

Electromagnetic Field in the Mini Tesla Coil Experiment

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The Tesla coil, an invention credited to Nikola Tesla, functions as a transformer operating at high frequencies and voltages. It generates electromagnetic induction around its coil, with the strength of this induction varying according to the voltage and electric current applied. Experimental findings indicate that increasing voltage results in a proportional increase in electric current, consequently amplifying the electromagnetic field generated during the experiment. This phenomenon can be quantified using the Electromagnetic Field equation, $B = \frac{\mu_0 IN}{l}$, allowing for precise calculation of the electromagnetic field produced. For example, when subjected to a voltage of 3 Volts, the coil produces a substantial electromagnetic field measuring 2.04×10^{-5} Tesla, whereas at 5 Volts, this field escalates to 3.45×10^{-5} Tesla. These observations suggest that incorporating additional coils enhances the transmission of electrical power wirelessly. The efficacy and efficiency of Tesla coils in transmitting power without wires have been extensively validated, indicating promising prospects for future technological advancements. This research also opens up possibilities for enhancing energy efficiency in the energy transfer process, thereby aiding in reducing energy losses within the system and advancing sustainability.

Keyword: *Magnetic field, Tesla Coil, Voltage, Solenoid, Experiment.*

1. INTRODUCTION

One of the most crucial and indispensable human needs in daily life is the requirement for electrical energy. Virtually incapable of adequately performing tasks or meeting needs without it, humans heavily rely on electricity. Its transmission to load centers is facilitated through a network of cables ranging from high to low voltage. Copper cables serve as the conduit for this electrical energy transfer, owing to their abundance of mobile electrons. When connected to a power source, electrons can freely move within copper. However, advancements in technology have led to the development of energy transfer technologies aimed at enhancing convenience and conserving materials used in cable production.

An emerging research concept in electrical energy transmission is wireless power transfer. Wireless transfer entails the conveyance of energy without the use of cables. In the 19th century, scientist Nikola Tesla pioneered research into transmitter and receiver systems for wireless power. Electromagnetic induction systems, such as those explored in Tesla coils, were developed for this purpose. Tesla's Wardenclyffe Tower was intended to serve as a global power and information transmitter but was ultimately demolished due to funding issues before becoming operational. The Tesla Coil, a high-frequency, high-voltage transformer devised by Nikola Tesla, can generate electromagnetic induction in its vicinity. Various factors influence the magnitude of this electromagnetic induction. Motivated by this backdrop, researchers are intrigued to investigate the Magnitude of Electromagnetic Induction in Mini Tesla Coils.

2. MATERIALS AND METHODS

2.1 Methods

The type of research used is Real Experiment research where researchers conduct experiments directly. The data in this study were obtained directly through the stages of experimentation and direct calculation.

To calculate the size of the resulting magnetic field, use the magnetic field equation at the center of the solenoid (Griffiths, 2013), namely

$$B = \frac{\mu_0 IN}{l}$$

2.2 Materials

Tesla Coil and Mini Tesla Coil

Tesla coil is a high voltage generator that has a high frequency but with a small current capable of producing electromagnetic waves (Zuliyanto, 2017) Mini Tesla Coil is a small version of the Tesla Coil designed for experimentation, demonstration, or as a hobby project. Although its size is smaller and its output power is not as high as the larger Tesla Coil, the Mini Tesla Coil still maintains some of the basic principles of the Tesla Coil in general.



Figure 2.1 Mini Tesla Coil

Working principle of Tesla Coil

The working principle of the Tesla Coil is almost the same as the working principle of the transformer. The primary coil produces electromagnetic wave induction when flowed by an electric current that surrounds the primary coil. Electric current flows from the end of the conductor wire to the other end to produce EMF (Electric Motion Force). The direction of the electromotive force can be adjusted from the power source. The amount of magnetic induction received is directly proportional to the voltage value and directly proportional to the number of turns (Tesla, 1892). So it can be concluded that voltage and magnetic induction are closely related. Magnetic fields are safer when exposed to biological creatures than electrical energy so that magnetic fields are safer to use in the energy transfer process (Zuliyanto, 2017).

Coils

There are two types of primary coil types: flat spiral and helix. Flat-spiral coils are shaped like mosquito coils while helix coils are vertically circular. If the secondary and primary coils have a similar frequency the performance of the circuit is optimized. Therefore, wire diameter, coil shape, type of enamel wire need to be considered. The inductance of the electro magnetic wave is very influential. The basic concept behind this electromagnetic wireless power transfer is magnetic induction between the sending and receiving coils. The primary coil is the transmitter and the receiver is the secondary coil, the magnetic field is generated by the current in the primary coil this field induces a current in the receiver. This received current is used to

generate power. The secondary coil has a much larger number of turns of wire than the primary coil. Therefore, a much larger voltage is induced in the secondary coil (Utama, et al 2021).

