# Heat

Heat as a form of energy

*Converting mechanical energy into heat*

# Converting mechanical energy into heat energy - Recording and evaluating with CASSY

**Description from CASSY Lab 2**

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

CASSY Lab 2 (2013-06-07)



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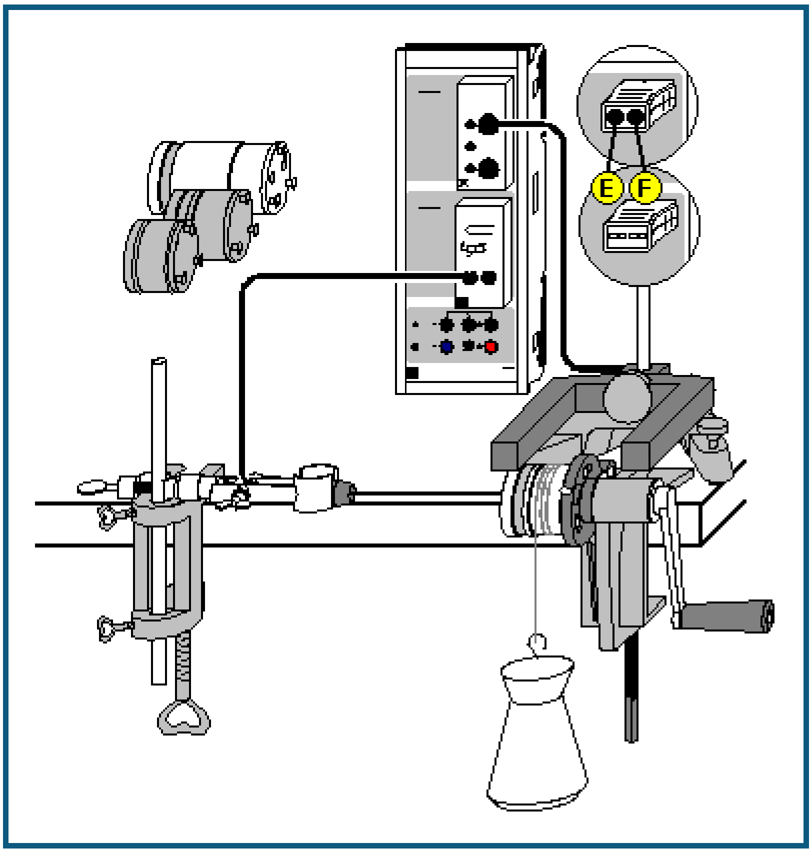
## Conversion of mechanical energy into thermal energy




can also be carried out with Pocket-CASSY

### Safety note

Make sure that the experimenter stands so that he or she cannot be injured when the 5 kg weight is dropped inadvertently.

### Experiment description

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

In this experiment, the equivalence of mechanical energy $E_m$ and thermal energy $E_{th}$ is established experimentally. Mechanical work $E_m$ is expended by turning a crank handle against the frictional force. This leads to a temperature rise of the calorimeter and thus to an increase in the thermal energy $E_{th}$. The two energy forms can be registered quantitatively in units of newton meter (Nm) and Joule (J) by measuring the temperature $\vartheta$ and the number of revolutions so that their numerical equivalence can be demonstrated experimentally: $E_m = E_{th}$.

### Equipment list

| | | |
|---|---|---|
| 1 | Sensor-CASSY | 524 010 or 524 013 |
| 1 | CASSY Lab 2 | 524 220 |
| 1 | Timer box or Timer S | 524 034 or 524 074 |
| | | |
| 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 | Forked light barrier, infrared | 337 46 |
| 1 | Multicore cable, 6-pole, 1.5 m | 501 16 |
| 1 | Equivalent of heat, basic apparatus | 388 00 |

