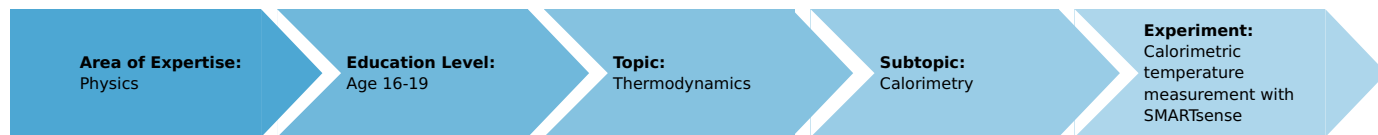


# Calorimetric temperature measurement with SMARTsense

(Item No.: P1044369)

## Curricular Relevance



### Difficulty



Intermediate

### Preparation Time



10 Minutes

### Execution Time



10 Minutes

### Recommended Group Size



2 Students

### Additional Requirements:

- Tablet PC with measureAPP

### Experiment Variations:

### Keywords:

Calorimetry, Mixture temperature

## Task and equipment

### Information for teachers

The temperature of a hot metal object is to be determined in a mixing experiment.

#### Notes on set-up and procedure

1. Because of the high temperature, the hanging loop must be made using wire instead of fishing line.
2. The wire should be at least 40 cm long.
3. There is a hissing sound when the hot body is immersed in the water because it is much hotter than 100 °C.
4. The aluminium body could be subject to damage in the burner flame - do not use it here.

#### Note

The temperatures of the two bodies should be about the same when they hang at the same position in the flame for the same length of time.

The temperatures of the metal bodies depends on how high above the flame and how long they hang. If they were hung, for example, for 5 minutes directly above the flame, then a temperature of 700 °C would be determined.

As this is a student experiment and the principle of temperature measurement is to be shown, it is sufficient to heat the bodies above the flame for 1 minute.

The measurement error is greater at higher temperatures.



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## Task and equipment

### Task

#### Application

Calorimetry can also be used to determine the temperature of a hot object that is difficult to measure by any other method, e.g. because it is too hot for the thermometers available. The heat content of the object can be calculated from the mixture temperature that is reached in the calorimeter. The initial temperature of the object can be calculated from this when the capacity of the object is known. Another important application is the determination of the calorific value from different materials like wood, coal or gas.



With calorimetry it is possible to determine the calorific value of coal for example.

### Task

How can the temperature of a hot object be determined?

Heat the metal object over a flame, put it into cold water in the calorimeter and determine the mixture temperature that is reached. Use this temperature to calculate the initial temperature of the object.

Equipment



Position No.	Material	Order No.	Quantity
1	Cobra SMARTsense - Temperature, - 40 ... 120 °C	12903-00	1
2	Support base, variable	02001-00	1
3	Support rod, l = 600 mm, d = 10 mm, split in 2 rods with screw threads	02035-00	1
4	Universal clamp	37715-00	1
5	Boss head	02043-00	1
6	Metal bodies, set of 3	04406-00	1
7	Lid for student calorimeter	04404-01	1
8	Agitator rod	04404-10	1
9	Felt sheet, 100 x 100 mm	04404-20	2
10	Beaker, low, BORO 3.3, 250 ml	46054-00	1
11	Beaker, low, BORO 3.3, 400 ml	46055-00	1
12	Beaker, low form, plastic, 100 ml	36011-01	1
13	Pipette with rubber bulb	64701-00	1
14	Graduated cylinder 100 ml, PP transparent	36629-01	1
15	Iron wire, d = 0.5 mm, l = 50 m	06105-00	1
16	Butane burner, Labogaz 206 type	32178-00	1
17	Butane cartridge C206, without valve, 190 g	47535-01	1
Additionally			
18	Tablet PC		1
19	PHYWE measure APP		1

Android

iPad



## Setup and procedure

### Setup



Fig. 1: Setup




#### Caution!

1. The wire used for hanging must be 40 cm long so that the upper end does not get too hot.
2. The metal objects get very hot! Take care not to drop or touch them.

