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Teaching Physics With Realistic Context

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Abstract
In this paper the module Physics in the kitchen is presented. This module can be considered as an example how to teach physics in connection with real life problems. This material includes knowledge of mathematics, science (physics, chemistry) and technique. Two basic parts of this problem are presented – energy consumption in the kitchen and properties of fluids used in the kitchen. The methodology of this module responds with the objectives of STEM (science, technique, engineering, mathematics) education. All practical activities can be provided in the school (classroom or laboratory) and at home.
Keywords: *physics, real life context, STEM*

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I. Introduction

PISA - Programme for International Student Assessment (PISA 2020) and TIMSS - Trends in International Mathematics and Science Study (TIMSS 2020) studies of the last few years show a lack in secondary school students' motivation to study mathematics and science in many European countries. This finding compared with the needs of the 21st century labour market has a number of negative impacts. For example we can point out that the majority of work relies on an understanding of science and mathematics so as decision-making processes in all fields of life.

As mentioned earlier (Holubova 2015) one way how to motivate learners is to use interdisciplinary relations. A positive feedback was found when realistic context was used.

Within the international Comenius project PROMOTE (EU LLP Comenius project 2018) a number of interdisciplinary materials was prepared. These materials can be used immediately in schools so as in teacher training at universities and in further in-service teacher training. The context is relevant and meaningful to students, and can contain out-of-classroom activities, real-life situations, nature of science issues. Several of these materials are supported by interactive ICT products.

It is obvious that one can find a plenty of teaching materials on the web. But the modules prepared within this project are purposefully determined to use interdisciplinary relations between science, mathematics and everyday life.

One of these modules will be described in this paper. The aim of this material is to show how physics works in everyday activities. We have chosen the topic Physics in the kitchen.

II. The module Physics in the kitchen

Learning outcomes of the module can be summarized as follow:

- Students can explain the data on the label
- Students do percent calculation
- Students can solve numerous problems listed
- Students carry out laboratory tasks
- Students compare the effectiveness of different sources of heat, draws graphs and histograms
- Students can measure the surface tension of liquids
- Students can measure the consistency of liquids

Required pre-competences are: knowledge about temperature, energy and their units, the theory about surface tension and viscosity. In mathematics they have to deal with expressions.

III. Description of the module

3.1 Motivation

Figure 1. a) Kitchen of the 19th century http://ubytovanipalda.cz/hrad-kost/hrad-kost-cerna-kuchyne/
b) Kitchen of the 21st century

Task: Compare the kitchen in figure 1a) and the kitchen in figure 1b) !
Make a list of the appliances that you have in the kitchen at home. Determine which of them are equipped with energy labels.

3.2 Part 1 – energy consumption in the kitchen
Task 1: What do the details on refrigerator energy label say?
Each appliance is classified by the efficiency index. It characterizes the energy consumption per litre of the appliance in comparison with the useful output. Consumption is derived under ideal operational conditions - ambient temperature of 20 °C and the filling of the refrigerators´ usable space at 70%. Currently manufactured are only refrigerators of the class A or higher.
In figure 2 you can see the energy labels of a refrigerator with a freezer and of a refrigerator.
Compare the two items!

