Experiment # 3:

Earth's magnetic field with Cobra4 Mobile-Link.

Related Topics:

Magnetic inclination and declination, isoclinic lines, isogonic lines, inclinometer, magnetic flow density, Helmholtz coils.

Principle:

A constant magnetic field, its magnitude and direction known, is superimposed on the unknown earth-magnetic field. The earth-magnetic field can then be calculated from the magnitude and direction of the resulting flux density.

Material:

- Pair of Helmholtz coils
- Power supply, universal
- Rheostat, 100 Ohm, 1.8A
- Cobra4 Mobile-link set, incl. rechargeable batteries, SD memory card, USB cable and software "measure"
- Cobra4 Sensor Tesla, magnetic field strength, resolution max. ±0.01mT
- Hall probe, axial
- Digital multimeter
- Magnetometer
- Barrel base PHYWE
- Right angle clamp PHYWE

- Support rod PHYWE, square, L = 250 mm
- Stand Tube
- Connecting cord, L = 1000 mm, red
- Connecting cord, L = 1000 mm, blue

Tasks

1- The magnetic flux of a pair of Helmholz coils is to be determined and plotted graphically as a function of the coil current. The Helmholz system Calibration factor is calculated from the slope of the line.

2- The horizontal component of the earth-magnetic field is determined through superimposition of the Helmholtz field

3- The angle of inclination must be determined in order to calculate the vertical component of the earth-magnetic field.

Set-up and procedure:

The experiment composition is as depicted in figure.

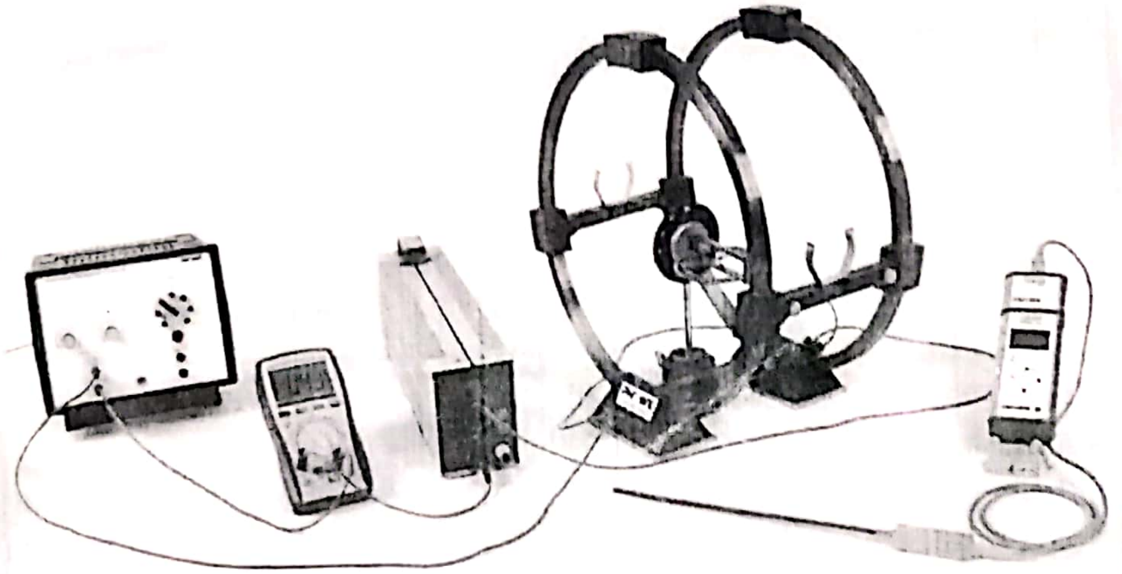
The Helmholtz coils, complete with mounted space holders, are connected in series (linkage of equally numbered connections) and connected with the DC-generator by the rheostat and the multimeter used as ammeter. The Hall probe is to be fixed on the support rod with barrel base pointing inward toward the coil axis in the center of the Helmholtz arrangement. In this arrangement, the horizontal flux density "^hB_H" of the pair of coils is to be determined as a function of the coil current I_H. The calibration factor $K = {}^hB_H / I_H$ is determined through the appertaining graphic representation.

Note:

Before measuring beings, the zero-point position of the Sensor-Unit Tesla must be set precisely.

