Electricity

Magnetostatics

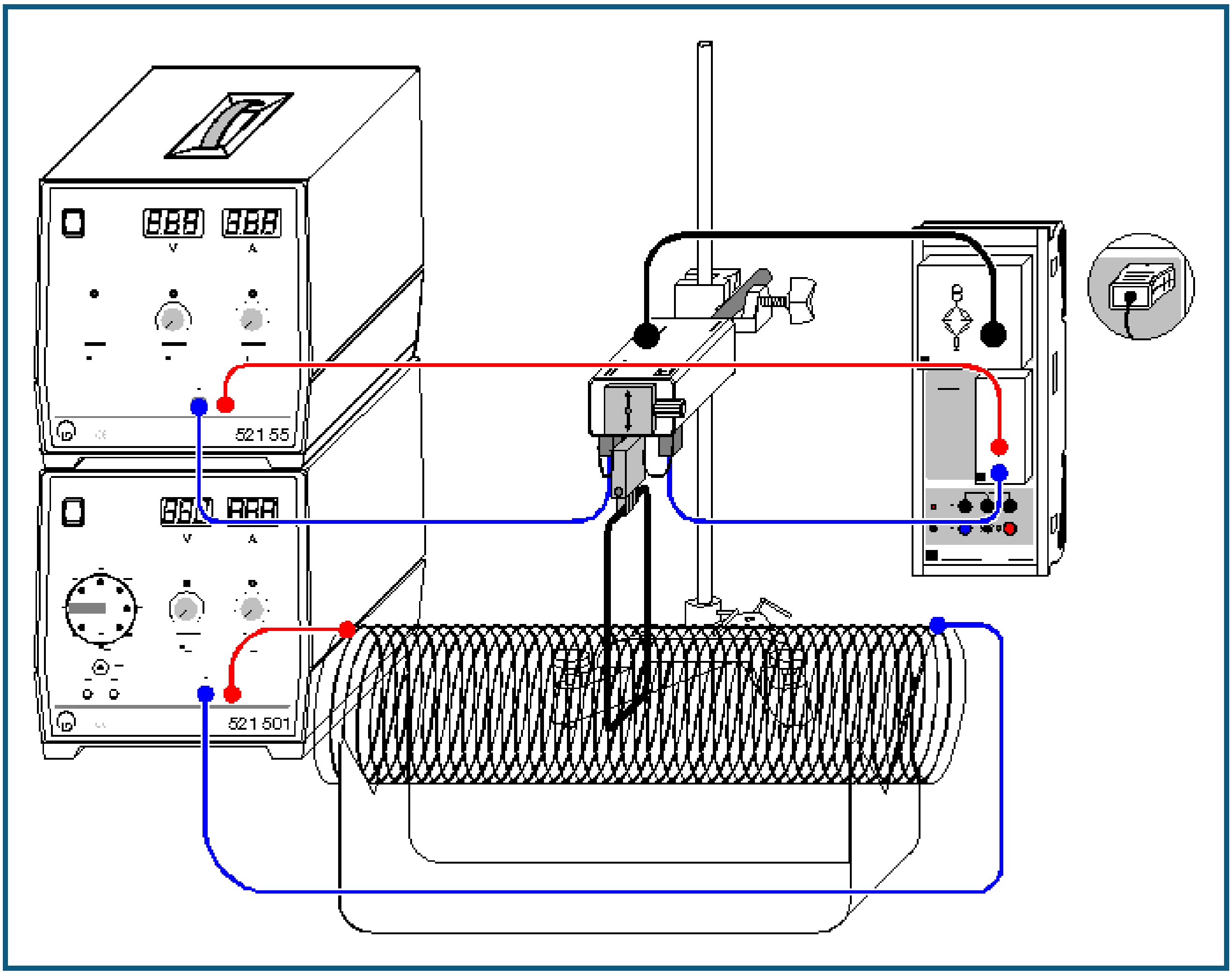
Effects of force in a magnetic field

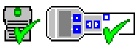
Measuring the force acting on current-carrying conductors in the magnetic field of an air coil - Recording with CASSY

Description from CASSY Lab 2

For loading examples and settings, please use the CASSY Lab 2 help.

Force in the magnetic field of an air coil



 can also be carried out with Pocket-CASSY and Mobile-CASSY

Experiment description

Magnetic flux density, or more simply the magnetic field **B**, is a vectorial quantity. A force **F** acts on a charge q passing through a magnetic field **B** with a velocity **v**; the size of the force depends on the strength and direction of the magnetic field. We can say

$\mathbf{F} = q \cdot (\mathbf{v} \times \mathbf{B})$.

