Heating of water with measureAPP (Item No.: P1043768)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	Age 14-16	Thermal physics	Heat energy, thermal capacity	Heating of water with measureAPP

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	10 Minutes	30 Minutes	2 Students

Additional Requirements:

- Apple iPad
- measureApp

Experiment Variations:

Keywords:

temperature increase rate, water quanteties, time for heating, constant performance

Information for teachers

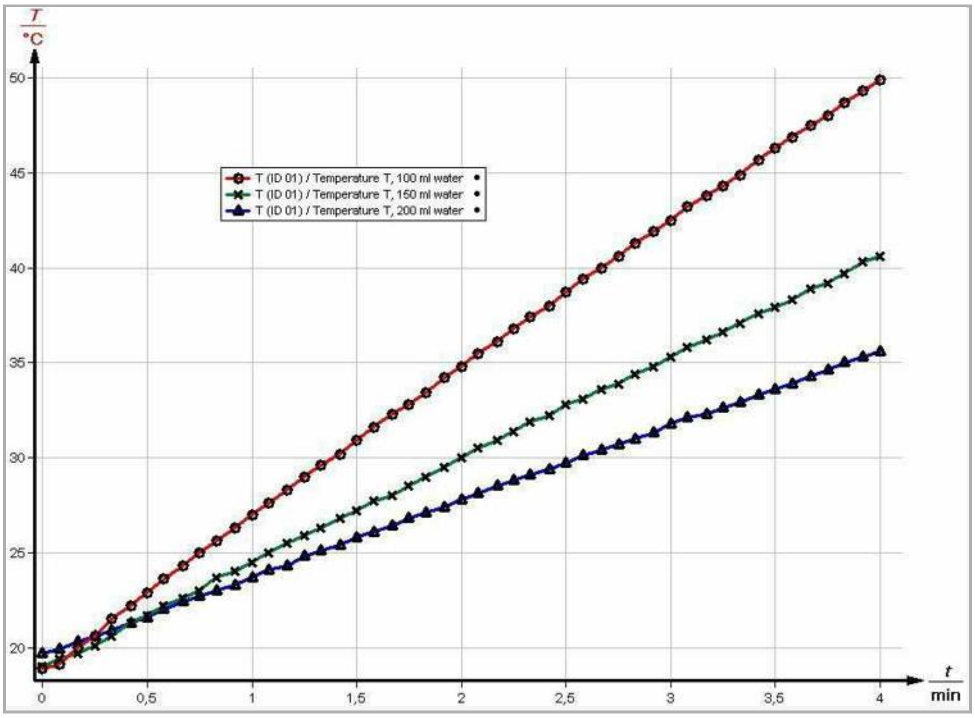
Various quantities of water are heated at constant performance by a heating coil in a calorimeter. The water volumes were selected for the capacity of the calorimeter (100 ml, 150 ml, 200 ml) and are in a simple ratio to each other, so that it can be clearly found that: The more water, the slower the increase in temperature. At the same heating performance, the temperature increase rate is inversely proportional to the amount of water.

Caution!
The heating coil must be in water when a 12 V voltage is applied, otherwise it will burn out!

- The 250 ml Erlenmeyer flask is used as stock vessel for water at room temperature to ensure that the initial temperatures are roughly the same.
- The water in the calorimeter must be continually stirred for a good, smooth measurement curve to be obtained.
- The temperature increase should not be much greater than that selected, as otherwise the heat loss resulting from the incomplete insulation of the calorimeter would make itself noticeable.

Additonal information for the evaluation

The following figure shows the examplary temperature curves for the heating of different amounts of water with another software to get a better impression of the results.


T / °C
50
45
40
35
30
25
20
T (ID 01) / Temperature T, 100 ml water
T (ID 01) / Temperature T, 150 ml water
T (ID 01) / Temperature T, 200 ml water
0
0,5
1
1,5
2
2,5
3
3,5
4
t / min

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Introduction

How fast does water heat up?

We have the first hot day of the year, so I let water into my home swimming pool to hopefully be able to cool off later. The water coming from the garden hose is pretty cold, so I have to move the pool into the sun to heat up a little. In the afternoon, it should have exactly the right temperature for a swim, although the sea nearby is still freezing. This is due to the different amounts of water, which have to be heated up in the sun. My little pool takes so much less water than the sea, so it will heat up much faster. The same effect can be seen, cooking in the kitchen. If I want to make pasta, it takes much longer to get the water boiling, than if I'm just making myself a cup of tea.
Within this experiment, you will investigate the relation between the amount of water and the time it takes, to heat it up.