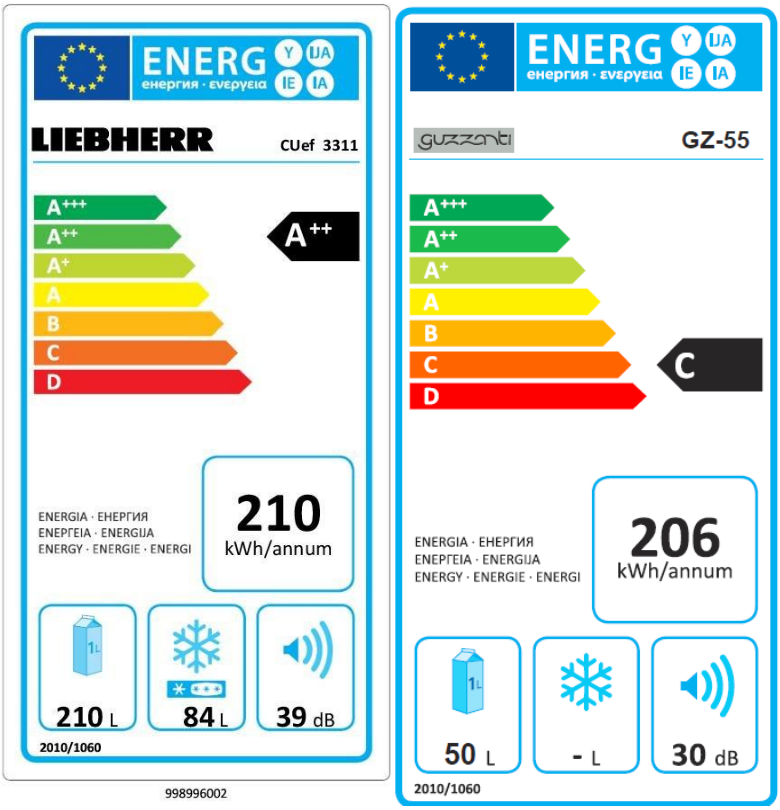


Figure 2. Energy labels

Learn more about energy labels ! Use the web page
https://en.wikipedia.org/wiki/European_Union_energy_label

Task 3: Energy consumption in the kitchen

To find the quality (efficiency) of machines we should determine their effectiveness. The efficiency of the device is determined as the ratio of the supplied power (consumption) and performance conducted.

Example 1 – the use of mathematics:

To heat 2 litres of water from 10 °C to 100 °C we need an energy of 600 000 J. How long will it take to boil water in a kettle with 2000 Watt consumption and 85% efficiency? (Information about the water temperature in this example is redundant.)

Solution procedure: $P_p = 2000$ W, $W = 600\,000$ J, $\eta = 0.85$, $\tau =?$ s, $t_1 = 10\ ^oC$, $t_2 = 100\ ^oC$

Output $P = \frac{W}{\tau}$

W ...work (J), τ...time (s)

$$\tau = \frac{W}{P} = \frac{W}{\eta \cdot P_p}$$

P_p … input (W), η … efficiency

$$\tau = \frac{600000}{0,85 \cdot 2000} = 353$$

$\tau = 353$ s = 5.9 min

Laboratory work 1

Equipment needed for this activity: Induction cooker, electric cooker, electric kettle, gas cooker, water (0.5 litre = 500 ml), oil, pots, protective equipment, stopwatch, thermometer, thermal imager

Tasks:

1. Compare the efficiency of heating a certain amount of water on different types of cookers. 2. Calculate in EUR, USD the cost of energy required for heating.

Procedure:

a) Gradually heat 500 ml of water in an ordinary pot with a lid and in the same pot without a lid on a gas stove. b) Heat in the same pot 500 ml of water on the electric stove - with and without lid. c) Compare the boiling time with or without the lid on the same source of heat. d) Calculate the energy consumed in each case. e) Calculate energy saving in case of using the lid in percent. f) Calculate the necessary energy costs in USD (EUR).

Data you need to put in your worksheet:

Weight of water - m (kg), initial water temperature - t_0 (^{o}C), the resulting water temperature - t (^{o}C), specific heat capacity of water - c = 4180 J·kg·K^{-1}**,** calculation of heat needed to heat the water - Q (J) $Q = mc\,(t - t_0)$, power of cookers - P_0 (nominal value indicated on the appliance) (W), heating time - τ (s), calculation of the total energy supplied during the heating - $W = P_0 \tau$ (J), calculation of cookers efficiency - η (%); $\eta = (Q / W)\cdot 100\%$.

Additional task:

Measure the temperature rise in fixed time intervals (e.g. after 30 seconds). The measured temperatures fill in a table and draw a graph of the increase in water temperature over time.

