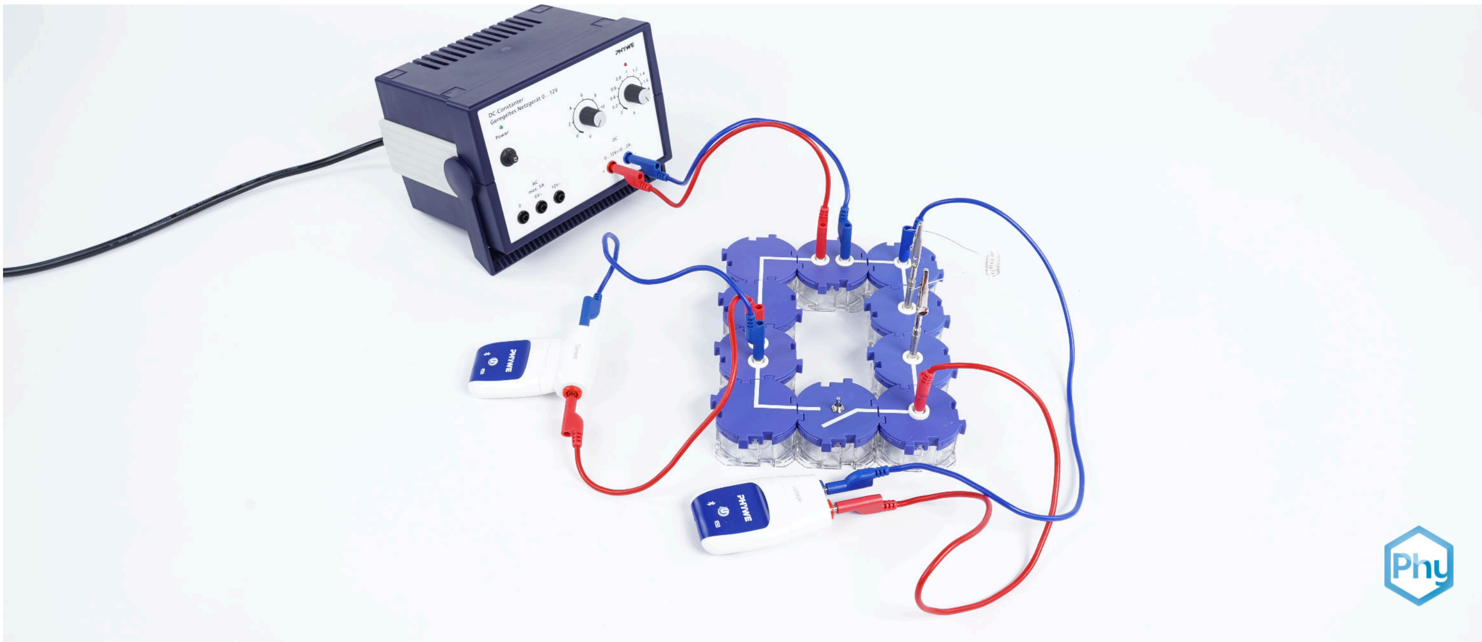
Conversion of electrical energy into thermal energy with Cobra SMARTsensey into thermal energy



Physics | Energy | Energy forms, conversion & conservation

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

This content can also be found online at:

https://www.curriculab.de/c/6840162254ef7c00028d4161

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Teacher information

Application

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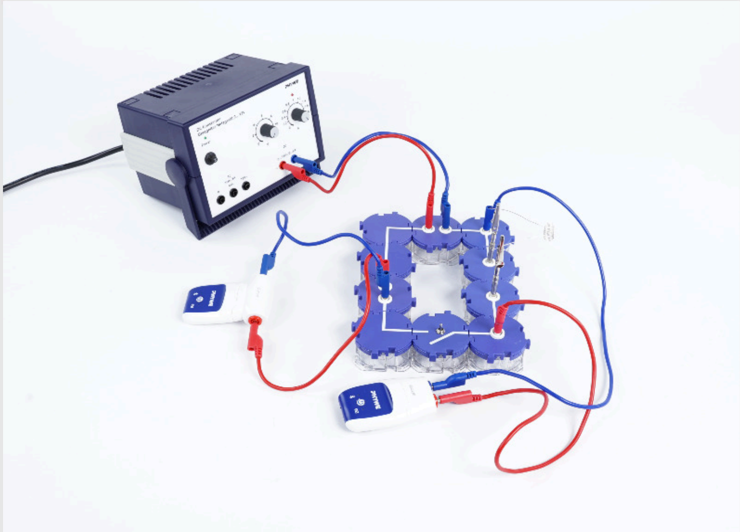

Fig. 1 Setup

Energy is a measure of stored work and can occur in various forms that can be converted into each other. In a closed system, the total energy remains constant during conversion processes, which makes it a fundamental quantity in physics.