Task

How does the time required to heat up water depend on the amount of water when a defined heating source is available?

Heat up various amounts of water with an electric heating coil and measure the time dependence of the temperature increase.

Equipment

Position No.	Material	Order No.	Quantity
1	Lid for student calorimeter	04404-01	1
2	Agitator rod	04404-10	1
3	Heating coil with sockets	04450-00	1
4	Felt sheet, 100 x 100 mm	04404-20	2
5	Beaker, low, BORO 3.3, 250 ml	46054-00	1
6	Beaker, low, BORO 3.3, 400 ml	46055-00	1
7	Erlenmeyer wide neck,boro.,250ml	46152-00	1
8	Graduated cylinder 100 ml, PP transparent	36629-01	1
9	Pipette with rubber bulb	64701-00	1
10	Connecting cord, 32 A, 500 mm, blue	07361-04	2
11	PHYWE power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
12	Cobra4 Wireless/USB-Link incl. USB cable	12601-10	1
13	Cobra4 Sensor-Unit 2 x Temperature, NiCr-Ni	12641-00	1
14	Immersion probe NiCr-Ni, steel, -50...400 °C	13615-03	1

Set-up and procedure

Set-up

You can find the set-up in figure 1.

- Make up a thermally insulating vessel (calorimeter) using two beakers (250 ml and 400 ml) and two felt sheets. The simplest way is to put the felt into the larger beaker and then slowly insert the smaller beaker.
- Carefully ease the heating coil through the slit in the calorimeter lid.
- Push the stirring rod up through the appropriate hole in the lid from below.
- Ensure that the power supply is still switched off.

Fig. 1: Experiment set-up

Procedure

Caution!
The heating coil must be in water when a 12 V voltage is applied, otherwise it will burn out!

- Connect the "Wireless/USB-Link" with the Sensor-Unit 2x Temperature and turn it on. Then plug in the immersion probe.
  Connect your tablet with the "Wireless/USB-Link" and open the measureApp.
  Select the connected sensor.
- Open the diagram mode in the app.
- Unselect the second temperature sensor in measurement channels.
- Now go into the configuration section and make sure you have a sampling rate of 1 Hz. Select the repeated measurement mode.
- Fill the Erlenmeyer flask with water (as supply vessel for the same initial temperatures). Keep the flask full as long as you are still experimenting, so that the temperatures are always almost equal.
- First fill 100 ml of this water into the graduated cylinder (use the pipette for accurate measurement) and pour the water into the calorimeter.
- Fit the lid with heating coil and stirring rod on the calorimeter and insert the temperature sensor so far through the remaining hole in the lid, that it dips in the water but does not touch the bottom.
- Connect the heating coil to the 12 V~ alternating voltage output (power supply off!) with the connecting cords.
- Wait until the temperature remains constant.
- Simultaneously start measured value recording in the measureApp and switch the power supply on.
  Measured temperature values will now be recorded every second.