With the use of suitable software (Excel, Geogebra, Mathematica) draw the graph.

Result - Comparison of the efficiency of various types of cookers**:**

The following table shows the efficiency of the various cookers, which are used for the heating of 1.9 litres of water from the temperature of 20 ^{o}C to the boiling point.

Table 1. Efficiency of cookers

Technology	**Time required for heating**	**Energy**	**Efficiency**
Induction cooker	4 minutes 46 seconds	745 kJ	83 to 90 %
Electricity cooker	9 minutes 0 seconds	1120 kJ	45 %
Gas	6 minutes 2 seconds	1220 kJ	55 %

Note: In the table only the efficiency of the cooker itself is considered. The efficiency of the transmission and distribution system of gas and electricity is not taken into account

Discussion
1. Describe the advantages and disadvantages of each cooker that was used in your laboratory work.
2. Try to create as many cases as possible in which you can use the data from the table.
3. Construct appropriate graphs (histograms), from which it will be clear which types of a cooker can be recommended for use in the household due to their efficiency.
4. Prepare a poster or a power point presentation with the results of your measurements.

Additional activity
Study the process of water heating on an electric cooker and an induction cooker with the use of a thermal camera. What do you observe? What conclusion do you come up with?
When answering the question you can study the figures below. The figure a) shows heating a pot with water on an induction cooker, the figure b) on an electric cooker.

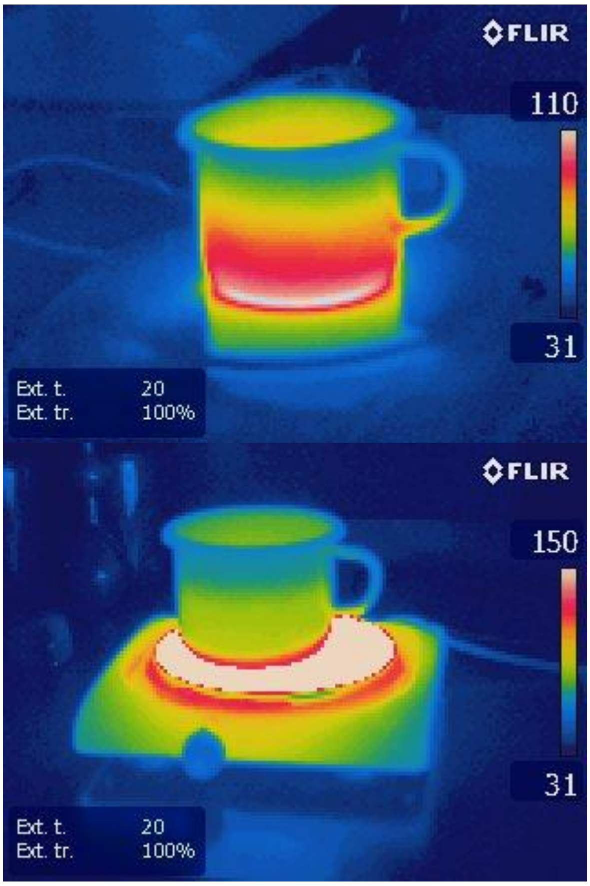


Figure 3. Heating a pot filled with water

Study the process of heating oil under the same conditions. Discuss your observations.
3.2 Part 2 - Liquids in the kitchen
The aim of this activity is to measure the surface tension, the viscosity, and consistivity of liquids used in the kitchen (water, dishwashing liquid, liquid soap).
Viscosity measurement was described in our previous paper (Holubova 2017). To measure surface tension various methods can be used. The accuracy of these methods can be compared and discussed. Commonly used methods are the capillary elevation method, the drop volume method, and the Du Noüy method. (Surface tension 2009, 2020)
Task 4: Consistency measurement
Consistency describes the flow of the liquid caused by gravity. It is measured by using a consistometer (Figure 4).

