T.C.

GEBZE TECHNICAL UNIVERSITY

PHYSICS DEPARTMENT

PHYSICS LABORATORY II

EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Magnetic Fields of Single Coils / Biot-Savart's Law

PREPARED BY

NAME AND SURNAME :
STUDENT NUMBER :
DEPARTMENT :
GROUP NO :
TEACHING ASSISTANT :
DATE OF THE EXPERIMENT : ….. / ….. / ……….
DATE : ….. / ….. / ……….

Signature:

Experimental Procedure:

The Biot-Savart law experiment for circular conducting loops is performed using rings of different radii, power supply, tesla meter. Basically, the magnetic field is generated by moving charges, i.e., electric current. In the experiment, we will examine how the magnetic field changes depending on the radius of the ring, the magnitude of the current passing through the ring and the distance from the center of the loop.

Experimental set-up is given in Figure 4.1.

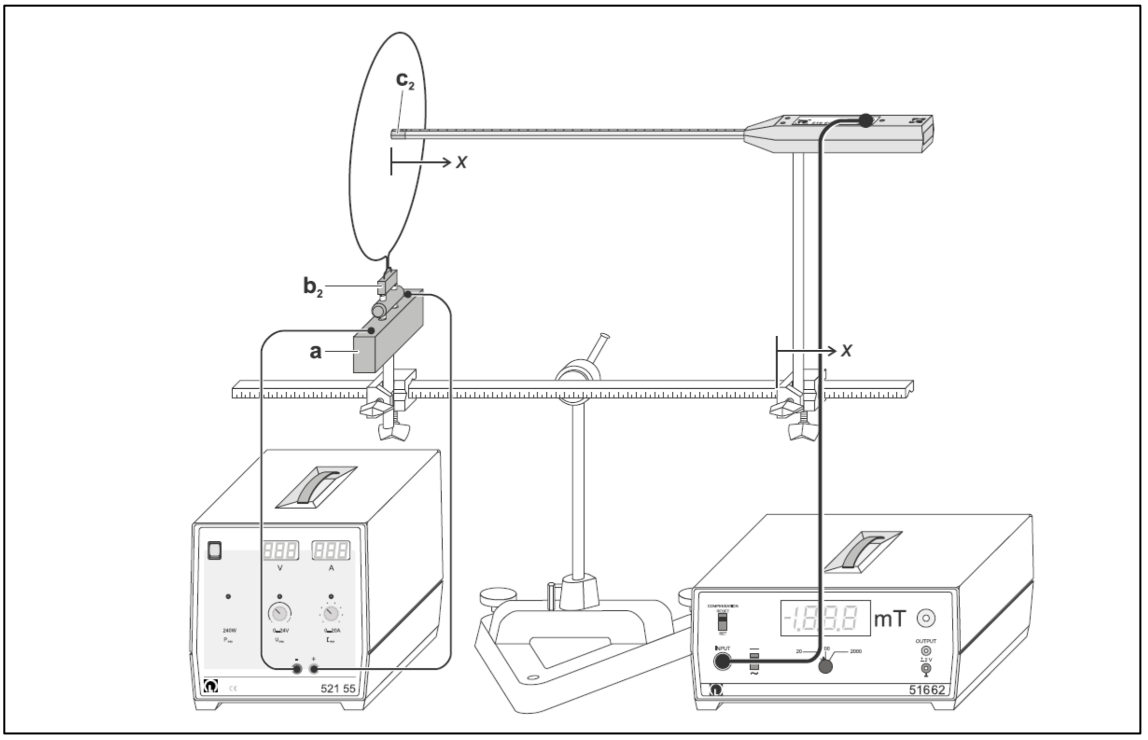


Figure 4.1: Biot-Savart experiment set-up for conductive rings.

