Heat

Heat as a form of energy

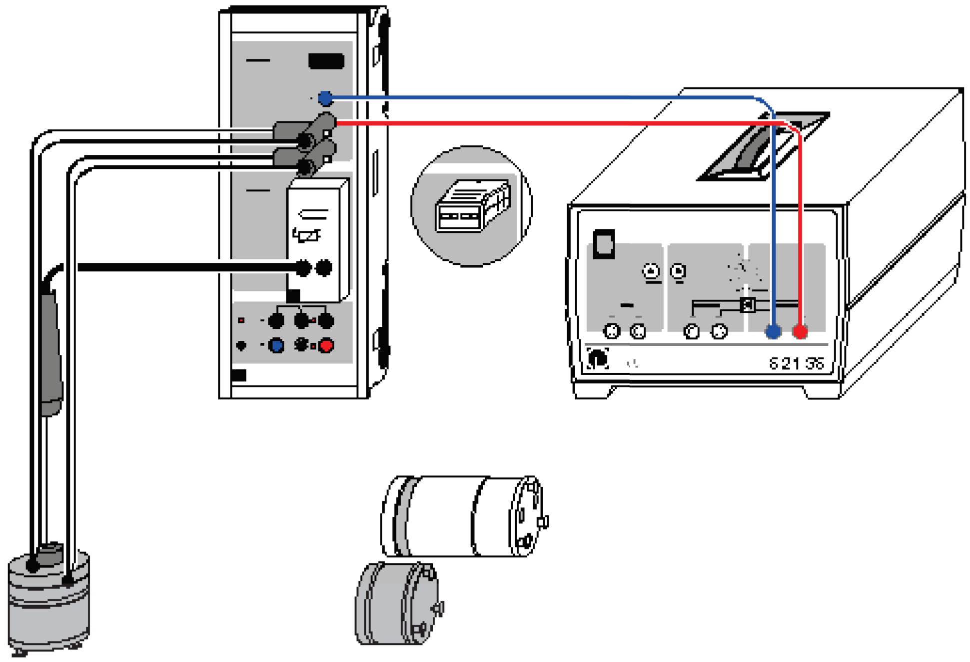
Converting electrical energy into heat

Converting electrical energy into heat energy - Measuring with CASSY

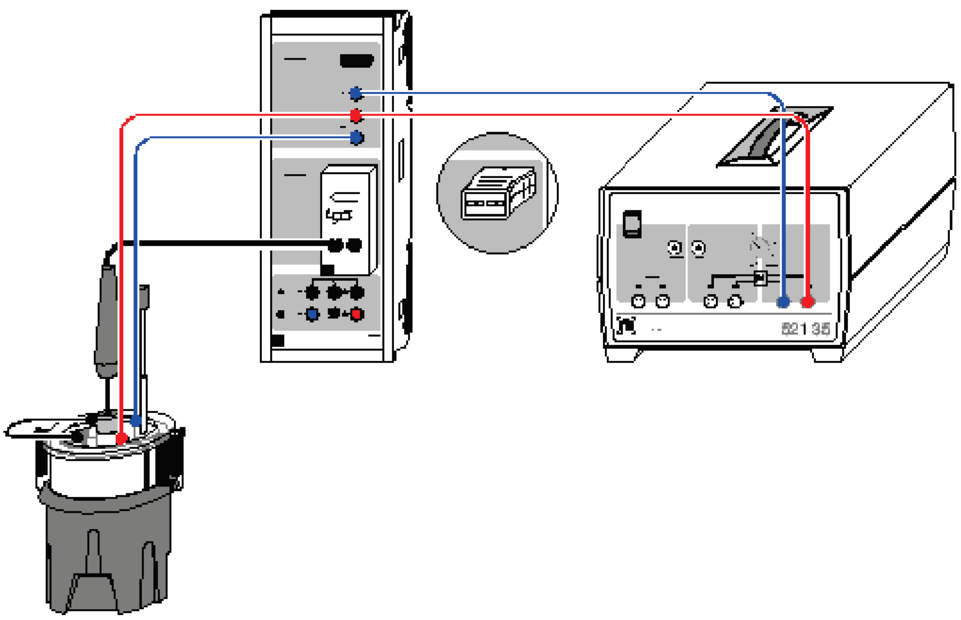
Description from CASSY Lab 2

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

Conversion of electrical energy into thermal energy



Alternatively:



Safety note

Danger of implosion: the Dewar vessel is a thin-walled, highly evacuated glass vessel which can break under mechanical stress.

Do not knock or drop the Dewar vessel.

Do not allow any hard objects to fall on or into the glass mantle.

Do not scratch the glass mantle with sharp objects.

Experiment description

Energy is a measure of stored work. It occurs in different forms, which can be converted one into the other. In a closed system, the total energy is conserved in conversion processes. therefore the energy is one of the fundamental quantities of physics.

In this experiment, the equivalence of electrical energy E_{el} and thermal energy E_{th} is established experimentally. The supplied electrical energy E_{el} is converted into heat E_{th} in the heating coil (or heating spiral). This leads to a temperature rise in the calorimeter (or water, in which the heating spiral is immersed). As the current I and the temperature ϑ are measured simultaneously as functions of the time, the constant voltage U being known, the two energy forms can be registered quantitatively in units of wattsecond (Ws) and Joule so that their numerical equivalence can be demonstrated experimentally: $E_{el} = E_{th}$.

