

HOT OR COLD?

OBJECTIVE

To understand the difference between heat and temperature through practical activities where thermal sensations are compared with measurements performed with temperature probes.

This simple experience makes the student realize that hot and cold sensations as detected by our senses do not only depend on other bodies temperature but also on our initial body temperature. It helps recognizing the difference between heat and temperature..

THEORY

Heat and temperature are concepts that frequently occur in ordinary language and are often confused being linked to sensorial perception. Even in the past the concept of heat has been associated and confused or substituted with that of temperature and also nowadays everyday language leads us to misunderstandings. When we speak of a hot object we refer to the temperature and not to the heat, a hot day is such when the temperature is high.

Heat is energy, or even better a way energy is transferred. There is obviously a connection between heat and temperature: heat passes from one body to another because of a temperature difference.

Temperature is interpreted as a measure of the energy of the body molecules. The link between the macroscopic quantity (temperature) and the microscopic properties of matter is studied by Statistical Mechanics.

The link between the mean kinetic energy of molecules and absolute temperature can be derived from the kinetic theory of gases and is given by the equation:

$$\frac{1}{2} m \bar{v}_m^2 = \frac{3}{2} k_B T$$

Where:

m is the mass

\bar{v}_m^2 is the velocity

T is the absolute temperature

k_B is the Boltzmann's constant.

Absolute temperature can be interpreted as a measure of the mean kinetic energy of the molecules.

EXPERIMENTAL SETUP

In this experiment you will compare thermal sensations of your fingers in order to understand that they are subjective and do not only depend upon the object temperature to be measured.

Take three containers: Two half-liter bottles and one plastic glass will do for the purpose

Fill one bottle with tap water and keep it in the fridge for a while. Fill the glass with tap water too.

Fill the other bottle with hot water (if you are at home you can use hot water from the tap – be careful not to hurt yourself – if in the lab you can heat it up to 60°C with an electric heater).

You will then have three systems at three different temperatures:

- Cold water (around 2°C – 5°C) in one bottle
- Hot water (around 50°C - 60°C) in the other bottle
- Water at room temperature (around 15°C – 20°C) in the glass.

Dip one finger in the hot water and one finger in the cold one, keep them in the water for a minute or so, then dip both in the glass of water.

Pay attention to your sensations, you will notice that they are different for the two fingers though they are immersed in the same liquid at uniform temperature.

Write down you observations and try to answer this question: why are sensations different from the fingers immersed in the glass of water?



Now try to reproduce the experiment using temperature probes. This will help you to answer the question more precisely

The experimental apparatus is made of:

- ? Graphic calculator
- ? [CBL2](#) interface
- ? Three steel temperature probes
- ? Black connecting cable ([see photo](#))
- ? DataMate program
- ? TI-GRAPH LINK cable and [TI Connect](#) software
- ? PC with TI Connect software, see:
<http://education.ti.com/us/product/accessory/connectivity/features/software.html>
downloadable from:
<http://education.ti.com/us/product/accessory/connectivity/down/download.html>

You can use also different calculators or data acquisition systems. It is advisable to have three probes, but the experiment can be performed also with two.

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Arrange three containers as in the previous experiment:

- ? Cold water (around 2°C – 5°C) in one bottle
- ? Hot water (around 50°C - 60°C) in the other bottle
- ? Water at room temperature (around 15°C – 20°C) in the glass.

Using temperature probes you can simulate the situation your fingers were in. Repeat with probes the actions you made with your fingers.



Put the first probe in hot water, the second in lukewarm water, the third in cold water and start collecting data (if you need help on how to set up data acquisition, go to [Data Acquisition](#) at the bottom of this page).

Let the probes there for one minute and then dip them all in the glass while continuing to collect data. The overall measurement lasts three minutes. We collected 60 samples every three seconds. How did your plot come out?

You can compare it with the one we got (click [here](#) or at the end of the Teacher's guide); If you are unable to perform the experiment you can analyse the Data Sample (by clicking at the bottom of this page).

Discuss with your school mates and your teacher the meaning of this experiment and draw your conclusions.

The teacher can find some suggestions in the section about educational issues.

DATA ACQUISITION (TI84)

In this experiment we shall measure the temperatures collected by the three probes.

Measurements can be collected using DataMate program.

Procedure can be divided into two stages: setup and collection.

Connect all cables:

- the calculator to the interface with the black cable (see photo)
- the probes to channels CH1, CH2, CH3 (see photo)

Arrange all necessary materials:

- fill the bottle with hot water (around 50°C)
- fill the other bottle with cold water (around 2°C – 5°C)
- fill the glass with lukewarm water (15°C – 20°C)

Start DataMate:

CHECKING SENSOR appears and near the channel labels CH 1: TEMP (C) - CH 2: TEMP (C) - CH3: TEMP (C) the temperature of each probe can be read.

To setup the measurement

- select 1:SETUP by pressing 1
- select MODE:TIME GRAPH and press ENTER
- from the menu SELECT MODE select 2:TIMEGRAPH
- select 2:CHANGE TIME SETTINGS
- when ENTER TIME BETWEEN SAMPLE appears press 3
- when ENTER NUMBER OF SAMPLES appears press 60, then ENTER
- to confirm select 1:OK by pressing 1

Insert the probes in the containers and start measurements by selecting 2:START.

After a minute move the probes from the bottles to the glass taking care they do not touch each other.

While measurement occurs the plots of the temperatures from the three probes is shown in real time; when the collection of data is over the plot is rescaled.

Collected data are recorded in the lists

- L1 time
- L2, L3, L4 temperature

To have a look at the plot obtained click [here](#) or go to the [Excel](#) document.

DATA SAMPLE

Data have been collected using:

- TI84 graphing calculator
- CBL2 interface ([see photo](#))
- Three temperature probes
- Black connecting cable ([see photo](#))
- DataMate program
- [TI-GRAPH LINK TM](#) cable and [software](#) (optional)

- PC with TI Connect software (optional)

<http://education.ti.com/us/product/accessory/connectivity/features/software.html>

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Original data in the TI84 calculator can be found in:

- **L1** times

- **L2** first probe temperature

- **L3** second probe temperature

- **L4** third probe temperature

DATA ANALYSIS (TI84)

The experiment does not require data reduction but only the analysis of the plot produced by the calculator and discussion of the whole activity which is a combination of qualitative observations (thermal sensations) and collected data.

A more detailed analysis could be performed by constructing a model of the phenomenon. For this purpose data transfer to PC and the use of a specific software would be advisable.

DATA ANALYSIS (MS Excel™)

Plots can be visualized and analysed using a specific program or a MS Excel™ sheet.

Transferring experimental data to the PC:

When collection is finished data can be transferred from the calculator to the PC using a TI GRAPH LINK cable and TI Connect Software that allows the content of the calculator to be explored (TI DEVICE EXPLORER) and data to be edited (TI DATA EDITOR)

Data are recorded in the calculator as follows:

- time in **L1**
- temperatures, in centigrade, in **L2, L3, L4**

Instruction for data transfer from calculator to PC are available [here](#).

Within TI Connect™, using the TI DEVICE EXPLORER option, lists can be saved in the PC. The list content can be visualized using TI DATA EDITOR and pasted in a MS Excel™ sheet.

A MS Excel document with sample data is available [here](#).

Selecting the data concerning cooling down of the first probe and warming up of the second, experimental data can interpolate with exponential curves (as for the experiment on Lambert-Beer's law).