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THE STUDY OF SOME THERMAL PHENOMENON BY COMPUTER-ASSISTED EXPERIMENTS AND MBLs

DANIELA STOICA[1,2], CRISTINA MIRON[1*], AL. JIPA[1], M.V. POPESCU[2]

[1] University of Bucharest, Faculty of Physics, RO-077125 Bucharest-Magurele, Romania
[2] “Ion Luca Caragiale” National College, Ploiesti, Romania
[*]Corresponding author: cmiron_2001@yahoo.com

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Abstract. In physics education, laboratory activities increase students’ interest in the theoretical subject taught in the class and help their learning. In this paper we describe some experiments of Microcomputer Based Laboratories (MBLs) during a data-logging activity and draws on recent relevant research. We treat aspects of students’ talk about real time graphs and results on their perceptions of using this type of experiment in physics classroom. MBLs and Computer-assisted experiments are tools which help students to relieve the difficulty of data collection in the traditional laboratory for the following topics: “The comparison between the specific heat of water and sand”, “The verification of Bergmann Rule”, “The influence of salt upon the melting point of ice” and help them establish the connections between physical phenomena and abstract representations. By making computer-assisted experiments, we wanted to investigate the way in which these experiments can contribute in order to have a better understanding of the studied phenomena and the way of using digital devices to get students’ interest and the motivation in the scientific activity.

Key words: Microcomputer Based Laboratories, computer-assisted experiments, data logger, sensors, experimental study of thermal phenomena.

1. INTRODUCTION

In Microcomputer Based Laboratories (MBLs) and data loggers, one or more sensors are connected to an interface and the interface to a computer. Computer-assisted experiments allow the real-time view of the variables of an experiment and enable students to collect, display and analyze data in real-time, provide graphic representations, and fit data with functions suggested by the adopted model [1]. These types of experiments help students to visualize and understand the connection between theory and the observed behavior in an easy and intuitive way. Research shows that the advantages of using this type of experiment go further than simply motivating students so that they can improve other skills, such as interpretation of graphs and it can help to develop other competences [2–5].

Laboratory experiments based on computers have been successfully implemented for many years in science and technology universities [6–8].

The use of digital technology can change the way of teaching physics and can make the transition from the teaching focused on the teacher, much like nowadays, to the teaching focused on the student himself, based on collaboration between them both [9].

Digital instruments introduced in schools can create a bridge between students' activity in school and real life, considering that they are already familiar with computers, mobile phones, tablets etc. This way can make students to use their life experience and to create the crossing conditions from a teaching way based on research [9–10].

Digital technology based on data logger and sensors, used during the physics class, changes the students' perception of the studied physical phenomenon. So, teamwork should be encouraged and students can critically evaluate collected data in real time during the experiment [11]. This way, they are involved in processing and interpreting activities using data collected by data logger. The use of digital instruments in labs leads to the development of the students' abilities to transfer knowledge from class to real life [12].

This way, by semi-independent lab activities, students have the opportunity to analyze collected data, to search on the Internet for information in order to enrich their knowledge about the studied phenomenon, to conclude and to learn to use the processed data [13].

During such an experiment, students can use data acquisition system, sensors and a computer or a tablet with multiple sensors incorporated.

The data acquisition system, which is connected to a computer, is used to record data from the sensors. The sensor is an instrument which measures a quantity that is converted in a signal that can be read directly by the person conducting the experiment or can be visualized on the computer screen, as the connection with the computer is made with a data logger [11].

If the student owns a tablet with built-in sensors or acquisition and data processing devices, he/she can continue the set of measurements started in class, thus increasing his/her curiosity and his/her desire to execute scientific measurements outside of school [11]. Students must be encouraged to become independent in studying digital devices in order to create a connection between the student's activity at school and at home. Also, this type of experiment encourages teamwork, student's collaboration for a project and creates the possibility to show the results of their work [14]. Based on data acquisition systems and data processing, this type of experiment creates a connection between physics, chemistry and biology. Such a complex subject can be treated in an interdisciplinary context with real life applications [14].

Experimental investigations of thermodynamic and molecular physics at first level have always been very limited, because of the difficulties in performing simple, but conceptually relevant laboratory experiments. User-friendly data acquisition systems have opened new possibilities in this field [15].