Equipment list

1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
1	Temperature box	524 045
1	Temperature sensor NiCr-Ni	666 193
	or	
1	NiCr-Ni adapter S	524 0673
1	Temperature sensor NiCr-Ni, type K	529 676
1	Voltage source, 0...12 V, e.g.	
	Variable extra-low voltage transformer S	521 35
1	Calorimeter with connecting cables, e.g.	
	copper calorimeter with heating	388 02
	pair of connecting cables for calorimeter	388 06
	or	
	aluminum calorimeter with heating	388 03
	pair of connecting cables for calorimeter	388 06
	or	
	large aluminum calorimeter with heating	388 04
	pair of connecting cables for calorimeter	388 06
	or	
	Electric calorimeter attachment	384 20
	Dewar vessel	386 48
	Beaker, squat shape, Duran, 250 ml	664 103
	Graduated cylinder, plastic base, 250 ml	665 755
	Pair of cables, 50 cm, red and blue	501 45
	Connecting lead, 50 cm, black	501 28
1	Pair of cables, 50 cm, red and blue	501 45
1	PC with Windows XP/Vista/7	

Experiment setup with calorimeter (see drawing)

- Set up the calorimeter so that the bore points upwards and pour water into the opening.
- Insert the gasket in the bore, and hold it with the locking screw.
- Insert the temperature sensor as deeply as possible in the opening of the calorimeter, and tighten the locking screw of the calorimeter.
- For the current and voltage measurement, connect the CASSY to the variable extra-low voltage transformer S as shown in the drawing.
- Connect the heating coil of the calorimeter to the input A of the Sensor-CASSY (plug the large banana plugs together and connect one cable to the blue safety socket and one cable to the red safety socket).
- Connect the temperature sensor to the input B of the Sensor-CASSY via the temperature box (socket T_1) for measuring the temperature ϑ_{B11}.

Experiment setup with electric calorimeter attachment (see drawing)

- Using the graduated cylinder, pour approx. 200 ml of water into the Dewar vessel.
- Put the electric calorimeter attachment into the Dewar vessel, and fix the cover with the aid of the springs.

- Immerse the temperature sensor with the sealing washer in the Dewar vessel through the rubber stopper. The temperature sensor has to be held by the sealing washer so that the tip of the sensor is below the heating spiral. However, the tip of the temperature sensor must not touch the bottom of the Dewar vessel.
- For the current and voltage measurement, connect the CASSY to the variable extra-low voltage transformer S as shown in the drawing.
- Connect the heating spirals in series to the input A of the Sensor-CASSY (lay a cable from one heating spiral to the red safety socket and another cable from the other heating spiral to the blue safety socket, and connect the free connectors with a black cable).
- Connect the temperature sensor to the input B of the Sensor-CASSY via the temperature box (socket T_1) for measuring the temperature ϑ_{B11}.

Experiment note

If the experiment is carried out with the electric calorimeter attachment, the water has to be stirred while the voltage is switched on in order that the warming takes place uniformly. Slowly move the stirrer up and down during the measurement.

Carrying out the experiment

Load settings

- Select the **Voltage U_{A1}** as measurement quantity in Settings IA1.
- Switch the variable extra-low voltage transformer S on, and set the voltage U_{A1} to approx. 9 V (calorimeter) or approx. 4 V (electric calorimeter attachment).
- Read the exact value of U_{A1}, and enter it in Settings U as parameter.
- Switch the variable extra-low voltage transformer S off, and select the **Current I_{A1}** as measurement quantity and **0...2.1 A** as range in Settings UA1.
- When the initial temperature ϑ_{B11} is constant, start the measurment with .
- Switch the variable extra-low voltage transformer S on, and switch it off again at the desired final temperature ϑ_{B11}.
- Stop the measurement with when a constant final temperature is reached.

Evaluation

The temperature ϑ_{B11} and the current I_{A1} are already displayed graphically as functions of the time during the measurement. The thermal energy $E_{th} = C \cdot (\vartheta_{B11} - \vartheta_1)$ is plotted against the electrical energy $E_{el} = \sum U \cdot I \cdot \Delta t$ in the prepared diagram **Evaluation**. The heat capacity C depends on the calorimeter used and has to be entered in the Settings C according to the following table:

Calorimeter	Heat capacity C/(J/K)
Copper (388 02)	264 + 4.2 (for 1 g water in the bore)
Aluminum (388 03)	188 + 4.2 (for 1 g water in the bore)
Aluminum, large (388 04)	384 + 4.2 (for 1 g water in the bore)
Electr. calorimeter attachment (384 20) with Dewar vessel (386 48)	$(m_{H2O}/g + 24) \cdot 4.2$ (with the mass of the water in g and the water equivalent m_D = 24 g of the Dewar vessel)

The equivalence of the electrical energy E_{el} and the thermal energy E_{th} can be confirmed by fitting a line through the origin. Usually the slope of the straight line through the origin is somewhat smaller than 1 because of heat loss due to emission of heat radiation. This becomes particularly obvious in the case of long measuring times, where the measuring data deviate significantly from the straight line through the origin.

Hint

As an alternative, the measurement can be evaluated manually: determine the mean value of the initial temperature ϑ_1 and the final temperature ϑ_2 (select Draw Mean with the right mouse button), and calculate the thermal energy $E_{th} = C \cdot (\vartheta_2 - \vartheta_1)$. Determine the time of electrical energy supply with Set Marker → Measure Difference, calculate $E_{el} = U \cdot I \cdot \Delta t$, and compare it with E_{th}.