By means of barrel base, stand tube and optic judgement, the magnetometer (with a leveled graduated circle) is placed between the coils so that the center of the graduated circle is approximately identical with the center of the pair of coils. First, the direction "north/south" is noted on the graduated circle for currentless coils. In order to secure the direction "north/south" of the magnetic needle, the needle should be slightly turned away from its resting position several times. Possible friction resistance can be reduced by gently tapping the instrument. In order to determine the horizontal component "^hB_E" of the earth-magnetic field, the deflection angle α of the magnetic needle is measured from its resting position as a function of small coil currents. If the polarity of the coil current is reversed, the measuring series must be repeated. In determining the exact angle, the indications from both needle tips must be considered. The angle ϕ between the direction "north/south" and the axis of the pair of coils is obtained through maximal needle deflection when the resistor is short-circuited the ammeter eliminated and the coil current set to approximately 4A. In conclusion, and for currentless coils, the graduated circle of the magnetometer is turned to the vertical plane so that the magnetic needle now indicates the inclination angle ϕ_1. Make sure that the spin axis is consistent with the direction "north/south". In order to check on ϕ_2, the magnetometer is turned by 180° and thus replaced on the vertical plane.

Diagram :-



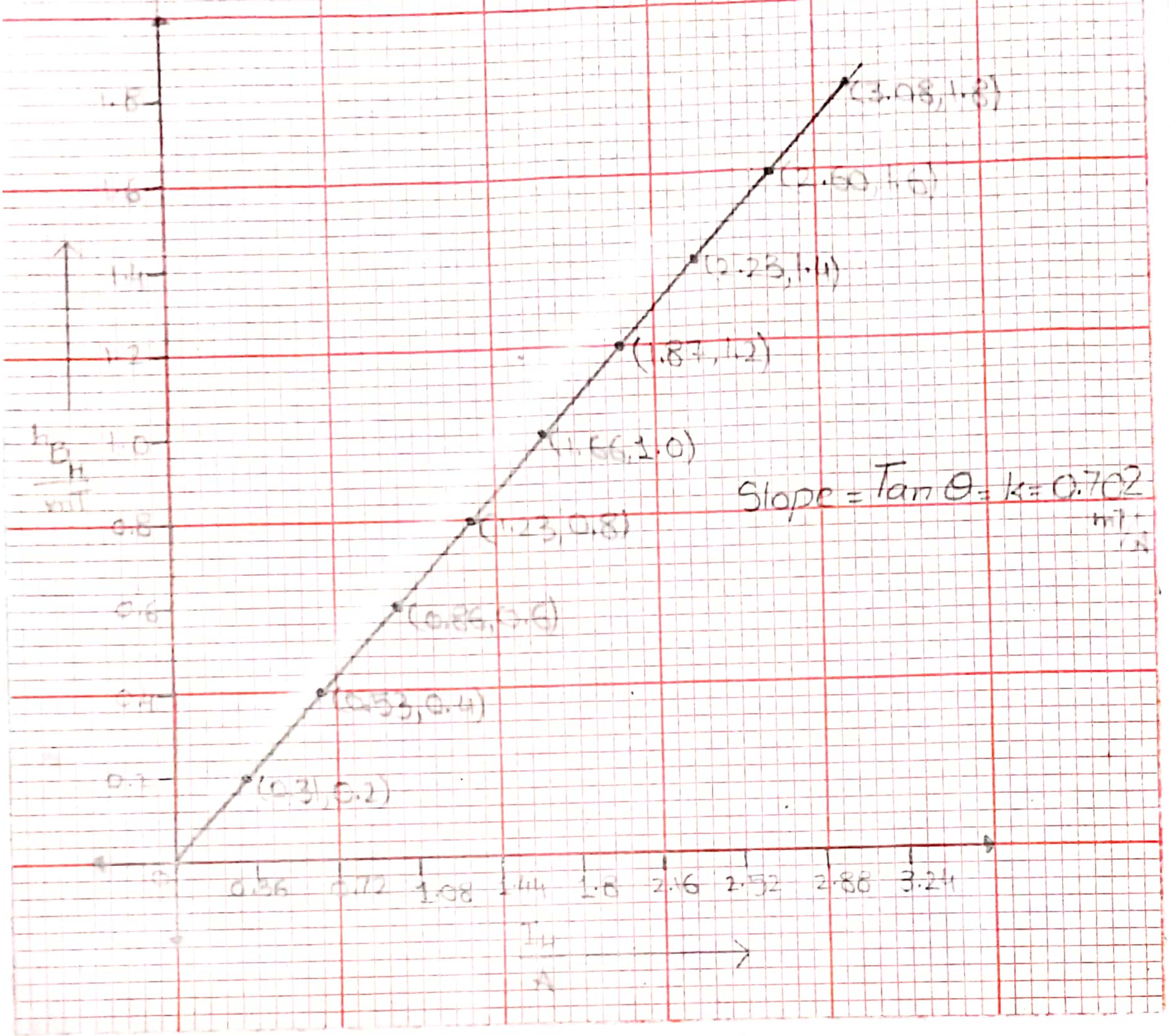
Observations and Calculations:

Step 1 :

Callibration of Helmholtz Coils.

