EXPERIMENT PROCEDURE

- Measurement of the force exerted on a current-carrying conductor as a function of the amperage.
- Measurement of the force exerted on a current-carrying conductor as a function of its length.
- Calibration of the magnetic field.

You can find technical information about the equipment at 3bscientific.com

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OBJECTIVE

Measurement of the force exerted on a current-carrying conductor located inside a magnetic field

SUMMARY

The electric balance is based on *André-Marie Ampères'* experiments on electric current. It measures the electro-dynamic force sometimes referred to as the Lorentz force on a current carrying conductor situated in a magnetic field using a balance. In this experiment the current conductor is suspended from a rigid suspension system and exerts the equal and opposite force on the permanent magnets as the electro-dynamic force generated by the magnetic field. The result is the apparent change in weight of the permanent magnets.

REQUIRED APPARATUS

Quantity	Description	Number
1	Current Balance Equipment Set	1019188
1	Electronic Scale Scout Pro 200 g (230 V, 50/60 Hz)	1009772
1	DC Power Supply 0 – 20 V, 0 – 5 A (230 V, 50/60 Hz)	1003312
1	Stainless Steel Rod 250 mm	1002933
1	Tripod Stand 150 mm	1002835
1	Two-pole Switch	1018439
3	Pair of Experiment Leads, 75 cm	1002850

BASIC PRINCIPLES

The electric balance is based on *André-Marie Ampères'* experiments on electrical current. It measures the force exerted on a current-carrying conductor located in a magnetic field with the aid of a balance. In the experiment a modern electronic precision balance weighs a permanent magnet. The weight measured changes in accordance with Newton's 3rd law when an electro-dynamic force is exerted on a current-carrying conductor entering a magnetic field.

On the balance lies a permanent magnet which generates a horizontal magnetic field $\mathbf{B}$. In this arrangement a horizontal current conductor of length L and suspended from a rigid bar is dipped vertically into the magnetic field. The electro-dynamic force from the magnet acts on the conductor

(1) $$\mathbf{F}_L = N \cdot e \cdot \mathbf{v} \times \mathbf{B},$$

e: elementary charge,
N: total number of all electrons participating in electrical conduction

The mean drift velocity $\mathbf{v}$ is all the greater, the greater the current I flowing through the conductor:

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

n: number of all electrons involved in the current conduction,
A: cross-section of the conductor

From

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

L: length of the conductor

we obtain

(4) $$\mathbf{F}_L = I \cdot L \cdot \mathbf{e} \times \mathbf{B}$$

or

(5) $$F_L = I \cdot L \cdot B$$

since the unit vector $\mathbf{e}$ pointing in the direction of the conductor is located perpendicular to the magnetic field. In accordance with Newton's third law, an equal and opposite force $\mathbf{F}$ is exerted on the permanent magnet. Depending on the sign, the weight $\mathbf{G}$ of the permanent magnet measured on the balance is either increased or decreased. Thanks to the balance's tare function, the weight G can be electronically offset so that the balance immediately displays the opposing force F.

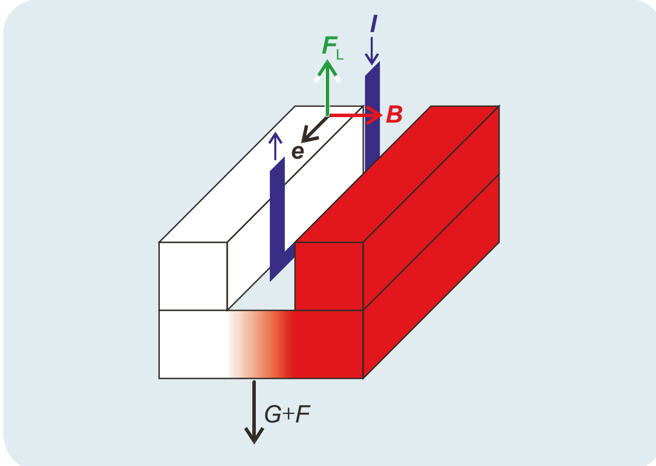

Fig. 1: Schematic depiction of the electro-dynamic force F_L on the current-carrying conductor and the total force $G + F$ on the balance.

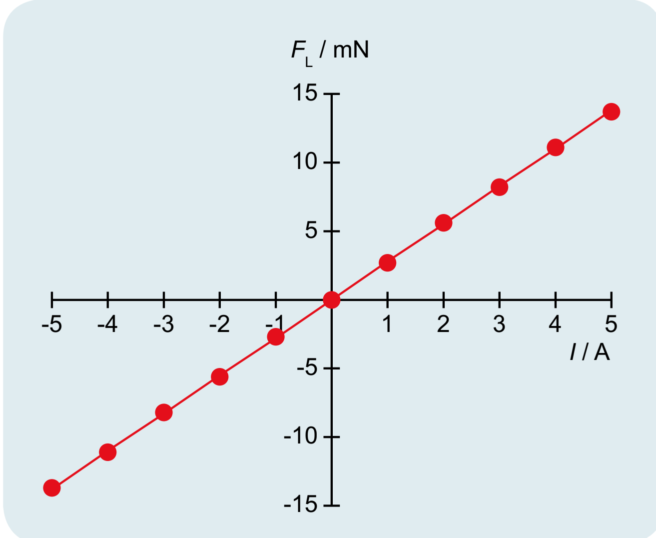

Fig. 2: Force F_L as a function of the amperage I

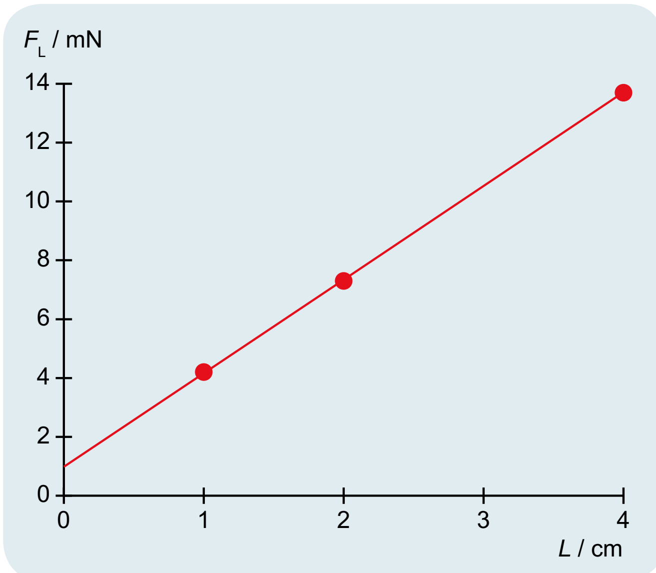

Fig. 3: Force F_L as a function of the conductor length L

EVALUATION

It has been demonstrated that the current dependency of the electro-dynamic force or Lorentz force can be accurately described by a straight line through the origin (Fig. 2). This is not the case for conductor length dependency (Fig. 3) due to the fact that here boundary effects play a role at the ends of the conductor. The magnetic field of the fully assembled permanent magnet is computed from the linear gradients $a_2 = B\,L$ in Fig. 2 and $a_3 = B\,I$ in Fig. 3.