understanding magnetic induction behavior and validating theoretical electromagnetic models [9].

Magnetic field measurement systems have developed significantly with the integration of digital sensors and automated data acquisition technology. Recent studies have been used that Hall-effect magnetic sensors are capable of producing accurate measurements of magnetic flux density variations under real-time experimental conditions [10]. Integrated magnetic field acquisition systems are increasingly important because they enable continuous magnetic field data recording, reducing manual measurement errors [11]. Real-time monitoring systems also improve magnetic field analysis by allowing direct observation of magnetic induction changes caused by distance variation and current fluctuation [12]. Portable digital magnetometers and sensor-based magnetic field instruments have been successfully implemented in experimental studies involving permanent magnets, current-carrying conductors, and electromagnetic systems [13]. Graphical visualization generated by digital acquisition systems further improves the interpretation of magnetic field characteristics because variations in magnetic induction can be monitor continuously during measurements [14].

Previous studies on magnetic field measurements have mainly focused on advanced magnetic sensor optimization, industrial electromagnetic monitoring, magnetic detection technologies, smartphine-based magnetometers, and portable Hall-effect devices [15]. However, limited studies have spesifically examined the use of an integrated data logger system for real time measurment of magnetic field strength around permanent magnets and straight current-carrying conductors [11]. Existing studies also rarely evaluated the stability of real-time magnetic field acquisition systems combined with graphical visualization within a single compact experimental platform [12]. Furthermore, implementation of the data logger for magnetic field measurements remains insufficiently explored despite its capability to integrate sensors, real-time acquisition, and graphical data analysis in one system [13]. Most available magnetic measurement studies additionally focus on industrial or environmental applications rather than controlled laboratory-scale magnetic field characterization involving both permanent magnets and current-carrying conductors [14].

Accurate magnetic field characterization requires stable sensor response, continuous signal acquisition, and reliable graphical representation of magnetic induction data. Real-time digital measurement systems are increasingly important because magnetic field strength changes rapidly with observation distance and current variation [15]. Continuous magnetic field recording also improves the precision of magnetic field analysis by minimizing inconsistencies caused by manual observation processes [2]. Recent studies reported that integrated magnetic sensing systems provide stable magnetic field acquisition performance while maintaining clear visualization of magnetic flux density distributions during experiments [4].

This research therefore aims to measure and analyze magnetic field strength using the data logger through experiments involving permanent magnets and straight conductors carrying electric current. The research focuses on investigating the relationship between magnetic field strength and observation distance from magnetic sources while evaluating the capability of the system to perform stable real-time magnetic field acquisition and graphical visualization. The experiments were conducted to analyze spatial magnetic induction variations around permanent magnets and straight current-carrying conductors using an integrated measurement system.

This research hypothesizes that magnetic field strength exhibits a decreasing trend with increasing distance from the magnetic source, in accordance with established electromagnetic theories governing permanent magnets and current-carrying conductors. It is further hypothesized that the data logger can reliably capture these variations and generate consistent real-time graphical outputs that accurately represent changes in magnetic induction during the experiments.

2 Research Method

This research investigated the characteristics of magnetic field strength around a permanent magnet and a straight current-carrying conductor using the data logger. The experimental system integrated a data logger, magnetic field sensor, probe cable, permanent magnet, straight conductor, power supply, connecting cables, wire support, and ruler into a single magnetic field measurement setup. The integrated apparatus was designed to facilitate real-time magnetic field acquisition and graphical visualization during the experiment. The configuration of the experimental setup used in this research is illustrated in Figure 1 for the permanent magnet experiment and Figure 2 for the straight current-carrying conductor experiment.