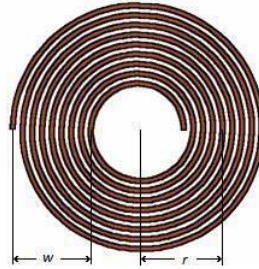


Figure 2.2 Flat Spiral Coil

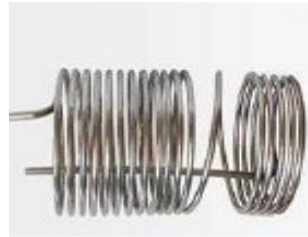


Figure 2.3 Helical Coil

Magnetostatics is a physics topic about magnetic fields whose magnitude is always constant, it is caused by electric currents that always move constantly without any change in current. On a wire that is electrified the magnetic field can be calculated using the Biot-Savart law; With infinitesimal magnitude of the magnetic field on the infinitesimal path of the current at point P is;

$$dB = \frac{\mu_0}{4\pi} \frac{i \, dl}{r^2} \sin \theta$$

Solenoids

A solenoid is a type of long wire coil arranged so that the electric current flowing through the coil creates a magnetic field along the axis of the coil. (Griffiths, 2013) Basic Principles of Solenoids :

1. **Wire Coils:** A solenoid usually consists of a coil of long wire arranged in a helical or spiral shape. Electric current flows through this coil.
2. **Magnetic Field:** The current flowing through the coil creates a magnetic field along the axis of the solenoid. This magnetic field pattern is similar to the magnetic field pattern of a magnetic rod, and the direction of the field can be determined using the right-hand rule.
3. **Magnetic Strength:** The magnetic strength of a solenoid depends on several factors, including the number of turns of wire, the current flowing, and the physical properties of the coil.

The magnetic field on a solenoid can be calculated using a formula based on the principles of electromagnetism. For a long solenoid, the formula for the magnetic field (B) at the center point of the solenoid can be expressed as follows:

$$B = \frac{\mu_0 IN}{l}$$

2.3 Data Collection Techniques

Data collection technique using the following table.

Table 2.1 Data Processing Table

Electric Voltage (V)	Magnetic Field (B)

2.4 Work Procedure

The procedures in this research are

1. Conducting literature studies
2. Preparing 1 set of Mini Tesla Coil tools
3. Conducting research / data collection activities
4. Calculating the magnitude of the electromagnetic field on the Mini Tesla Coil.
5. Data analyst.

3. RESULTS AND DISCUSSION

This research is done by changing the voltage to find out how much electric current enters the mini tesla coil. Data on voltage and electric current can be seen in the following table:

Table 3.1 Voltage and Electric Current

Voltage (V)	Current (I)	Average Current (I)
3	1,88	1,866667
	1,87	
	1,85	
3,2	1,97	1,973333
	1,97	

	1,98	
3,4	2,13	2,14
	2,15	
	2,14	
3,6	2,28	2,29
	2,3	
	2,29	
3,8	2,4	2,4
	2,39	
	2,41	
4.0	2,56	2,56
	2,55	
	2,57	
4,2	2,71	2,72
	2,72	
	2,73	
4,4	2,84	2,85
	2,86	
	2,85	
4,6	2,96	2,97
	2,98	
	2,97	
4,8	3,09	3,093333
	3,09	
	3,1	
5,0	3,15	3,16
	3,17	
	3,16	

