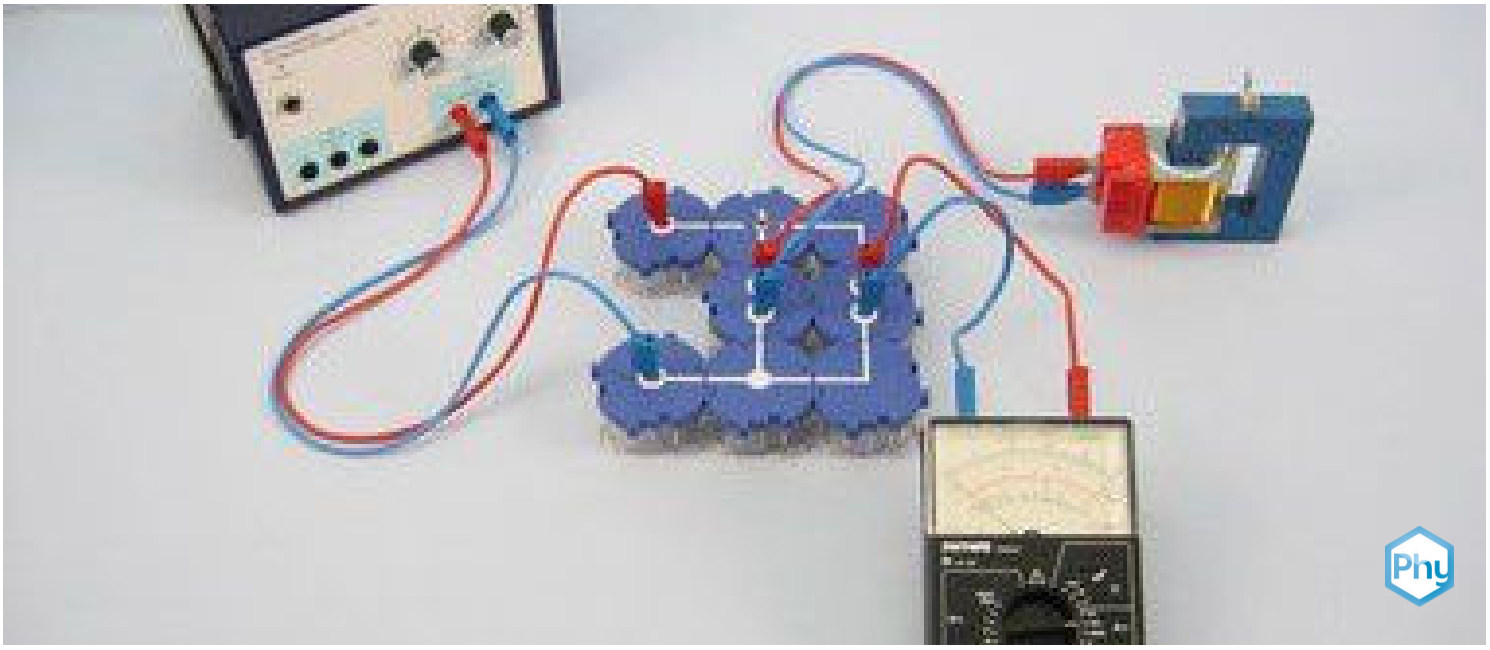
Self-induction when switching a circuit off



Physics | Electricity & Magnetism | Electromagnetism & Induction

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/631462f4971a9300037ff635

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Teacher information

Application

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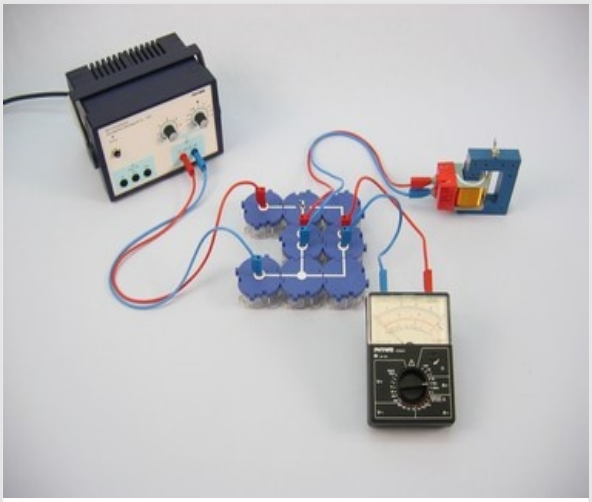