Fig. 1. Experimental Setup *for* Permanent Magnet

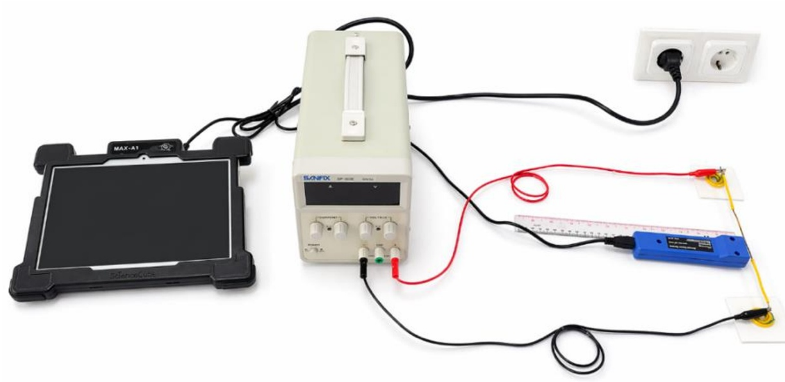

Fig. 2. Experimental Setup for Straight Current-Carrying Conductor

Magnetic field measurements on the permanent magnet were conducted by positioning a bar magnet on a ruler with the blue side of the magnet placed at the 0 cm position. The magnetic field sensor was connected to the data logger using a probe cable, and the Built-in data acquisition application installed on the data logger was used to record and display magnetic field data. The Line/Scatter mode was selected in the application settings, while the data acquisition mode was configured as Event Based with the x-axis parameter defined as distance (cm). The experiment was initiated by pressing the start button on the data logger application after ensuring that the magnetic field readings had stabilized.

Measurements of the magnetic field strength around the permanent magnet were carried out by systematically varying the distance between the magnetic field sensor and the magnet surface from 0.5 cm to 10 cm in 0.5 cm increments. One measurement was recorded at each distance to determine the corresponding magnetic field strength. At each distance, the magnetic field value displayed on the data logger was allowed to stabilize before the corresponding distance value was entered manually into the application. The measured data were automatically stored and displayed graphically form by the data logger system, enabling dricet observation of the relationships between magnetic field strength and distance from the magnet.

Magnetic field measurements on the straight current-carrying conductor were conducted using a straight wire connected to a DC power supply through banana cables and alligator clips. The straight conductor was placed horizontally on a wire support above a ruler, with the wire aligned directly above the 0 cm position on the ruler. The power supply was connected to an electrical source and regulated to provide stable operating conditions, maintaining an electric current of approximately 5 A and a voltage of approximately 2 V throughout the experiment. The magnetic field sensor was connected to the data logger using a probe cable, and the Built-in data acquisition application was configured using the same settings as those applied in the permanent magnet experiment.

Measurements of the magnetic field strength around the straight conductor were performed after electric current flowed through the wire. The measurement process was started by pressing the start button in the Built-in data acquisition application. The magnetic field sensor was positioned at distances of 0.5 cm, 1 cm, 1.5 cm, 2 cm, and 2.5 cm from the current-carrying conductor. The magnetic field value displayed on the data logger was observed until the reading became stable before the corresponding distance value was entered into the application. The sensor orientation was kept fixed throughout the measurements, and the recorded values represent the magnetic field component detected along the sensor measurement axis. The magnetic field data obtained from each measurement point were automatically stored and visualized in graphical form by the data logger.

Potential measurement errors occasionally appeared during the initial stage of data acquisition when the sensor readings had not fully stabilized. Data collection was therefore conducted only after the displayed magnetic field values remained constant for several seconds. The recorded data were analyzed using graphical representations generated directly by the data logger to evaluate the relationship between magnetic field strength and observation distance for both permanent magnets and straight current-carrying conductors.

3 Result and Discussion

Magnetic field measurements were carried out on two magnetic sources, a permanent bar magnet and a straight conductor carrying electric current, using the data logger integrated with a magnetic field sensor. The experiments aimed to analyze the relationship between magnetic field strength and the distance between the magnetic source and the observation point. Magnetic field data were recorded automatically and displayed in graphical form through the Built-in data acquisition application installed on the data logger. The obtained experimental data for the permanent magnet are presented in Table 1.

Table 1. Magnetic Field Strength Measurements on a Permanent Magnet

Distance from Magnet (cm)	Magnetic Field Strength (G)
0.5	31.470
1.0	26.611
1.5	21.191
2.0	16.016
2.5	12.036
3.0	9.399
3.5	6.909
4.0	5.322
4.5	4.004
5.0	3.174
5.5	2.612
6.0	1.904
6.5	1.538
7.0	1.221
7.5	0.928
8.0	0.659
8.5	0.513
9.0	0.366
9.5	0.244
10.0	0.098

Based on the data in Table 1, the magnetic field strength produced by the permanent magnet decreased significantly as the distance between the magnetic sensor and the magnet increased. The highest magnetic field, 31.470 G was recorded at a distance of 0.5 cm, whereas the lowest 0.098 G was obtained at a distance of 10 cm. The results indicate that magnetic field intensity weakens rapidly as the observation point moves farther from the magnet surface. This behavior is consistent with the theoretical characteristics of magnetic induction around permanent magnets, where magnetic flux density decreases as the observation point moves away from the magnet because magnetic field lines become less concentrated away from the magnetic poles.