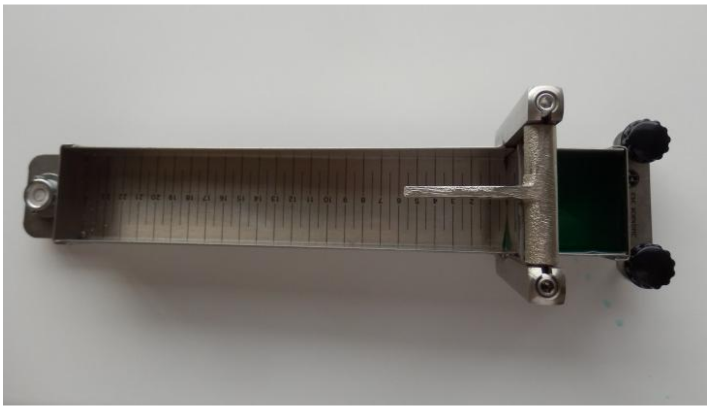


Figure 4. Bostwick consistometer

Consistency measurement is simple and is cheaper than viscosity measurement. It is used in many technical application but there is no an absolute standard for the measurement. (Mc Carthy 2008)
For school practice, the Bostwick consistometer can be used. The quality of different brands of ketchup, mustard, liquid soaps, etc. can be compared.
The consistometer (Fig. 4) is made of stainless steel. It consists of a hopper, a stop operated by a strong spring and a rail with an engraved scale, the division of the scale is 0.5 centimeters. The required amount of liquid for each measurement is 75 ml. After filling the reservoir with the tested liquid, the stop is opened by hitting the latch and the liquid is allowed to flow out for 15 (30, 45) seconds. The distance to which the liquid "touched" during this fixed time is measured.
Figure 5 shows the measurement of the consistency of the bath foam - the temperature of the sample was 28 ^{o}C, the measurement time was 15 s.

The distance traveled for a given time in centimeters is the required consistency (the so-called Bostwick value). In order for the liquid to drain only due to its own weight, the rail must be in a horizontal position. Adjusting screws are used for alignment. All samples must be measured at a constant temperature. When replacing the sample, the consistometer must be cleaned and dried. Each laboratory creates its own standards for measuring individual liquids.

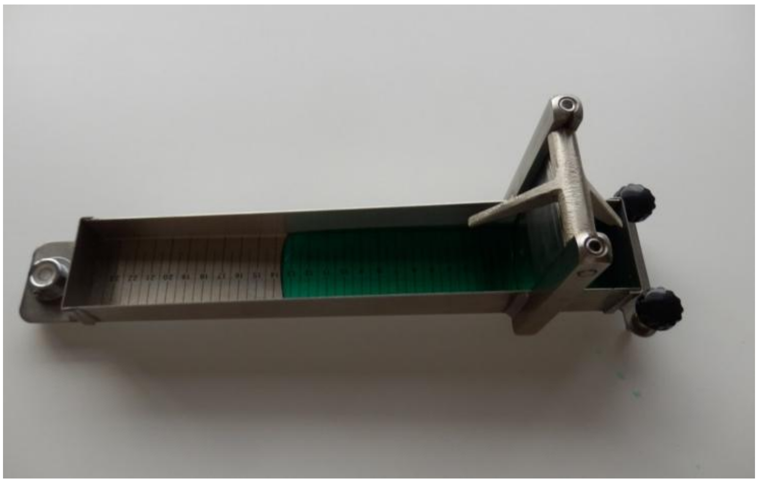
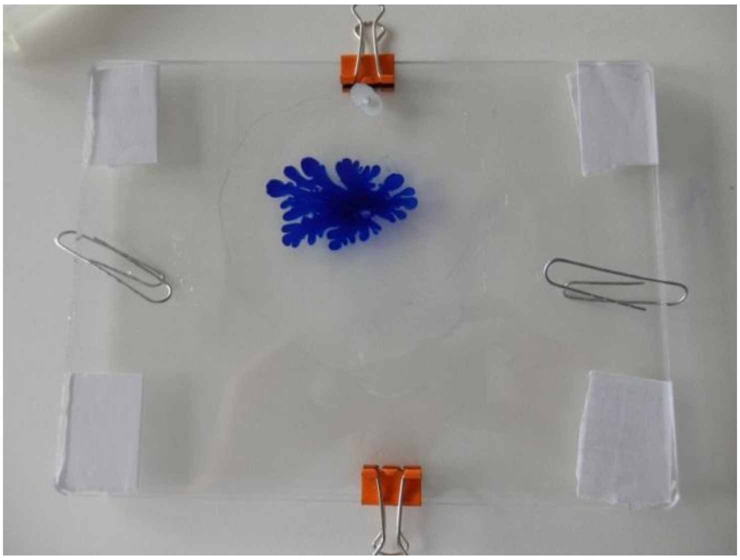