Warning: ***During the experiment, conducting rings could be hot because of high current. Do not touch or interfere with the rings when power supply is on. Please turn off the power supply when making changes to the experimental set-up.***

I. The dependence of the magnetic field on the current passing through the conducting ring:

1. Switch on the tesla meter and calibrate the zero with the key compensation.
2. Connect the conducting ring with radius 2 cm to the power supply.
3. Place the tip of magnetic field sensor probe at center of the ring.
4. Switch on the power supply, and increase the current I from 0 to 12 A in steps of 2 A. Each time measure the magnetic field B, and fill in tables below.
5. Repeat the same procedure for rings with a radius of 4 and 6 cm.

Table 4.1: Magnetic field as a function of current for the ring with radius of 2 cm.

I (A)	0	2	4	6	8	10	12
B (mT)							

Table 4.2: Magnetic field as a function of current for the ring with radius of 4 cm.

I (A)	0	2	4	6	8	10	12
B (mT)							

Table 4.3: Magnetic field as a function of current for the ring with radius of 6 cm.

I (A)	0	2	4	6	8	10	12
B (mT)							

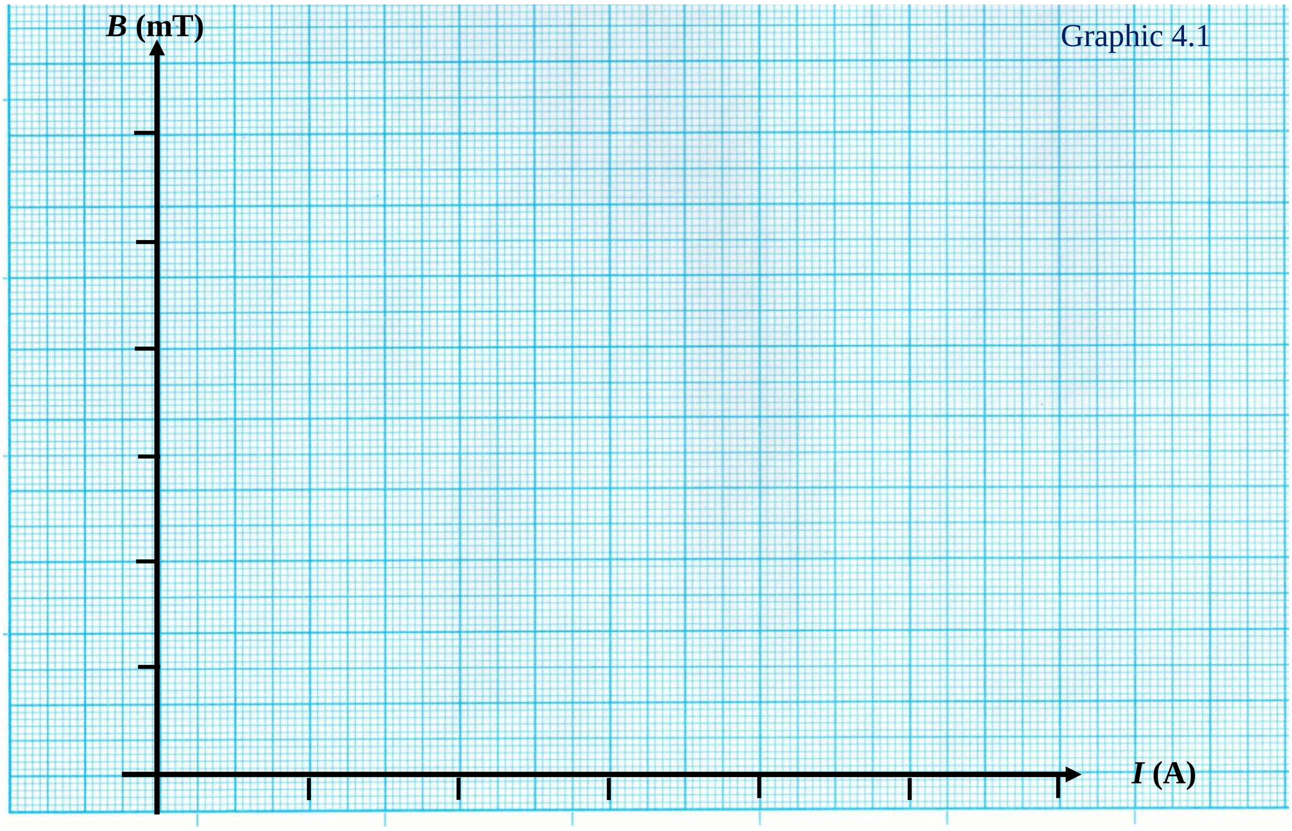
According to the Biot Savart law, the magnetic field at the center of current carrying circular conductive loop is given by the Equation 4.6,