The decrease in magnetic field strength occurred nonlinearly. At short distances, the magnetic field value decreased sharply, whereas at larger distances the decrease became more gradual. For example, the magnetic field strength decreased from 31.470 G to 16.016 G when the distance increased from 0.5 cm to 2 cm, representing a reduction of nearly 49%. However, between 8 cm and 10 cm, the magnetic field only decreased from 0.659 G to 0.098 G. This pattern indicates that the magnetic field gradient near the magnet surface is considerably steeper than at farther distances. Such behavior occurs because the density of magnetic field lines is greatest near the magnet poles and progressively spreads out with increasing distance from the magnetic source.

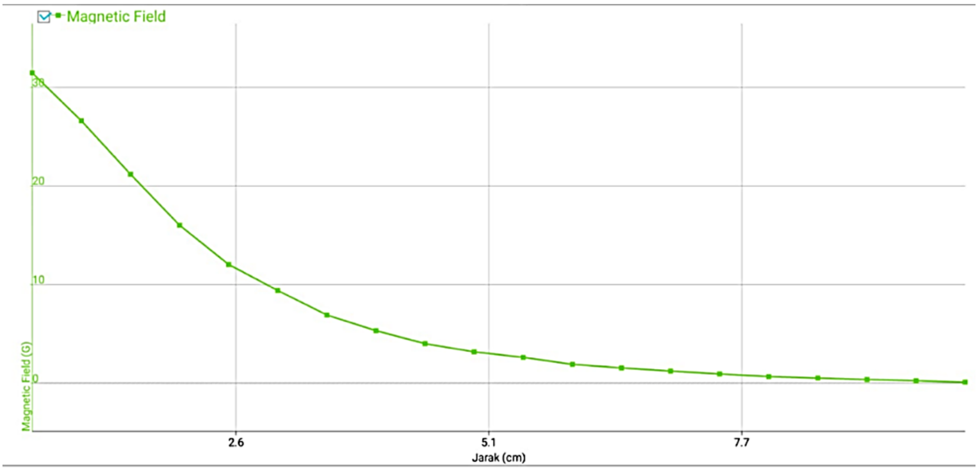

Fig. 3. Graph of the Relationship between Distance and Magnetic Field Strength for the Permanent Magnet

The graphical visualization generated by the data logger showed a continuously decreasing curve, confirming that magnetic field strength decreases with increasing observation distance. The obtained graph also demonstrated stable and consistent magnetic field acquisition throughout the measurement process. No significant fluctuations were observed in the recorded data after the sensor readings stabilized, indicating that the integrated acquisition system was capable of maintaining reliable magnetic field measurements during continuous observation. The real-time graphical display provided by the data logger additionally simplified the interpretation of magnetic field variations because changes in magnetic induction could be observed directly during the experiment.

Table 2. Magnetic Field Strength Measurements on a Straight Current-Carrying Conductor

Distance from Conductor (cm)	Magnetic Field Strength (G)
0.5	0.317
1.0	0.098
1.5	0.000
2.0	-0.024
2.5	-0.073

The magnetic field measurements on the straight current-carrying conductor are presented in Table 2. The measurement results in Table 2 show that the magnetic field strength around the straight conductor also decreased as the observation distance increased. The highest magnetic field value was measured at a distance of 0.5 cm with a magnetic field strength of 0.317 G. The measured value gradually decreased to 0.098 G at 1 cm and approached zero at 1.5 cm. At larger distances, the recorded magnetic field values became negative, reaching −0.073 G at a distance of 2.5 cm.

Comparison with Equation (1) shows that the measured magnetic field values were lower than the theoretical predictions. At a distance of 0.5 cm and a current of approximately 5 A, the theoretical magnetic field is about 2.0 G, whereas the measured value was 0.317 G. This discrepancy may be attributed to practical factors such as finite conductor length, sensor alignment, and environmental magnetic interference. Nevertheless, the experimental results still followed the expected inverse relationship between magnetic field strength and distance from the conductor.

The measured magnetic field values were substantially lower than the theoretical predictions for an ideal infinitely long conductor. This difference indicates the presence of experimental limitations that may have reduced the detected magnetic field component. Possible contributing factors include finite wire geometry, sensor positioning inaccuracies, background magnetic fields, and the orientation dependence of the Hall-effect sensor. Therefore, the measurements should be interpreted primarily as demonstrating the spatial trend of magnetic field variation rather than providing high-precision validation of the theoretical magnitude.