In this paper, we describe the real-time laboratory experiment of: *The comparison between the specific heat of water and sand*, *The verification of Bergmann Rule*, and *The influence of salt upon the melting point of ice*.

2. DATA ACQUISITION SETUP AND EXPERIMENTAL RESULTS

During the physics classes the following experiments were made: *The comparison between the specific heat of water and sand*, *The verification of Bergmann Rule* and *The influence of salt (NaCl) upon the melting point of ice*. These experiments were conducted using the data acquisition and processing system Cobra 3, temperature sensors, Fourier's Nova Link data logger, temperature sensors and Einstein tablet along with another data logger, with the aim to determine the relative humidity of air and the temperature of the environment.

2.1. EXPERIMENT 1 – *THE COMPARISON BETWEEN THE SPECIFIC HEAT OF WATER AND SAND*

In this experiment, we used the data acquisition and processing system, Cobra 3, along with two temperature sensors and we tried to compare the specific heat of water and sand.

For this experiment, we used two plastic dishes in which we introduced the same amount of water and sand. Immersion probes were positioned over the water and sand and connected to the computer using the acquisition and data processing system Cobra 3 [16].

In the first stage of the experiment, the temperature of water and sand was registered using the two temperature sensors for 200 seconds, then, a lamp was switched on, while the temperature registration continued. After that, the lamp was switched off, but it continued to monitor the water and sand temperatures. The recorded data were sent to the students by e-mail for processing. In Fig. 1 the experimental set-up is being reproduced.

Taking into consideration that both water and sand receive the same amount of warmth from the incandescent lamp, we can observe that sand is getting warmer than water.

Figure 3 shows the graphs of temperature variation depending on time for sand and water during the heating process. Figure 4 shows the graphs of temperature variation of water and sand in the cooling process.

Fig. 1 – Experimental set-up for the experiment *Comparison between specific heat of water and sand*. The colored versions can be accessed at http://www.infim.ro/rrp/.

Figure 2 shows the temperature curve obtained for water and for sand.

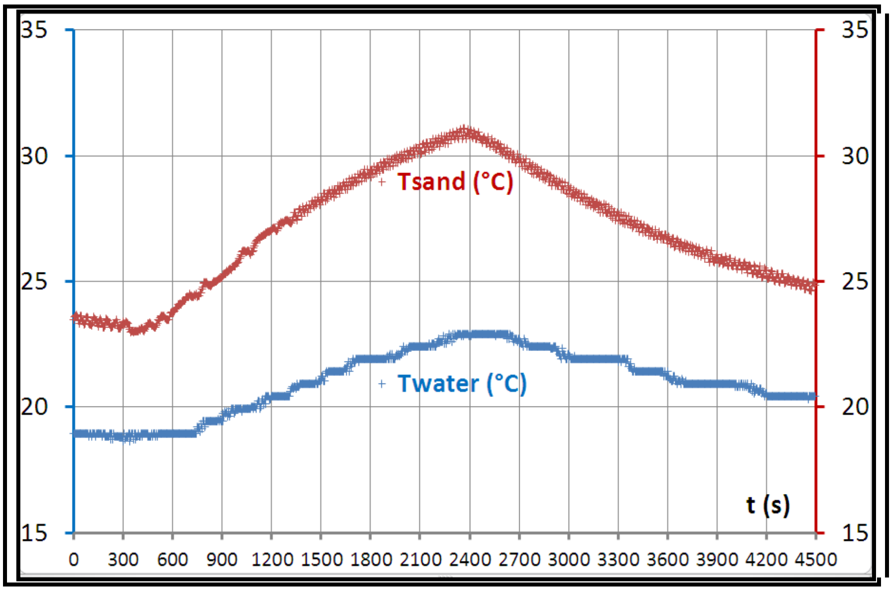

Fig. 2 – The variation of water and sand temperature depending on time. The colored versions can be accessed at http://www.infim.ro/rrp/.