$$B = \frac{\mu_0}{2\,R} I \qquad 4.6$$

To observe the relationship between current and magnetic field for a ring, plot I – B graphs using rows of Tables 4.1–3.

In Equation, 4.1, if magnetic permeability μ_0 and the radius R of the ring are constant, it is clear that magnetic field B is directly proportional to the current I. Therefore, we expect a line in the form of $y = mx$, where m is the slope of the line, passing through the data points and the origin. The slope of the line should be calculated by means of the statistical linear fitting method called the "*least squares method*" its formulae are given below.

For each circular conducting loop, plot I vs. B graphs. Represent the current I and magnetic field B values on x– and y–axis, respectively. Mark the data points on your graph, and draw the straight lines $y = mx$, where the slopes m are calculated in the previous steps, passing from the origin.



Calculate the slopes of the lines that fit the data points on your I *vs.* B graphs, which are plotted in the previous step. In the following formulae, the x_i's represent the current I, while the y_i's represent the magnetic field B at center of the loop. k is the number of data used in calculations.

i) *R* = 2 cm;

$$\sum_{i=1}^{k} x_i\, y_i =$$

$$m_1 = \frac{\sum_{i=1}^{k} x_i\, y_i}{\sum_{i=1}^{k} x_i^2} =$$

$$\sum_{i=1}^{k} x_i^2 =$$

ii) *R* = 4 cm;

$$\sum_{i=1}^{k} x_i\, y_i =$$

$$m_2 = \frac{\sum_{i=1}^{k} x_i\, y_i}{\sum_{i=1}^{k} x_i^2} =$$

$$\sum_{i=1}^{k} x_i^2 =$$

iii) *R* = 6 cm;

$$\sum_{i=1}^{k} x_i\, y_i =$$

$$\sum_{i=1}^{k} x_i^2 =$$

$$m_3 = \frac{\sum_{i=1}^{k} x_i\, y_i}{\sum_{i=1}^{k} x_i^2} =$$

Using calculated m values and known R parameters, we can calculate the magnetic permeability μ_0 using the equation $\left[B = \frac{\mu_0}{2\,R} I \Rightarrow \mu_0 = \frac{B}{I} 2R \Rightarrow \mu_0 = m\, 2R\right]$.Then, compare your results with theoretical value of μ_0 (1.2566×10^{-6} T·m/A).(*Show the calculations in the space given below.*)

$i)\ R = 2\ cm = 2 \times 10^{-2}\ m \ \Rightarrow \mu_0 = m_1\ 2R =$ $\mu_0 =$ ___________T·m/A

$ii)\ R = 4\ cm = 4 \times 10^{-2}\ m \ \Rightarrow \mu_0 = m_2\ 2R =$ $\mu_0 =$ ___________T·m/A

$iii)\ R = 6\ cm = 6 \times 10^{-2}\ m \ \Rightarrow \mu_0 = m_3\ 2R =$ $\mu_0 =$ ___________T·m/A

Are the calculated magnetic permeability μ_0 values equal? If not, discuss the possible reasons.

II. The dependence of the magnetic field on the radius of the conducting rings:

In order to examine the relationship between the magnetic field B at the center of the rings and their radii R, create the following Table 4.4 using only the data in columns of I = 12A of Tables 4.1–3.

Table 4.4: Magnetic field as a function of radius of conducting loop.

R (cm)	B (mT)	$\log R$	$\log B$
2			
4			
6			

You are asked to plot R vs. B graph using first two columns of Table 4.4. Choose the x–axis as *radius of the ring* (R) and the y–axis as *magnetic field* (B). Represent the data as points on your plots. Draw the curve on your graph that fits best to your data points by *crude eye estimation*. What type of a curve is expected to pass through those points, why?

