Thermal conduction in water (Item No.: P1429400)

Curricular Relevance

Area of Expertise: ILIAS

Education Level: Physik

Topic: Klasse 7-10

Subtopic: Wärmelehre

Experiment: Wärmetransport und Wärmedämmung

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

Additional Requirements:

- water

Experiment Variations:

Keywords:

heat current, thermal conduction, temperature compensation

Overview

Introduction

A container with water is usually heated from the bottom. Due to its smaller density, the warmer water rises to the top creating a thermal current which steadily heats up the total amount of water.
To demonstrate the thermal conduction, the heating current has to be eliminated. Therefore, an only the water surface is heated while measuring the water temperature in the top and bottom of the container.

Educational goal

The experiment 'Heat convection in liquids and gases' showed the heat transfer due to density changes. Now, the heat current has to be eliminated. Nevertheless, a heat transfer can be observed. This is due to thermal conduction or heat diffusion, where thermal energy flows from a warmer to a colder region. This experiment investigates the thermal conductivity of water.

Student's Sheet

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Equipment

Position No.	Material	Order No.	Quantity
1	Demo Physics board with stand	02150-00	1
2	Clamping holder, d = 0..13 mm, fixing magnet	02151-07	2
3	Clamp on fixing magnet	02151-01	1
4	Pointers f. Demonst.Board, 4 pcs	02154-01	1
5	Holder for wire gauze on fix. magnet	02163-00	1
6	Wire gauze with ceramic, 160 x 160 mm	33287-01	1
7	Glass beaker, BORO 3.3, 600 ml, short form	46056-00	1
8	Immersion heater, 300 W, 220..250V	05947-93	1
9	Heat sensitive paper	04260-00	1
10	Immersion probe, NiCr-Ni, steal, -50..400°C	13615-03	2
11	Holder for Cobra4, magn.	02161-10	1
12	Cobra4 Mobile-Link 2	12620-10	1
13	Cobra4 Sensor-Unit 2 x Temperature, NiCr-Ni	12641-00	1
14	Cobra4 Display-Connect TX, transmitter for using the Cobra4 Mobile-Link with large-scale displays	12623-00	1
15	Cobra4 Display-Connect RX, receiver for using the Cobra4 Mobile-Link with large-scale displays	12623-01	1
16	Large-scale display, digital	07157-93	1

Fig. 1a: Equipment for measuring instruments.

Fig. 1b: Further equipment

Set-up & Implementation

Set-up

Set-Up of the measurment instruments:

1. Stick the Cobra4 Display connect for large-scale display showings and the Cobra4 Sensor-Unit 2x Temperature to the Cobra4 Mobile-Link 2. Connect two immersion probes (NiCr-Ni) to the temperature sensor-unit.
2. Place the Cobra4 Mobile-Link to the board using the magnetic holder and turn it on by pressing the green On-button.
3. Link the receiver of the Display-Connect unit to the large-scale display.
4. Insert the power plug in the fitting port of the display and plug in for power.
5. Attach the large-scale display to a rod with a clamp and afterwards attach it to the top of the magnetic board with a clamp on holder.

Set up the experiment accoring to fig. 2:

1. Place the holder for the wire gauze at the bottom of the board and place the wire gauze on top of it.

   Note:
   In this experiment the holder for the wire gauze is used for the beaker with hot water since it has a higher magnetical force then the support plate on the fixing magnet.

2. Fill the 600 ml beaker with about 500 ml water and place it on the wire gauze.
3. Stick a piece of heat sensitive paper to the outer side of the beaker.
4. Insert the handhold of the immersion heater to the clamp on fixing magnet and place it above the beaker with water. Then lower it down so that the minimum mark on the heater is covered with water.
5. Clamp both immersion probes for the temperature measurement in a clamping holder (d=0..13 mm) respectively and position them on the board in such a way, that the first temperature sensor is covered with about 1 cm of water and the other one is about 1 cm above the bottom of the beaker. None of them should touch the heater.