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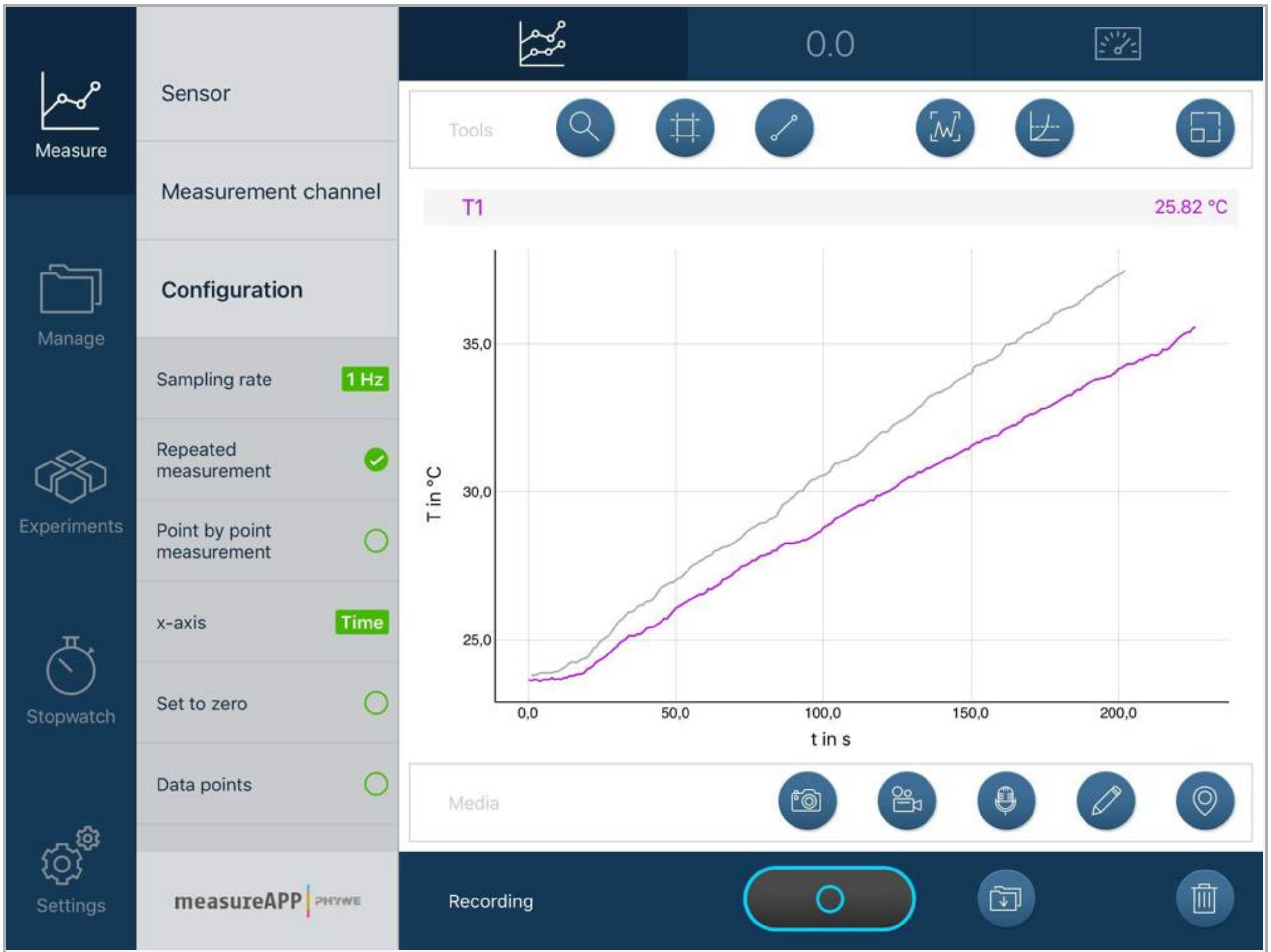

Fig. 3: Measurement window

- The water in the calorimeter must be carefully stirred (agitated) during measurement to uniformly distribute the heat. Start stirring immediately after measurement starts. You can tell from the noise made by the heating coil if stirring is sufficient.
- End the measurement after 200 s and safe the data!
- Switch the power supply off!
- Repeat the experiment with 150 ml, then 200 ml of water, but first give the beaker a cold rinse and dry it.
It might be nessessary to let the measurement run longer than 200 s if the water did not heat up more than 10 °C in comparison to the initial temperature.
It's best to take a screenshot of the repeated measurement after the 2. and 3. measurement to be able to compare the different measurement curves.

Evaluation

1. To start with, estimate how the time of heating depends from the amount of water. You can easily do this with the repeated measurment function you selected in the app by comparing the current measurement with the one before like it is shown in fig. 4a and 4b.

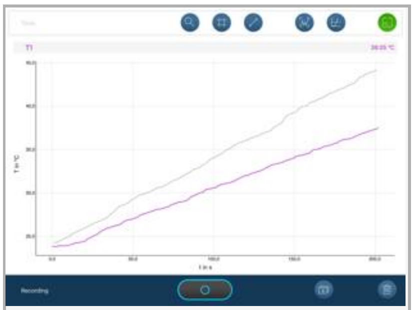

Fig. 4a: Screenshot of the repeated measurment with 100 ml and 150 ml of water.

Fig. 4b: Screenshot of the repeated measurement 150 ml and 200 ml of water.

2. Use the measurement curves to read off how long it takes to reach a temperature increase $\Delta\theta$of 10 °C by using the “Survey“ function in the measureApp (confere fig. 4c). The temperature increase is the value noted by Δy, while the time difference, you want to read off, is given by Δx. Enter the results in table 1 in the report giving two significant digits each.