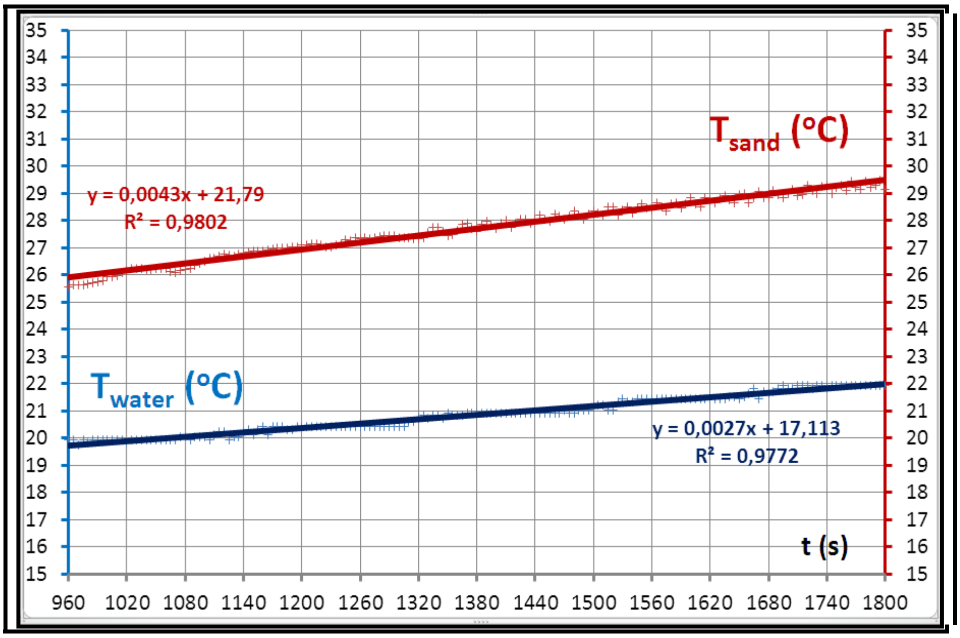

Fig. 3 – The variation of water and sand temperature depending on time during the heating process. The colored versions can be accessed at http://www.infim.ro/rrp/.

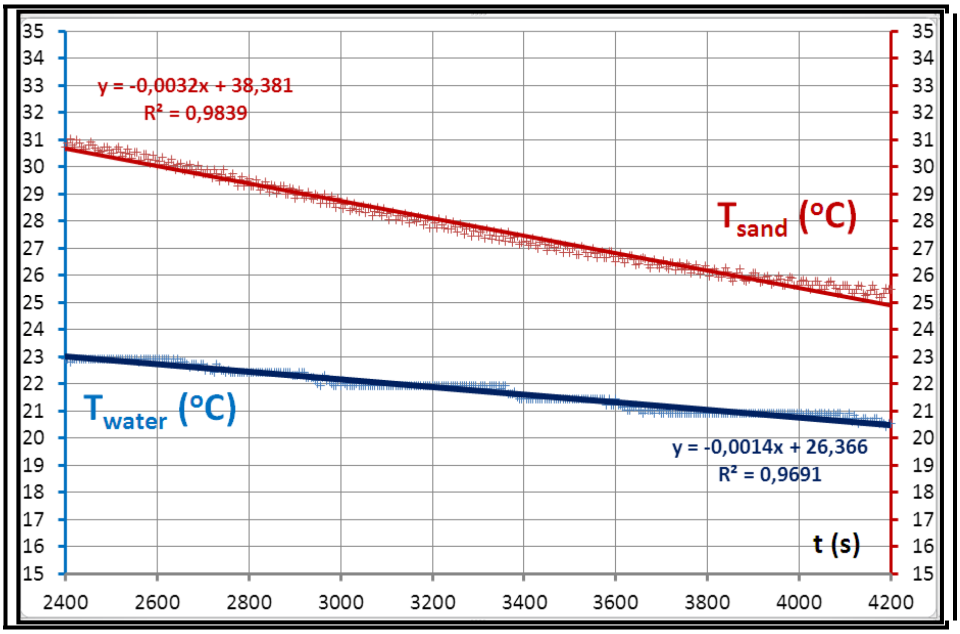

Fig. 4 – The variation of water and sand temperature depending on time during the cooling process. The colored versions can be accessed at http://www.infim.ro/rrp/.

From the analysis of the graphs for the specific heat of the sand, the following values were obtained:

$c_{\text{sand heating}} = 2342$ J/kg · K

$c_{\text{sand cooling}} = 1260$ J/kg · K

$c_{\text{sand average}} = 1801$ J/kg · K

During heating the specific heat of sand is higher because it is wet. The heating causes evaporation and therefore, during the cooling process, the specific heat of the sand is lower.