The Lorentz force **F** is also a vectorial quantity, and is perpendicular to the plane defined by **v** and **B**.

We can understand the force acting on a current-carrying conductor in a magnetic field as the sum of the individual forces acting on the moving charge carriers which make up the current. The Lorentz force **F** acts on every single charge carrier q moving with the drift velocity **v**. For a straight conductor, this gives us the total force

$\mathbf{F} = q \cdot nAs \cdot (\mathbf{v} \times \mathbf{B})$,

as the number of charge carriers in the conductor is the product of the density n of the charge carriers, the conductor cross-section A and the length s of the section of the conductor within the magnetic field.

It is common to introduce the vector **s**, which points along the direction of the conductor segment. Also, the product qnAv is equivalent to the current I. Thus, the force of a magnetic field on a straight, current-carrying conductor section is defined by

$\mathbf{F} = I \cdot (\mathbf{s} \times \mathbf{B})$

and the absolute value of the force by

$F = I \cdot s \cdot B$,

when **s** and **B** are perpendicular to each other. The force F and the current I are thus proportional to each other, and the proportionality factor is B.

This experiment measures the force on a conductor loop in a homogeneous magnetic field of an air coil as a function of the conductor loop current I. The homogeneous magnetic field is generated in a long, slotted air coil, and the conductor loop with the length s = 8 cm attached to the force sensor is inserted in the slit. Only the horizontal part of the conductor generates a force component that can be measured by the force sensor. Thus, the proportionality between force F and conductor loop current I can be used to determine the magnetic flux density B.

The advantage of the air coil is that the magnetic flux density B within it can be calculated easily and compared with the value arrived at through experiment. For a long air coil, we can say

$B = \mu_0 \cdot N \cdot I_C / L$

with the magnetic field constant $\mu_0 = 4\pi \cdot 10^{-7}$ Vs/Am, the number of turns N of the coils, the coil current I_C and the length L of the air coil.

Equipment list

1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
1	Bridge box	524 041
	with Force sensor and	314 261
	Multicore cable, 6-pole, 1.5 m	501 16
	or	
1	Force sensor S, ±1 N	524 060
1	30-A box	524 043
1	Support for conductor loops	314 265
1	Conductor loops for force measurement	516 34
1	Field coil, d = 120 mm	516 244
1	Stand for tubes and coils	516 249
1	High current power supply	521 55
1	AC/DC power supply 0...15 V	521 501
1	Stand base, V-shape, 20 cm	300 02
1	Stand rod, 47 cm	300 42
1	Leybold multiclamp	301 01
1	Connecting lead, 50 cm, blue	501 26
2	Connecting leads, 100 cm, red	501 30
2	Connecting leads, 100 cm, blue	501 31
1	PC with Windows XP/Vista/7/8	

Experiment setup (see drawing)

The force sensor holds the 8 cm long conductor loop via the support and is positioned so that the conductor loop is inserted in the slot of the air coil. The conductor loop must not touch the air coil. The two 4-mm sockets on the bottom of the force sensor are intended for supplying the conductor loop support. They are not connected internally. The force sensor is connected to the bridge box at input A of Sensor-CASSY.

The current flows from the 20 A supply unit via the 30 A box on input B of Sensor-CASSY through the conductor loop and back to the power supply. The current of the second 5 A power supply flows through the air coil.

Carrying out the experiment

Load settings

- Set the force zero point in Settings Force FA1 with → **0** ← and, where necessary, switch on the smoothing LED of the bridge box with **LED On/Off**.
- You may want to set the current zero point in Settings IB1 with → **0** ←.
- At the power supply of the air coil, set about I_C = 5 A.
- Increase the conductor loop current I from 0-20 A in steps of 2 to 5 A, and record a measured value with each time. You can delete a faulty measurement from the table with Table → Delete Last Table Row.
- If only negative forces are measured, reverse the connections on the conductor loop support.
- Carry out the experiment rapidly, as the conductor loop and support may be subjected to loads of 20 A only briefly.
- At the end of the experiment, set the conductor loop current to 0 A.

Evaluation

The force increases linearly with the current. The proportionality factor F/I = B·s is derived from the slope of the straight line fit. This in turn enables us to determine the magnetic field strength B.

In this example F/I = 0.138 mN/A and with s = 0.08 m it follows that B = 1.725 mT.

Using $B = \mu_0 \cdot N \cdot I_C / L$ the values μ_0 = 1.257 µVs/Am, N = 120, I_C = 4.75 A and L = 0.41 m give us the calculated value B = 1.75 mT. The two results agree very well within the limits of measuring accuracy.