HACETTEPE ÜNİVERSİTESİ
FİZİK MÜHENDİSLİĞİ BÖLÜMÜ

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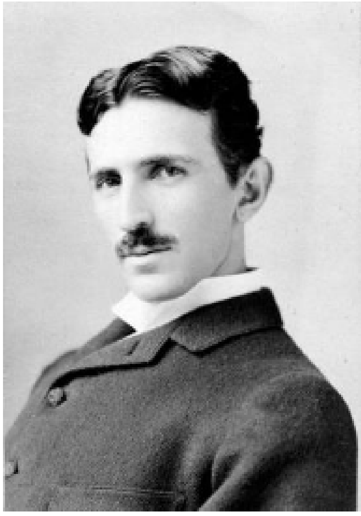
Experiment-7: Magnetic Field



Nikola Tesla (1856-1943) A **Serbian-American** physicist, inventor, electrical engineer and mechanical engineer.

Tesla was born on July 10, 1856 in Similjan, Serbia. His father was a priest and he wanted his son to be a priest like himself. Her mother was illiterate, but she was an inventor of household appliances. With the support of his mother, Nikola furthered his knowledge of physics and mathematics and studied at the Austrian Polytechnic University in Graz in 1878. Tesla is considered the father of our modern technological age and often cited as the "Genius Who Lit the World". He is best known for his inventions, especially in the design of the modern AC (alternating current) electricity supply system, which is the predominant electrical system used across the world today. At the **General Conference on Weights and Measures** in 1960, the unit of "Magnetic Flux Density" was accepted as Tesla in honour of Nikola Tesla.

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Checked.

Supervisor:

Signature:

Objectives:

Our goals in this experiment are to first examine the effect of the magnetic field generated by the Helmholtz Coil on the compass. Then the horizontal and vertical components of the Earth's magnetic field are measured and B_h is calculated.

Equipment:

Compass, Rheostat, Ammeter, Connection cables, DC power supply, Helmholtz coil, Teslameter, Hall probe.

What is Magnetic Field (B_h)?

- A moving charged particle produces a magnetic field.
- Magnetic field lines aren't visible.
- The magnetic field is a vector quantity.
- The direction of the magnetic field line is from north(N) to south(S).
- The magnetic field is represented by the letter B.
- The unit of magnetic field is tesla(T).

Lorentz's law for magnetic force

As the charge q passes through the electric field and magnetic field at velocity v, it encounters a force F. This force is explained by this law. It is the force acting on a moving point charge by electromagnetic fields.

$$\boxed{\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})}$$

- F is the force on the particle.
- q is the electric charge of the particle.
- v is the velocity of the particle.
- The first term ($q\vec{E}$) in this equation belongs to the electrostatic theory, and only the secont part ($q(\vec{v} \times \vec{B})$) will be covered in this experiment.

What is a magnet?

- There are materials that create magnetic field.
- Fe, Ni, Co are widely known magnetic materials.
- It doesn't affect some metals and non-metal materials such as Copper and Aluminum.
- Magnet consist of two poles. These are north (N) and south (S) in Fig.1.
- The equal poles of the two magnets repel each other, while the opposite poles attract each other.
- Magnetic field lines are formed between the poles of a magnet as in Fig.2.

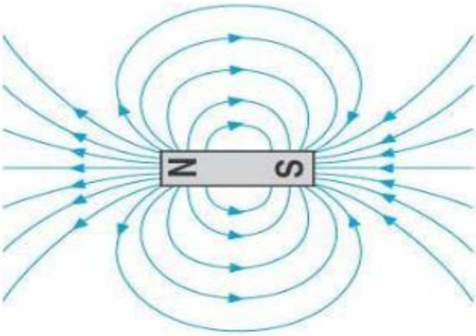

Figure.1

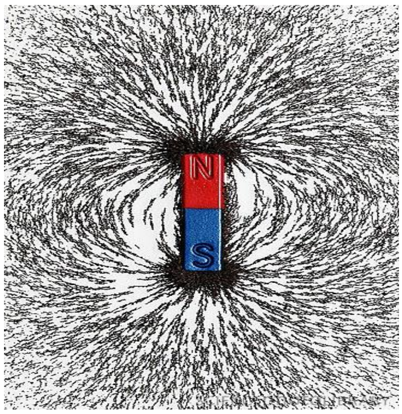

Figure.2

What is The Helmholtz Coil?

