

AE405 LAB-5 Magnetic field of single coils / Biot-Savart's law with a teslameter



Fig.1: Experimental Setup

PRINCIPLE AND TASK

The magnetic field along the axis of wire loops and coils of different dimensions is measured with a teslameter (Hall probe). The relationship between the maximum field strength and the dimensions is investigated and a comparison is made between the measured and the theoretical effects of position.

The goal of this experiment is to investigate the magnetic field produced by a single coil.

1. To measure the magnetic flux density in the middle of various wire loops with the Hall probe and to investigate its dependence on the radius and number of turns.
2. To determine the magnetic field constant μ_0 .
3. To measure the magnetic flux density along the axis of long coils and compare it with theoretical values.

Equipment

PHYWE Power supply, universal DC: 0...18 V, 0...5 A / AC: 2/4/6/8/10/12/15 V, 5A

PHYWE Teslameter, digital

Hall probe, axial

Induction coils, 1 set (7 coils)

Conductors, circular, set

Meter scale, l=1000 mm

Digital multimeter, 600V AC/DC, 10A AC/DC, 20 MΩ, 200μF, 20kHz, -20°C

Barrel base expert

Support rod, stainless steel, l= 250 mm, d=10 mm

Distributor

Right angle clamp expert

G-clamp

Lab jack, 200 x 200 mm

Reducing plug 4mm/2mm socket, 2

Connecting cord, 32 A, 500 mm, blue

Connecting cord, 32 A, 500 mm, red

Universal clamp

THEORY

From Maxwell's equation

$$\oint_K \vec{H} d\vec{s} = I + \int_F \vec{D} d\vec{f} \quad (1)$$

Where K is a closed curve around area F, H is the magnetic field strength, I is the current flowing through area F, and D is the electric flux density, we obtain for direct currents ($\dot{D}=0$), the magnetic flux law:

$$\oint_K \vec{H} d\vec{s} = I \quad (2)$$

With the notations from Fig.2, the magnetic flux law (2) is written in the form of Biot-Savart's law:

$$d\vec{H} = \frac{I}{4\pi} \frac{d\vec{l} \times \vec{\rho}}{\rho^3} \quad (3)$$

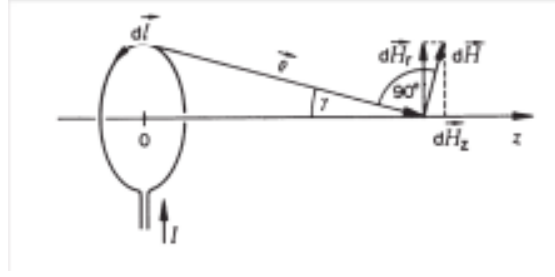


Fig.2: Drawing for the calculation of the magnetic field along the axis of a wire loop.

The vector $\vec{dl}$ is perpendicular to $\vec{r}$ in addition to this $\vec{r}$ and $\vec{dH}$ lie in the plane of the drawing, so that

$$dH = \frac{I}{4\pi\rho^2} dl = \frac{I}{4\pi} \frac{dl}{R^2 + z^2} \quad (4)$$

$\vec{dH}$ can be resolved into a radial dH_r and an axial dH_z component.

The dH_z components have the same direction for all conductors elements $\vec{dl}$ and the quantities are added;

Therefore;

$$H_r(z) = 0 \quad (5)$$

And

$$H(z) = H_z(z) = \frac{I}{2} \frac{R^2}{(R^2 + z^2)^{3/2}} \quad (6)$$

Along the axis of the wire loop, while the magnetic flux density

$$B(z) = \frac{\mu_0 \cdot I}{2} \cdot \frac{R^2}{(R^2 + z^2)^{3/2}} \quad (7)$$

Where $\mu_0 = 1.2566 \times 10^{-6} \text{ H/m}$ is the magnetic field constant. If there is a small number of identical loops close together, the magnetic flux density is obtained by multiplying by the number of turns n .

SETUP AND PROCEDURE

Set up the experiment as shown in Fig. 1. Operate the power supply as a constant current source, setting the voltage to 18 V and the current to the desired value. Measure the magnetic field strength of the coils ($I = 1 \text{ A}$) along the z -axis with the Hall probe and plot the results on a graph. Make the measurements only at the centre of the circular conductors ($I = 5 \text{ A}$). To eliminate interference fields and asymmetry in the experimental set-up, switch on the power and measure the relative change in the field. Reverse the current and measure the change again. The result is given by the average of the measured values.

CALCULATIONS

- 1- Turn on the teslameter and adjust zero point. Operate the power supply at 18V and 1A on the screen of the multimeter. Measure the magnetic flux density at different positions inside of the coils and record them in the tables. Be careful about the central measurements. Measure the length, l , of each coil. Φ is the diameter of each of the coil.

1a) For 300 turns and $\Phi = 33\text{mm}$, $l = \dots\dots\dots \text{mm}$

Distance (cm)	B (mT)
0 (center)	

1b) For 200 turns and $\Phi = 41\text{mm}$, $l = \dots\dots\dots \text{mm}$

Distance (cm)	B (mT)
0 (center)	

- 2- Determine magnetic field constant μ_0 for 1a and 1b and take average of them. (Use magnetic fields at the center of coils you measured and the formula is given)

$$B(0) = \frac{\mu_0 * I * n}{2l} * (R^2 + \frac{l}{2})^{-1/2}$$

- 3- Calculate magnetic flux density theoretically in the middle of the coils of (where $\mu_0 = 1.2566 * 10^{-6} \text{H/m}$)