We can see that the specific heat of sand is aproximately two times lower than the water's specific heat. The students realised that an object with a lower specific heat is getting warm faster. Also, the students discovered the practical consequences of this experiment, by making connections with everyday life. In this way, they justified that one of the consequences of the difference between the two specific heats is the inequal warmth of the Earth. This is how we explain why during summer the temperatures on the seaside are lower than on the rest of the continent and the opposite happens during winter. Having higher specific heat, water loses heat slowly than earth and sand that have lower specific heats.

Another application of the data obtained in the studied experiment would be the choice of material that the radiators are made off. They are made of aluminum, iron or steel because these metals have higher specific heat than other materials such as copper and lead.

2.2. EXPERIMENT 2 – *THE VERIFICATION OF BERGMANN RULE*

According to Bergmann's rule, animals from cold areas are bigger and stronger than their relatives from warmer areas. So, polar animals's body mass helps to limit heat loss [17]. In addition to body weight, fur acts as a thermal insulator, too.

The reason why the loss of heat of the animals from the cold areas is lower is that these animals have a smaller surface area than their volume, while smaller animals have a larger surface area than their volume.

In order to verify this rule, an experiment was performed using the acquisition and data processing system Cobra and Einstein tablet. For this experiment, we used two long-neck round-bottom flasks, of the same shape but different sizes, filled with hot water. They were each fitted with a stopper through which one temperature sensor was inserted. Figure 5 reproduces the used equipment.

Figure 6 shows the temperature curve of water from the smaller round bottom flask (T_1) and Fig. 7 shows the graphic of the water temperature from the bigger round bottom flask (T_2).

Fig. 5 – Experimental set-up of the „Bergmann’s rule verification experiment” using uninsulated battom flasks. The colored versions can be accessed at http://www.infim.ro/rrp/.

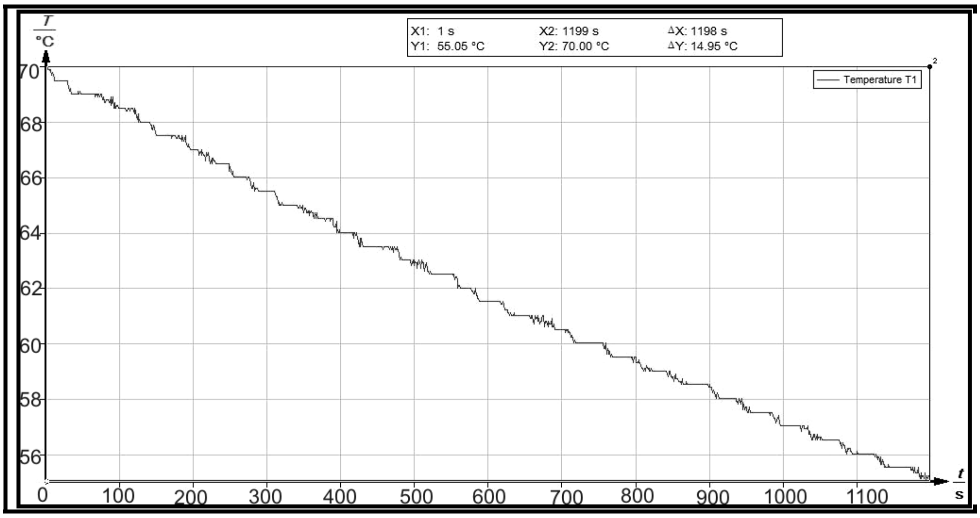

Fig. 6 – The temperature curve of water from the smaller round bottom flask (T_1). The colored versions can be accessed at http://www.infim.ro/rrp/.

