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# MEASUREMENT OF AMPERAGE BETWEEN CONDUCTORS IN CASSY LAB DEVICE

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**Abstract**

In this experiment a conductor with the length s = 0.30 m is suspended at a distance r of just a few millimeters above a somewhat longer conductor. This experiment measures the force F acting on the suspended conductor at different currents I and distances r. The result verifies the ampere definition.

**Keywords**: Force, magnetic field, voltage, measurement, ampere definition, high current power supply, distance.

## The Main Part

The force F acting on a conductor with the length s and carrying a current I in a field with the magnetic flux density B is

$$F = IsB.$$

If the flux density B is generated by a long conductor at a distance r, we say

$B = \text{const.} \cdot I / r.$

Thus, the force F acting between two parallel conductors carrying the same current I is determined using

$F = \text{const.} \cdot I^2 \cdot s / r.$

Electrical current (the ampere) is defined as follows: the current I has the value 1 A when the absolute value of the force per unit of length s between two parallel, straight and infinitely long conductors with a diameter tending to zero and carrying the identical current is

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$F / s = 2 \cdot 10^{-7}$ N/m.

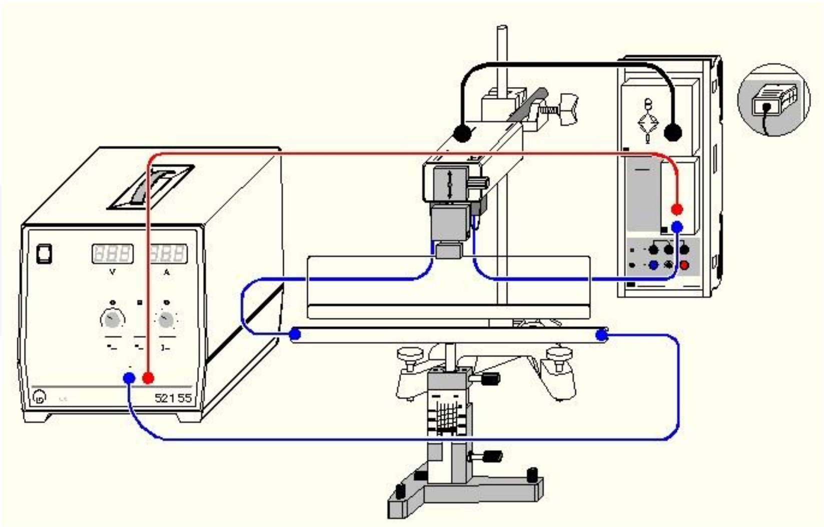
const. = $2 \cdot 10^{-7}$ N/A² is expressed as $\mu_0/2\pi$, which gives us:

$F = \mu_0/2\pi \cdot I^2 \cdot s / r$

where $\mu_0 = 4\pi \cdot 10^{-7}$ N/A² = $4\pi \cdot 10^{-7}$ Vs/Am.

To determine the amperage between two conductors, we need the following equipment: Sensor-CASSY, CASSY Lab 2, Bridge box with Force sensor and Multicore cable, 6-pole, 1.5 m, Force sensor S, ±1 N, 30-A box, Support for conductor loops, Set of conductors for ampere definition, Vertically adjustable stand, High current power supply, Stand base, V-shape, 20 cm, Stand rod, 47 cm, Leybold multiclamp, Connecting leads, 50 cm, blue, Connecting lead, 100 cm, red, Connecting lead, 100 cm, blue, PC with Windows XP/Vista/7/8.

The device is assembled as shown in Figure 1.




(Pic. 1)

The force sensor holds the top conductor loop with the support and is positioned so that the distance between the two conductor loops is about 5 mm for medium extension of the vertically adjustable stand.

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 two conductor loops in series and back to the power supply.

Now, slowly bring the conductor loop on the stand closer to the suspended conductor loop until the two are just touching (the wire centers now have the distance r = 2 mm). Check to make sure that the vertically adjustable stand is still parallel to the conductor loop, and adjust it if necessary using the adjusting screws.

