Heating of various liquids with SMARTsense

(Item No.: P1043869)

Curricular Relevance

Area of Expertise: Physics

Education Level: Age 14-16

Topic: Thermal physics

Subtopic: Heat energy, thermal capacity

Experiment: Heating of various liquids with SMARTsense

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	20 Minutes	2 Students

Additional Requirements:

- tablet PC
- measureApp

Experiment Variations:

Keywords:

specific heat capacity, heat uptake, dependency of density and mass

Information for teachers

The dependence of the heat uptake of a liquid on its specific heat capacity is to be worked out here. As absolute heat capacities are dependent on the density, the specific heat capacities differ with regard to volume, amount of substance or mass. The specific heat capacities of gases and solids do not differ very much with regard to mass, but very much with regard to volume. As the term “amount of substance“ cannot yet be assumed to be known, the specific heat capacity should only be understood as the heat capacity per mass.
Only heat capacities relative to water are determined here. A determination of the heating power is not made.

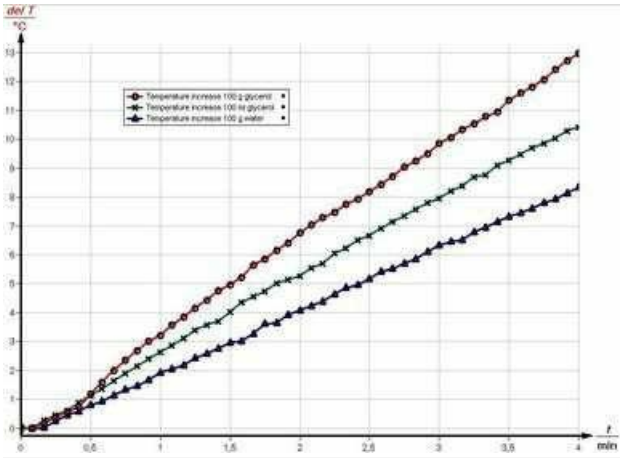
Note
Glycerol is hygroscopic. According to the water content of it, therefore, the density and heat capacity of it can deviate from the literature value of $c_{\mathrm{Glycerol}} = 2.4\ \mathrm{J\ g^{-1}K^{-1}} = 0.57\ c_{\mathrm{Water}}$ for dry glycerol.

Notes on set-up and procedure

- A balance can be used to measure the amount used – but the handling of a graduated cylinder is simpler and sufficiently accurate here.
- Glycerol should not be poured to drain but be collected after use and re-used in future experiments.
- Stirring is particularly important for the viscous glycerol – it is best to start stirring it before the start of measurement.
- If you have a magnetic stirrer, it is recommended to use it for stirring the fluids to ensure a steady heat distribution.
- Only the lower heating power of 6 V~ should be used, so that measurement errors due to bad distribution of the heat and losses of heat through the insulation of the calorimeter stay negligible.

Additonal information for the evaluation

The following figure represents an exemplary result for the dependency of the temperature curves. It is difficult to stirr the glycerin regularly so that the results might show some variance to the theoretical results presented here.



Exemplary result: Behaviour of the temperature of various quantities of water over time with electic heating.

Heating of various liquids with SMARTsense (Item No.: P1043869)

Introduction

Dinner is prepared in the kitchen. On the stove you have a pot with water to make pasta. Another pot contains oil for frying. Now, all we need to know, is how fast the different liquids heat up, since you want them to be ready at the same time. If they would behave equally, you could turn up the heat for both in the same way. To be able to choose the right heating level and time, it is necessary to investigate how different fluids heat up by the same power. Instead of oil, the experiment is conducted with glycerol and water.

Task

Do different liquids behave differently when they are heated?

Do different liquids heat up to the same extent when subject to the same heating?

Heat 100 g and 100 ml of water and of glycerol with an electric heating coil and measure the temperature in dependence on time.

Caution!

- The heating coil must dip in water before the power supply is switched on!
- Do not pour used glycerol to drain. Collect it for use in future experiments.

