T.C.

GEBZE TECHNICAL UNIVERSITY

PHYSICS DEPARTMENT

PHYSICS LABORATORY II

EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Magnetic moment of a conducting loop in the magnetic field

PREPARED BY

NAME AND SURNAME:

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DEPARTMENT:

GROUP NO :

TEACHING ASSISTANT:

DATE OF THE EXPERIMENT : ….. / ….. / ……….

DATE : ….. / ….. / ……….

Signature:

Experiment Setup:

The experimental setup is shown below at Figure 7.4.

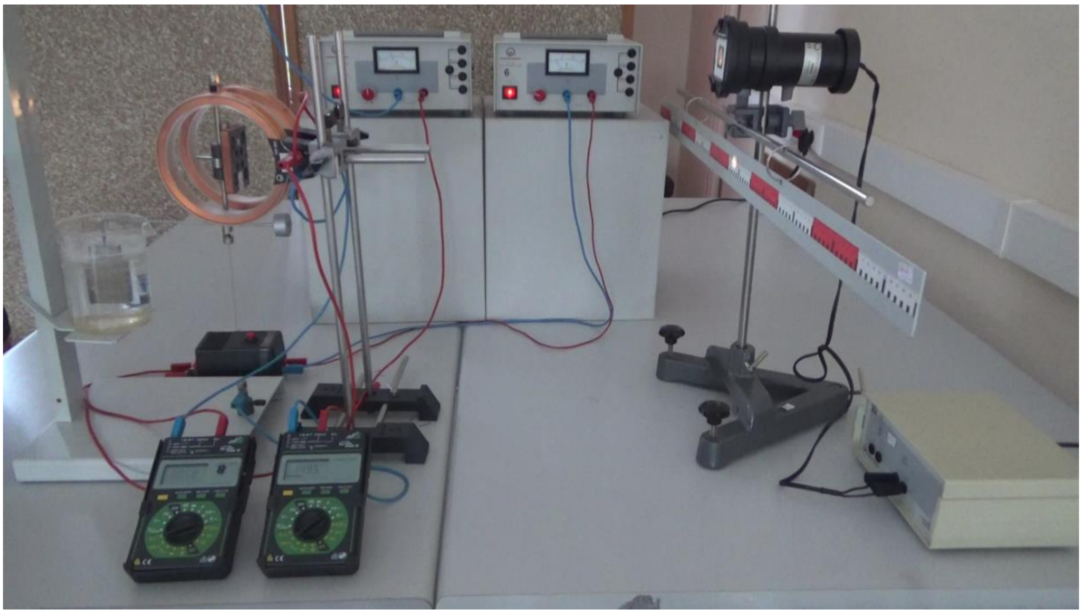


Figure 7.4: Magnetic moment of a conducting loop in the magnetic field experimental setup

Experimental Procedure:

1. Make sure the power supplies are turned off.
2. Set multimeters to DC / Ampere mode.
3. Plug in the halogen lamp's power supply.
4. Make sure the light falls on the ruler.
5. Measure the distance between the ruler and the mirror. ($L = 60\ cm$)
6. Switch on the power supply connected to the Helmholtz coils.
7. You can check the polarity of the current using the pole switch.
8. Set the Helmholtz current (I_H) by using power supply connected to the Helmholtz coils. Keep the current constant during the experiment.
9. Adjust the position of the light on the ruler to be $x_0 = 50\ cm$.
10. Turn on the power supply to which the rectangular loop is connected.
11. Set the current (I_L) on rectangular loop by using the power supply connected to the loop. Wait for the light falling on the ruler to stabilize.
12. Read the deviations x_1 and x_2, where the light falls on the ruler.
13. Calculate the angular deviations, $\left[\alpha_{avg} = \frac{|x_1 - x_2|}{2L}\right]$, and the magnetic torques via Equation 7.11, $[\tau = D\alpha_{avg}]$.
14. Afterwards, repeat the same steps by keeping the current applied to the rectangular loop (I_L) constant, read the deviations x_1 and x_2 by scanning the current (I_H) applied to the Helmholtz coils.

