

A Coil Of Wire 0.20 M Long And Having 200 Turns Carries A Current Of 10 A.(a) What Is The Magnitude Of

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Understanding electromagnetic phenomena and the properties of coils is fundamental in physics and electrical engineering. When dealing with a coil of wire, such as one that is 0.20 meters long with 200 turns carrying a current of 10 amperes, several key parameters come into play. These include magnetic field strength, magnetic flux, inductance, and other related quantities. In this article, we delve into the calculation of these properties, especially focusing on the magnetic field magnitude, and explore related concepts to provide a comprehensive understanding of coils in electromagnetic contexts.

Introduction to Coils and Their Magnetic Properties

A coil of wire, often called a solenoid when wound in a cylindrical shape, is a fundamental component in electromagnetism. When an electric current passes through the coil, it produces a magnetic field similar to that of a bar magnet. This magnetic field's strength and characteristics are crucial in designing electromagnets, transformers, inductors, and various electrical devices.

The key parameters affecting the coil's magnetic properties include:

- Number of turns (N)
- Length of the coil (L)
- Current passing through the coil (I)
- The core material (if any)

In our scenario, the specific parameters are:

- Length of the coil, $L = 0.20$ meters
- Number of turns, $N = 200$
- Current, $I = 10$ amperes

Using these, we can determine the magnetic field at the center of the coil, magnetic flux, and inductance.

Calculating the Magnetic Field of a Coil

The magnetic field generated by a solenoid (a coil of wire) at its center is a primary quantity of interest. It is given by a well-known formula derived from Ampère's Law:

Magnetic Field at the Center of a Solenoid

$$B = \mu_0 \times \frac{N}{L} \times I$$

Where:

- B = Magnetic flux density (Tesla)
- μ_0 = Permeability of free space ($4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}$)
- N = Number of turns
- L = Length of the coil (meters)
- I = Current (amperes)

Applying the given data:

$$B = 4\pi \times 10^{-7} \times \frac{200}{0.20} \times 10$$

Calculating step-by-step:

1. Calculate $\frac{N}{L}$:

$$\frac{200}{0.20} = 1000 \text{ turns/m}$$

2. Multiply by current:

$$1000 \times 10 = 10,000$$

3. Multiply by μ_0 :

$$4\pi \times 10^{-7} \times 10,000$$

$$= 4\pi \times 10^{-7} \times 10^4$$

$$= 4\pi \times 10^{-3}$$

4. Final calculation:

$$[B = 4 \times 3.1416 \times 10^{-3}]$$

$$[\approx 12.5664 \times 10^{-3}]$$

$$[= 0.01257 \text{ , } \text{Tesla}]$$

Therefore, the magnetic field at the center of the coil is approximately 0.01257 Tesla.

Understanding the Significance of the Magnetic Field

A magnetic field of approximately 12.57 millitesla (mT) is significant in various applications, such as:

- Electromagnetic relays
- Magnetic sensors
- Inductive components in circuits

The magnitude of the magnetic field directly influences the coil's efficiency in generating magnetic flux, which is essential in energy transfer and magnetic coupling.

Calculating Magnetic Flux Through the Coil

Magnetic flux (Φ) is the amount of magnetic field passing through a given area. For a solenoid, assuming a uniform magnetic field within the coil, the flux is calculated as:

$$[\Phi = B \times A]$$

Where:

- (A) = Cross-sectional area of the coil (square meters)

To find (Φ), the cross-sectional area must be known or estimated. If the coil's radius or diameter is provided, we can proceed. Otherwise, this remains a theoretical calculation.

Suppose the coil's radius (r) is known or estimated; then:

$$[A = \pi r^2]$$

Once (A) is known, compute:

$$\Phi = 0.01257 \times A$$

This flux is crucial in understanding how much magnetic energy is stored and how the coil interacts with other magnetic components.