As it can be seen from your previous R vs. B graph, the relation between those quantities is not linear. However, it can still be investigated using the linear fitting methods by manipulating the radius (R)–magnetic field (B) relationship. We begin with assuming a relationship between magnetic field and radius of loop in the following form:

$$B \propto R^{\alpha} \Rightarrow B = \kappa R^{\alpha} \qquad 4.7$$

If we take the logarithm of Equation 4.7, we get Equation 4.8

$$\log B = \log \kappa + \alpha \log R \qquad 4.8$$

Note that this is a linear relation of the form $y = n + mx$. So if we take $\log B$ and $\log R$ as our variables from Table 4.4, we can determine the values of α and $\log \kappa$ by linear fitting techniques.

Calculate the slope α and the intercept $\log \kappa$ of the line using the linear fitting formula that fits the data points on your $\log R - \log B$ graph. In the following sums, the x_i's represent the $\log R$ values on the x–axis, while the y_i's represent the $\log B$ values on the y–axis of your graphs. k is the number of data used in calculations.

$$\sum_{i=1}^{k} x_i =$$

$$\sum_{i=1}^{k} y_i =$$

$$\sum_{i=1}^{k} x_i^2 =$$

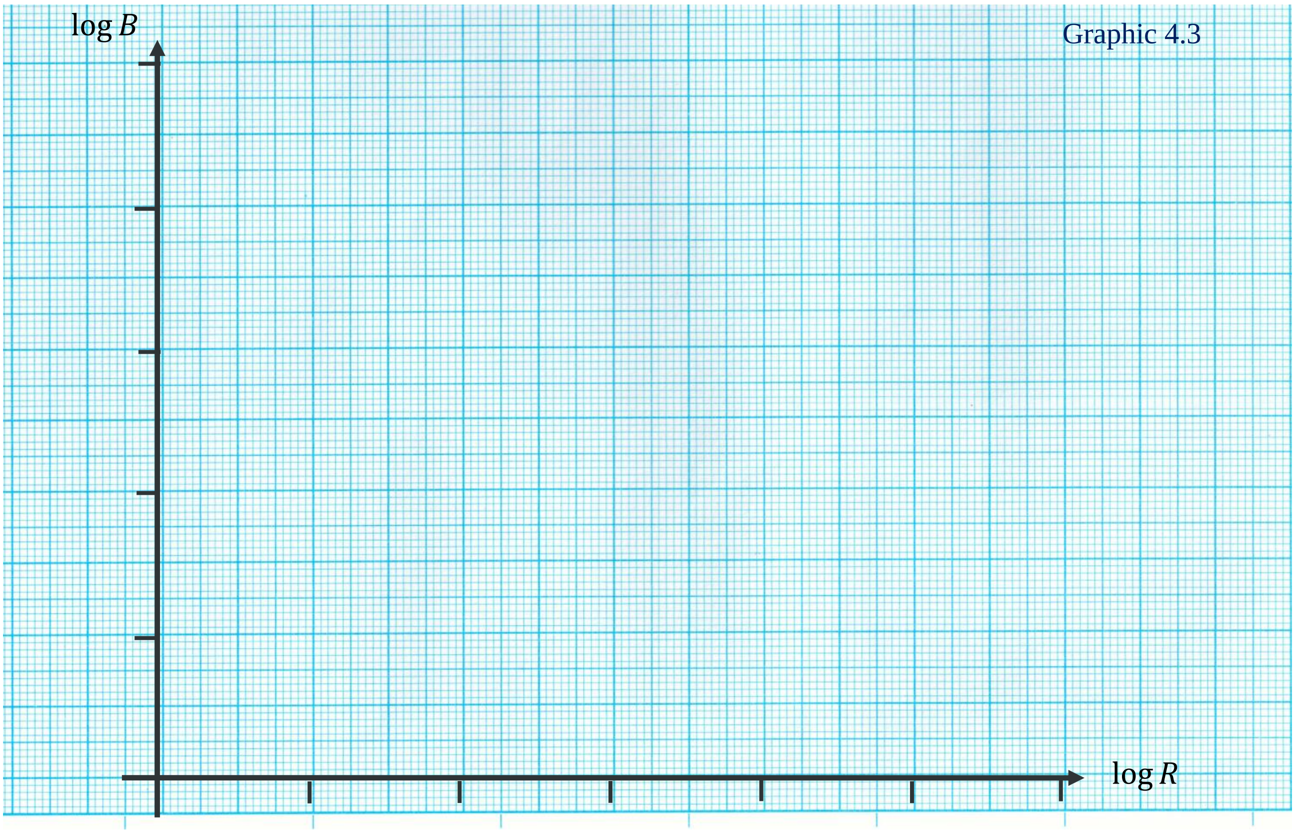
$$\sum_{i=1}^{k} x_i\, y_i =$$

$$\alpha = \frac{3\sum_{i=1}^{3} x_i\, y_i - \sum_{i=1}^{3} x_i \sum_{i=1}^{3} y_i}{3\sum_{i=1}^{3} x_i^2 - \left(\sum_{i=1}^{3} x_i\right)^2} =$$

$$\log \kappa = \frac{\sum_{i=1}^{3} x_i^2 \sum_{i=1}^{3} y_i - \sum_{i=1}^{3} x_i\, y_i \sum_{i=1}^{3} x_i}{3\sum_{i=1}^{3} x_i^2 - \left(\sum_{i=1}^{3} x_i\right)^2} =$$