#### Setup

- Set the stand up as shown in Fig. 1.
- Thread a 40 cm long piece of wire through the brass body, bend it to a loop and hang it on the universal clamp.
- Make up a thermally insulating vessel (calorimeter) using two beakers (250 ml and 400 ml) and two felt sheets.
- Fill 200 ml of water in the calorimeter. Measure it out accurately from the plastic beaker using the graduated cylinder and the pipette.
- Push the agitator rod up through the appropriate hole in the calorimeter lid from below.

## Procedure

- Turn on the Cobra SMARTsense-Temperature.
- Open the PHYWE measure App  and select the sensor "temperature".
- Set the sampling rate to 1 Hz.
- Insert the temperature sensor through a hole in the calorimeter lid so that it dips in the water but does not touch the bottom.
- Start measured value recording in measureApp , a measured temperature value will now be recorded every second.
- Hang the brass body about 5 cm above the flame of the burner and heat it for one minute.
- During this, stir in the calorimeter – the temperature display should become constant.
- Transfer the brass body into the calorimeter and immediately close it.
- Carefully stir the water in the calorimeter so that heat is evenly distributed.
- End measurement, when the temperature slowly decreases, or at the latest after 100 s. Save afterwards . For further analysis open the measurement under "my measurements".
- Repeat the experiment in the same way with the iron body.

## Evaluation

The two metal bodies have the same mass  $m_{\text{metal}} = 60 \text{ g}$ .

The mass of water in the calorimeter is  $m_{\text{water}} = 200 \text{ g}$ .

The specific heat capacities are:

$$c_{\text{water}} = 4,2 \text{ J}/(\text{g} \cdot ^\circ\text{C})$$

$$c_{\text{brass}} = 0,39 \text{ J}/(\text{g} \cdot ^\circ\text{C})$$

$$c_{\text{iron}} = 0,45 \text{ J}/(\text{g} \cdot ^\circ\text{C})$$

Assume that the calorimeter has a heat capacity corresponding to a water equivalent of  $20 \text{ g}$  or  $C = 84 \text{ J}/^\circ\text{C}$ .

When a metal body is transferred to the calorimeter, the temperature of the calorimeter, the water in the calorimeter and the metal body come to the common temperature  $\vartheta_{\text{cal},2}$ .

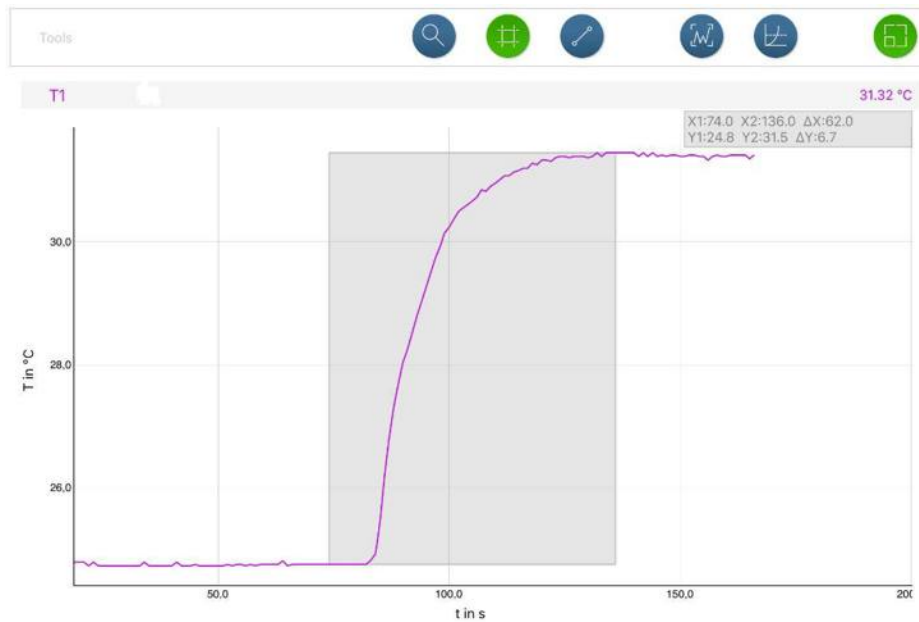


Fig. 2: Behaviour of the temperature display over time, with the measureApp "Survey" tool switched on. Example for brass

