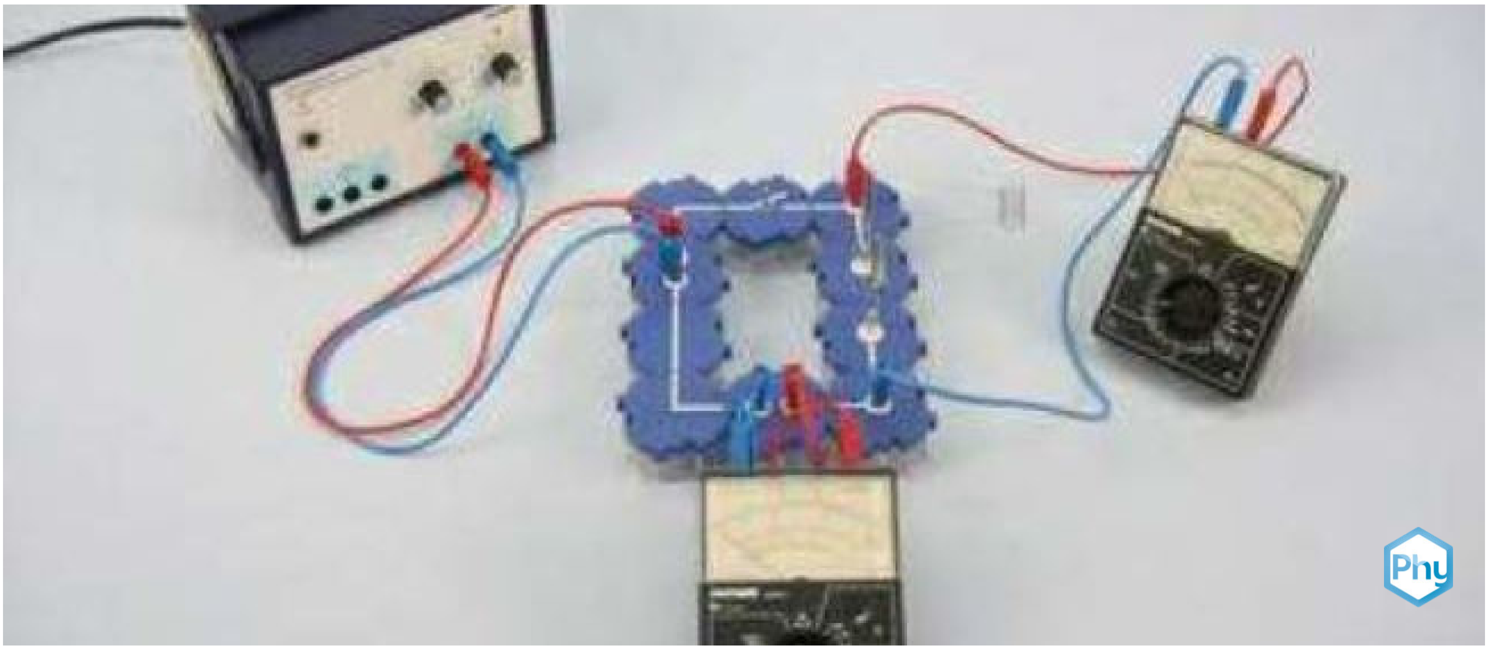
Conversion of electrical energy into thermal energy



P1374700

Physics	Energy	Energy forms, conversion & conservation

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

This content can also be found online at:

http://localhost:1337/c/6479ce2273f0d10002818a77

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Teacher information

Application

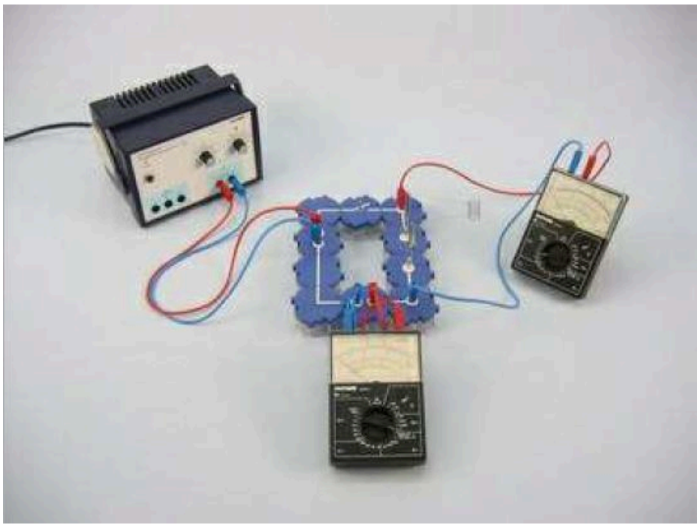

fig. 1 setup

Energy is a measure of stored work and can manifest in different forms that can be converted into one another. In a closed system, the total energy remains constant during conversion processes, making it a fundamental quantity in physics.

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Other teacher information (1/4)

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Prior

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

Principle

The heat and light effects of the electric current are familiar to the students from everyday life, and they have also already
experimented with incandescent lamps and used their luminous or light effect as a measure of electric current intensity.

