TP n° 5

Measurement of a magnetic field

The purpose of the experiments is to measure a magnetic field by three different methods : a fluxmeter, a Cotton balance and a Hall probe.

1 Preparation

1.1 Fluxmeter

1.2 Cotton balance

1.3 Hall probe

2 Measurements

2.1 Fluxmeter

2.2 Cotton balance

2.3 Hall probe

1 Preparation

We want to measure the magnetic field produced by an electromagnet. The two coils are connected in series.

1.1 Fluxmeter

A fluxmeter is a galvanometer with no restoring torque and strong damping connected to a pickup coil. A $\Delta\Phi$ flux change will induce an electromagnetic force (emf) and a change of the galvanometer reading. The flux change $\Delta\Phi$ is related to the reading $\theta_0 - \theta_1$:

$$\Delta\Phi = K\left(\theta_1 - \theta_0\right)$$

where K is a constant given in Wb/division, characteristic of the apparatus.

- Knowing the surface S of the pickup coil, give the relation between the field and the reading of the fluxmeter.

1.2 Cotton balance

The balance is composed of a small coil and a hanging-pan fixed on a mobile beam (EOF). A moving nut allows to zero the balance. When the lower part of the coil is submitted to a magnetic field, the balance is in equilibrium if the torque due to the Laplace force exerted on the portion CD of the circuit (length l, current i) is compensated by the torque due to the weights in the pan.

- Give the relation which enable to deduce the magnetic field. We give MO = OF = 151 mm and CD = l = (20,0 ± 0,1) mm

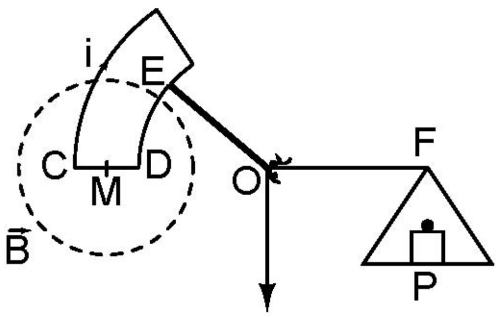

Fig. 1 : Cotton balance

1.3 Hall probe

A Hall probe is made of a conducting ribbon of width l, thickness d and length L (fig. 2). Electrodes are connected to pass a current I along the length of the ribbon.

If a magnetic field $\vec{B}$ is applied perpendicularly to the ribbon, the charges will be deflected due to the Lorentz force, and a potential difference called Hall voltage will appear between the upper and lower edges of the ribbon. In a steady state, this force is balanced by the electric force due to the build up of charges on the upper and lower edges of the ribbon.

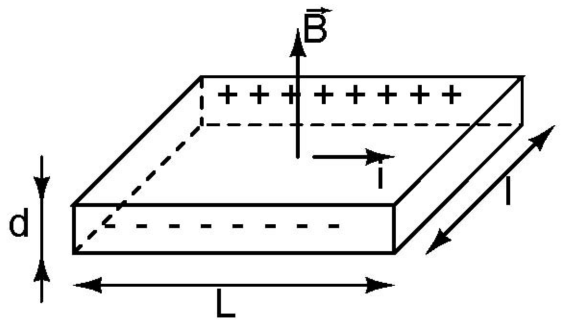

Fig. 2 : Hall probe

- If $\vec{j} = n\ q\ \vec{v}$ is the current density flowing through the ribbon, with n the mobile charge carriers per unit volume, q the charge of one carrier, $\vec{v}$ the speed of the carriers, give the relation between the magnetic field and the Hall voltage V.
- Show that such a relation can be written as : V = C i B with C a constant depending on n and on the ribbon geometry.
- What about the Hall voltage if we change the sign of the applied magnetic field ?
- Actually, the measured voltage is the sum of the Hall voltage and a parasite voltage present even if no magnetic field is applied. Explain the origin of this parasite voltage and how to determine its strength for a given current i flowing through the ribbon.

2 Measurements

- Explain why the power supply connected to the magnet has to be operated in stabilized current mode rather than in stabilized voltage mode.

2.1 Fluxmeter

- Measure the magnetic field B in the center of the gap produced by excitation current up to 2 A.
- Plot the curve $B = f\ (I)$.
- Show the error bars.
- Is the field equal to zero with no excitation current ?

2.2 Cotton balance

- Put 0.5 g in the pan of the balance. Drive 2 A in the electromagnet. Use a standard resistance to measure the current needed to equilibrate the balance.
- Compare the deduced field to the value given by the fluxmeter

2.3 Hall probe

- Measure the voltage delivered by the Hall probe in the center of the gap for an excitation current of 2 A.
- Estimate the voltage deliverd with no field applied to the probe.
- Give the relation between the field and the voltage delivered by the Hall probe.
- Use the probe to measure the field as a function of the position within the gap.
- Plot the results.
- Give the length over which the field is constant within 5%.