Student's name ____

Experiment M4

DETERMINATION OF HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FIELD USING HELMHOLTZ COIL

Objective: To determine the horizontal component of the Earth's magnetic field using Helmholtz coil.

1 EQUIPMENT

1) Accumulator;
2) Helmholtz coil;
3) compass;
4) milliammeter;
5) rheostat.

2 THEORY

The planet Earth has its own magnetic field. Though relatively weak, this field is able to rotate magnetic needle of a compass and is widely used in navigation. Other important effect of the Earth's magnetic field is its action on the charged space particles. These particles are declined by magnetic field and hit in atmosphere mostly in polar regions. This causes so called northern lights (aurora borealis). Magnetic needle is ordered in parallel with the magnetic field $\vec{B}$ at a given point. This direction is tangential to magnetic field line which passes through this point (see fig. 2.1). The magnitude of $\vec{B}$ for the Earth are in range from $0{,}42\cdot 10^{-4}$ T on equator to $0{,}70\cdot 10^{-4}$ T at poles. The most probably, liquid iron nuclei of our planet is the source of the Earth's magnetic field.

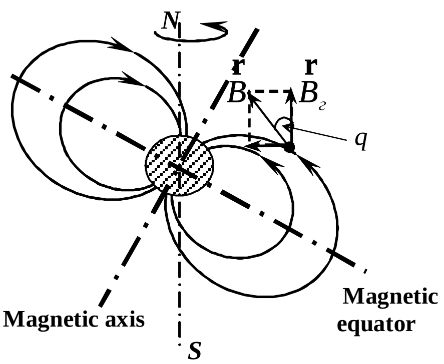

Figure 2.1

One can measure the horizontal component $\vec{B}_г$ of the Earth's magnetic field by Helmholtz coil, composed by two planar coils (or two loops), arranged in parallel at a distance equal to the radius of the coil.

If the symmetry axis $\mathbf{OO_1}$ of Helmholtz coil is perpendicular to the magnetic meridian plane then the magnetic field $\vec{B}_0$ of a current in this coil tends to decline a magnetic needle in a compass from its direction along the magnetic meridian of the Earth. The competition of these fields allows us to express the magnetic field of the Earth through the magnetic field of the coil and the angle a of declination as

$$tg a = \frac{B_0}{B_г}. \tag{2.1}$$

Magnetic field $\vec{B}_0$ of a current loop on its axis $\mathbf{OO_1}$ is directed along the noted axis, as a result of superposition of elementary magnetic fields $d\vec{B}$ created by every segment dl of the loop. The direction of the resultant magnetic field vector can be determined by the right-hand-rule: if one curl the four fingers of right hand along the direction of the current then the extended thumb, which is at a right angle to the fingers, points in the direction of the field. (see fig. 2.3).

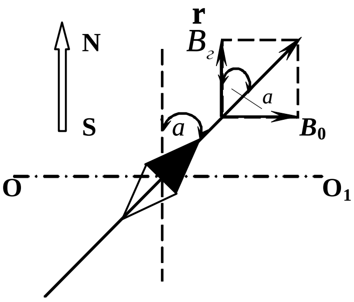

Figure 2.2

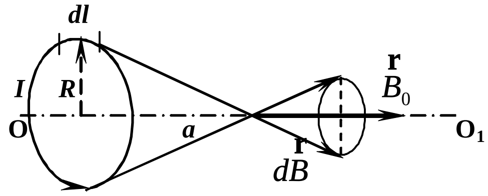

Figure 2.3

The magnitude of magnetic field strength on axis of the coil is given by formula

$$H = \frac{I \cdot n \cdot R^2}{2\left(R^2 + a^2\right)^{3/2}}, \tag{2.2}$$

where ***R*** stands for the radius of the coil, ***a*** is the distance from the coil's center to the point of measurement, ***n*** is number of turns in the coil. This formula may be obtained using Biot-Savart law and superposition principle. Magnetic field $\vec{B}_0$ itself is connected with magnetic field strength $\vec{H}_0$ by relation

$$\vec{B}_0 = \mu\mu_0 \vec{H}_0, \tag{2.3}$$

where μ_0 is magnetic constant ($\mu_0 = 4\pi \cdot 10^{-7}$ H/m), μ is magnetic permeability of the medium ($\mu \approx 1$ for an air). Magnetic field lines which are used to describe a magnetic field, are always closed and in every point the magnetic field $\vec{B}$ is tangential to the magnetic lines (see fig. 2.1).

Forasmuch the Helmholtz coil is constructed of two planar coils, distance between which is ***R***. Their field are superposed, so the total field in a center is given by

$$H_0 = \frac{I \cdot n \cdot R^2}{\left(R^2 + R^2/4\right)^{3/2}} = \frac{8}{5\sqrt{5}} \cdot \frac{I \cdot n}{R} = 0{,}7156 \cdot \frac{I \cdot n}{R}, \tag{2.4}$$

$$B_0 = 8{,}988 \cdot 10^{-7} \cdot \frac{I \cdot n}{R}. \tag{2.5}$$

On this basis, for the horizontal component of the Earth's magnetic field we obtain calculation formulas

$$H_г = \frac{0{,}7156}{tg\alpha} \cdot \frac{I \cdot n}{R}, \text{ (A/m)} \tag{2.6}$$

$$B_г = \frac{8{,}988 \cdot 10^{-7}}{tg\alpha} \cdot \frac{I \cdot n}{R}. \text{ (T)} \tag{2.7}$$

3 PROCEDURE AND ANALYSIS

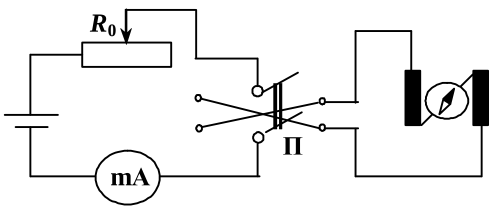

Figure 3.1

3.1 Assemble the circuit as shown in fig. 3.1.

3.2 Arrange the Helmholtz coil along magnetic meridian, using compass. The magnetic needle should point zero on a scale of compass.

3.3 Switch on a current and using rheostat change the current magnitude. In this way point the magnetic needle to 30° on the scale of compass. By ammeter, determine the current magnitude which corresponds to this angle.

3.4 Repeat the measurement for 45° i 60°.

3.5 Determine radius ***R*** of the coil and number ***n*** of turns in it.

3.6 Calculate the values of ***H**¿* and ***B*** from formulas (2.6) and (2.6).

3.7 Fill the table 4.1 with results of experiments and calculations.

Table 4.1

	a	***I,*** **A**	***n***	***R,*** **m**	***B*** **T,**	***H,*** **A/m**
1						
2						
3						
Mean value						