If water is heated in a vessel the increase in temperature depends on the heating duration and the mass of the heated water. In this experiment, different amounts of water are heated at constant heat output of the burner and the temperature is measured at different time intervals.

Material

1	Demo physics board	02150.00
1	Clamping holder, *d* = 0 ... 13 mm, fixing magnet	02151.07
1	Holder for hand-held meters	02161.00
1	Burner-holder on fixing magnet	02162.00
1	Wire gauze holder on fix. magnet.	02163.00
1	Wire gauze 160 mm x 160 mm, ceramic cen.	33287.01
1	Glass beaker DURAN, short, 600 ml	36015.00
1	Graduated cylinder 250 ml, BORO 3.3	36630.00
1	Glass rod, l=200mm, d=6mm	40485.04
1	Temp. meter 2xNiCr-Ni, hand-held	07140.00
1	Immersion probe NiCr-Ni, stainl. steel	13615.03
1	Large-scale display, digital, RS-232 port	07157.93
1	Data cable RS 232, SUB-D/USB	07157.01
1	Butane burner, Labogaz 206 type	32178.00
1	Butane cartridge without valve, 190 g	47535.00
1	Stop clock	03074.00
	Matches	

Fig. 1

Setup

- The setup is according to Fig. 1.
- Place the holder for burner at the bottom of the board
- Place the holder for the wire gauze at the marked height of 240 (this height applies for the butane cartridge) and put the wire gauze on top of it
- Place the hand-held meter into the magnetically adhesive holder on the board and connect it to the large-display unit
- Connect the temperature sensors (immersion probes) to the hand-held meter
- Initially place the clamping holder above the wire gauze close to the upper edge, attach the temperature sensor within it and attach its cable to the meter in such a way that it does not sag (e.g. above the board edge).

Implementation

- Measure out 500 ml of cold water with the aid of the graduated cylinder and fill it into the 600 ml glass beaker
- Make an additional 250 ml of cold water available in the graduated cylinder
- Briefly remove the temperature sensor from the holder to measure the initial temperature ϑ_0 in the glass beaker, enter this at the time t = 0 min in table 1
- Light the butane burner, place the burner on the holder
- Place the 600 ml glass beaker with 500 ml water on the wire gauze and start the stop clock
- Shift the clamping holder until the temperature sensor is half immersed into the water
- Measure the temperature at 1 minute intervals respectively, regularly stirring as you do so
- Terminate the measurement after 10 minutes, but do not turn off the burner, remove the burner
- Empty the glass beaker, rinse it out cold and fill with 250 ml of cold water from the grad. cylinder
- Repeat the measurement with 250 ml, while doing so place the 600 ml glass beaker and the burner at the same point if at all possible
- Enter all the measured values in table 2, repeat the measurement after 5 minutes

The initial temperatures ϑ_0 should be at the same level if possible

Measurement results

Table 1: Glass beaker with 500 ml water

$\frac{t}{\text{min}}$	$\frac{\vartheta}{°C}$	$\frac{\Delta\vartheta}{°C}$
0	19.4	0.0
1	23.5	4.1
2	27.1	7.7
3	30.0	10.6
4	34.8	15.4
5	38.8	19.4
6	42.6	23.2
7	46.4	27.0
8	49.8	30.4
9	53.2	33.8
10	56.2	36.8

Table 2: Glass beaker with 250 ml water

$\frac{t}{\text{min}}$	$\frac{\vartheta}{°C}$	$\frac{\Delta\vartheta}{°C}$
0	19.3	0.0
1	25.7	6.4
2	32.8	13.5
3	39.6	20.3
4	46.7	27.4
5	53.3	34.0

Evaluation

The results are graphically displayed in Fig. 2.

Thermal energy is supplied to the water using the burner. The longer the water is heated the more thermal energy will be supplied to it and the greater the water temperature increase will be.
A larger amount of water must be heated longer compared to a smaller amount if the same temperature should be reached while the heat output of the burner remains the same. Double the amount of water requires approximately double the time to achieve the same increase in temperature, this means it requires double the amount of thermal energy.

