Newton’s law of cooling

Teacher Notes

PHYSICS
Heat

Driving Question:
How fast an object cools down and what are the factors, which affect the rate of cooling?

Applied Technology: Data-logging

Student Level: High School Level (14-18)

Duration: 1 lesson period

Recommended Settings: Student Investigations

Learning Objectives

- To measure temperature during a cooling process
- To understand that the rate of cooling (rate of temperature change) depends on the temperature difference between the object and its surroundings
- To test the validity of Newton's law of cooling for collected data

Didactical Approach

In this activity students record temperature during a cooling process of hot water and check the validity of Newton's law of cooling for the collected data.

Common student difficulties:

– Objects of different temperatures, which are in constant contact with each other, or in contact with air at a different temperature, do not necessarily move toward the same temperature.

Concepts learnt in this activity:

– The rate of cooling of a substance depends upon the temperature difference.

Materials

– Data-logger e.g. CLAB,
– Temperature sensor,
– A beaker,
– Hot water (to avoid burns we advice to use water below 50° Celsius).

Procedure

- Let the students setup and perform experiments. You can divide students in groups and let each group to have the same quantity of water at different temperatures. Then compare and discuss the results.

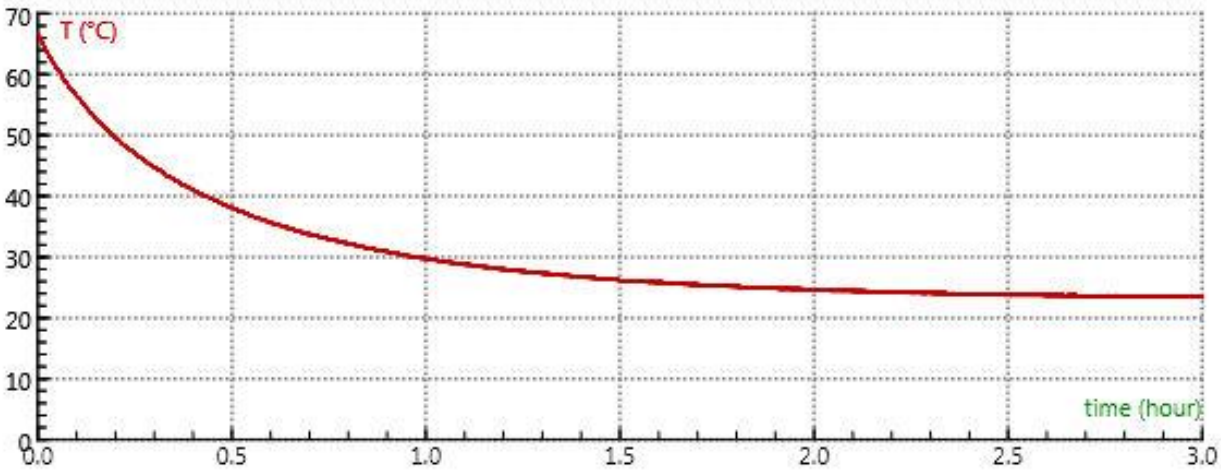
- Data collection takes 15 minutes so other activities may take place during data collection.
- Discuss with the students Newton's law of cooling (let them read 'Science background' of this activity) and possible methods of verifying the law.

Questions and Assignments

- How fast does the temperature change in the first minute of the measurement?
- How fast does the temperature change in the next minutes of the measurement?
- What do you think affect the rate of cooling?
- What are other possible factors that can influence the rate of cooling? How would you test these?
- Is Newton's law of cooling valid for the collected data?
- How do you determine the value of the constant k from your data?
- What do you think this constant represents?
- What unit would this constant have?
- What should you do: add the room temperature coffee cream after 2 minutes or after 12 minutes if you wish to drink the coffee as hot as possible about 15 minutes after it is poured?

Data Analysis

The graph below shows typical data.



Temperature measurement during cooling down a cup of coffee.

The water does not cool equally in each minute of the measurement: in the first minute it cools the most, a minute later a little bit less, in the last minute it cools the least. The rate of cooling (the rate of temperature change) depends on the temperature difference between the beaker with warm water and the temperature of the surrounding air. It is approximately proportional to the temperature difference between the beaker and its surroundings, known as Newton's law of cooling.

Using one of the following methods students can test the validity of the Newton's law for their collected data:

- Method 1: Fit the exponential function to your data.
- Method 2: Plot a graph of the $\ln(T-T_s)$ versus time (t) as a body cools. This graph should give a straight line with a slope (-k).

Resources

Coach Activity: Newton's law of cooling.cma

Coach Result: Newton's law of cooling.cmr

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