Equipment

Position No.	Material	Order No.	Quantity
1	Cobra SMARTsense - Temperature, - 40 ... 120 °C	12903-00	1
2	Lid for student calorimeter	04404-01	1
3	Agitator rod	04404-10	1
4	Heating coil with sockets	04450-00	1
5	Felt sheet, 100 x 100 mm	04404-20	2
6	Beaker, low form, plastic, 100 ml	36011-01	1
7	Beaker, low, BORO 3.3, 250 ml	46054-00	1
8	Beaker, low, BORO 3.3, 400 ml	46055-00	1
9	Graduated cylinder 100 ml, PP transparent	36629-01	1
10	Pipette with rubber bulb	64701-00	1
11	Connecting cord, 32 A, 500 mm, blue	07361-04	2
12	PHYWE power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
13	Glycerol, 250 ml	30084-25	1
Additional material:			
14	Tablet PC with measureApp		1

Android iPad

GET IT ON Google Play Download on the App Store

Set-up and procedure

Set-up

In this experiment, 100 g and 100 ml each of two different liquids are to be heated. The density of the liquids can be assumed as known. You can determine the required volumes from the following table:

Liquid	Density	Mass	Volume
Water	1.00 g/ml	100 g	100.0 ml
Glycerol	1.26 g/ml	100 g	79.4 ml

Only one measurement has to be made for water as a volume of 100 ml corresponds to a mass of 100 g.

Set-up

- Make up a thermally insulating vessel (calorimeter) using two beakers (250 ml and 400 ml) and two felt sheets.
- 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

- Turn on the Cobra SMARTsense-Temperature sensor. Open the „measure“ app and select the temperature sensor.
- Fill the plastic beaker with water.
- 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.
- Use the connecting cords to connect the heating coil to the 6 V~ alternating voltage output (power supply off!).
- Stir and wait until the temperature display remains constant.
- Set the temperature to zero by selecting "Set to zero". You are only interested in the temperature difference towards the inital temperature not the absolut temperature.
- Simultaneously start measured value recording in app and switch the power supply on.
- Stir the liquid in the calorimeter carefully throughout measurement so that the heat is uniformly distributed. Start stirring immediately after the start of measurement.
- End the measurement after roughly 250 s. Save your data for further analysis.
- Switch the power supply off!
- Repeat the experiment with 79.4 ml of glycerol, which corresponds to 100 g, and also with 100 ml of glycerol, which you can measure out as for water. Before filling glycerol in, give the glass beaker a cold rinse and dry it as well as the graduated cylinder and the plastic beaker.

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com

Evaluation

1. Load your measurements and go down to the data table. Fill in every 10th value into the table in the report to be able to compare the three measurements. Every curve should almost be a straight line with different slops.
2. Follow the report for further evaluation.

Additional tasks

Heat is supplied to the liquid by the heating coil. The longer the heating time, the more heat that is supplied. The amount of heat supplied by the heating coil is proportional to the heating time.

- Read the heating time $t_{\Delta\theta=5^\circ C}$ which is required for a temperature increase $\Delta\theta$ of 5 °C from the measurement curves for each liquid and enter the values in your report. You can use the “Survey“ function # of the measureApp for the reading from the diagram. Enter two significant digits.

  Set the edge of the survey box onto Y1=5 and read off the time in seconds in X1.

Fig. 3: Exemplary evaluation for the curve of water.

- This difference in the heating time (heat uptake) is described by the term heat capacity C. Calculate the ratio of the heating time for glycerol to the heating time for water for a temperature increase of 5 °C and enter these values also in Table 2 in your report.