Fig. 4c: Exemplary evaluation for 100 ml water.

Additional tasks

- The temperature curves are nearly linear neglecting the starting phase. The slope of the curve gives the temperature change per time. Determine the slope for all three volumes with help of the regression tool in the app. Take notes and enter your observations in the report.

Fig. 4d: Estimation of the temperature change per time with the regression tool in the app.

Report: Heating of water with measureAPP

Evaluation - Question 1

From the repeated measurement (check screenshots) you can now estimate, how the time for heating depends on the amount of water.

The larger the amount of water heated, the .... does the heating process go.

Evaluation - Question 2

Which assmuption can you make for the relation of the temperature increase $\Delta\theta$ with the heating time for a defined quantity of water, e.g.100 ml?

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Evaluation - Table 1

Determine the temperature increase $\Delta\theta$ as described in the evaluation. Pay attention to the units. Devide $\Delta\theta$ by the particular volume and fill in the table below.

Volume of water V/ml	Time for temperature increase of $\Delta\theta$ = 10 °C $t_{\Delta\theta = 10\ °C}$ in min	TIme for the Temperature increase per Volume $t_{\Delta\theta = 10\ °C}/V$ in min/ml
100	1.6 [1]	0.016 [1]
150	2.3 [1]	0.015 [1]
200	2.9 [1]	0.015 [1]

Evaluation - Question 3

What does this indicate with regard to the dependency of the heating time required for a certain temperature increase on the quantity of water? Formulate the relation.

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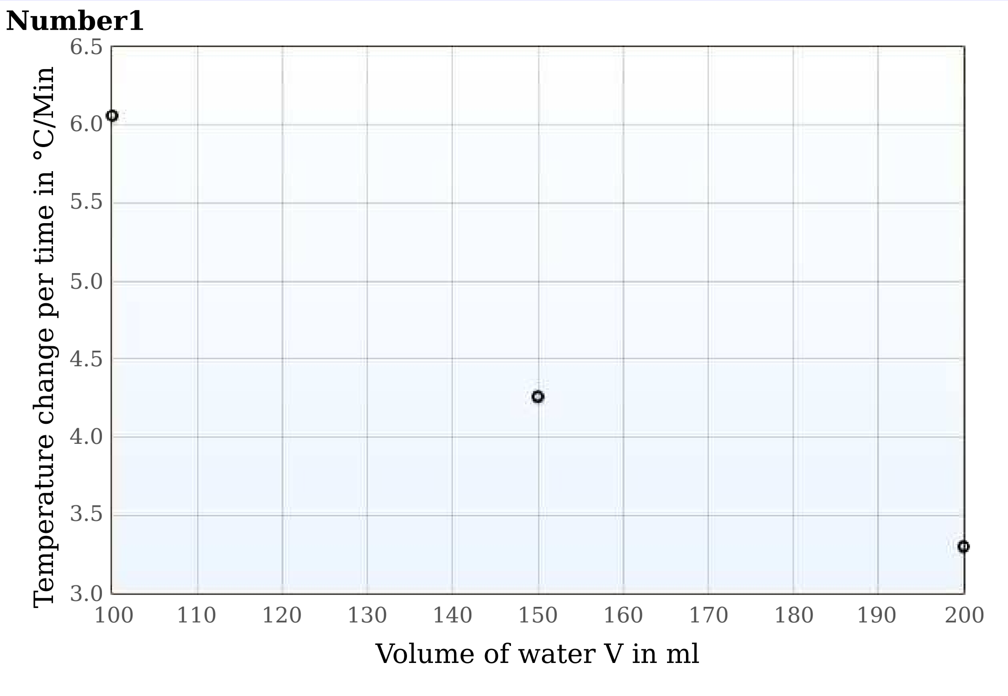
Evaluation - additional task

Determine the temperature increase rate as described in the evaluation section. Supplement the table. Pay attention to the units. The temperature change per time in °C/s is exactly the slope of the temperature curves.

Volume of water V in ml	Temperature increase rate in °C/s	Temperature increase rate in °C/min
100	0.101	6.06
150	0.071	4.26
200	0.055	3.3



Evaluation - Additonal task

How does the temperature change per time depend on the amount of water? You can read it off from the plot in the question before.

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