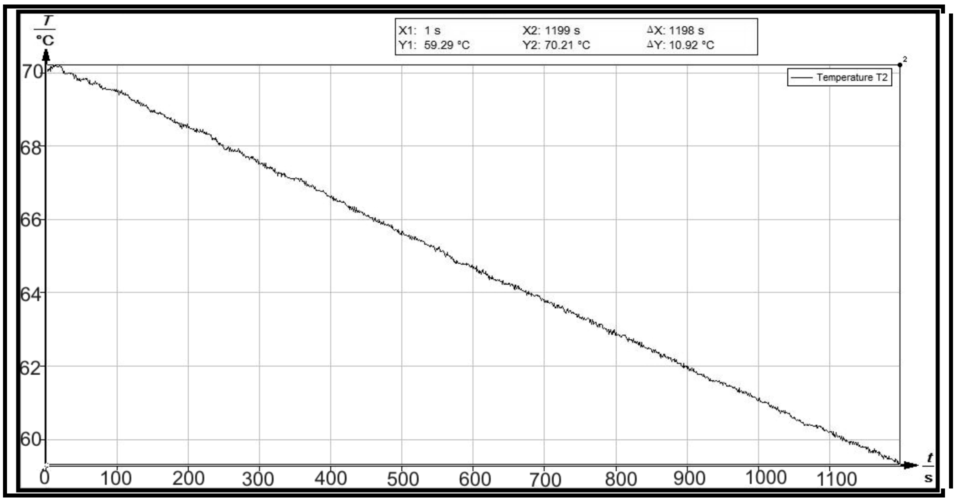

Fig. 7 – The temperature curve of water from the bigger round bottom flask (T2). The colored versions can be accessed at http://www.infim.ro/rrp/.

From the two graphs we found out that at the same time, the water temperature from the smaller round bottom flask has decreased with 14.95 ºC, while the water temperature from the bigger round bottom flask has decreased with 10.92 ºC. The conclusion from this experiment is that the heat loss is higher for the water from the smaller round bottom flask.

We repeated the experiment, covering the two round bottom flasks with fur to highlight the role of thermal insulation fur. Figure 8 reproduces the used adjustment in this second part of the experiment.

Fig. 8 – The experimental setup to verify the Bergmann's rule using covered round bottoms flasks with fur. The colored versions can be accessed at http://www.infim.ro/rrp/.

Figure 9 shows the temperature curve of water from the smaller round bottom flask (T1) and Fig. 10 shows the graphic of the water temperature from the bigger round bottom flask (T2).

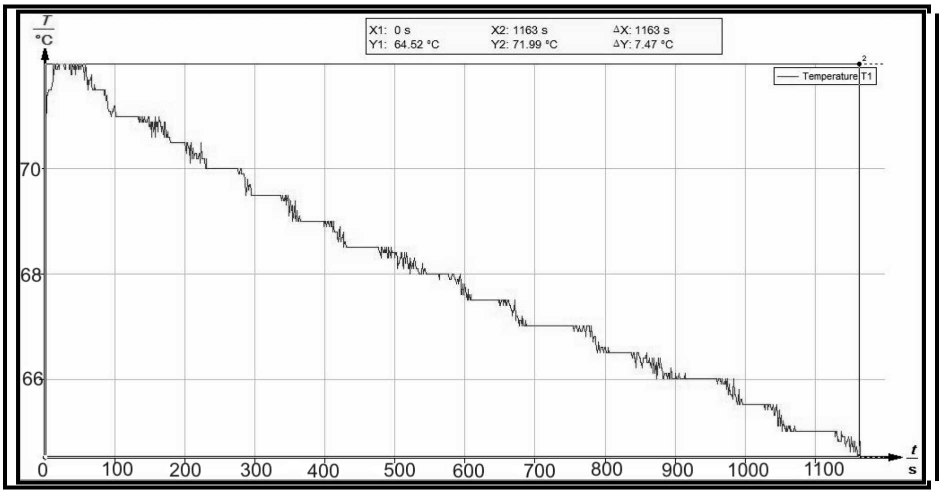

Fig. 9 – The temperature curve of water from the smaller round bottom flask (T_1). The colored versions can be accessed at http://www.infim.ro/rrp/.