Calculating the Inductance of the Coil

Inductance (L) indicates the coil's ability to oppose changes in current. For a solenoid, the inductance is given by:

$$L = \mu_0 \times \frac{N^2}{l} \times A$$

Where:

- A = Cross-sectional area (square meters)

Assuming the coil's radius (r) is known, the calculation proceeds as follows:

1. Calculate A :

$$A = \pi r^2$$

2. Insert into the inductance formula:

$$L = 4\pi \times 10^{-7} \times \frac{(200)^2}{0.20} \times A$$

3. Simplify:

$$L = 4\pi \times 10^{-7} \times \frac{40,000}{0.20} \times A$$

$$L = 4\pi \times 10^{-7} \times 200,000 \times A$$

$$L = (4\pi \times 200,000) \times 10^{-7} \times A$$

$$L = (800,000\pi) \times 10^{-7} \times A$$

$$L \approx 2.513 \times A, \text{ (Henry)}$$

This demonstrates the proportionality between the coil's cross-sectional area and its inductance.

Practical Applications of Such Coils

Coils with specified parameters are vital in multiple electrical and electronic devices. Some common applications include:

- Electromagnets: Used in cranes, magnetic locks, and relays.
- Transformers: Coils of specific turns and sizes facilitate voltage conversion.
- Inductive Sensors: Detect proximity, position, or current.
- Wireless Charging: Inductive coils transfer energy wirelessly.

Understanding the magnetic properties enables engineers to design these components effectively.

Factors Affecting the Magnetic Field and Inductance

While the calculations above assume ideal conditions, real-world factors influence the magnetic properties:

- Core Material: Using ferromagnetic cores increases magnetic flux density significantly.
- Wire Resistance: Resistance causes energy loss and heat.
- Coil Winding Precision: Uniform turns ensure consistent magnetic fields.
- Surrounding Environment: Nearby magnetic materials can distort the field.

Designers must consider these factors to optimize coil performance.

Conclusion

In summary, a coil of wire measuring 0.20 meters in length, with 200 turns carrying a current of 10 amperes, produces a magnetic field of approximately 0.01257 Tesla at its center. This magnetic field underpins many practical applications in electromagnetism and electrical engineering. Calculations of magnetic flux and inductance further inform the coil's behavior and potential uses. By understanding these parameters, engineers and students can better design and utilize coils for various technological solutions, from electromagnetic devices to energy transfer systems.

Additional Resources for Further Learning

- Electromagnetism Tutorials – Understanding magnetic fields and their relation to current
- Designing Coils and Solenoids – Practical guidelines and calculations

- Inductance and Magnetic Flux – Deep dive into coil properties
- Applications of Electromagnetic Coils – Real-world devices and innovations

Whether you're a student, engineer, or hobbyist, mastering the fundamentals of coil magnetic properties is essential for advancing in the field of electromagnetism and electrical engineering.

Frequently Asked Questions

What is the magnetic field strength at the center of a coil of wire that is 0.20 m long with 200 turns carrying a 10 A current?

The magnetic field at the center of the coil can be calculated using $B = (\mu_0 N I) / (2 R)$. First, determine the radius from the coil length and turns, then apply the formula. Assuming a solenoid approximation, $B \approx \mu_0 n I$, where $n = N / \text{length}$. Plugging in the values gives $B \approx (4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}) (200 / 0.20 \text{ m}) 10 \text{ A} \approx 0.1256 \text{ Tesla}$.

How do you calculate the magnetic field produced by a coil with 200 turns and a current of 10 A?

Use the formula for the magnetic field of a solenoid: $B = \mu_0 (N / L) I$, where N is the number of turns, L is the length of the coil, and I is the current. Substituting $N=200$, $L=0.20 \text{ m}$, and $I=10 \text{ A}$ yields $B \approx 0.1256 \text{ Tesla}$.

What is the significance of the number of turns in a coil carrying a current of 10 A?

The number of turns (200 in this case) directly affects the magnetic field strength; more turns result in a stronger magnetic field for the same current, as the field is proportional to N in the solenoid formula.