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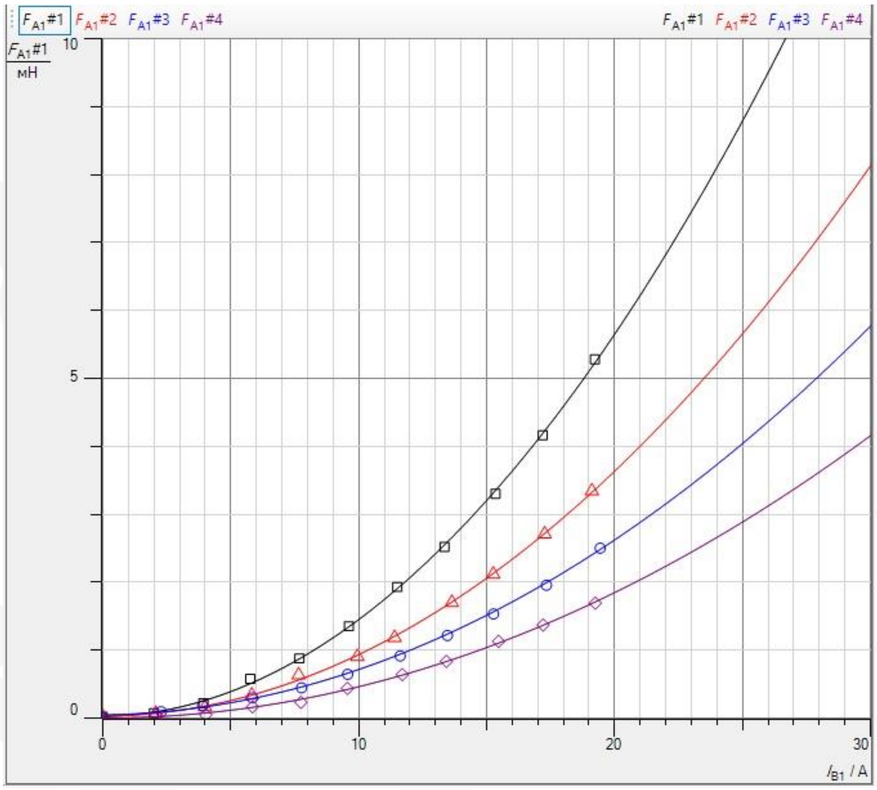
The zero point slider of the vertical adjustable stand is set to the specified mark and the required distance between the two conductor rings is set using the height adjustment mechanism (for example, r = 4 mm).
Set the force zero point in Settings Force FA1 with → **0** ← and, where necessary, switch 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** ←.
Increase the conductor loop current I from 0-20 A in steps of 2 A, and record measured values 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.
Record additional measurement curves with different conductor spacings r. Select

**Measurement → Append new Measurement Series**.
Fit a parabola to each measurement series F(I). After each best-fit straight line, switch to the display **Ampere Definition**. Here, an additional table is filled out by dragging the parameter $F/I^2$ of the parabola just determined from the status line using the mouse and dropping it next to the respective conductor loop spacing r in the table (drag & drop). Enter the conductor loop spacing r directly via the keyboard. The desired diagram is generated as you enter the values.
In this display, the parameter $F/I^2 \cdot r$ of a hyperbola 1/x gives us the constant for the ampere definition as
$\mu_0/2\pi = F/I^2 \cdot r / s = F/I^2 \cdot r / 0.3$ m.
In our example this means
$\mu_0/2\pi = 0.000062$ mN·m/A² / 0.3 m = $2.1 \cdot 10^{-7}$ N/A² = $2.1 \cdot 10^{-7}$ Vs/Am.
Alternatively, you can convert the x-axis from r to 1/r in the ampere definition display (click on the axis with the right mouse button). In this display, we obtain the value $\mu_0/2\pi$ by fitting a straight line.
The analysis of the experiment is presented in the table below.

| $I_{B1}$#1/A | $F_{A1}$#1/mN | $I_{B1}$#2/A | $F_{A1}$#2/mN | $I_{B1}$#3/A | $F_{A1}$#3/mN | $I_{B1}$#4/A | $F_{A1}$#4/mN |
|---|---|---|---|---|---|---|---|
| -0.02 | 0.02 | -0.02 | 0.03 | -0.02 | 0.01 | -0.02 | 0.00 |
| 2.00 | 0.07 | 2.07 | 0.07 | 2.25 | 0.11 | 2.07 | 0.06 |
| 3.93 | 0.22 | 3.99 | 0.17 | 3.87 | 0.19 | 4.02 | 0.05 |
| 5.76 | 0.58 | 5.82 | 0.34 | 5.82 | 0.31 | 5.85 | 0.17 |
| 7.68 | 0.88 | 7.65 | 0.64 | 7.74 | 0.46 | 7.74 | 0.23 |
| 9.62 | 1.35 | 9.95 | 0.91 | 9.54 | 0.66 | 9.56 | 0.44 |
| 11.51 | 1.93 | -0.02 | 1.19 | 11.60 | 0.93 | 11.70 | 0.64 |
| 13.35 | 2.52 | 13.64 | 1.70 | 13.44 | 1.23 | 13.43 | 0.84 |
| 15.35 | 3.30 | -0.02 | 2.12 | 15.24 | 1.54 | 15.47 | 1.13 |
| 17.19 | 4.16 | 17.27 | 2.71 | 17.31 | 1.97 | 17.21 | 1.37 |
| 19.23 | 5.28 | 19.11 | 3.34 | 19.41 | 2.51 | 19.25 | 1.69 |




(Pic.2)

**Summary**

This measurement contains systematic errors. For one thing, the conductor has a finite length. That means that the assumed magnetic field does not exist at the end of the conductor, so that the forces are less. Additionally, a minute opposing force component acts on the suspended conductor due to the conductor segment running upward.

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