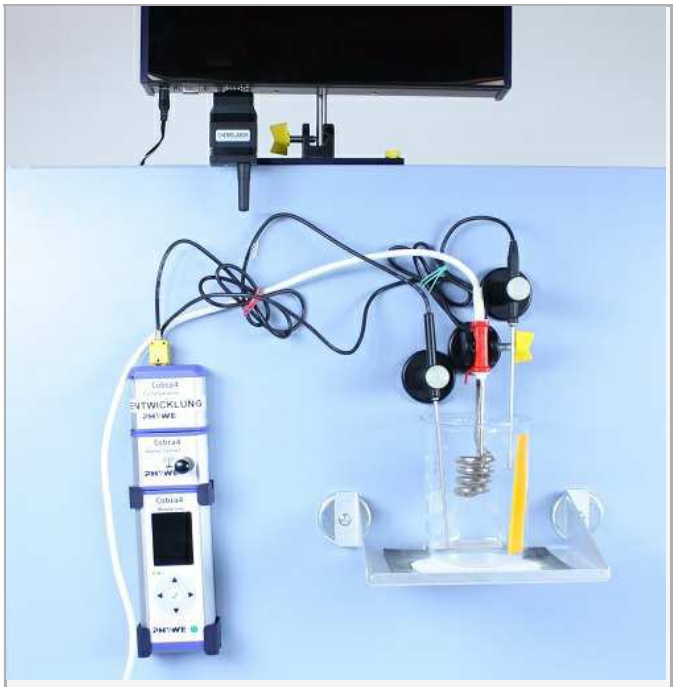

Fig. 2: Set-up

Remark:
Please consider the information in the user manual of the immersion heater since it is equipped with a thermal cutout which reacts within seconds and terminally turns of the heater in dry usage for safety. Therefore, the heater has to always be covered at least until the minimum mark and be turned off before taking it out of the water.

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Implementation

1. Turn on the immersion heater by plugging in the power plug.
2. Observe the displayed temperatures and the heat sensitive paper. (It can be reused since the colour changes back after cooling again.)
3. Turn off the heater when the water starts boiling in the upper part of the beaker.
4. Continue the temperature and paper observation.
5. For clarification of the temperature measurement the positions of the immersion probes can be marked with red or blue pointers and write down the temperatures next to them.

Remark:
The cooling of the water takes up a lot of time. The process does not have to be observed the hole time. It is enough to observe the experiment for a short time after turning of the heater and then check on the temperature and heat sensitive paper again after 10-15 minutes to get an overview over the general process.

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Results & Evaluation

Results

After turning on the heater, the water in the upper region is heated up, while the water below stays cold. The heat sensitive paper starts changing its colour (orange to red) at the water surface. The colour change spreads slowly during the experiment.

Fig. 2: Observation of the heat sensitive paper.

In the case of boiling water in the upper region, the thermometer shows temperatures above 90°C. Nevertheless, the lower temperature only shows values near room temperature (with an initial temperature of approx. 20°C the temperature sensor for the low region shows values of 21.5°C for the boiling time).

After turning off the heater, the upper thermometer shows decreasing temperatures. Although the decrease happens a lot slower than the heating up. Furthermore, the heat sensitiv paper keeps spreading the colour change. The temperature near the bottom keeps increasing.

The colour change of the heat sentitive paper remains for a long time.

Evaluation

The immersion heater only heats up the surface region of the water while it remains cold near the bottom (temperature increases fairly slow there). This is due to the missing heat current so that the different tempered water regions do not immingle.

A colour change of the heat sensitive paper shows temperatures above 45°C. There again it becomes obvious that the water heats up near the surface at first.

After turning off the heater the temperature in the surface region decreases again because thermal energy is transfered into the air. Nevertheless, the temperature in the bottom region keeps increasing.
The slow temperature changes in the bottom region during the heating and cooling process of the upper region is explained with thermal conduction in water. The thermal conductivity of water is very small (literature value λ = 0.598 W/mK). Therefore, the heat diffuses only slowly in water. A temperature difference in water stays for a long time. At the same time, the slow cooling of water is explained which becomes clear with the long remaining change of colour of the heat sensitive paper.