Instruction for exercise 3

Title: Study of the magnetic field

Theoretical topics

1. Describe the parameters of the magnetic field: field strength, magnetic induction, magnetization.
2. Discuss the magnetic field of the rectilinear conductor and the solenoid through which the current flows.
3. Present the essence of the Hall effect quantitatively, using the model of free electrons in metals.
4. Magnetic properties of matter (diamagnetism, paramagnetism, ferromagnetism).

Topics for a test

1. Explain what the magnetic field is.
2. What is the impact of the magnetic field on living organisms?

The purpose of the exercise:

Magnetic field testing, measurement of magnetic induction values inside solenoid, calculating the magnetic induction value of a given source geometry. Study of magnetic field source.

Instruments:

The measurement set shown in Fig.1 consists of two independent circuits: the Hall sensor with a power supply, and the coil circuit with an independent power supply whose magnetic field we are examining.

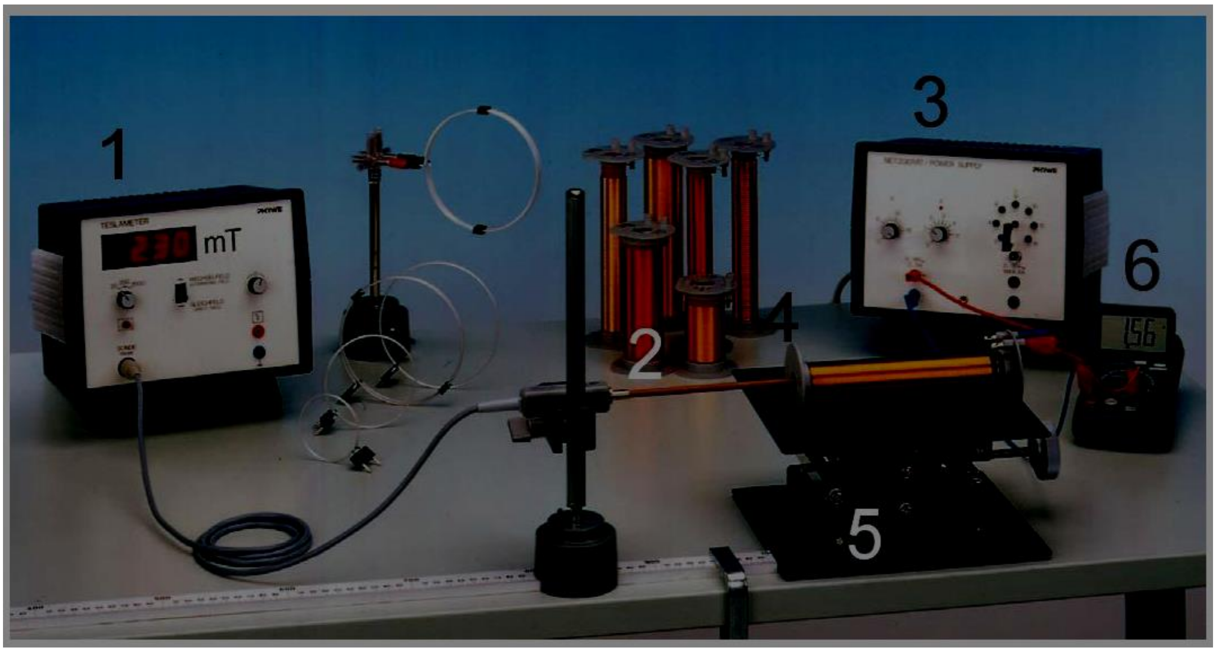

Fig.1 Measuring set: 1- teslameter, 2- Hall probe, 3- Solenoid power supply, 4- solenoid (coil), 5 – coil elevator, 6- ammeter

Technical Introduction:

1. Set the tripod with the Hall probe on the linear gauge.
2. Set the coil lifter at the end of the linear gauge.
3. Connect the Hall probe to the teslameter with the output for a constant magnetic field, select the range 20 mT.
4. Connect the coil of known parameters (length L, radius R, number of coils n) and ammeter for power supply with the DC output.

   Warning! - The current in the coil cannot exceed 1A!
5. Measure the magnetic induction along the axis of the coil moving the Hall probe in 1 cm increments, at a fixed current value in the coil.
6. Perform the measurements as in point 5 but for the opposite directed current flow. The measurements described in points 5 and 6 should be repeated three times. As a result take the average value.
7. Measure the magnetic induction for a fixed position (in half length of the coil z = 0) of the Hall probe, changing the current flow in the coil.

Measurements and reporting:

1. Make a graph of the dependence: B = f (z) - the magnetic induction as a function of the coordinate (z) of the position of the Hall probe along the axis of the coil when: I = const., N = const., R = const. and compare with the theoretical values of magnetic induction, calculated according to the following equation:

$$B(z) = \frac{\mu_0 \cdot I \cdot n}{2L}\left(\frac{a}{\sqrt{R^2+a^2}} - \frac{b}{\sqrt{R^2+b^2}}\right),$$

where μ_0= 1.256·10$^{-6}\frac{T\cdot m}{A}$ is the magnetic permeability of the vacuum, $a = z + \frac{L}{2}, b = z - \frac{L}{2}$.

2. Draw a dependence graph of the magnetic induction on the current in the coil **- B = f (I)**, at the position of the Hall probe in the center of the coil (z = 0) and compare with the values theoretically calculated according to the expression:

$$B_{z=0}(I) = \frac{\mu_0 \cdot I \cdot n}{\sqrt{4R^2 + L^2}}$$

3. Calculate a measurement error of magnetic induction ΔB by means of the formula presented below and discuss the results.

Appendix Estimation of measurement error

Calculate a measurement error of magnetic induction using the equation:

$$\Delta B_{z=0}(I) = \frac{\mu_0 \cdot n \cdot \Delta I}{\sqrt{4R^2 + L^2}} + \frac{4R \cdot \mu_0 \cdot I \cdot n \cdot \Delta R}{\sqrt{(4R^2 + L^2)^3}} + \frac{L \cdot \mu_0 \cdot I \cdot n \cdot \Delta L}{\sqrt{(4R^2 + L^2)^3}}$$

assuming the following scale errors:

ΔI=0.07A, ΔL=1mm, ΔR=1mm.