LORENTZ FORCE

EXPERIMENT PROCEDURE

- Determine the direction of the Lorentz force.
- Measure the force as a function of the current.
- Measure the force as a function of the effective length of the conductor.
- Measure the force as a function of the distance between the poleshoes of the permanent magnet.

OBJECTIVE

Measure the force on a current-carrying conductor in a magnetic field.

SUMMARY

The experiment involves measuring the Lorentz force on a current-carrying copper rod suspended in a horizontal position from a pair of vertical wires (like a swing) and subjected to a magnetic field. When the current is switched on the "swing" is deflected from the vertical position and the Lorentz force can be calculated from the angle of deflection. The current through the rod, the magnetic field strength and the effective length of the conductor in the magnetic field are varied and the effects are measured.

REQUIRED APPARATUS

Quantity	Description	Number
1	Equipment Set Electromagnetism	1002661
1	Permanent Magnet with Adjustable Pole Spacing	1002660
1	DC Power Supply 0 – 20 V, 0 – 5 A (230 V, 50/60 Hz)	1003312 or
	DC Power Supply 0 – 20 V, 0 – 5 A (115 V, 50/60 Hz)	1003311
1	Pair of Safety Experimental Leads, 75cm, red/blue	1017718

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BASIC PRINCIPLES

Electrons moving in a magnetic field are deflected in a direction perpendicular to the magnetic field and also perpendicular to the direction of motion. However, the deflecting force on a single electron – the Lorentz force – cannot easily be measured in practice, as it is extremely small, even for an electron moving very fast in a very strong magnetic field. A different situation exists when a current-carrying conductor is placed in a uniform magnetic field. In the conductor there are a large number of charge-carriers, all moving with the same drift velocity *v*. A force then acts on the conductor, which results from the sum of the Lorentz force components on all the individual charge-carriers.

In a straight conductor of length L and cross-sectional area A, the total number of electrons is:

(1) $$N = n \cdot A \cdot L$$

n: Electrons per unit volume

If the electrons move with a drift velocity $\boldsymbol{v}$ in the direction of the length of the conductor, the current I through it is as follows:

(2) $$I = n \cdot e \cdot A \cdot v$$

e: Elementary charge of an electron.

If the conductor is in a magnetic field of flux density B, the combined Lorentz force on all the "drifting" electrons is as follows:

(3) $$F = N \cdot e \cdot v \times B$$

If the axis of the conductor is perpendicular to the magnetic field direction, Equation (3) can be simplified to the following:

(4) $$F = I \cdot B \cdot L$$

Then the force F is perpendicular to the axis of the conductor and to the magnetic field.

The experiment involves measuring the Lorentz force F on a current-carrying copper rod, suspended in a horizontal position from a pair of vertical wires (like a swing) and subjected to a magnetic field (see Fig. 1). When the current is switched on the "swing" is deflected by an angle φ from the vertical position by the Lorentz force F, which can then be calculated from Equation (5).

(5) $$F = m \cdot g \cdot \tan\varphi$$

m = 6.23 g, the mass of the copper rod.

The magnetic field B is provided by a permanent magnet, and can be varied by altering the distance d between the poleshoes of the magnet. It is also possible to rotate the pole-shoes through 90°, thus changing the width b along the direction of the conductor and thereby the effective length L of the conductor, i.e. the part of it that is inside the magnetic field. This effective length L is slightly greater than the width b of the space between the poleshoes, as the magnetic field "bulges out", forming a non-uniform region beyond the edges of the poleshoes. The extent of this non-uniform part of the field increases with the distance d between the pole-shoes. To a good approximation:

(6) $$L = b + d$$

EVALUATION

The angle φ can be determined from the length of the pendulum s (the supporting wires) and the horizontal deflection x of the copper rod:

$$\frac{x}{\sqrt{s^2 - x^2}} = \tan\varphi$$

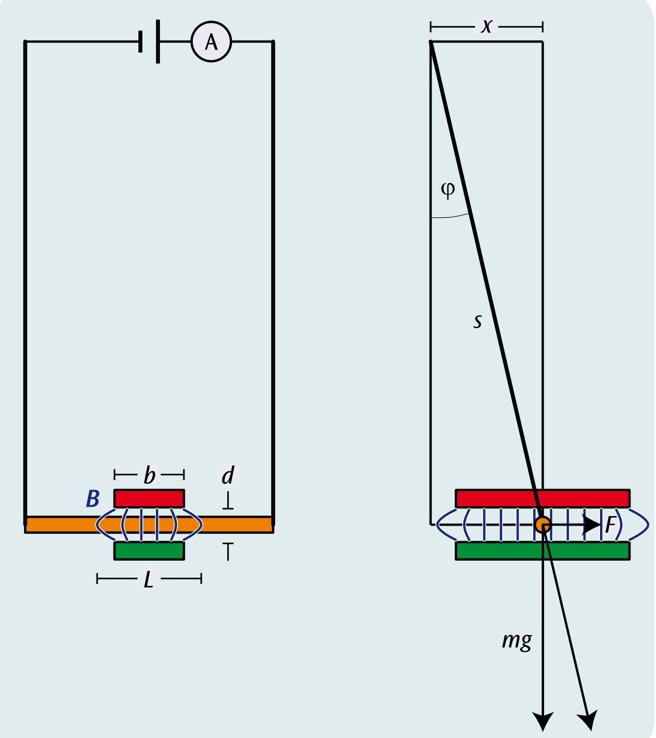

Fig. 1: Experiment set-up, viewed from the side and from the front.

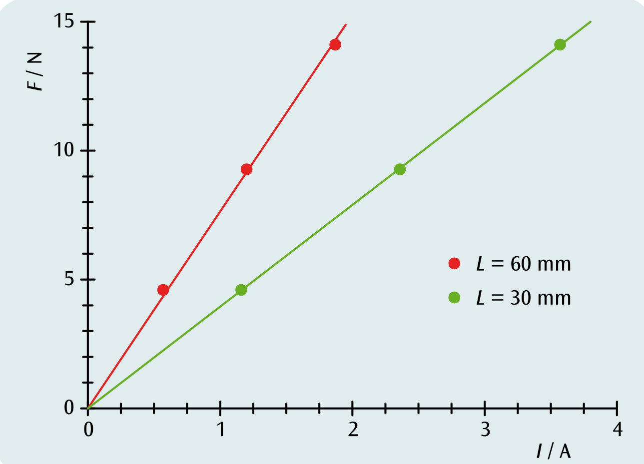

Fig. 2: Force on a current-carrying conductor as a function of current I for two different effective conductor lengths L. The gradients of the straight lines through the origin are proportional to L.