Current I_H (A)	Horizontal Magnetic flux density ${}^{h}B_H$ (mT)
0.31	0.2
0.53	0.4
0.86	0.6
1.23	0.8
1.66	1.0
1.87	1.2
2.23	1.4
2.60	1.6
3.08	1.8

Graph between ^hB_H and I_H



Calibration factor $k = {}^hB_H / I_H$ (mT/A)

$k_{\text{Theo. value}} = 0.722$ mT/A

Slope of Graph = $\tan\theta = k_{\text{Exp. value}} = {}^hB_H / I_H$

$k_{\text{Exp. value}} = \dfrac{Y_2 - Y_1}{X_2 - X_1} = \dfrac{Y_{avg}}{X_{avg}} = \dfrac{1.4 - 1.0}{2.23 - 1.66} = \dfrac{0.4}{0.57} = 0.702$ mT/A

% error in Calibration factor k

$$\% \text{ error} = \frac{\text{Theo. value} - \text{Exp. value}}{\text{Theo. value}} \times \frac{100}{100}$$

$$= \frac{0.722 - 0.702}{0.722} \times 100\%$$

$$= 2.77\%$$

Step 2:

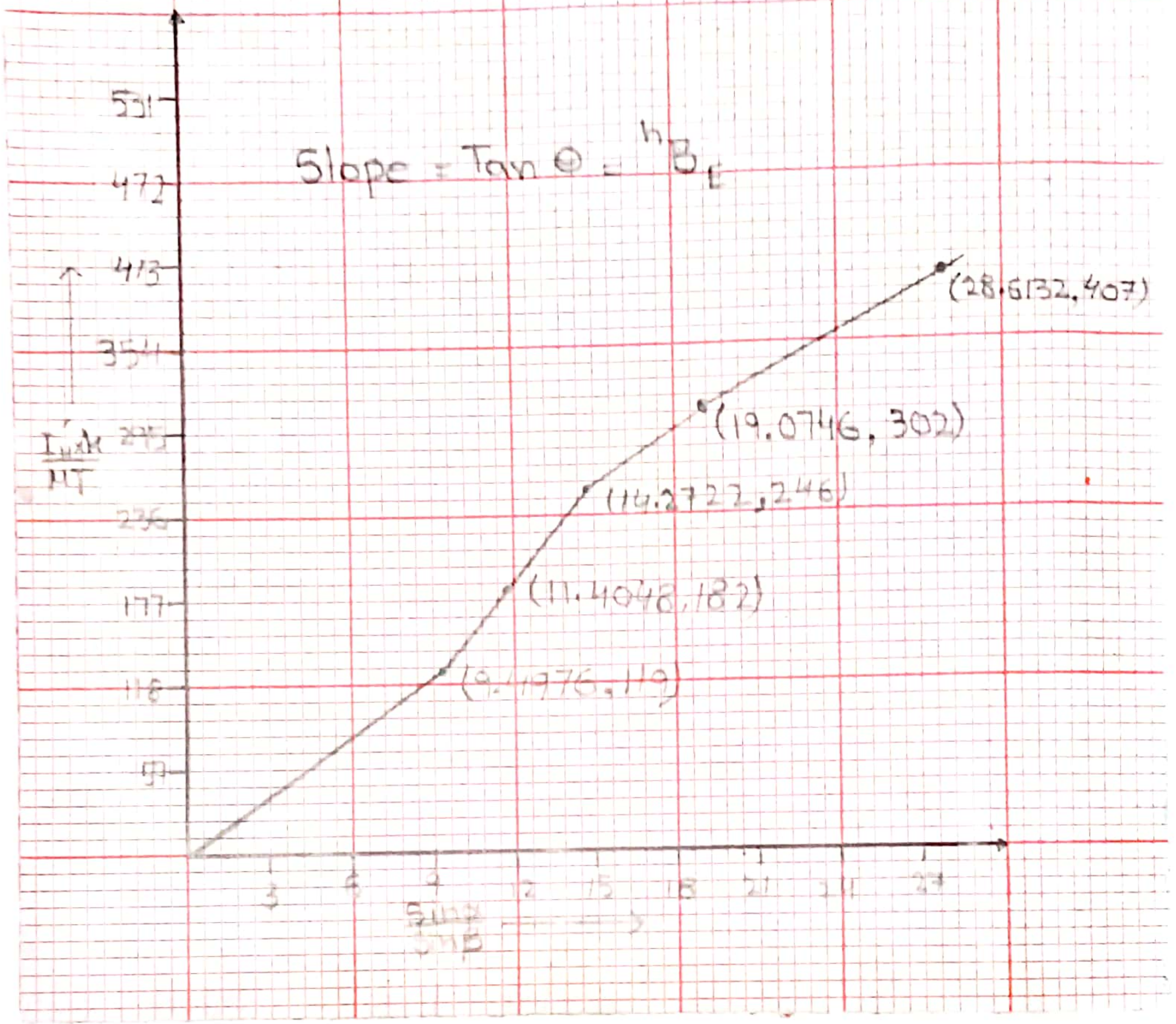
Finding Horizontal Component of Earth Magnetic field. ${}^{h}B_{E}$