Table 7.1: $I_H = 0.50\ A$; $D = 3{,}9 \times 10^{-4}$ N·m$/rad$; $L = 60\ cm$

$I_L(A)$	x_1(cm)	x_2 (cm)	$\alpha_{avg} = \frac{\lvert x_1 - x_2 \rvert}{2L}\ (rad)$	$\tau = D\alpha_{avg}$ (N·m)
0.05				
0.10				
0.15				
0.20				

Table 7.2: $I_H = 1.00\ A$; $D = 3{,}9 \times 10^{-4}$ N·m$/rad$; $L = 60\ cm$

I_L (A)	x_1(cm)	x_2 (cm)	$\alpha_{avg} = \frac{\lvert x_1 - x_2 \rvert}{2L}\ (rad)$	$\tau = D\alpha_{avg}$ (N·m)
0.05				
0.10				
0.15				
0.20				

Table 7.3: $I_L = 0.05\ A$; $D = 3{,}9 \times 10^{-4}$ N·m$/rad$; $L = 60\ cm$

I_H (A)	x_1(cm)	x_2 (cm)	$\alpha_{avg} = \frac{\lvert x_1 - x_2 \rvert}{2L}\ (rad)$	$\tau = D\alpha_{avg}$ (N·m)
0.50				
1.00				
1.50				
2.00				

Table 7.4: $I_L = 0.10\ A$; $D = 3{,}9 \times 10^{-4}$ N·m$/rad$; $L = 60\ cm$

I_H (A)	x_1(cm)	x_2 (cm)	$\alpha_{avg} = \frac{\lvert x_1 - x_2 \rvert}{2L}\ (rad)$	$\tau = D\alpha_{avg}$ (N·m)
0.50				
1.00				
1.50				
2.00				

Calculations and Analysis:

In the experiment, the magnetic torque τ_{mag} is measured depending on the current. The current passing through the Helmholtz coils will cause the magnetic field, which induces a torque on the current loop, that causes it to rotate. As the loop is attached to a vertically pinched wire of finite torsional stiffness, magnetic torque τ_{mag} is balanced by an elastic torque τ_{el} With the help of this balance, the effects of the current passing through the rectangular loop and Helmholtz coils on the magnetic torque will be analyzed.

I. Torque as a function of the current in the rectangular loop:

According to equation $\vec{\tau} = \vec{\mu} \times \vec{B}$ where $\vec{\mu} = NI_L\vec{A}$, the magnetic torque is directly proportional to the current on the conducting rectangular loop $\tau \propto I_L$. Hence, We expect a line in the form of $y = mx$, where m is the slope of the line, passing through those points and the origin. Use τ and I_L columns of Tables 7.1–2 and calculate the slopes of the lines by means of the statistical linear fitting method called "*least squares method*" its formulae are given below.