Experimental setup

Current-carrying coils have a magnetic field that must first be built after the DC circuit is closed and then reduced after the circuit is opened. This results in a self-induction voltage.

According to Lenz's law, the self-induction voltage always counteracts its cause. The following applies: $U_i = -L \cdot (\mathrm{d}I/\mathrm{d}t)$ with self-inductance L, and the unit Henry $(1\,H = 1\,\Omega s)$.

This principle is used, for example, as a damper in electrical measurement technology. Other examples of induction applications include charging stations or induction cookers.

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Other teacher information (1/3)

Prior knowledge

The students should be able to construct and understand a simple electric circuit. They should know that a voltage is induced in a coil as long as the magnetic field encompassed by the coil changes. They should be familiar with electromagnets and therefore also know that a current-carrying coil has a magnetic field and what the strength of the magnetic field depends on.

Principle

Self-inductance is a property of electrical circuits or components, especially coils. The self-inductance of a circuit relates the time rate of change of the electric current to the electric voltage. Both switching on and switching off counteracts the change and thus causes a delay in the change.

Other teacher information (2/3)

Learning objective

The students should realise with the planned experiment that a self-induction voltage is created when the power is switched off, which counteracts the drop in current. They should also realise that these voltages are sometimes very high.

Tasks

The first experiment, measuring the self-induction current, could take on the character of a confirmation experiment if the students can predict its result based on their knowledge of the law of induction and Lenz's law.

The second experiment is also intended to show that the self-induction voltage can assume values that exceed the original voltage many times over.

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Other teacher information (2/3)

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Other teacher information (3/3)

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During the first experiment, the teacher may have to point out that the switching in position 2 is not too slow. Slow switching can lead to the magnetic field across the opening spark having already largely collapsed before the self-induction current can flow through the ammeter. To save time, it is advisable to have the hands of the ammeters adjusted before the first experiment and then reset to zero. A student could do this outside of class.

Before starting the second experiment, the teacher should discuss the ignition and operating voltage of the available glow lamp and, if necessary, demonstrate the ignition voltage in a preliminary experiment. For this purpose, a series circuit consisting of the glow lamp and a resistor of $100\ k\Omega$ and a DC voltage is applied, which - in the case of $0\ V$ slowly until the glow lamp ignites. The power supply unit, for example, can be used as a current source. $0...600\ V$ (order no. 13672-93) must be used. High self-induction voltages during switch-off processes can, under certain circumstances, cause damage to technical switching systems and electronic components. This must be prevented by suitable measures, e.g. by connecting capacitors in parallel.

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Safety instructions

The general instructions for safe experimentation in science lessons apply to this experiment.

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Motivation

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Induction cooker

Induction is a principle that is used in many ways in electrical devices. Therefore, one often encounters this phenomenon in everyday life without being aware of it.

The most obvious example of induction is the induction cooker. Here, eddy currents are used to heat the bottom of the pot on the cooker. Another example where induction plays a role is wireless charging, where a time-varying magnetic field induces an electric field, which in turn generates a current.

In this experiment, you will learn about the self-induction of a coil and what effect this has on an electric circuit.