How does the length of the wire coil (0.20 m) influence the magnetic field generated?

The length of the coil inversely affects the magnetic field strength; a shorter coil with the same number of turns and current produces a stronger magnetic field, as N/L increases the magnetic field according to the solenoid formula.

What is the typical application of a coil with these specifications carrying

10 A current?

Such a coil can be used in electromagnets, inductors, or transformer cores where controlled magnetic fields are necessary for applications like electric motors, magnetic resonance imaging (MRI), or inductive charging systems.

How would increasing the number of turns in the coil affect the magnetic field if the current remains constant?

Increasing the number of turns increases the magnetic field strength proportionally, as $B \propto N$, resulting in a stronger magnetic field for the same current.

Additional Resources

A Coil Of Wire 0.20 M Long And Having 200 Turns Carries A Current Of 10 A: An In-Depth Analysis of Magnetic Properties and Calculations

When exploring electromagnetic phenomena, coils of wire are fundamental components that demonstrate the principles of electromagnetism vividly. The specific scenario involving a coil of wire that is 0.20 meters long, has 200 turns, and carries a current of 10 amperes offers an excellent opportunity to understand the magnetic field production, inductance, and related electromagnetic concepts. This article aims to dissect this problem thoroughly, providing detailed calculations, theoretical insights, and practical implications, thereby enriching your understanding of coils in electromagnetic applications.

Understanding the Basic Parameters of the Coil

Before delving into calculations, it's essential to understand the given parameters:

- Length of the coil, L : 0.20 meters
- Number of turns, N : 200
- Current flowing through the wire, I : 10 amperes

These parameters set the stage for analyzing the magnetic field, inductance, and other electromagnetic characteristics of the coil.

Magnetic Field at the Center of the Coil

Calculating the Magnetic Field (B)

One of the primary reasons for studying coils is their ability to produce magnetic fields. For a solenoid (a long coil), the magnetic field at the center is given approximately by:

$$B = \mu_0 \times \frac{N}{L} \times I$$

Where:

- μ_0 = permeability of free space = $4\pi \times 10^{-7} \text{ T} \cdot \text{m/A}$
- N = number of turns
- L = length of the coil
- I = current

Substituting the known values:

$$B = 4\pi \times 10^{-7} \times \frac{200}{0.20} \times 10$$

Calculating step-by-step:

- $\frac{200}{0.20} = 1000$
- $4\pi \times 10^{-7} \times 1000 \times 10$

Simplify:

$$B = 4\pi \times 10^{-7} \times 10,000$$

$$B = 4\pi \times 10^{-3} \text{ T}$$

Since $4\pi \approx 12.566$, the magnetic field becomes:

$$B \approx 12.566 \times 10^{-3} \text{ T}$$

$$B \approx 0.0126 \text{ T}$$

Result: The magnetic field at the center of the coil is approximately 12.6 milliteslas (mT).

Features & Implications of the Magnetic Field Calculation

- The magnetic field strength depends directly on the current and the number of turns per unit length.
- This magnetic field is uniform at the center of a long solenoid, which makes such coils ideal for applications requiring consistent magnetic fields.

- The calculated value indicates a moderate magnetic field suitable for various laboratory and industrial applications.

Pros:

- Simple formula provides quick estimation.
- Demonstrates the influence of coil parameters on magnetic field strength.

Cons:

- Assumes an ideal solenoid with infinitely long length; real coils have edge effects.
- Does not account for the coil's wire thickness or magnetic materials, which can enhance or diminish the field.

Calculating the Magnetic Field Using the Biot-Savart Law

While the previous approximation works well for long solenoids, the Biot–Savart Law offers a more precise method, especially for coils of finite length.

Biot–Savart Law Overview

The Biot–Savart Law states that the magnetic field $\mathbf{B}$ at a point in space due to a current element $d\mathbf{l}$ is:

$$d\mathbf{B} = \frac{\mu_0}{4\pi} \frac{I d\mathbf{l} \times \hat{\mathbf{r}}}{r^2}$$

For a coil, integrating this law over all current elements provides the magnetic field at desired points, often requiring numerical methods or approximations.

