University of Al-Mustaqbal
College of Science
Department of Medical Physics

Magnetism

the practical aspect

Second Stage

Measurement of the Magnetic Moment of a Circular Coil

Lec 8

Asst. lec. Ali Jaafar

Asst. lec. Zainab jassim

Mohammed abdulzahra

The objective of the experiment :

The purpose of this experiment is to determine the magnetic moment of a circular current-carrying coil by measuring the magnetic field it produces at its center. The experiment also aims to verify the relationship between coil geometry, current, and the resulting magnetic field, and to compare experimental values with theoretical predictions based on electromagnetism principles.

Equipment used in the experiment :

1. Circular coil with known number of turns (N)
2. DC power supply
3. Ammeter
4. Gaussmeter or magnetic field sensor
5. Rheostat (variable resistor)
6. Ruler or caliper (for coil radius measurement)
7. Compass (optional for direction verification)
8. Connecting wires
9. Stand or holder for the coil

Theory of the Experiment:

A circular loop carrying electric current produces a magnetic field. The magnitude of this magnetic field depends on several factors including the radius of the loop, the current passing through it, and the number of turns of the coil.

Magnetic Field at the Center of a Circular Coil:

The magnetic field generated at the center of a circular coil of radius (R), carrying current (I), with (N) turns, is given by:

$B = \mu_0 NI/2R$

Where:

- (B) = magnetic field at the center (Tesla)
- (I) = current in the coil (Ampere)
- (R) = radius of the coil (meter)
- (N) = number of turns
- ($\mu_0 = 4\pi \times 10^{-7}$ T·m/A)

Explanation of the Formula:

This formula comes from the **Biot–Savart law**, which describes the magnetic field produced by a small segment of current. When the entire circular loop is considered, integrating the contributions from each element gives the above expression.

The field increases when:

- current increases
- number of turns increases
- radius decreases

This shows the inverse relationship between coil size and field strength.

Magnetic Moment of a Coil:

The **magnetic moment (m)** of a current-carrying coil is defined as:

$$m = N\,I\,A$$

Where:

- ($A = \pi r^2$) is the coil area
- (NI) is the magnetizing current multiplied by number of turns

Physical Meaning

The magnetic moment is a measure of the coil's ability to produce magnetic torque when placed in an external magnetic field. Larger magnetic moments indicate stronger “magnetic strength.”

Relationship Between Magnetic Field and Magnetic Moment:

The magnetic field at the center of a circular coil can be rewritten using magnetic moment:

$$B = \frac{\mu_0 m}{2\pi R^3}$$

This shows a powerful physical relationship:

- The magnetic field is proportional to the magnetic moment
- The field decreases rapidly (with $1/R^3$) as distance increases

This is the basis for measuring magnetic moment experimentally.

Strategy of the Experiment

By measuring (B) and knowing (I), (N), and (R), we can compute the magnetic moment using:

m = N I \πR^2

OR, using the measured field:

m= $2\pi R^3 B/\mu_0$

Comparing both gives the experimental error.

The method of work :

1. Measure the radius of the circular coil using a ruler or caliper.
2. Connect the coil in series with the ammeter, rheostat, and DC power supply.
3. Position the Gaussmeter sensor at the center of the coil.
4. Set the current to a known value and record the magnetic field reading.
5. Repeat the measurement for various current values (e.g., 0.2 A, 0.4 A, 0.6 A,…).
6. For each current, calculate theoretical (B) using the formula:

$$B = \mu_0 NI/2R$$

Compute magnetic moment using both formulas:

m = N I \πR^2

m= $2\pi R^3 B/\mu_0$

7. Compare the experimental and theoretical values.
8. Calculate percentage error.
9. Plot graphs:
    - (B) vs (I)
    - (m) vs (I)

Discussion

1. The magnetic moment of a circular coil is given by:

A. (NI/R)
B. (NI^2)
C. (NI\πR^2)
D. (IR^3)
E. (N/ R^2)

2. Magnetic field at the center of a circular coil is:

A. inversely proportional to current
B. directly proportional to current
C. independent of current
D. proportional to (R^3)
E. zero

3. Increasing the number of turns (N) will:

A. decrease magnetic field
B. reverse the field
C. increase magnetic field
D. have no effect
E. turn the coil into a capacitor

4. The area of a circular coil is:

A. (2R)
B. (4\ π R)
C. (πR^2)
D. (R^3)
E. (R/2)

5. The magnetic moment represents:

A. electric power
B. resistance
C. magnetic strength
D. energy loss
E. coil temperature

6. The SI unit of magnetic moment is:

A. Tesla
B. Ampere
C. Joule
D. $A \cdot m^2$
E. Henry

7. The magnetic field at the center of a coil decreases when:

A. current increases
B. radius increases
C. number of turns increases
D. permeability increases
E. coil area decreases

8. The constant (mμ_0) is:

A. electric charge constant
B. gravitational constant
C. permeability of free space
D. resistivity constant
E. none

9. The relationship between (B) and (m) at the center of the coil is:

A. (B \prop to m)
B. (B \prop to 1/m)
C. (B = m^2)
D. (B) independent of (m)
E. (B = 0)

10. Which instrument measures magnetic field?

A. Voltmeter
B. Ohmmeter
C. Gaussmeter
D. Ammeter
E. Potentiometer

11. The coil is placed horizontally so that:

A. it heats evenly
B. field spreads equally
C. Gaussmeter can measure B correctly
D. wires do not tangle
E. current increases

12. Increasing coil radius does what to magnetic moment?

A. Increases (because (m \prop to R^2))
B. Decreases
C. No effect
D. Makes it infinite
E. Makes it zero

13. The Biot–Savart law helps calculate:

A. resistance
B. magnetic field from current
C. electric field
D. heat loss
E. coil energy

14. Magnetic moment is maximum when:

A. current → zero
B. radius → zero
C. area and current both large
D. core is removed
E. coil is broken

15. In the experiment, percentage error compares:

A. voltage and power
B. measured and theoretical values
C. two resistors
D. coil temperature
E. number of turns