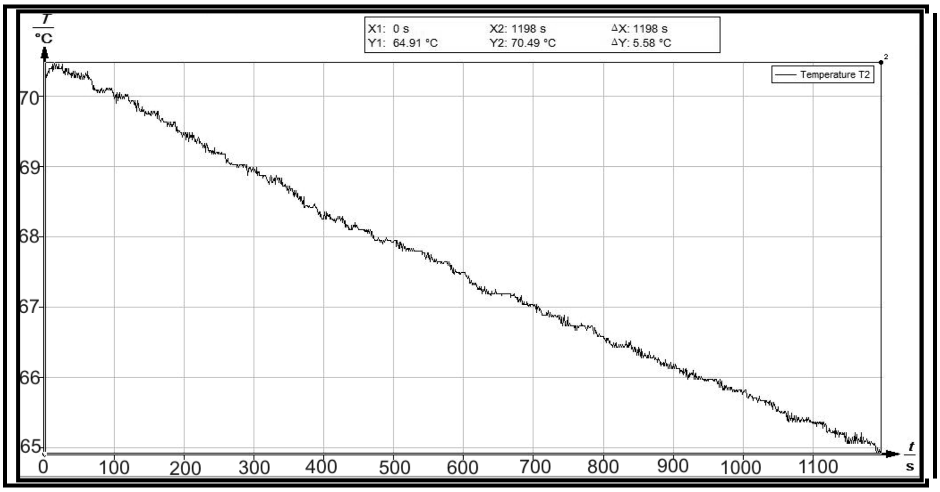

Fig. 10 – The temperature curve of water from the bigger round bottom flask (T_2). The colored versions can be accessed at http://www.infim.ro/rrp/.

Analizing the two curves, we find out that the temperature of the water from the smaller round bottom flask has decreased with 7.63 ºC, while the temperature of the water from the bigger round bottom flask has decreased with 5.58 ºC, in the same time. In this case, it seems that the higher round bottom flask keeps the heat better than the smaller round bottom flask, but temperature shifts are lower when the round bottoms flasks were isolated. In this way we emphasise the role of the fur in thermal insulation of the bottoms. In Fig. 11 the graph of temperature and humidity of the air from the lab based on time during the experiment of uninsulated bottom flasks is shown. Both graphs were recorded using Einstein tablet.

Fig. 11 – The graph of temperature and humidity of the air from the lab based on time during the experiment (The green curve indicates the temperature and the yellow curve indicates the relative humidity of the air). The colored versions can be accessed at http://www.infim.ro/rrp/.

The results of these experiments are presented in Table 1.

Table 1

Experimental results – The verification of Bergmann rule

The bottom condition	Time Δt (s)	The temperature variation $\Delta\theta$ (^{0}C)	$\Delta\theta/\Delta t$ (^{0}C/s)
Uninsulated small bottom	1198	14.95	0.0124
Uninsulated big bottom	1198	10.92	0.0091
Small bottom isolated with fur	1198	7.63	0.0063
Big bottom isolated with fur	1198	5.58	0.0046

2.3. EXPERIMENT 3 – *THE INFLUENCE OF SALT ON THE MELTING POINT OF ICE*

This experiment was conducted using Fourier's Nova Link data logger, a temperature sensor and a data logger that measures temperature and relative humidity of the surrounding air.

This experiment revealed the influence of salt on the melting point of ice.

We used a transparent plastic food box, on the bottom of which a layer of crushed ice about 5 cm thick was placed. In that box, we placed a metallic box half fulled with cold water. Around the box, ice was introduced until the upper side of the metallic box was reached. In the food box, salt was then introduced. The box was covered with its lid which has a gap for the temperature sensor. The aim was to follow the variation of water temperature based on time in the metallic box. Outside the food box, a data logger was placed to measure the temperature and the relative humidity of air.

Figure12 reproduces the used equipment.

Fig. 12 – Experimental setup for the experiment "The influence of salt on the melting point of ice". The colored versions can be accessed at http://www.infim.ro/rrp/.

It can be seen that outside the box, a skim of ice appears. After a certain period of time we see that the water from the metallic box freezes.

Figure 13 reproduces the image of the ice formed inside the box.

We repeated the same experiment, but inside the food box salt wasn't introduced, only pure ice was introduced.

In Fig. 14, we can see the graph of the water temperature from the metallic box based on time for the experiment in which the salt was used. In Fig. 15 it is shown the variation of the water temperature from the metallic box based on time, when pure ice was used.

It is noticed that the water inside the box which contains ice and salt begins to freeze after near 600 s and that the water inside the box, placed in the bowl with pure ice does not freeze.

The ice melting is achieved with heat absorbtion. From where can we take this heat that is neccessary for the melting process? It comes from the water inside the box, which is yelding heat, which will decrease the temperature and it will freeze.