- The Helmholtz coil is a tool for generating a magnetic field.
- The Helmholtz coil consists of two solenoid electromagnets on the same axis. It must be identical in the two magnetic coils. The radius of the coils and the distance between them should be equal.
- It is often used to neutralize the external magnetic field. It produces a magnetic field strenght that is very close to zero.

We now: $B_1(x) = \dfrac{\mu_0 . N . I . R^2}{2(R^2+x^2)^{3/2}}$, $x = R/2$, $\mu_0 = 4\pi . 10^{-7}$ Tm/A

$$B_H = 2B_1\left(\frac{R}{2}\right) = \left(\frac{4}{5}\right)^{3/2} \frac{\mu_0 . N . I}{R} \qquad k = \left(\frac{4}{5}\right)^{3/2} \frac{\mu_0 . N}{R}$$

$$B_H = k . I$$

Section.1

Our aim is to determine the proportionality constant k. The Helmholtz coil is connected in series with the rheostat, power supply and ammeter. The Hall probe is placed in the center of the coils and the B_h values are measured. Graph is drawn with the created Table.1 and k constant is found.

Table.1

- Number of turns per coil $N = 154$
- Radius of the coils $R = 0.20\,m$

I(A)	B_h (mT)
0.5	0.34
1.0	0.69
1.5	1.04
2.0	1.39
2.5	1.74
3.0	2.08

Calculations.1

- Experimental k

$$B_H = k.I$$

$$\frac{\Delta B_H}{\Delta I} = k$$

$\Delta B_H = 1.1\,mT = 1.1 \times 10^{-3} T$

$\Delta I = 1.6\,A$

- $k_{experimental} = \dfrac{1.1 \times 10^{-3} T}{1.6\,A}$

$= 0.6875 \times 10^{-3} T/A$

- Theorical k

$$k = \left(\frac{4}{5}\right)^{3/2} \cdot \frac{\mu_0 . N}{R}$$

$$\mu_0 = 4\pi \times 10^{-7}\, T.m/A$$

- $k_{theorical} = \left(\dfrac{4}{5}\right)^{3/2} \cdot \dfrac{4\pi . 10^{-7}\, T.m/A \,.\, 154}{0.20\,m}$

$= 0.6923 \times 10^{-3}\, T/A$

Theorical error of k;

$$\% \text{ error} = \frac{|k_{theorical} - k_{experimental}|}{k_{theorical}} \times 100$$

$$= \frac{|0.6923 \times 10^{-3} T/A - 0.6875 \times 10^{-3} T/A|}{0.6923 \times 10^{-3} T/A} \times 100$$

$$= \%0.69$$

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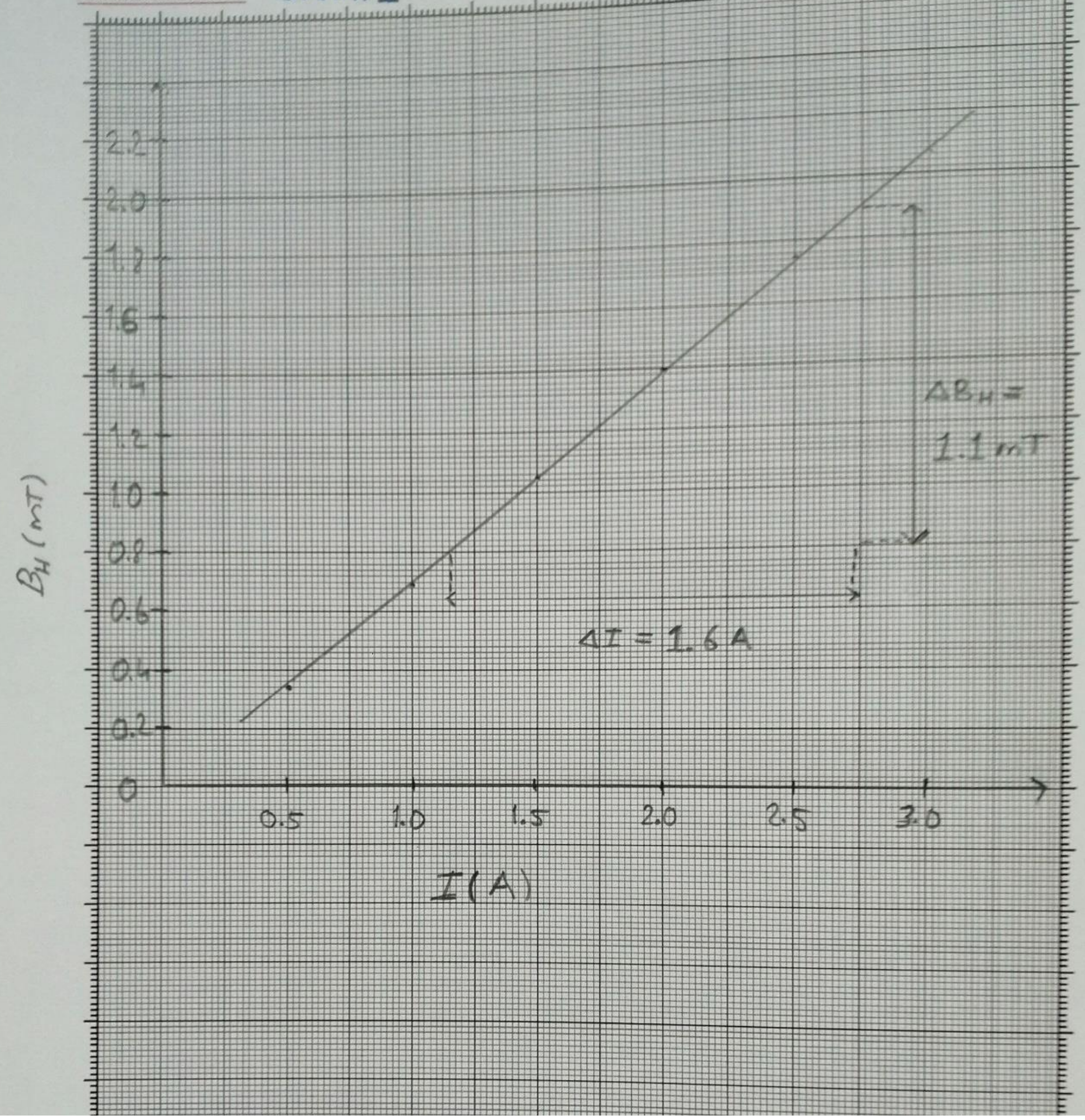
GRAPH.1