i) I_H=0.50 A

$$\sum_{i=1}^{k} I_{L_i}\tau_i =$$

$$\sum_{i=1}^{k} I_{L_i}^2 =$$

$$m_{0.50} = \frac{\sum_{i=1}^{k} I_{L_i}\tau_i}{\sum_{i=1}^{k} I_{L_i}^2} =$$

ii) I_H=1.00 A

$$\sum_{i=1}^{k} I_{L_i}\tau_i =$$

$$\sum_{i=1}^{k} I_{L_i}^2 =$$

$$m_{1.00} = \frac{\sum_{i=1}^{k} I_{L_i}\tau_i}{\sum_{i=1}^{k} I_{L_i}^2} =$$

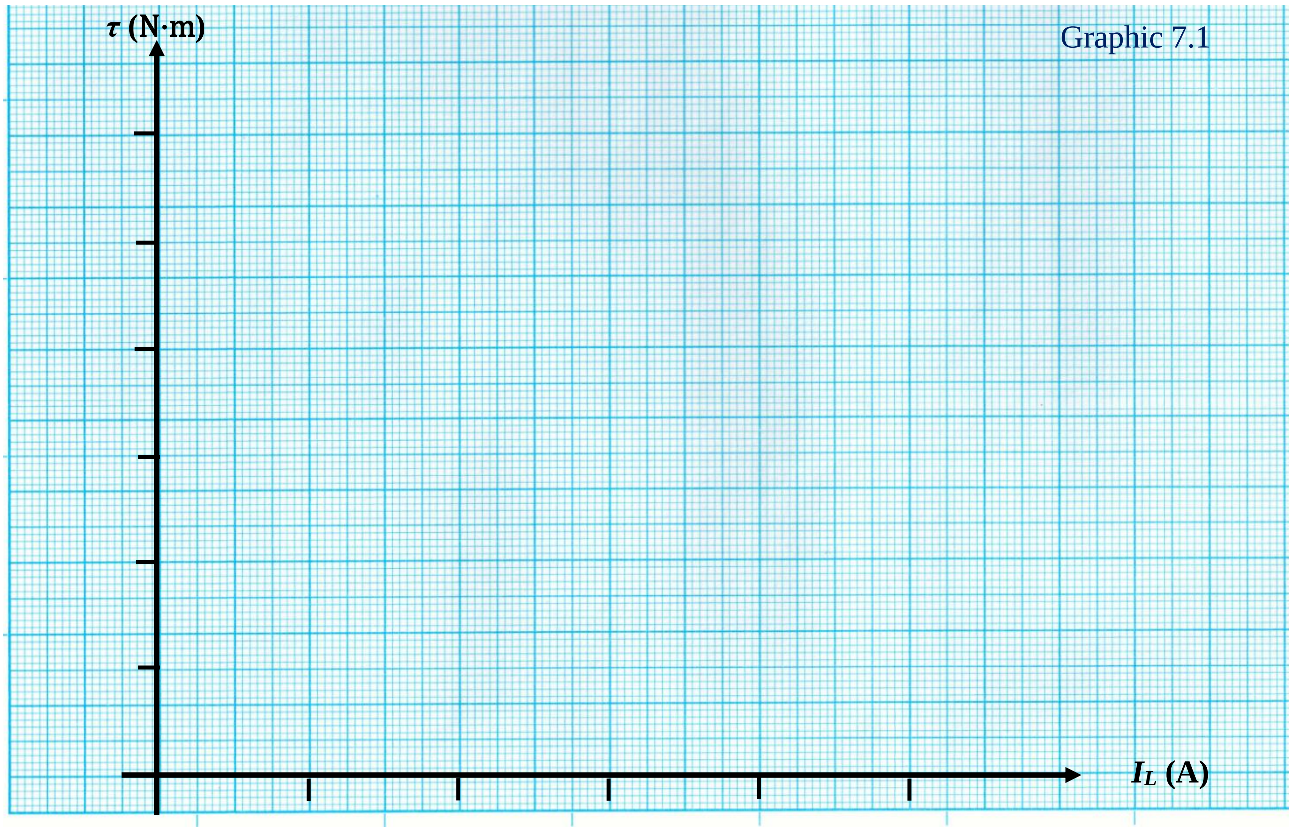
As we know from equation, if the steady current I_H flows through the Helmholtz coils; the induced magnetic field B is constant. Calculate and compare the magnetic fields B induced by the coils. Write the unit of the magnetic field B in terms of Tesla.