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| | | |
|---|---|---|
| 1 | Calorimeter | |
| | e.g. | |
| | water calorimeter | 388 01 |
| | or | |
| | copper calorimeter with heating | 388 02 |
| | or | |
| | aluminum calorimeter with heating | 388 03 |
| | or | |
| | large aluminum calorimeter with heating | 388 04 |
| 1 | Bench clamp, simple | 301 07 |
| 1 | Stand base, V-shape, 20 cm | 300 02 |
| 1 | Stand rod, 10 cm | 300 40 |
| 1 | Stand rod, 25 cm | 300 41 |
| 1 | Clamp with jaw clamp | 301 11 |
| 1 | Weight, 5 kg | 388 24 |
| 1 | PC with Windows XP/Vista/7/8 | |

### Experiment setup (see drawing)

- Fasten the equivalent of heat basic apparatus to a corner of the table.
- Fasten the bench clamp at the edge of the table at a distance of approx. 40 cm from the plastic mounting of the basic apparatus. Clamp the clamp with jaw clamp with the aid of the stand rod 25 cm in order to be able to fix the temperature sensor as shown in the 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.
- Attach the filled calorimeter body to the basic apparatus by inserting the rivet pins in the sockets of the plastic mounting and twisting the calorimeter body to lock the pins in place.
- Insert the temperature sensor as deeply as possible in the opening of the calorimeter, and tighten the locking screw of the calorimeter. Fix the temperature sensor by means of the stand material that has already been prepared as shown in the drawing.
- Put the 5 kg weight under the calorimeter body.
- Wind the nylon band approx. 4 times (6 at maximum) around the calorimeter, and attach it to the weight on the floor. The weight has to hang down on the side of the crank on the front.
- Operate the crank handle, and check whether the 5 kg weight is lifted a few centimeters and is kept at a constant height when the handle is turned further. If it is lifted too high, reduce the number of turns of the nylon band; if it does not lift at all, increase the number of turns.
- For measuring the number of revolutions $N_{A1}$ (=number of obscurations), position the forked light barrier with the aid of the stand base as shown in the drawing, and connect it to the input A of the Sensor-CASSY via the timer box.
- Connect the temperature sensor to the input B of the Sensor-CASSY via the temperature box (socket $T_1$) for measuring the temperature $\vartheta_{B11}$.

### Carrying out the experiment

- Load settings
- Set the number of revolutions to zero by clicking → **0** ← in Settings NA1.
- Start the measurement with .
- Turn the crank handle, and measure the increase in temperature as a function of the number of revolutions.
- Stop the measurement with  at the desired final temperature $\vartheta_{B11}$.

### Evaluation

The temperature $\vartheta_{B11}$ is already displayed graphically as a function of the number of revolutions $N_{A1}$ during the measurement. In the prepared diagram **Evaluation**, the thermal energy is plotted against the mechanical energy that has been provided by turning the crank against the friction. The mechanical energy $E_m$ is equal to the product of the frictional force and the covered path s:

$E_m = F \cdot s$

with $F = m \cdot g$

F = frictional force
m = mass of the weight = 5 kg
g = acceleration of gravity = 9.81 $m/s^2$

and $s = N \cdot d \cdot \pi$

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s = frictional path
N = number of revolutions
d = diameter of the calorimeter = 0.047 m

Thus the mechanical energy is: $E_m = m \cdot g \cdot d \cdot \pi \cdot N$.

The increase in thermal energy as a result of the temperature increase is given by:

$E_{th} = C \cdot (\vartheta_2 - \vartheta_1)$

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) |
|---|---|
| Water (388 01) | $40 + m_{H2O}/g \cdot 4.2$ (mass of the water in g) |
| 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) |

The equivalence of the mechanical energy $E_m$ and the thermal energy $E_{th}$ can be confirmed by means of a fit to a line through the origin. Usually the slope of the straight line through the origin is somewhat smaller than 1. This is due to heat loss which is not registered, e.g. by thermal contact of the calorimeter with the nylon band or the plastic mounting.


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