The presence of zero and negative magnetic field values does not indicate the absence of magnetic fields. Instead, reflects changes in the detected magnetic field direction relative to the orientation of the sensor. Magnetic fields around straight conductors form circular patterns surrounding the wire according to the right-hand rule. When the detected magnetic field direction is aligned with the sensor orientation, the measured magnetic field value becomes positive. Conversely, when the magnetic field direction opposes the sensor orientation, the recorded value becomes negative. The near-zero value observed at 1.5 cm indicates that the detected magnetic field component was extremely small or located near a transition region where the detected magnetic field direction changed relative to the sensor axis.

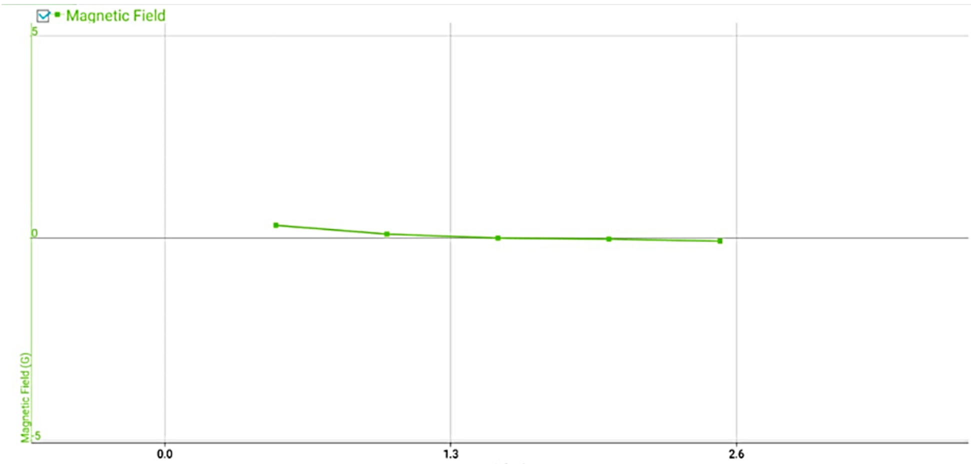

Fig. 4. Graph of the Relationship between Distance and Magnetic Field Strength for the Straight Current-Carrying Conductor

The graphical representation produced by the data logger showed a downward trend with measured values changing from positive to negative values as the observation distance increased. This behavior confirms that the data logger system was capable not only of measuring magnetic field magnitude but also detecting directional changes in magnetic field components around the conductor. The recorded data additionally demonstrated stable real-time acquisition performance during the experiment because the magnetic field readings remained consistent after sensor stabilization. The ability of the data logger to automatically record and visualize magnetic field variations provided more efficient analysis compared with manual measurement methods.

Although the experiments employed standard magnetic field measurements, the integrated data logger provided automated data acquisition, real-time visualization, and digital data storage within a single platform. These features reduced manual recording efforts and enabled more efficient analysis of magnetic field variations during the experiment.

Comparison between the permanent magnet experiment and the straight current-carrying conductor experiment reveals significant differences in magnetic field magnitude and spatial characteristics. The permanent magnet produced substantially larger magnetic field values because permanent magnets possess intrinsic magnetic domains that generate strong and stable magnetic flux density. The straight conductor, on the other hand, generated weaker magnetic fields because the magnetic induction originated solely from the electric current flowing through the wire. The permanent magnet measurements also showed only positive magnetic field values because the sensor orientation relative to the magnetic pole remained constant throughout the experiment, whereas the conductor measurements exhibited positive, zero, and negative values due to directional changes in the surrounding circular magnetic field.

A limitation of this study is that only one measurement was performed at each distance. Consequently, measurement uncertainty and standard deviation could not be determined. Future studies should include repeated measurements to enable statistical analysis and uncertainty evaluation.

4 Conclusion

Magnetic Magnetic field measurements conducted using a data logger successfully demonstrated the relationship between magnetic field strength and the distance from magnetic sources. The experimental results showed that magnetic field strength decreased with increasing observation distance for both permanent magnets and straight current-carrying conductors, consistent with the theoretical characteristics of magnetic induction. In addition, the measurements around the current-carrying conductor revealed variations in both magnetic field magnitude and direction, reflecting the circular magnetic field distribution surrounding the conductor.

The data logger enabled stable real-time acquisition of magnetic field data throughout the experiments and provided clear graphical visualization of magnetic field variations. The recorded data facilitated effective analysis of magnetic field behavior under different experimental conditions, allowing direct observation of changes in magnetic field strength as a function of distance. Overall, the results demonstrate that a data logger can be effectively utilized for real-time measurement and analysis of magnetic fields, supporting reliable magnetic field characterization in applied physics experiments.

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