## Report: Calorimetric temperature measurement with SMARTsense

### Evaluation - Question 1 (6 points)

Select the "Survey" tool in the measureApp with button to determine the initial temperature in the calorimeter  $\vartheta_{\text{Kal},1}$  and the mixed temperature in the calorimeter  $\vartheta_{\text{Kal},2}$  for both measurement curves; The mixed temperature is the maximum temperature that is reached. Supplement Table 1.

Calculate the temperature difference between the temperature of the calorimeter)  $\Delta\vartheta_{\text{Kal}} = \vartheta_{\text{Kal},2} - \vartheta_{\text{Kal},1}$  before and after transfer of the metal sample into the calorimeter and complete Table 1.

Brass	$\vartheta_{\text{cal},1} / ^\circ\text{C}$	$\frac{1}{\pm 10}$	$\Delta\vartheta_{\text{cal}} / ^\circ\text{C}$	$\frac{1}{\pm 3}$
	$\vartheta_{\text{cal},2} / ^\circ\text{C}$	$\frac{1}{\pm 10}$		
Iron	$\vartheta_{\text{cal},1} / ^\circ\text{C}$	$\frac{1}{\pm 10}$	$\Delta\vartheta_{\text{cal}} / ^\circ\text{C}$	$\frac{1}{\pm 5}$
	$\vartheta_{\text{cal},2} / ^\circ\text{C}$	$\frac{1}{\pm 10}$		



**Evaluation - Question 2 (4 points)**

The water and the calorimeter have together the heat capacity

$$C_{\text{cal}} = c_{\text{water}} \cdot m_{\text{water}} + C = 4,2\text{J}/(\text{g} \cdot ^\circ\text{C}) \cdot 200\text{g} + 84\text{J}/^\circ\text{C} = 924\text{J}/^\circ\text{C}$$

The amount of heat that the metal body releases is the same as the amount of heat that the waterfilled calorimeter takes up:

$$\Delta Q = C_{\text{cal}} \cdot \Delta\vartheta_{\text{cal}} = 924\text{J}/^\circ\text{C} \cdot \Delta\vartheta_{\text{cal}} \quad (1)$$

Calculate the amount of heat  $\Delta Q$  that the calorimeter takes up from (1), enter it in Table 2.

The metal body first had the unknown temperature  $\vartheta_{\text{metal},1}$  and, at the end, the temperature of the calorimeter  $\vartheta_{\text{metal},2} = \vartheta_{\text{cal},2}$  and for the amount of heat that the metal body releases we have:

$$\Delta Q = c_{\text{metal}} \cdot m_{\text{metal}} \cdot \Delta\vartheta_{\text{metal}} = c_{\text{metal}} \cdot m_{\text{metal}} \cdot (\vartheta_{\text{metal},1} - \vartheta_{\text{cal},2}) \quad (2)$$

so that we have for the initial temperature of the metal body that we want to determine:

$$\vartheta_{\text{metal},1} = \frac{\Delta Q}{c_{\text{metal}} m_{\text{metal}}} + \vartheta_{\text{cal},2} = \frac{C_{\text{cal}} \cdot \Delta\vartheta_{\text{cal}}}{c_{\text{metal}} m_{\text{metal}}} + \vartheta_{\text{cal},2} \quad (3)$$

Use the measured values in Table 1 and equation (3) to calculate the initial temperatures of the metal bodies and enter them in Table 2:

	$\Delta Q / \text{J}$	$\vartheta_{\text{metal},1}$
Brass	$1 \pm 300$	$1 \pm 30$
Iron	$1 \pm 300$	$1 \pm 30$