By using Magneto meter

$\phi = 89^{\circ}$

I'_H	$I'_H \times k$ (μT)	α	$\beta = \phi - \alpha$	$\sin\alpha$	$\sin\beta$	$\sin\alpha / \sin\beta$
0.17	0.119	83	6	0.9925	0.1045	9.4976
0.26	0.182	84	5	0.9945	0.0872	11.4048
0.35	0.246	85	4	0.9962	0.0698	14.2722
0.43	0.302	86	3	0.9976	0.0523	19.0746
0.58	0.407	87	2	0.9986	0.0349	28.6132

Graph between $I_H' \times k$ and $\frac{\sin\alpha}{\sin\beta}$



Horizontal Component of Earth Magnetic field $\;{}^hB_E = \frac{I_H' \times k}{\sin\alpha / \sin\beta}$

$${}^hB_{E\ \text{Theo. value}} = 19.06\ \mu T$$

Slope of Graph = Tan θ = ${}^hB_{E\ \text{Exp. value}} = \frac{I_H' \times k}{\sin\alpha / \sin\beta}$

$${}^hB_{E\ \text{Exp. value}} = \frac{Y_2 - Y_1}{X_2 - X_1} = \frac{Y_{avg}}{X_{avg}} = \frac{302 - 119}{19.0746 - 9.4976} = \frac{183}{9.577} = 19.11\ \mu T$$

% error in Horizontal Component o
Earth Magnetic field

$$\% \text{ error} = \frac{\text{Theo. value} - \text{Exp. value}}{\text{Theo. value}}$$

$$= \frac{19.06 - 19.11}{19.06} \times 100\%$$

$$= 0.262\%$$

Step 3:
Finding Vertical Component of Earth
Magnetic field

$\phi = 69°$ (full curve

Rotate Magnetometer To 90°

$\phi_1 = 71°$; $\phi = 61°$

$$\phi'_{\text{Exp. value}} = \phi_1 + \phi_2 / 2 = \frac{71° + 61°}{2} = \frac{132}{2}$$

$$\phi_{\text{Theo. value}} = 66.57°$$

% error in ϕ

$$\% \text{ error} = \frac{\text{Theo. value} - \text{Exp. v}}{\text{Theo. value}}$$

$$= \frac{66.57° - 66°}{66.57°}$$

Scanned with CamScanner

$^{v}B_{E\ \text{Theo.value}} = 43.96\,\mu T$

% error in vertical Component of Earth Magn field

$$\%\ \text{error} = \frac{\text{Theo. value} - \text{Exp. value}}{\text{Theo. value}} \times \frac{100}{100}$$

$$= \frac{43.96° - 42.9218°}{43.96°} \times 100\%$$

$$= 2.362\%$$

Step 4:

Finding Earth Magnetic field E

$B_{E\ \text{Theo. value}} = 47.91\,\mu T$

$^{h}B_E = 19.11\,\mu T$

$^{v}B_E = 42.9218\,\mu T$

By Pythagoras Theorem

$$B_E^2 = {}^{h}B_E^2 + {}^{v}B_E^2$$

$$B_E = \sqrt{{}^{h}B_E^2 + {}^{v}B_E^2}$$

$$B_E = \sqrt{(19.11)^2 + (42.9218)^2}$$

$$B_E = \sqrt{2207.4730}$$

$$B_{E\ \text{Exp. value}} = 46.9838\,\mu T$$

% error in Earth Magnetic field B_E