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Equipment

Position	Material	Item No.	Quantity
1	Straight connector module, SB	05601-01	1
2	Angled connector module, SB	05601-02	4
3	T-shaped connector module, SB	05601-03	2
4	Interrupted connector module with sockets, SB	05601-04	2
5	Junction module, SB	05601-10	2
6	On-off switch module, SB	05602-01	1
7	Change-over switch module, SB	05602-02	1
8	Socket module for incandescent lamp E10, SB	05604-00	1
9	Coil, 1600 turns	07830-01	1
10	Iron core, U-shaped, laminated	07832-00	1
11	Iron core, I-shaped, laminated	07833-00	1
12	Tightening screw	07834-00	1
13	Neon lamp 110 V AC, E10	07506-90	1
14	Connecting cord, 32 A, 250 mm, red	07360-01	1
15	Connecting cord, 32 A, 250 mm, blue	07360-04	1
16	Connecting cord, 32 A, 500 mm, red	07361-01	2
17	Connecting cord, 32 A, 500 mm, blue	07361-04	2
18	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
19	PHYWE Analog multimeter, 600V AC/DC, 10A AC/DC, 2 MΩ, overload protection	07021-11	1

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Set-up

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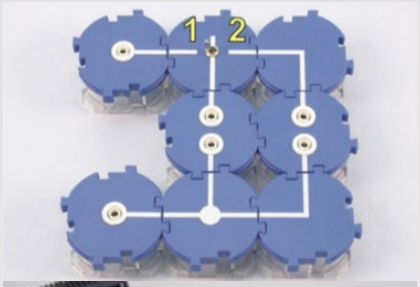

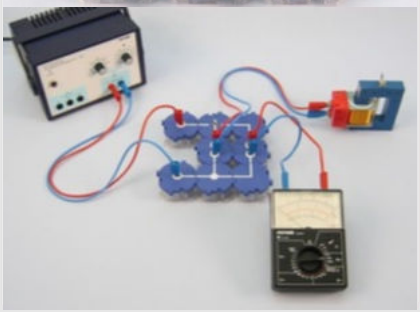

- Build the experiment according to the illustrations.
- Place the coil on the U-core.
- Press the U-core and the yoke firmly together with the clamping screw.
- The change-over switch should initially be in position 1.
- Measuring range $30\,mA$- and move the pointer of the ammeter out of the zero position by turning the adjusting screw at the reset of the ammeter to the right.

Attention! Since the direction of the self-induction current is not yet known before the experiment, it must be possible for the pointer to swing to the left without damaging the measuring instrument! Alternatively, use a measuring instrument with zero point in the centre of the scale.

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Procedure (1/2)

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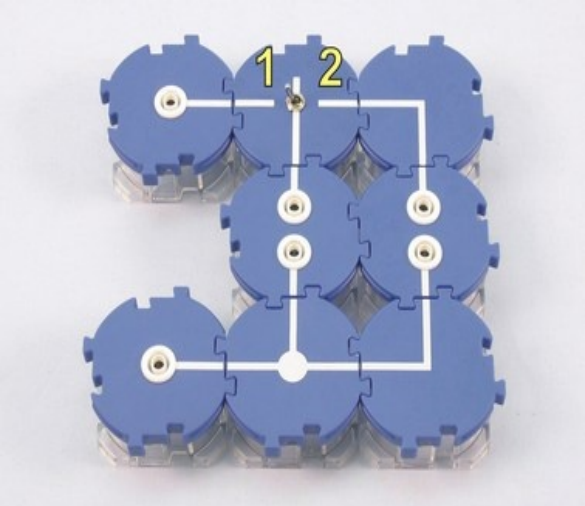
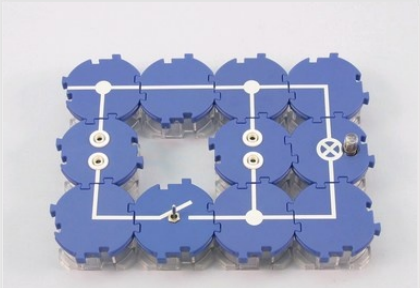
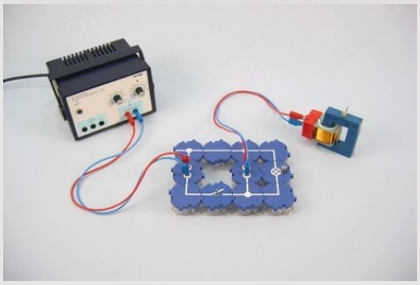