Number of turns of rectangular loop is $N = 100$, area of the loop is $A = 35 \times 10^{-4}\, m^2$. $\left[\vec{\tau} = \vec{\mu} \times \vec{B} = NI_LAB \Rightarrow \frac{\tau}{I_L} = m \Rightarrow B = \frac{m}{N \cdot A}\right]$

i) $B_{0.50} = \frac{m_{0.50}}{N \cdot A} =$

ii) $B_{1.00} = \frac{m_{1.00}}{N \cdot A} =$

In order to examine torque due to a magnetic moment in a uniform magnetic field as a function of the rectangular loop current I_L, plot $\tau - I_L$ graph for each current on Helmholtz coils I_H using data sets from Tables 7.1–2. Represent the I_L values on the x-axis, while the τvalues on the y-axis of your graphs. Mark the data points on your graph and draw the straight lines $y = mx$, where the slopes m's are calculated for each current on Helmholtz coils I_H in the previous step. Use those m values to plot the lines that are passing from the origin on your graph and observe how they fit with your experimental data points.



Graphic 7.1

Why are the slopes of the lines different from each other? Please explain. What can you say about the effect of I_L on magnetic torque and magnetic moment of the rectangular loop?

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II. Torque as a function of the current in the Helmholtz coils:

According to Equation 7.10 [$\tau = NI_L A \cdot \kappa I_H \cdot \sin\alpha = \mu \cdot B \cdot \sin\alpha$], torque is directly proportional to the inducted magnetic fields of the Helmholtz coils ($B = \kappa I_H$), hence $\tau \propto I_H$. Therefore, we expect a line in the form of $y = mx$, where m is the slope of the line, passing through those points and the origin. Use τ and I_H columns of Tables 7.3–4 and calculate the slope of the line by means of the statistical linear fitting method called "*least squares method*" its formulae are given below.

i) I_L = 0.05 A

$$\sum_{i=1}^{k} I_{H_i}\tau_i =$$

$$m_{0.05} = \frac{\sum_{i=1}^{k} I_{H_i}\tau_i}{\sum_{i=1}^{k} I_{H_i}^2} =$$

$$\sum_{i=1}^{k} I_{H_i}^2 =$$

ii) I_L = 0.10 A

$$\sum_{i=1}^{k} I_{H_i}\tau_i =$$

$$m_{0.10} = \frac{\sum_{i=1}^{k} I_{H_i}\tau_i}{\sum_{i=1}^{k} I_{H_i}^2} =$$

$$\sum_{i=1}^{k} I_{H_i}^2 =$$

Number of turns of rectangular loop is $N = 100$, area of the loop is $A = 35 \times 10^{-4}\ m^2$.

Calculate magnetic dipole moments (μ) of rectangular loop for the currents I_L.

$i)\ I_L = 0.05\ A \Rightarrow\ \mu_{0.05} = NI_L A =$

$ii)\ I_L = 0.10\ A \Rightarrow \mu_{0.10} = NI_L A =$

Use Equation 7.10 [$\tau = NI_L A \cdot \kappa I_H$] and calculate the proportionality coefficients κ.