Section.2

Our aim in this section is to find the horizontal component of the Earth's magnetic field (B_E^h). We set the 0 degrees of the compass as the north-south direction. We set the generated magnetic field to be perpendicular to the north-south direction. We calculated the required angles with different current values and recorded them in Table.2.

Table.2

I (mA)	α	tanα
0	0	0
20	32.37	0.63
40	51.72	1.27
60	62.25	1.90
80	68.47	2.54
100	72.48	3.17
120	75.26	3.80
140	77.29	4.43
160	78.84	5.07
180	80.05	5.70

• $10^3 mT = 1T$

• $10^3 mA = 1A$

• $10^4 G = 1T$

Calculations.2

• $\tan\alpha = \dfrac{B_H}{B_E^h} = \dfrac{k.I}{B_E^h}$

• Slope $= \dfrac{\Delta \tan\alpha}{\Delta I} = \dfrac{k}{B_E^h} [1/mA]$

• $k_{theorical} = 0.6923 \times 10^{-3} T/A = 0.6923\ mT/A$

• $B_E^h = \dfrac{k\,[mT/A]}{\text{Slope}\,[1/mA]} = \dfrac{0.6923\,mT/A}{3.16/100\,mA} = \dfrac{0.6923\,mT/A}{31.6\ A^{-1}} = 0.022\,mT$