Other teacher information (2/4)

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Learning

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

Tasks

By measuring the current I and the temperature ϑ in parallel as a function of time t, the two forms of energy can be quantified with the units watt-second (Ws) and joule (J) at a known constant voltage U

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Other teacher information (3/4)

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Additional information

In this experiment, the equivalence of electrical energy E_{el} and thermal energy E_{th} is experimentally demonstrated. The electrical energy E_{el} supplied in the experiment is converted into heat E_{th} in the heating coil (or heating spiral). This leads to an increase in temperature of the heating coil (or water, in which the heating coil can be immersed). By simultaneously measuring the current I and the temperature ϑ as a function of time t, both forms of energy can be quantitatively captured, given a known constant voltage U. This allows for the experimental verification of their numerical equivalence: E_{el} = E_{th}.

$$E_{el} = Q \; with \; E_{el} = U \cdot I \cdot t$$

The heat capacity of the glass vessel must be taken into consideration in the evaluation.

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

Other teacher information (3/4)

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Additional information

The specific heat capacity (c) of glass is usually expressed in joules per gram per kelvin (J/g-K) or joules per kilogram per kelvin (J/kg-K). However, the exact values vary depending on the glass composition and can range from about 0.8 J/g-K to 1.2 J/g-K.

The heat capacity of water is about 4.18 joules per gram per kelvin (J/g-K) or 4.18 kilojoules per kilogram per kelvin (kJ/kg-K). This value is valid for pure water at normal conditions (approximately 25 °C).

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Safety instructions

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Notes

A current strength of 2 A is sufficient to bring the wire coil to a (weak) red glow when taking it out of the water. Make sure that all electrical connections are made properly and safely to avoid accidents.
Note: Even if the coil does not come to glow, it has such a high temperature that it is important to warn the students of the danger of being burnt on touching the coil.

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

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

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Student Information

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Motivation

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fig. 2 water boiler

Electrical energy can be converted into thermal energy and an immersion heater is a great example to explain this process. An immersion heater consists of a heating coil through which an electric current flows and a metal shell that surrounds the water. When the immersion heater is immersed in water and the power is on, the electric current flows through the heating coil. This heating coil is made of a material with high electrical resistance, which means that it makes it difficult for electricity to flow. This causes the heating coil to heat up. The heating coil transfers the generated thermal energy to the surrounding water. Through the process of heat transfer, the water around the immersion heater heats up.

Tasks

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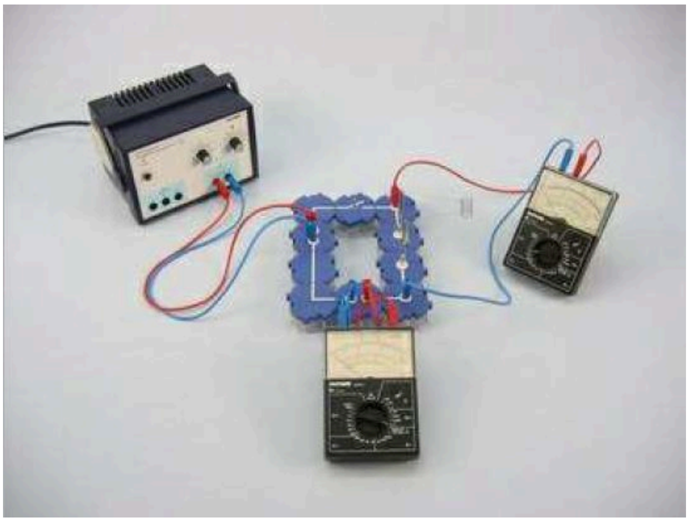

fig. 3 setup

Build a circuit with the electronic building blocks to create an immersion heater model and convert electrical energy into thermal energy. Measure the voltage in parallel and the current in series using the multimeters.

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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	2
3	Interrupted connector module with sockets, SB	05601-04	2
4	Junction module, SB	05601-10	2
5	Angled connector module with socket, SB	05601-12	2
6	On-off switch module, SB	05602-01	1
7	Trough, grooved, w/o lid	34568-01	1
8	Alligator clips, bare, 10 pcs	07274-03	1
9	Connecting plug, 2 pcs.	07278-05	1
10	Connecting cord, 32 A, 250 mm, red	07360-01	1
11	Connecting cord, 32 A, 250 mm, blue	07360-04	1
12	Connecting cord, 32 A, 500 mm, red	07361-01	2
13	Connecting cord, 32 A, 500 mm, blue	07361-04	2
14	Constantan wire, 6.9 Ohm/m, d = 0.3 mm, l = 100 m	06101-00	1
15	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
16	Digitalmultimeter 9804A+, 1000V AC/DC, 20A AC/DC, 200MΩ, 20mF, 20 MHz, -20...1000°C	07028-12	2
17	Digital stopwatch, 24 h, 1/100 s and 1 s	24025-00	1