Application to the Coil

For a finite solenoid, the magnetic field at the center can be approximated as:

$$B = \frac{\mu_0 N I}{2L} \left(\frac{z_2}{\sqrt{z_2^2 + R^2}} - \frac{z_1}{\sqrt{z_1^2 + R^2}} \right)$$

Where:

- R is the coil radius
- z_1 and z_2 are the positions along the axis (for center, symmetric)

Since the problem doesn't specify the radius, the initial approximation suffices.

Calculating the Magnetic Dipole Moment

The magnetic dipole moment μ is an important characteristic of the coil, especially for understanding its behavior in external magnetic fields.

$$\mu = N I A$$

Where:

- N = number of turns
- I = current
- A = cross-sectional area of the coil

Assuming a radius r , the area:

$$A = \pi r^2$$

Without the radius, we can only express the magnetic dipole moment in terms of r :

$$\mu = 200 \times 10 \times \pi r^2 = 2000 \pi r^2, \text{A}\cdot\text{m}^2$$

This value indicates the coil's ability to interact with magnetic fields—larger dipole moments imply stronger interactions.

Inductance of the Coil

Inductance is crucial for understanding the coil's response in AC circuits and transient phenomena.

Formula for a Solenoid

The inductance L of a long solenoid is given by:

$$L = \mu_0 N^2 \frac{A}{l}$$

Expressed explicitly:

$$L = \mu_0 \times N^2 \times \frac{\pi r^2}{l}$$

Again, without the radius (r), this remains a variable expression:

$$L = 4\pi \times 10^{-7} \times 200^2 \times \frac{\pi r^2}{0.2}$$

Calculating constants:

$$L = 4\pi \times 10^{-7} \times 40,000 \times \frac{\pi r^2}{0.2}$$

$$L = (4\pi \times 40,000 \times \pi / 0.2) \times 10^{-7} r^2$$

Simplifying:

$$L = \left(4 \times 3.1416 \times 40,000 \times 3.1416 / 0.2\right) \times 10^{-7} r^2$$

Further calculation:

- $(4 \times 3.1416 \approx 12.566)$
- $(12.566 \times 40,000 \approx 502,654.4)$
- $(502,654.4 \times 3.1416 \approx 1,577,664.4)$
- Dividing by 0.2:

$$\frac{1,577,664.4}{0.2} \approx 7,888,322$$

Finally, including 10^{-7} :

$$L \approx 7.888 \times 10^{-1} r^2, \text{H}$$

Or,

$$L \approx 0.789 r^2, \text{Henrys}$$

Thus, the inductance depends quadratically on the radius of the coil.

Features & Implications:

- Larger radii increase the inductance significantly.
- Inductance determines how the coil opposes changes in current, affecting transient response.

Practical Applications and Significance

Coils such as the one described are ubiquitous in various electrical devices:

- Transformers: Coils with many turns are used to transfer energy between circuits.
- Electromagnets: Coils generate strong magnetic fields for lifting or magnetic separation.
- Inductors in Circuits: Coils store magnetic energy and oppose rapid current changes in AC circuits.
- Wireless Charging: Coils facilitate the transfer of energy wirelessly through magnetic coupling.

Pros:

- Versatility in applications, from power electronics to sensing.
- Simple construction and understanding.

Cons:

- Resistance losses due to wire material and length.
- Limited magnetic field strength compared to core-enhanced devices.
- Finite size effects reduce ideality, especially in short coils.

Additional Considerations and Advanced Topics

- Core Material: Introducing ferromagnetic cores increases the magnetic field strength substantially.
- Skin Effect: At high frequencies, current tends to concentrate near the wire surface, affecting inductance and resistance.
- Mutual Induction: Multiple coils interacting can produce complex behaviors, crucial in transformers and inductive coupling.
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