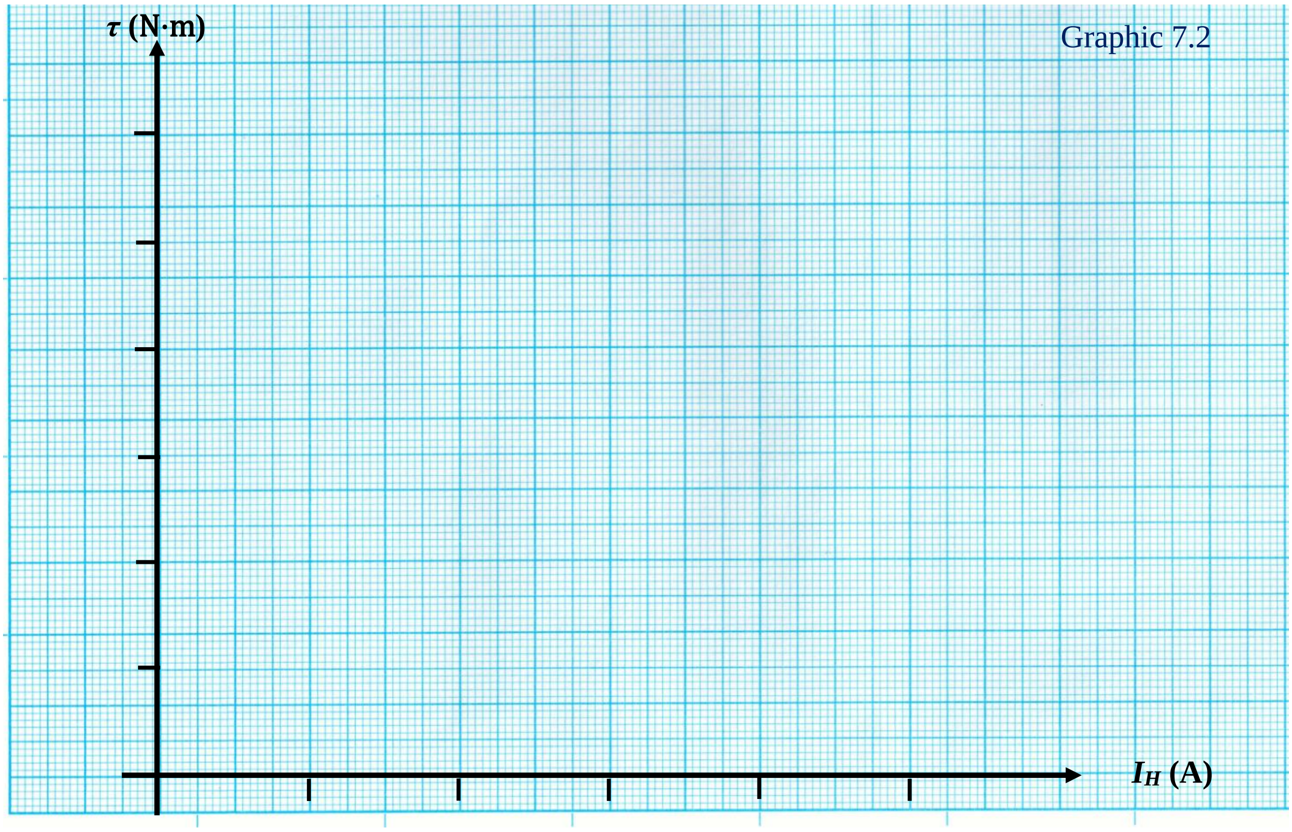
$$\left[\kappa = \left(\frac{\tau}{I_H}\right)\left(\frac{1}{NI_L A}\right) = \frac{m}{\mu}\right]$$

$i)\ \kappa_{0.05} = \dfrac{m_{0.05}}{\mu_{0.05}} =$

$ii)\ \kappa_{0.10} = \dfrac{m_{0.10}}{\mu_{0.10}} =$

What is your expectation about the κvalues, should the calculated κ be equal or not? If the result is different from your predictions, please explain why? What does κ represent, what is its physical meaning in the setup.

In order to examine torque due to a magnetic moment in a uniform magnetic field as a function of the Helmholtz coils current I_H, plot $\tau - I_H$ graph for each current on rectangular loop I_L using data sets from Tables 7.3–4. Represent the I_H values on the $x-$axis, while the τ values on the $y-$axis of your graphs. Mark the data points on your graph and draw the straight lines $y = mx$, where the slopes m's are calculated for each current on Helmholtz coils I_H in the previous step. Use those m values to plot the lines that are passing from the origin on your graph and observe how they fit with your experimental data points.



Why are the slopes of the lines different from each other? Please explain. What can you say about the effect of I_H on the exerted magnetic torque to the rectangular loop?

Conclusion, Comment and Discussion:

(Tips: Explain your general observations and experimental findings objectively and scientifically with your original sentences. Please give detailed explanations about what you have learned from the experiment and also explain the possible errors and their reasons.)

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Questions:

1. Describe the operating principle of the electric motor.

2. Obtain the magnetic torque ($\vec{\tau} = \vec{\mu} \times \vec{B}$) formula using the torque formula ($\vec{\tau} = \vec{r} \times \vec{F}$).

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