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Other teacher information (1/4)

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Prior knowledge

In this experiment, it is important to know that electrical energy can be converted into thermal energy in the form of heat.

The heat and light effects of electric current are familiar to the pupils from everyday life, and they have already experienced the effects of electric current. They have experimented with light bulbs and used their luminosity or light effect as a measure of current.

Principle

An electric current is applied to a constantan wire. The wire lies in a trough of water and heats it up. The temperature change and the electrical power are measured.

Other teacher information (2/4)

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Learning objective

In this experiment, the equivalence of the electrical energy E_{el} and thermal energy E_{th} is experimentally proven

Tasks

Parallel measurement of the current I and the temperature T depending on the time t the two forms of energy with the units watt-second $[\mathrm{Ws}]$ and Joule $[\mathrm{J}]$ at a known constant voltage U be quantified

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Other teacher information (3/4)

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Additional information

In this experiment, the equivalence of the electrical energy E_{el} and thermal energy E_{th} is experimentally proven. The electrical energy E_{el} is converted into thermal energy within the heating coil E_{th}. This leads to an increase in the temperature of the heating coil (or the water in which the heating coil can be immersed). By simultaneously measuring the current I and the temperature T depending on the time t both forms of energy at a known constant voltage U can be recorded quantitatively. This enables the experimental verification of their numerical equivalence E_{el} = E_{th}, where:

$$E_{el} = U \cdot I \cdot t$$

The heat capacity of the glass vessel must be taken into account in the assessment.

$$E_{th} = Q = [(C_{glass} + C_{wasser}) \cdot m_{wasser}] \cdot \Delta T$$

Other teacher information (4/4)

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Additional information

The specific heat capacity C of glass is usually expressed in joules per gram per Kelvin $[\mathrm{J/gK}]$ or joules per kilogramme per Kelvin $[\mathrm{J/kgK}]$. However, the exact values vary depending on the glass composition and can range from approx. $0.8\ \mathrm{J/gK}$ to $1.2\ \mathrm{J/gK}$.

The heat capacity of water is approximately $4.18\ \mathrm{J/gK}$ or $4.18\ \mathrm{kJ/kgK}$. This value applies to pure water under normal conditions (e.g. $25\ ^\circ\mathrm{C}$).

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Safety instructions

Notes

A current of $2\ \mathrm{A}$ is sufficient to make the wire coil glow (faintly) red when it is removed from the water. Make sure that all electrical connections are made properly and safely to avoid accidents.

Note: Even if the coil does not glow, it has such a high temperature that it is important to warn the students of the danger of burning themselves when touching the coil.

Make sure that the thermometer measures the water bath correctly and does not come into contact with the heating coil in order to avoid measurement errors.

Student information

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Motivation

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Fig. 2 Water boiler

Electrical energy can be converted into heat — an immersion heater illustrates this process well. It consists of a heating coil with high electrical resistance, through which electric current flows. The resistance causes the coil to heat up, and this heat is then transferred to the surrounding water, causing it to warm.

Tasks

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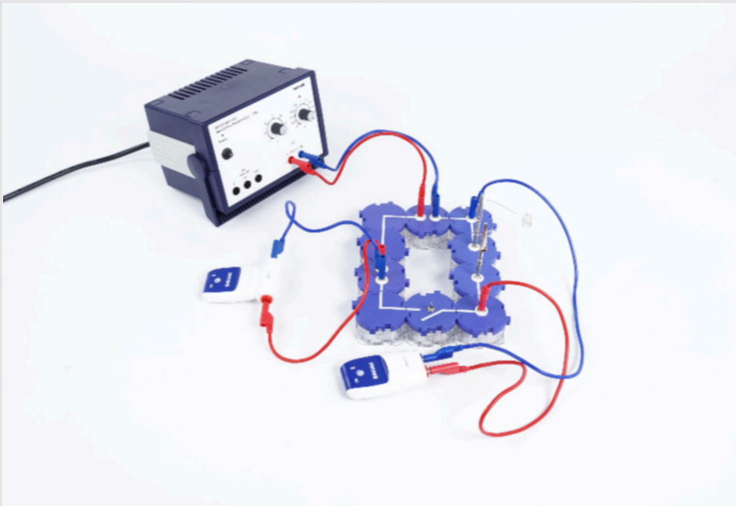

Fig. 3 Setup

1. Build a circuit with the electronic components to create an immersion heater model.
2. Convert electrical energy into thermal energy.
3. Measure voltage and current.