Fig. 13 – The ice formed inside the box.
The colored versions can be accessed at http://www.infim.ro/rrp/

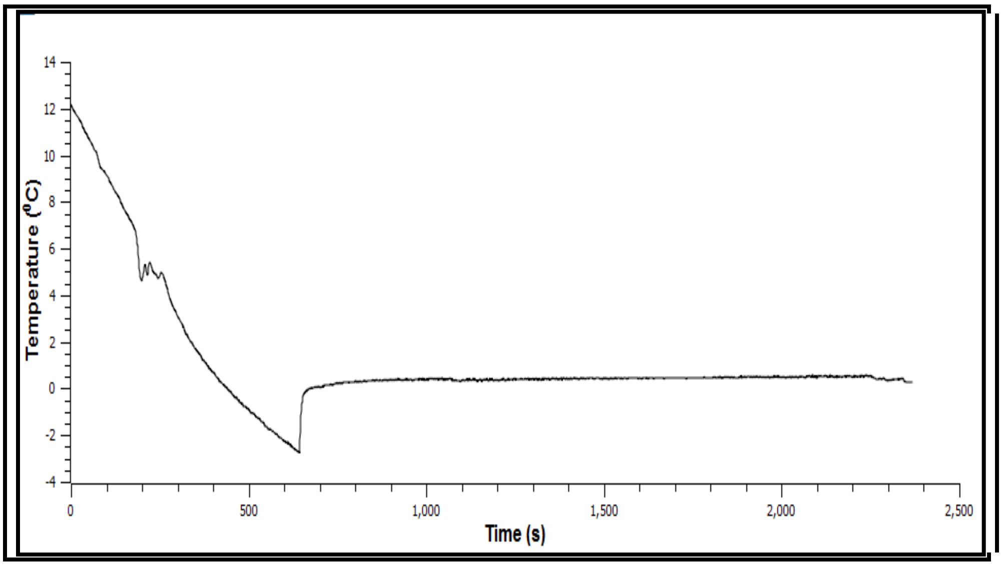

Fig. 14 – The dependence of the water temperature
from the metallic box based on time when it was used NaCl.

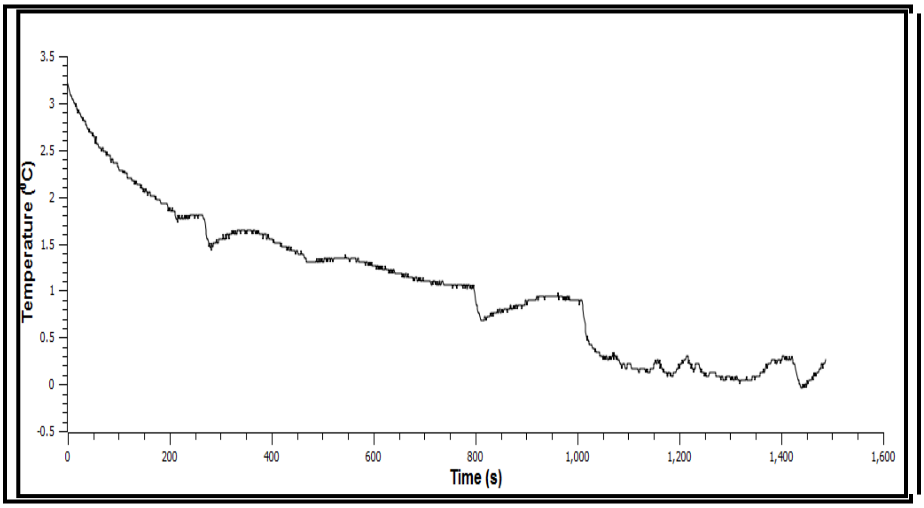

Fig. 15 – The dependence of water temperature
from the metallic box based on time when pure ice was used.