Switch positions

- Switch on the power supply unit and set the DC voltage to 10 V.
- Move the change-over switch to position 2 and thus open the left circuit and close the right circuit. Observe the ammeter deflection. Switching from position 1 to position 2 should be as fast as possible.
- Repeatedly actuate the changeover switch and record the observation on the ammeter in the report.
- Switch off the mains unit.

Procedure (2/2)





- Convert the experiment according to the illustrations.
- Switch on the power supply unit and set the DC voltage to 10 V again. Close the switch.
- Open the switch and observe the glow lamp.
- Close and open the switch repeatedly, observe the glow lamp and note the observation in the report.
- Switch off the mains unit.

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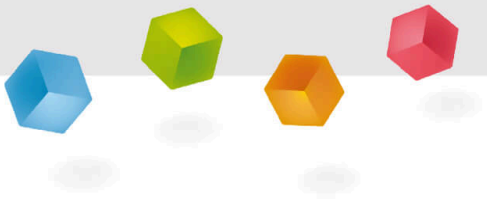

Report

Observations

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Describe your observations of the procedure (1/2).

Describe your observations of the procedure (2/2).

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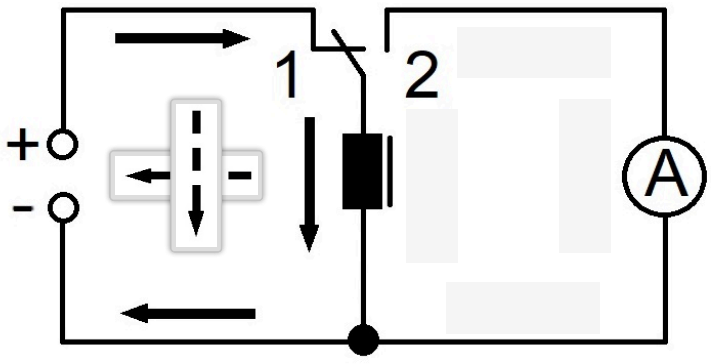
Task 1

Which statement can be made from the observation during the 1st experiment about the direction of the self-induction current and thus also the self-induction voltage during the switch-off process?

- The self-induction voltage during the switch-off process is opposite to that during the switch-on process and thus acts in the same direction as the applied voltage source
- The self-induction voltage during the switch-off process is opposite to that during the switch-on process and thus acts in the opposite direction to the applied voltage source.
- The self-induction voltage during the switch-off process is equal to the direction during the switch-on process and thus acts in the same direction as the applied voltage source.

Task 2



Think about the direction in which the self-induction current flows during the switch-off process. Draw the arrows for the induction current in the correct fields!

Direction of the original coil current.

Direction of the self-induction current.

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Task 3

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Which statement about the level of the self-induction voltage follows from the observation in the 2nd experiment? Compare the applied voltage with the ignition voltage of the glow lamp!

- ○ No conclusion for the self-induction voltage can be drawn from the comparison of the applied voltage and the ignition voltage.
- ○ The self-induction voltage is so high that the bulb glows. This means that the self-induction voltage must be at least the quotient of the applied voltage and the ignition voltage.
- ○ The self-induction voltage is so high that the bulb glows. This means that the self-induction voltage must be at least equal to the difference between the applied voltage and the ignition voltage.

Check

Task 4

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Drag the words into the correct boxes!

The self-induction voltage during the switching-on process _____ the applied voltage. The voltage during the switch-off process has a _____ effect according to Lenz's rule. This results in a very _____. This must be considered for circuits with sensitive components.

boosting
counteracts
high voltage

Check

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