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Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense Current - Sensor for measuring electrical current	12902-01	1
2	Cobra SMARTsense Voltage - Sensor for measuring electrical voltage	12901-01	1
3	Straight connector module, SB	05601-01	1
4	Angled connector module, SB	05601-02	2
5	Interrupted connector module with sockets, SB	05601-04	2
6	Junction module, SB	05601-10	2
7	Angled connector module with socket, SB	05601-12	2
8	On-off switch module, SB	05602-01	1
9	Trough, grooved, w/o lid	34568-01	1
10	Alligator clips, bare, 10 pcs	07274-03	1
11	Connecting plug, 2 pcs.	07278-05	1
12	Connecting cord, 32 A, 250 mm, red	07360-01	1
13	Connecting cord, 32 A, 250 mm, blue	07360-04	1
14	Connecting cord, 32 A, 500 mm, red	07361-01	2
15	Connecting cord, 32 A, 500 mm, blue	07361-04	2
16	Constantan wire, 6.9 Ohm/m, d = 0.3 mm, l = 100 m	06101-00	1
17	PHYWE Power supply, 230 V,DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
18	Students thermometer, -10...+110°C, l = 230 mm	38005-10	1
19	measureAPP - the free measurement software for all devices a	14581-61	1

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Setup (1/3)

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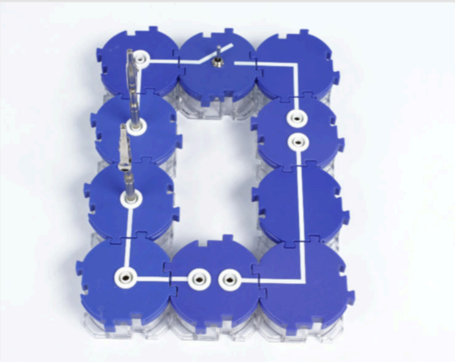
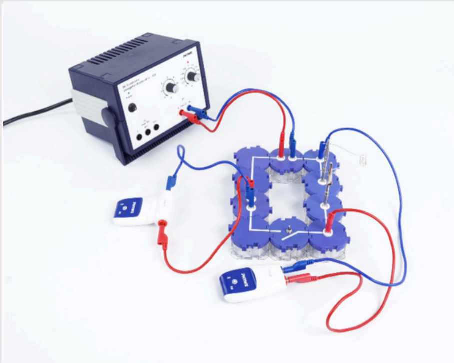
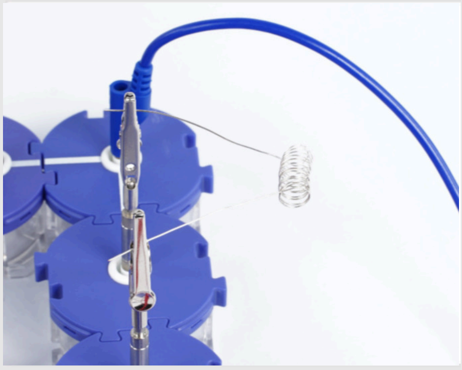
- Build the circuit as shown in the illustrations below. Use the crocodile clip to clamp the spiral. Build the spiral by wrapping the wire around a pin, for example.







Setup (2/3)

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For measurement with the **Cobra SMARTsense sensors** the **PHYWE measureAPP** required. The app can be downloaded free of charge from the relevant app store (see below for QR codes). Before starting the app, please check whether your device (smartphone, tablet, desktop PC) is running **Bluetooth activated** is.

iOS

Android

Windows

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Setup (3/3)

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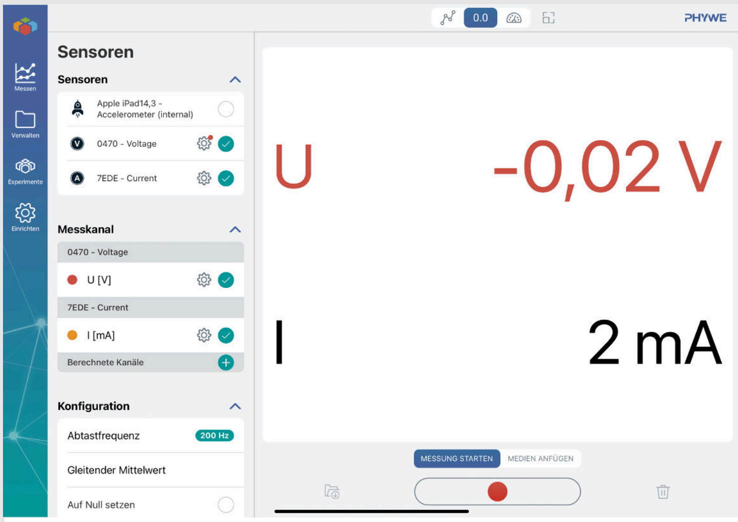

Example screenshot of the app

- Start the two Cobra SMARTsense sensors by pressing and holding the on/off button on both for about three seconds.
- Now start the measureAPP and connect to both sensors. Set the display so that the measured values are shown as numbers. You can do this by clicking on "0.0" at the top of the app. You can see what this looks like on the left-hand side.