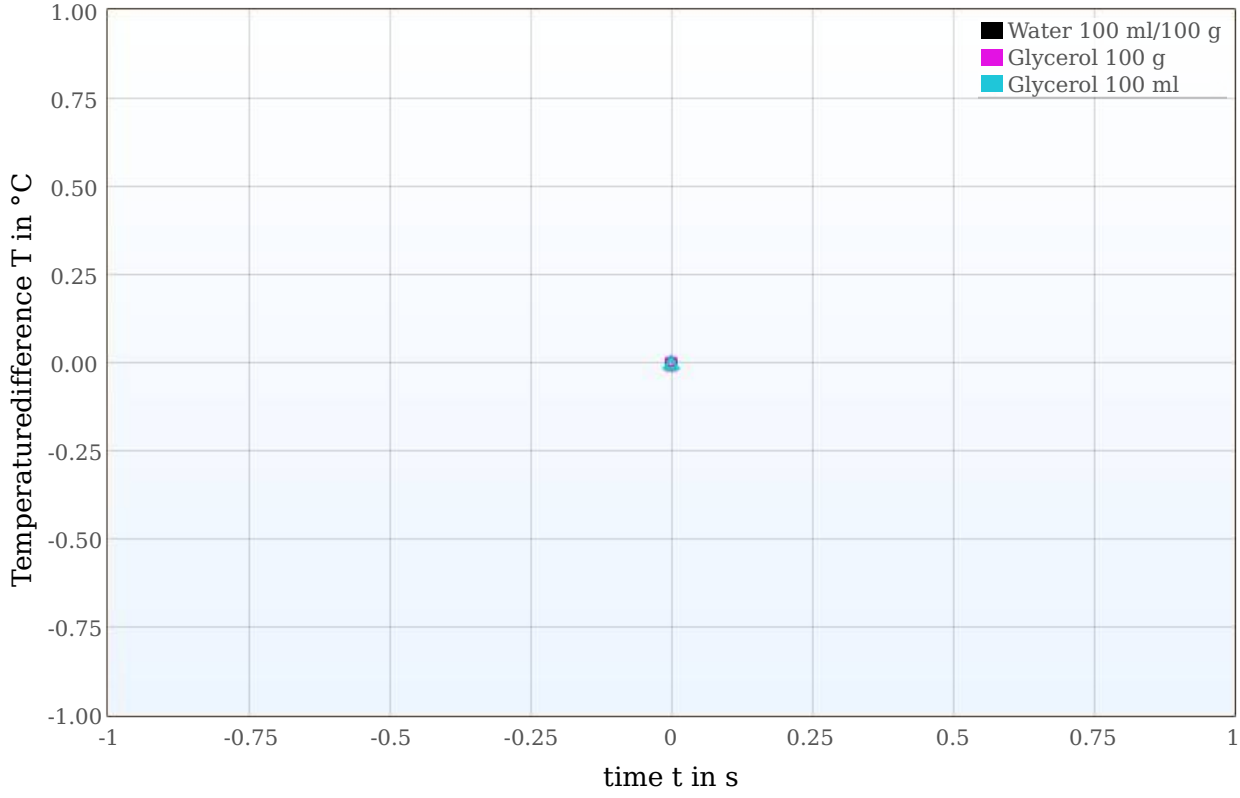
Report: Heating of various liquids with SMARTsense

Observation - Table 1 (60 points)

To be able to compare the three measurements, fill in the values from the measurement table on the tablet.

Time t in s	Water 100 ml Temperature T in °C	Glycerol 100g/ 79,4 ml Temperature T in °C	Glycerol 100 ml Temperature T in °C
0	0	0	0
10	1 ±1	1 ±1	1 ±1
	1 ±1	1 ±1	1 ±1
30	1 ±1	1 ±1	1 ±1
40	1 ±1	1 ±1	1 ±1
50	1 ±1	1 ±1	1 ±1
60	1 ±1	1 ±1	1 ±1
70	1 ±1	1 ±1	1 ±1
80	1 ±1	1 ±1	1
90	1 ±1	1 ±1	1 ±1
100	1 ±1	1 ±1	1 ±1
110	1 ±1	1 ±1	1 ±1
	1 ±1	1 ±1	1 ±1
130	1 ±1	1 ±1	1 ±1
140	1 ±1	1 ±1	1 ±1
150	1 ±1	1 ±1	1 ±1
160	1 ±1	1 ±1	1 ±1
	1 ±1	1 ±1	1 ±1
180	1 ±1	1 ±1	1 ±1
190	1 ±1	1 ±1	1 ±1
200	1 ±1	1 ±1	1 ±1

Number1



Result - Observation 1 (10 points)

Compare the increases in temperature with each other after 4 minutes. What information does this give you?

.....

.....

.....

.....

Robert-Bosch-Breite 10
D - 37079 Göttingen

Tel: +49 551 604 - 0
Fax: +49 551 604 - 107

info@phywe.de
www.phywe.com

Result - Additional Task - Table 2 (6 points)

Fill in the table with your notes and calculations.

Liquid	$t_{\Delta\theta = 5\ °C}$ in s	Relation to water
100 ml / 100 g water	170 1	1 1
100 g glycerol	90 1	0.53 1
100 ml glycerol	115 1	0.68 1

Evaluation - Question 1 (10 points)

The heat capacity of 100 g of glycerol differs from that of 100 ml of glycerol. Which of the two is higher and why?

.....

.....

.....

.....

Evaluation - Question 2 (10 points)

The heat capacity C per masse m is decribed as the specific heat capacity $c = \frac{C}{m}$. Compare the specific heat capacity of water with that of glycerol.

.....

.....

.....

.....