Tea – Time Physics

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Abstract

Heat and energy flow are very difficult to present, although we have many experiences with the topics from everyday life.

In the classroom is also the connection with everyday life often missing, so we used experiences with drinking a cup of hot tea as a starting point. How to drink your morning cup of tea in a hurry and not get burned?

The set of experiments we suggest is very simple to perform and effectively display the features heat flow depends on). Measurement of temperature simultaneously in two cups, differing in only one variable, reveals its effect on heat flow and shows pupils that physics works in everyday life, not only in the classroom.

Introduction

School physics often seems remote and disconnected from everyday life. Pupils tend to classify knowledge in two groups: part, originating (and also useful) in everyday life circumstances (conceptions and misconceptions) and the other part, learned in school and also useful only there, or in very limited and unrealistic circumstances. Our aim was to design a set of experiments, familiar from daily life, but intentionally simplified to some degree, to be able to change only one variable at a time. So a complex and untransparent phenomena can be presented in the classroom and dependence on only one variable can be studied at a time.

1 Tea – Time Heat Flow

Heat flow (P), depends on heat conductivity of the conducting material (λ), the surface region (S), temperature difference between the system and the surroundings ($T_i - T_o$) and the thickness of the conducting layer (d):

$$P = -\lambda \frac{S(T_i - T_o)}{d}.$$

A situation, occurring very often in a morning hurry or during short breaks, was chosen to exploit the phenomena of heat flow: What can be done to drink a cup of freshly made tea in five minutes time and not get burned?

1.1 Experiment No. 1

The first suggestion is of course adding cold milk or cream. Adding cold liquid itself cools the tea, but it is there something more in it? Is it wise to add the cream at the beginning of the break, wait till the end of it and then drink the tea, or wait till the end of the break, add cold cream and immediately drink the tea? Or does it matter at all?

Suppose we let the cup of very hot water in the surroundings at room temperature and measure the temperature of the water for several minutes.

The temperature rapidly decreases in the beginning, while the temperature difference between the water and the surroundings is great. Later, when the temperature difference is small, temperature of the water approaches the temperature of the surroundings very slowly. The reason why water cools is heat, flowing from the water to the surroundings, in other words, heat flow from the water towards surroundings. So we can say that heat flow depends on temperature difference; the greater the temperature difference, the bigger the heat flow.

Applying this to the tea cup, we expect that adding cold cream at the beginning (cup 1) would lower temperature difference and slow down the heat flow, so the liquid cools slowly during the break. On the contrary, waiting with cream till the end (cup 2), enables the heat to flow rapidly from the cup and cooling the liquid substantially. When the cream is added at the end, it cools the liquid additionally.

For the measurements equal amounts of water at the same temperature were prepared in identical cups. Equal amounts of cold water were added at the beginning or at the end of five minutes interval, during which the temperature was measured and water stirred regularly. Temperature difference between the two, differently prepared cups of tea, at the end of five minutes interval is between 3 and 5°C in the normal circumstances.

1.2 Experiment No. 2

Another suggestion to solve the problem might be putting the liquid in cups of different sizes. Eventually, increasing the surface area accelerates the cooling. For the experiment we prepare equal amounts of water at the same temperature in differently shaped cups; one narrow and tall, the other wide and low. Temperature was measured for five minutes and the liquid stirred regularly.

Results show that the greater the surface area, the bigger the temperature change in the cup is. This comes in favour of confirming the equation, describing the heat flow, but in fact the evaporation from the surface of the liquid represents the main part of heat loss.

1.3 Experiment No. 3

To show how the thickness of the cup influences the cooling of the liquid, we simply put several plastic cups in one another to make the wall thicker and repeat the experiment.

2 Physics works

Summing up all the knowledge we have gained, we prepare an experiment, which answers the question we used as motivation at the beginning. Equal amounts of water are prepared in different cups, one narrow and the other wide. We added cold cream in the narrow cup at the beginning and in the wide cup only at the end of five minutes interval. All other circumstances remained unchanged. Measurements of the temperature in both cups revealed that physics can be useful: temperature difference at the end of experiment was 11 degrees in our case (see Fig. 1).

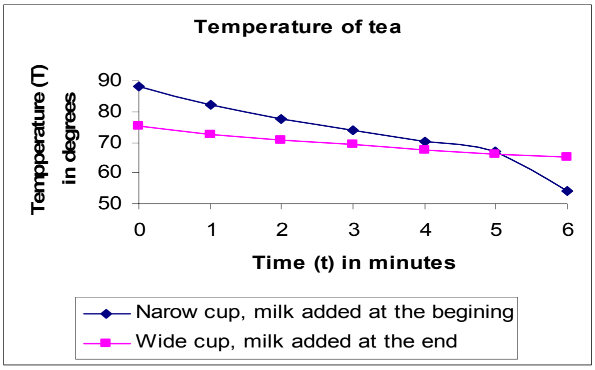

Figure 1: Temperature of tea in differently prepared cups.

Conclusions

Showing physics works in everyday situations helps pupils and teachers at their work. Looking around us, we can find even more physics in a cup of tea and around it. Drinking tea on a sunny morning at polished or glass – covered table, surprises us with a double shadow of a tea cup on the wall (see Fig. 2).

Figure 2: The double shadow of the tea cup offers a challenge to explore the light.

How the double shadow of the cup could be explained? It offers a starting point to explore the light.