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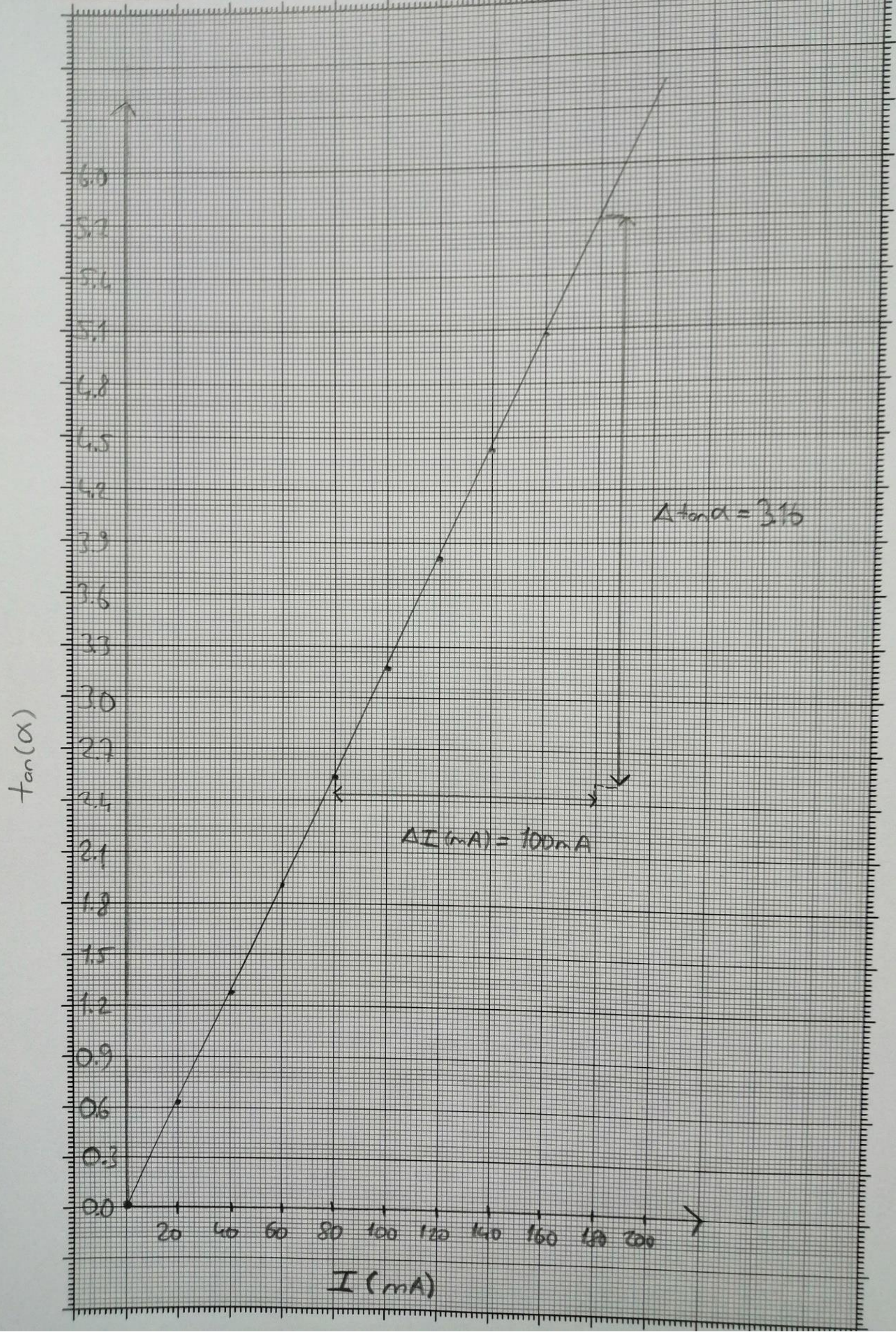
GRAPH.2



Section.3

Our aim in this section is to measure the vertical component of the Earth's magnetic field (B_E^v). In this section, only the earth's magnetic field is processed, that is, no current flows through the coils. Place the compass in an upright position. The tip of the needle shows the Earth's magnetic field (B_E). B_E^v is found by the angle that the needle makes with the horizontal. (θ_{avg}).

Table.3

θ_1	θ_2	θ_{avg}
60.90	60.65	60.775

Calculations.3

- $\theta_{avg} = \frac{\theta_1 + \theta_2}{2} = \frac{60.90 + 60.65}{2} = 60.775$

- $B_E^h = 0.022 mT$

- $\tan\theta = \frac{B_E^v}{B_E^h}$ $\quad$ $B_E^v = \tan\theta . B_E^h$

- $B_E^v = \tan(60.775) \times 0.022 mT = 0.039 mT$

- $B_E = \sqrt{(B_E^v)^2 + (B_E^h)^2} = \sqrt{(0.039 mT)^2 + (0.022 mT)^2}$

- $B_E = \sqrt{0.002005 mT^2} = 0.048 mT$

$= 0.48 G$

Result and Discussions:

The error rate of the constant k we found in the first section is 0.69%. This value is responsable for laboratory conditions. The presence of materials that can affect the magnetic field in the experiment may cause this error. In addition, the average values taken in the calculations may cause this error.

The magnetic field of the Earth we found in the second part is 0.486. The range calculated on the Earth's surface is between 0.256 and 0.656. Our value in the experiment is in this range. While calculating the B_{avg} value, the elektromagnetic fields that may occur in the environment were ignored. For example, mobile phone, base station or laboratory's electrical wiring. This section proves the Helmholtz coil theory.

Finally, when we look at the whole experiment, the Lorentz force law and Helmholtz coil theory prove their validity.