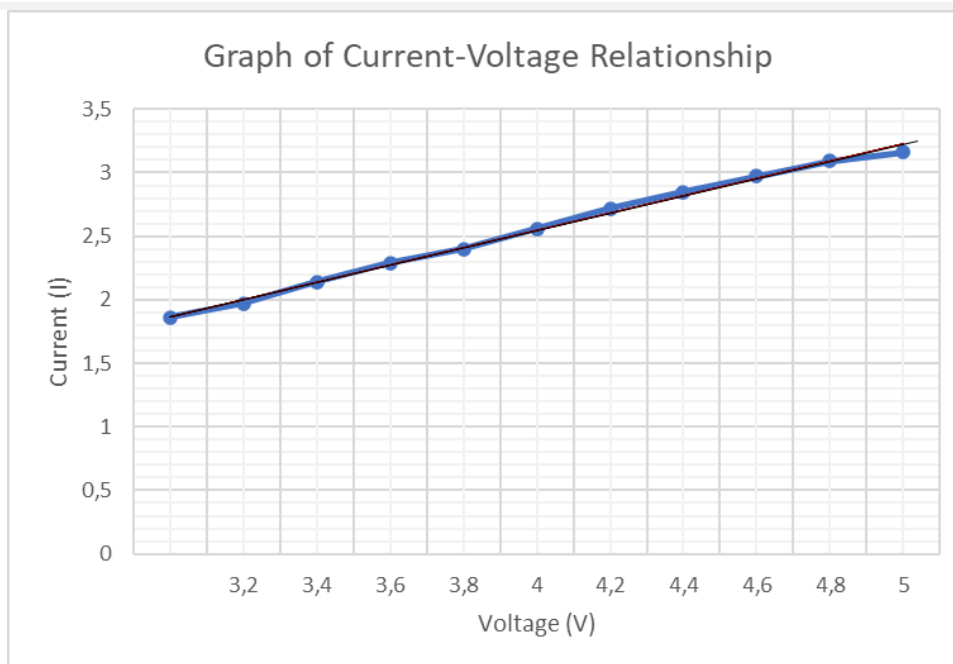


Figure 3. 1 The relation of Current & Voltage

It can be seen based on the table of experimental results that the electric current generated is not constant or changing so that researchers must take the average value of the resulting current. Based on the graph, it can be seen that the change in electric current based on voltage is not linear or abstract.

Table 3.2 the change in electric current based on voltage

Voltage (V)	Magnetic Field (B)
3	$2,04 \times 10^{-5}$
3,2	$2,15 \times 10^{-5}$
3,4	$2,33 \times 10^{-5}$
3,6	$2,50 \times 10^{-5}$
3,8	$2,62 \times 10^{-5}$
4	$2,79 \times 10^{-5}$
4,2	$2,97 \times 10^{-5}$
4,4	$3,11 \times 10^{-5}$
4,6	$3,24 \times 10^{-5}$
4,8	$3,37 \times 10^{-5}$
5	$3,45 \times 10^{-5}$

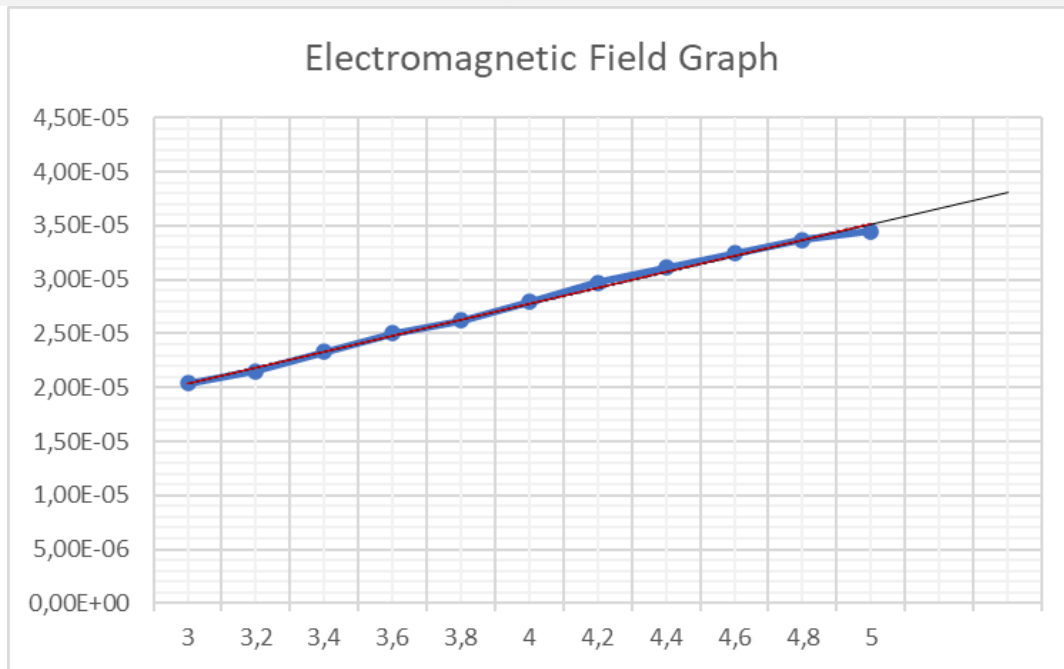


Figure 3. 2 Electromagnetic Field Graph

Based on the table of magnetic field size based on voltage, it can be seen that the greater the voltage, the greater the magnetic field produced. The calculation of the magnetic field is calculated using the magnetic field equation at the center of the solenoid, namely $B = \frac{\mu_0 I N}{l}$. It can be seen through the graph that the amount of magnetic field produced is not linear or abstract, but we can predict the amount of magnetic field at a greater voltage

4. CONCLUSION

Based on the results of the experiment, it is found that the magnitude of the electromagnetic field in the mini tesla coil experiment will be greater as the voltage increases. The experiment was conducted starting from a voltage of 3 V because at that voltage the electric spark began to appear on the mini tesla coil. At a voltage of 3 V, the electromagnetic field is 2.04×10^{-5} and at a voltage of 5 V it is 3.45×10^{-5} .

The efficacy and efficiency of Tesla coils in transmitting power without wires have been extensively validated, indicating promising prospects for future technological advancements. This research also opens up possibilities for enhancing energy efficiency in the energy transfer process, thereby aiding in reducing energy losses within the system and advancing sustainability.



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