Electricity

Electromagnetic induction

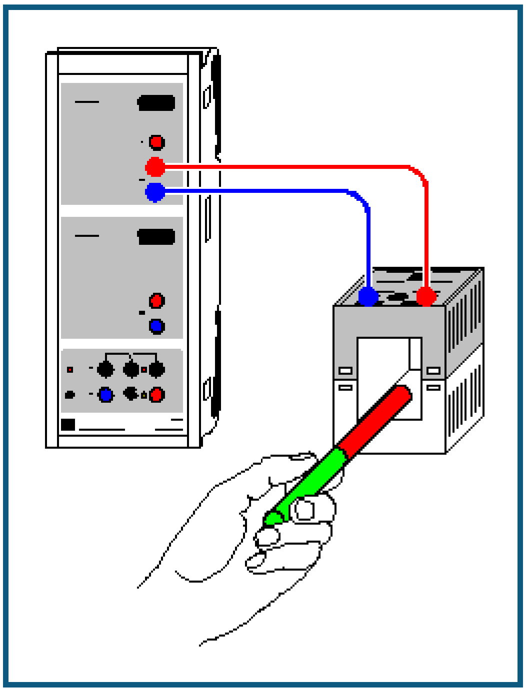
Voltage impulse

Generating a voltage surge in a conductor loop with a moving permanent magnet

Description from CASSY Lab 2

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

Impulse of voltage (Faraday's law of induction)



can also be carried out with Pocket-CASSY

Experiment description

In 1831, Faraday discovered that each change in the magnetic flux Φ through a closed conductor loop generates an electrical voltage in that loop. The magnetic flux here is given by the integral of the conductor-loop area of the magnetic flux density resp. induction **B**:

$$\Phi = \int_A \mathbf{B} \cdot d\mathbf{A}$$

In particular, he demonstrated that this induced voltage is proportional to the derivation of the magnetic flux Φ over time, and thus that the voltage impulse

$$\int_1^2 U(t) \cdot dt \propto \Phi_2 - \Phi_1 = \Delta\Phi$$

is dependent only on the change in the magnetic flux. He thus discovered Faraday's law of induction

$$U = -\frac{d\Phi}{dt}.$$

This experiment measures the induced voltage U(t) for various magnetic flux densities B and numbers of turns N for various coils, determines the time integral and thus the voltage impulse in the evaluation of a recorded curve and ultimately verifies Faraday's law of induction.

Equipment list

1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
2	Round bar magnets	510 11
1	Coil with 250 turns	562 13
1	Coil with 500 turns	562 14
1	Coil with 1000 turns	562 15
1	Pair of cables, 100 cm, red and blue	501 46
1	PC with Windows XP/Vista/7/8	

Experiment setup (see drawing)

Connect a coil to input A of Sensor-CASSY.

Carrying out the experiment

a) Measuring as a function of the magnetic flux Φ

- Load settings
- Connect the coil with 250 turns to input A.
- Start the measurement with .
- Insert one magnet half-way and remove it.
- Stop the measurement with (or the measurement stops automatically after 10 seconds).
- Start the measurement with and wait until the new measurement has proceeded far enough so that it no longer covers the old measurement.
- Insert two magnets half-way and remove them.
- Stop the measurement with (or the measurement stops automatically after 10 seconds).

b) Measuring as a function of the number of turns N

- Load settings
- Connect the coil with 250 turns to input A.
- Start the measurement with .
- Insert the magnet half-way and remove it.
- Stop the measurement with (or the measurement stops automatically after 10 seconds).
- Connect the coil with 500 turns to input A.
- Start the measurement with and wait until the new measurement has proceeded far enough so that it no longer covers the old measurement.
- Insert the magnet half-way and remove it.
- Stop the measurement with (or the measurement stops automatically after 10 seconds).
- Connect the coil with 1000 turns to input A.
- Start the measurement with and wait until the new measurement has proceeded far enough so that it no longer covers the old measurement.
- Insert the magnet half-way and remove it.
- Stop the measurement with (or the measurement stops automatically after 10 seconds).

Evaluation

In experiment part a), the integral quickly reveals that the voltage impulses have the same absolute value but different signs when the magnet is inserted in and withdrawn from the coil, i.e.

$$\int_{\downarrow} U(t) \cdot \mathrm{d}t = -\int_{\uparrow} U(t) \cdot \mathrm{d}t$$

The use of two magnets additionally verifies the proportionality between the voltage impulses and the number of magnets used resp.

$$\int_1^2 U(t) \cdot \mathrm{d}t \propto \Phi_2 - \Phi_1 = \Delta\Phi .$$

the difference in the magnetic flux produced in this manner:

$$U = -\frac{\mathrm{d}\Phi}{\mathrm{d}t}$$

By means of differentiation we verify Faraday's law of induction

The magnetic flux through a coil depends on the number of turns, as each individual turn causes a flux difference $\Delta\Phi_0$ and the total flux is calculated as $\Delta\Phi = N \cdot \Delta\Phi_0$.

When we look at experiment part b), the relationship between a voltage impulse and the number of turns N of the respective coil, we can also confirm this relationship. To do this we determine e.g. all positive areas and enter these in the **Number of Turns** display together with the number of turns N (click on the correct table cells). Once again, the proportionality gives us

$$\int_1^2 U(t) \cdot \mathrm{d}t \propto N \cdot \Delta\Phi_0 = \Delta\Phi .$$

The slope of the straight line in the display of voltage impulses as a function of the number of turns corresponds to the magnetic flux Φ_0 generated by the magnet in each individual coil winding.

Hints on integration

To integrate, you need to find the start of the range, which is not always easy when multiple curves are superimposed. It is easier when the measurement is stopped with immediately following the voltage impulse (do not wait for the 10 seconds to elapse) and the integral is calculated immediately after measuring. If you wait until after the end of the previous measuring curve before starting the next voltage impulse measurement, no curve covers the others while integrating.