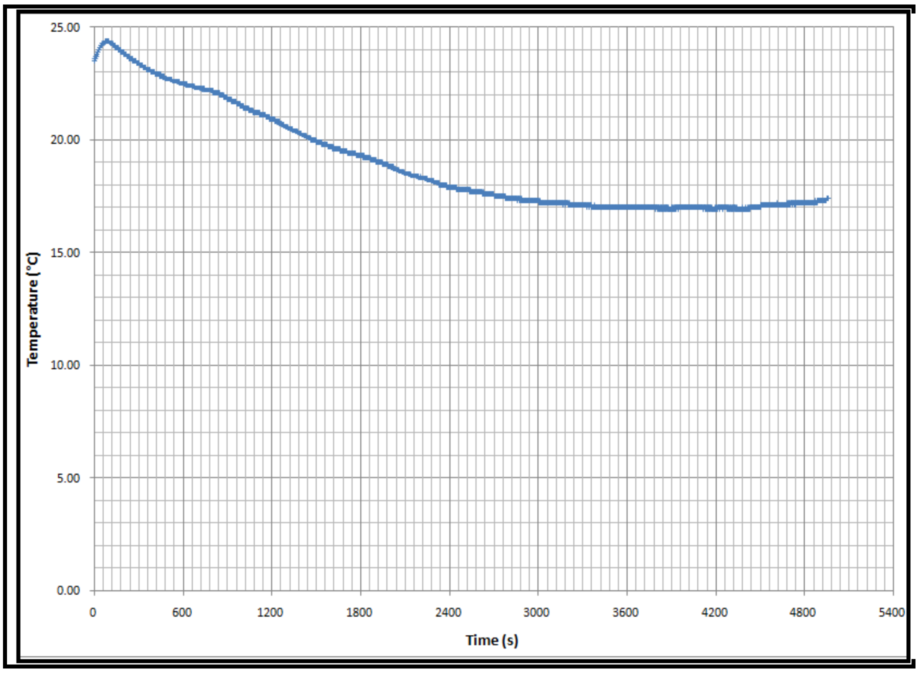

Fig. 16 – The graph of the enviroment's temperature according to the time.
The colored versions can be accessed at http://www.infim.ro/rrp/.

From the moment we added the salt (NaCl), the melting process is accelerated, so this explains why the water inside the box with ice and salt freezes faster than the water situated in the box with pure ice [18]. This is why we use salt on public streets during winter, in order to melt the compressed snow.

In Fig. 16 it is shown the graph of the temperature variation in the enviroment based on time. In Fig. 17 it is shown the relative humidity dependency of air based on time. Both quantities are registered with the help of a data logger situated near the plastic box. The recordings were made according to the first experiment.

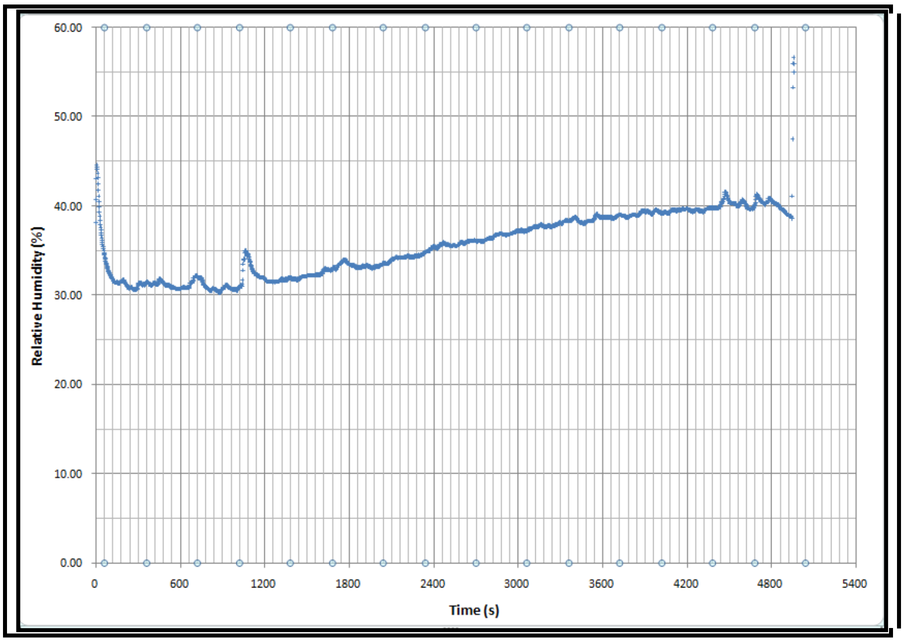

Fig. 17 – The relative humidity dependency on the enviroment's air according to the time. The colored versions can be accessed at http://www.infim.ro/rrp/.

After analyzing the graphs, we can say that the temperature of the air decreases and the relative humidity of the air also drops in the first 500 s, then it stays almost constant and in the end it increases.

3. CONCLUSIONS

The data recieved from the experiment was forwarded to the students. They have elaborated them, compared the graphs and had different opinions, linking them to the daily life; for example, the comparison of the specific heats of sand and water.

The laboratories, both real [19–20] and virtual [21–22], play the influential role in new strategies for both teaching and studying physics.

We think that such results are indicative of our students' development concerning the topics under study: *specific heat of the sand*, *check Bergmann's rule*, *influence of salt on the melting point of ice*.

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