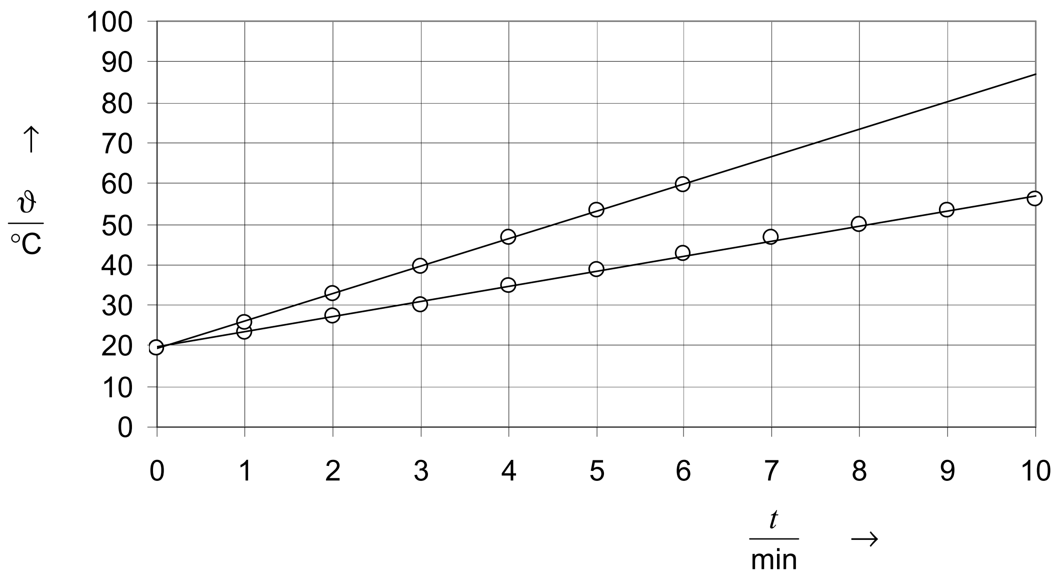

Fig. 2

The temperature increase vs. the heating time is plotted in Fig. 2 for both quantities of water. Two straight lines result. These demonstrate the temperature increase $\Delta\vartheta = \vartheta - \vartheta_0$ is proportional to the heating time t and as a result (if the heat output is constant) proportional to the thermal energy added.

$$\Delta\vartheta \sim t \quad \text{and} \quad \Delta\vartheta \sim Q$$

The comparison of the two straight lines demonstrates that in the event of a constant temperature increase $\Delta\vartheta$ approx. double the amount of time is also required to heat double the amount of water: The mass to be heated is proportional to the heating time or the required thermal energy.

$$m \sim t \quad \text{and} \quad m \sim Q$$

Remarks

1. The thermal energy necessary for a certain temperature increase is not just dependent upon the mass to be heated but also upon the material. The following applies:

   $$Q = c \cdot m \cdot \Delta\vartheta,$$

   in this case *c* is a constant of material, the specific effective heat capacity. If this should be measured electric heating should be used to heat instead of a burner, for which the electrical energy can be calculated.

   $$Q_{el} = U \; I \; t \, .$$

2. The measurements with 250 g and 500 g of water do not give rise to any ideal values. If 250 g of water is heated for 5 minute then the temperature is always lower than if 500 g of water is heated for 10 minutes. In addition to the heat losses the cause is above all that the effective heat capacity of the glass beaker is not taken into account. Both have a greater influence for the smaller amount of water than for the larger amount.

3. It is recommended when performing the experiment that the burner is initially placed under the wire gauze and then just the glass beaker upon the wire gauze that is already hot.
   In the case of the reverse sequence wire gauze and the holder would also have to be heated for the first minute, as a result the first measured value would be clearly at least 1 ° C too low.

4. The temperature sensor (immersion probe) reacts very quickly to temperature fluctuations during the stirring.

Room for notes