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Tasks

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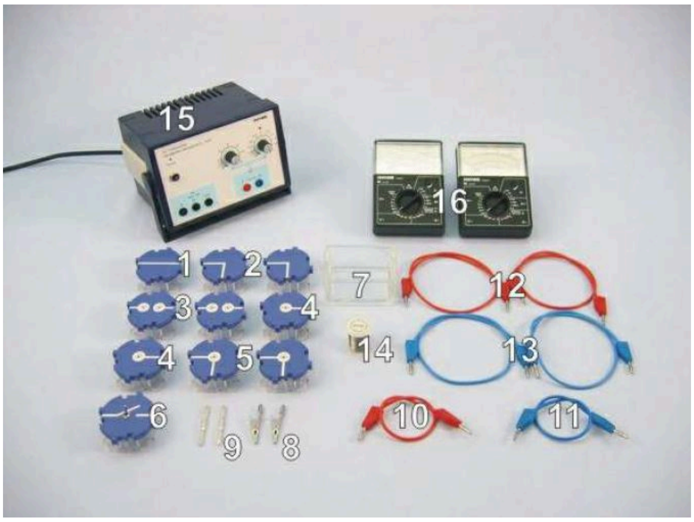

fig. 4 parts overview

Build a circuit with the electronic building blocks to create a heater model and convert electrical energy into thermal energy.

Structure (1/1)

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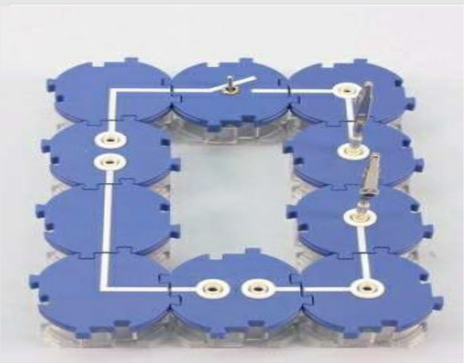
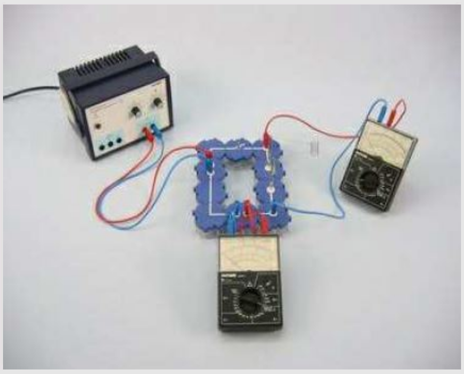
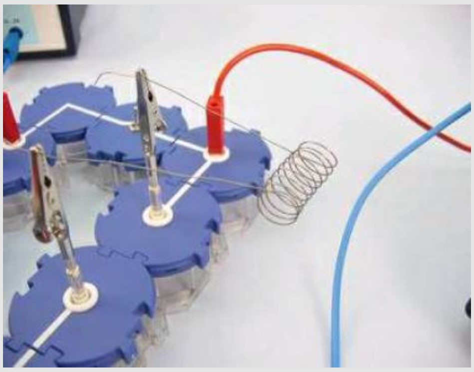
Build a corresponding circuit with the building blocks. Use the alligator clips to attach the heating coil.

Do not switch on the power supply yet. The control unit remain in zero positon. Connect the connecting corts to the circuit and connect the multimeters accordingly so that the voltage and current can be measured.







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procedure (1/3)

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1st experiment

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

procedure (2/3)

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1st experiment

- Stir water several times, open switch after 5 min, measure water temperature and record in table 1
- Pour out the water, rinse the grooved trough with cold water and fill it again with 100 ml cold water
- Repeat measurement at a current of 1.4 A
- Enter the measured values in Table 2

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procedure (3/3)

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2nd experiment

- Take the heating coil out of the water, close the switch
- Set the current to I = 2 A again
- Observe the heating coil. CAUTION! Do not touch the hot coil!
- Open the switch and turn off the power supply
- Write down your observations in your protocol

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Report

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Task 1/4

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Enter your readings for the temperature of water, voltage and with a current of I = 2A in the table

time in min	T in °C	U in Volt	I in Ampere
0			
1			
2			
3			
4			
5			

tab. 1

Task 2/4

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Enter your readings for the temperature of water, voltage and with a current of I=1,4 A in the table

time in min	T in °C	U in Volt	I in Ampere
0			
1			
2			
3			
4			
5			

tab. 2

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task 3/4

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$P = U \cdot I$

$E_{el} = Q \; with \; E_{el} = U \cdot I \cdot t$

The heat capacity of the glass vessel must be taken into consideration in the evaluation.

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

task 4/4

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To calculate the thermal energy E_{th} for the heating coil in this experiment, you can use the formula:

$E_{th} = P \cdot t$

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

The power (P) is calculated by the product of voltage (U) and current (I):

$P = U \cdot I$

If you have measured the voltage (U) and 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} Note, however, that this represents the thermal energy only for the heating coil itself and not the energy that is actually transferred to the water.

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Question 1/3

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Which unit is used to measure electrical energy?

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

Check

Question 1/3

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Which unit is used to measure electrical energy?

- Volt (V)
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Check

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Question 2/3

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

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

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Question 3/3

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What does the heat capacity (C) indicate?

- The amount of energy needed to raise the temperature of a system
- the Electrical power consumption
- The amount of thermal energy
- The temperature change fo a system

Check

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