Figure 5. Measurement of bath foam consistency

Task 5: The behavior of two different liquids studied by a Helle-Shaw cell

Students have to prepare a simply Helle –Shaw cell made from two glass plates, one of it with a small hole in the center. The plates are placed on top of each other with a small space between them. When the liquids of different viscosity are pushed in this space between these plates, a two-dimensional model of patterns can be seen. This fingering can be analyzed as a two-dimensional model of fractals.(Xu 2017)

If a liquid with a higher viscosity is pushed into a liquid with a lower viscosity, a smooth interface is created between the two liquids. A liquid with a higher viscosity seems to push the liquid less viscous. If we push a less viscous liquid into a liquid with a higher viscosity, viscous channels (branches, fingers) are formed. Each branch is further developed and a complex network of channels is created. This creates a viscous fingering model. The boundary between the two fluids is hydro dynamically unstable. What the image looks like depends on the viscosity of the fluids used.



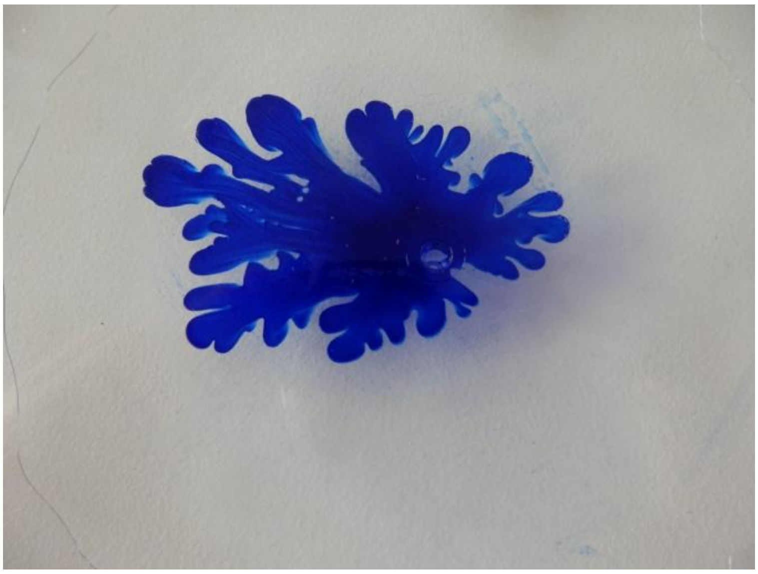


Figure 6. Helle – Shaw cell (coloured water and liquid soap)

Fingering in a Hele-Shaw cell will be compared for various liquids and the calculation of their fractal dimensions can be provided.

IV. Conclusion

All these activities can be realized by high school learners within classroom activities so as during non-contact education. The project can be split into parts according to the studied topic and the time options. Teaching methods that are suitable for this module are group work and team teaching. What is important the activities have real life content and some of the experiments so as numerical tasks can be provided at home. No expensive laboratory aids are needed. Students can add their own ideas and formulate hypothesis that can be proofed. This module can be provided as a first step to the inquiry based learning methodology.

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