Compare your calculated α to its expected value. Discuss the reasons for possible causes of differences.

In the following graph, plot $\log R - \log B$ using $\log R$ and $\log B$ columns of Table 4.4 as x– and y–axis, respectively. Represent the data as points on your graph and draw the straight line $\log B = \log \kappa + \alpha \log R$



Considering the graph you plotted above, what can you say about the relationship between the magnetic field of a conducting circular loop and its radius. Please explain, the effect of the radius of the loop on the induced magnetic field at the center of the circular loop.

III. The dependence of the magnetic field on the distance from center of the conducting ring:

1. Switch on the tesla meter and calibrate the zero with the key compensation.
2. Connect the circular conducting loop with radius 4 cm to the power supply.
3. Place the tip of magnetic field sensor probe at center of the ring.
4. Switch on the power supply, and set the current *I* to 12 A.
5. Move the tip of magnetic field sensor probe away from the ring. Beginning from center of the ring, increase the distance *x* up to 5 cm in 1 cm steps. Each time measure the magnetic field *B*, and fill in tables below.
6. Repeat the same procedure for rings with a radius of 4 and 6 cm.

Table 4.5: Magnetic field as a function of distance from the center of the ring with 2 cm in radius.

x (cm)	0	1	2	3	4	5
B (mT)						

Table 4.6: Magnetic field as a function of distance from the center of the ring with 4 cm in radius.

x (cm)	0	1	2	3	4	5
B (mT)						

Table 4.7: Magnetic field as a function of distance from the center of the ring with 6 cm in radius.