Procedure (1/3)

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1st experiment

- Fill the grooved tray with $100\ \mathrm{ml}$ of cold water, place it next to the blocks and immerse the heating coil completely in the water.
- Measure the water temperature and record the temperature under $t = 0\ \mathrm{min}$ in Table 1 of the protocol.
- Switch on the power supply. Close the switch and start the stopwatch
- Set the voltage so that the current is $2\ \mathrm{A}$ and enter the measured values for voltage and current in Table 1

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Procedure (2/3)

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1st experiment

- Stir the water several times. Open the switch once every minute to measure the water temperature. Enter the results in Table 1. Then close the switch again each time. After $5\ \mathrm{min}$ leave the switch open.
- Pour out the water, rinse the grooved trough with cold water and fill it again with $100\ \mathrm{ml}$ of cold water.
- Repeat the measurements at a current of $1.4\ \mathrm{A}$
- Enter the measured values in Table 2

Procedure (3/3)

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2nd experiment

- Remove the heating coil from the water, close the switch
- Restore the power $I = 2\ \mathrm{A}$
- Observe the heating coil. CAUTION: Do not touch the hot coil!
- Open the switch and switch off the power supply.
- Note your observations in your log

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Report

Table (1/2)

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Enter the measured values for the temperature of the water, voltage and current $I = 2\ \mathrm{A}$ into the table.

Time in min	T in °C	U in Volts	I in Amperes
1			
2			
3			
4			
5			

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Table (2/2)

Enter the measured values for the temperature of the water, voltage and current $I = 1{,}4\ \mathrm{A}$ into the table.

Time in min	T in °C	U in Volts	I in Amperes
1			
2			
3			
4			
5			

Task (1/4)

Calculate the thermal energy absorbed by the water using the following equation:

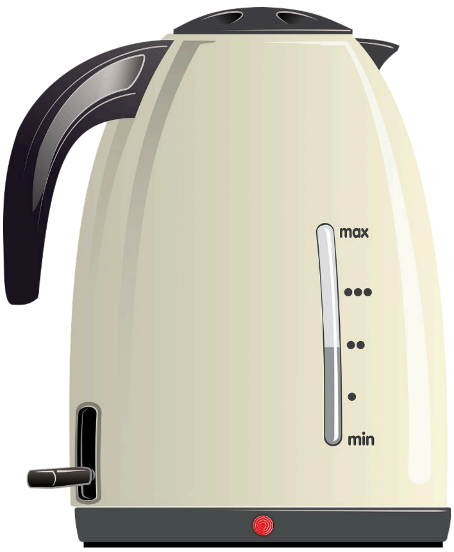
$$Q = [(C_{glass} + C_{wasser}) \cdot m_{wasser}] \cdot \Delta T$$

ΔT is the change in temperature per measuring step. It is approximately

$$C_{glass} = 1\ \mathrm{J/gK}, C_{wasser} = 4,18\ \mathrm{J/gK}$$

The mass must be stated accordingly in grams.

Note down your calculated value on the next page.



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Task (2/4)

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$Q =$ [ ]

$E_{th} =$ [ ]

Now calculate the thermal energy E_{th} for the heating coil. You can use the following formula in this experiment:

$$E_{th} = P \cdot t$$

P is the power consumption of the heating coil and t is the time.

The performance P is determined by the product of voltage U and electricity I:

$$P = U \cdot I$$

If you have measured the voltage U and the current I of the heating coil in the circuit, you can calculate the power P. Then multiply the power by the time t to get the thermal energy E_{th}. Is E_{th} larger or smaller Q? Why is there this ratio?

Task (3/4)

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Which unit is used to measure electrical energy?

- Volt (V)
- Joule (J)
- Ampere (A)
- Watt (W)

See

How do you calculate the power (P) in a circuit?

- P = U - I
- P = U / I
- P = U + I
- P = U * I

See

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Task (4/4)

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What does the heat capacity mean C?

- The amount of thermal energy
- The temperature change of a system
- The electrical power consumption
- The amount of energy required to increase the temperature of a system

See

Slide	Result/In Total
Slide 23: Multiple tasks	0/2
Slide 24: What is the correct answer?	0/1
In total	**0/3**

Solutions Repeat Export text

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