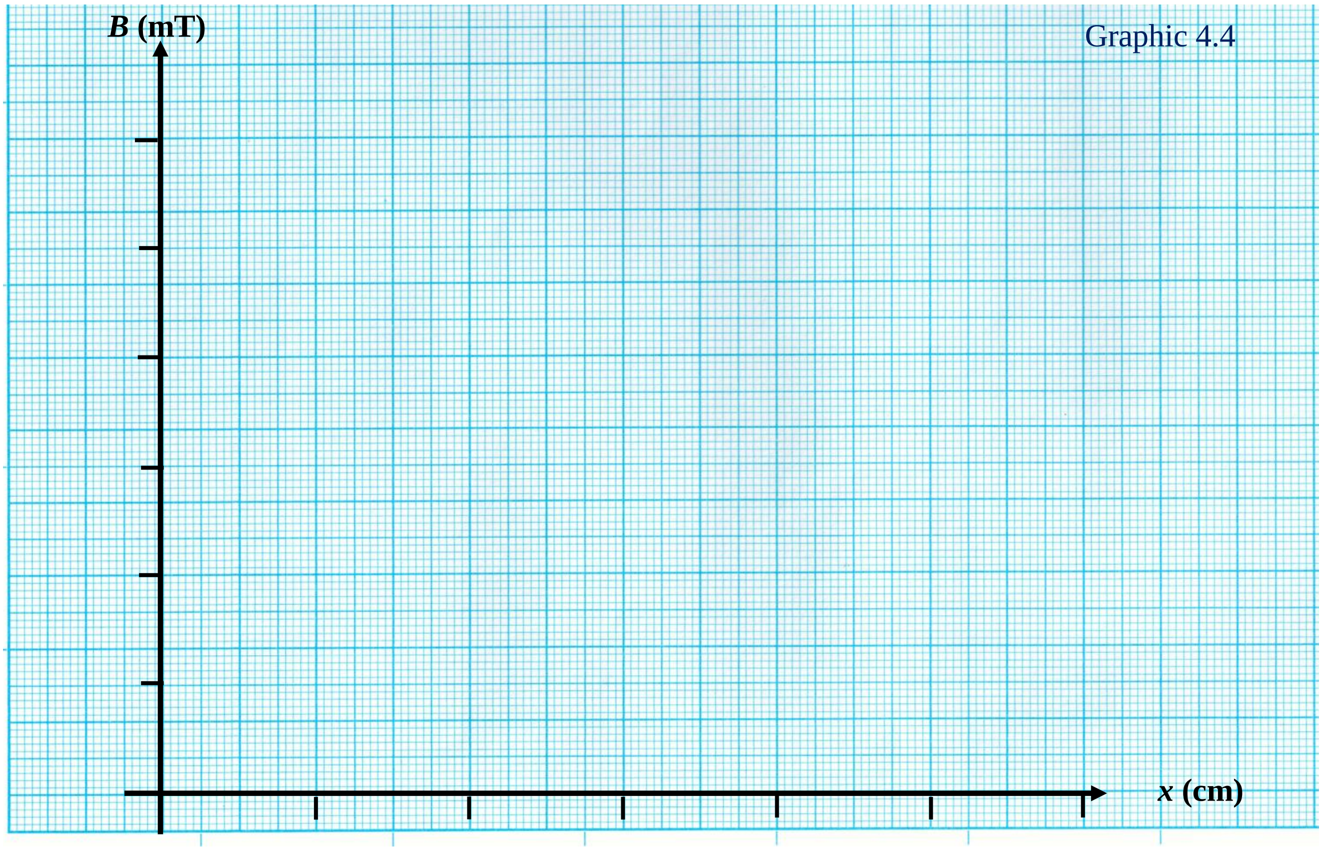
x (cm)	0	1	2	3	4	5
B (mT)						

According to the Biot Savart law, the magnetic field at the distance from the center of current carrying circular conductive loop is given by Equation 4.5;

$$B_x = \frac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}} \qquad 4.5$$

To investigate the dependence of magnetic field *B* on the distance *x* from center ring, plot *x* – *B* graphs using rows of Tables 4.5–7.

You are asked to plot *x* vs. *B* graph using Tables 4.5–7. Choose the *x*–axis as *the distance from the center of the rings* (*x*) and the *y*–axis as *magnetic field* (*B*). Represent the data as points on your plots. Draw the curve on your graph that fits best to your data points by <u>*crude eye estimation*</u>. According to Equation 4.5, what type of a curve is expected to pass through those points?



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.)

Signature:

Questions:

1. Write down the definitions of magnetization (M), magnetic dipole moment (μ), magnetic flux (Φ), magnetic induction (magnetic flux density) (B) and magnetic field strength (H).

2. Write down the units of the physical quantities that you defined in the previous question and find their derived units in terms of basic quantities of the SI system.

3. Write down the physical meaning of magnetic permeability μ_0, and find its derived units in terms of basic quantities of the SI system.

Signature: