

# COMPUTER-AIDED EXPERIMENTS IN STUDENT PHYSICS LABORATORY\*

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The need to use computer-aided experiments in the physics teaching process was discussed and justified. The benefits of using computer-aided measuring methods have been shown. The application of selected measuring consoles equipped with sensors and coupled with a computer in the process of performing and analyzing the results of experiments was shown. The results of three computer-aided experiments were presented in which the electromotive force and internal resistance of the battery, hysteresis loop and the Dulong–Petit law were determined.

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## 1. Introduction

In recent years, the computer-aided experiments play an increasing role in teaching physics at various levels of education. Performing experiments in the student physics laboratory is one of the most important teaching methods used to learn physics. The computers linked with the measuring console equipped with appropriate software and sensors give many possibilities to carry out experiments requiring recording the changes in physical parameters over time such as temperature, light intensity, charge during capacitor charging and discharging, collision time or period of harmonic vibrations [1]. The dedicated software enables to practically learn about collecting, processing, visualization, analysis of the obtained results and simulation of the experiment. The computer-aided experiment enables to become acquainted with modern measurement methods used in scientific laboratories and the methodology for analyzing their results. Moreover, it increases interest in scientific research and prepares for future work in industrial laboratories. It turns out that in many cases the use of computer-aided measuring systems

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accelerates the learning process and understanding of the studied physical phenomena [2]. As already mentioned above, many physical processes take place in a very short time and without computer-aided systems, it would not be possible to register them [3, 4]. In addition, the computer enables use of databases and information available other than the Internet, which speeds up the process of processing of the obtained data and their interpretation. No less important is the software that gives the possibility to create models of physical phenomena and their simulation, which allows comparison of theoretical predictions with the obtained experimental results. In addition, many physical experiments require very expensive and complex equipment. The solution to this problem can be specialized software, multimedia presentations, or remote access to measuring equipment.

This work presents the possibilities offered by use of the **Cobra3** and **CoachLabII+** measuring consoles in the physics lab equipped with appropriate software and measuring sensors. Practical implementations of selected experiments as well as examples of presentation and processing of measurement results are described.

## 2. Why a computer?

In natural sciences, the learning process is inextricably linked to performing experiments, analyzing results, modeling phenomena, and using various methods to develop quantitative data. The learning process itself usually consists of such stages as: formulating hypotheses, conducting experiments, collecting, reviewing and analyzing measurement data, creating and testing models. The modern computers equipped with very efficient microprocessors and a large operational memories are used for data processing and control of measuring instruments in scientific laboratories. Thanks to their universality and multimediality, they can play a valuable role in supporting the teaching process at the university. A computer equipped with an appropriate measuring interface with sensors and dedicated software replaces a number of separate devices and fulfills the role of a universal measuring system. A computer-aided experiments allow:

- testing and observing physical phenomena often impossible using simple measuring instruments,
- acquiring the ability to perform measurements using the methods used in scientific laboratories,
- getting familiar with the methodology of statistical elaboration of the measurement uncertainties,

- presenting obtained results in the form of tables and graphs, and comparing them with the phenomenon model,
- modeling and predicting the nature of the physical phenomenon.

When assembling computer-controlled experiments, simple instruments available in the laboratory are often used that support the performance of measurements and perfectly complement the systems. It is equally important to prepare instructions for students describing the studied physical phenomenon, methodology of experiment performance, instruments and software used. Moreover, it is also necessary to provide information on the statistical methods for developing measurement uncertainties and the methods of presentation of the obtained measurements results. The direct contact of the students with the modern measuring systems enables more effective assimilation of knowledge and acquisition of important practical skills useful in outstanding professional work. In addition, some students are encouraged to pursue a future academic career in a given field of knowledge.

### 3. Examples of computer-aided physics experiments

The modern methods of data acquisition and computer control systems of a physics experiment require the use of specialized measurement interfaces, sensors and software with an appropriate graphical interface and digital tools enabling the processing of measurement data. Currently, on the market can be find a number of interfaces dedicated to both scientific laboratories and educational purposes at universities. However, devices for educational purposes should be inexpensive and have quality and functionality similar to those used in scientific laboratories. In the student physics laboratory at Stanisław Staszic State University of Applied Sciences in Piła, Poland the **Cobra3** measuring consoles from Phywe [5] and **CoachLabII+** from CMA [6] are used. Many experiments implemented in this lab on vibration and collision dynamics have already been described previously in [7–9].

#### 3.1. Electromotive force and internal resistance

**CoachLabII+** measuring console equipped with a direct current and voltage sensors has been connected to a computer with installed **Coach6** software enabling the analysis and processing of measurement data. Figure 1 shows a screenshot of the measurement window of the **Coach6** software with obtained results for a single 1.5 V AA battery. From Ohm's law for the closed circuit follows that the dependence of the voltage drop  $U$  across the external resistance is a linear function of the current  $I$  in the circuit  $U = -Ir + \mathcal{E}$ , where  $r$  is internal resistance and  $\mathcal{E}$  is electromotive force. The measurement

results were fitted by the linear function using the function matching module in Coach6 software (Fig. 1). Determined in this way were internal resistance  $r = 0.37 \Omega$  and electromotive force  $\mathcal{E} = 1.46 \text{ V}$ .

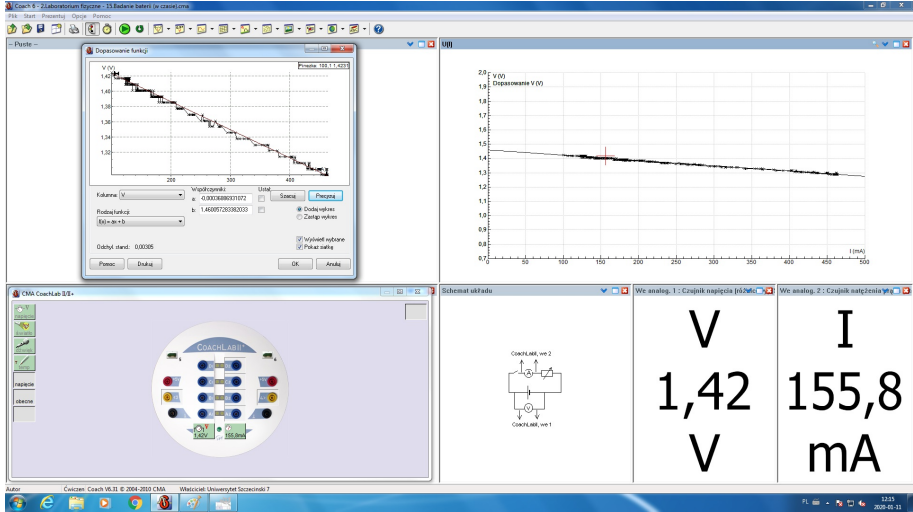


Fig. 1. The electromotive force and internal resistance of the 1.5 V AA battery.

### 3.2. Magnetic hysteresis loop

One of the characteristic features of ferromagnetic materials is the occurrence of the hysteresis loops during a continuous change of the direct current in the coil in which the ferromagnetic is located. The main purpose of the experiment is to consolidate concepts such as induction, magnetic flux, magnetic field strength, magnetic field in the coil, determination of the coercive field, and remanence. The experimental set-up consists of the computer equipped with the **Cobra3** console, tangent Hall probe, solid iron U-shaped core, commutator switch, power supply, rheostat ( $10 \Omega$ ), two 600 turns coils and Measure software. The obtained hysteresis loop exhibits the initial magnetization curve — OA, saturation remanence — OB and coercive field — OC (Fig. 2). The magnetic field strength  $H$  in the coil with  $n$  number of turns and average line length  $l$  in the coil is

$$H = n \frac{I}{l}, \quad (1)$$

where  $I$  is a current in the coil. In the described experiment, a current is determined from the voltage drop on the  $10 \Omega$  rheostat from Ohm's law,  $I = U/(10 \Omega)$  and the  $n/l$  number equals 2586 [5]. The remanence read directly from the graph in Fig. 2 is equal to *ca.* 128 mT but coercive field is about 370 A/m.

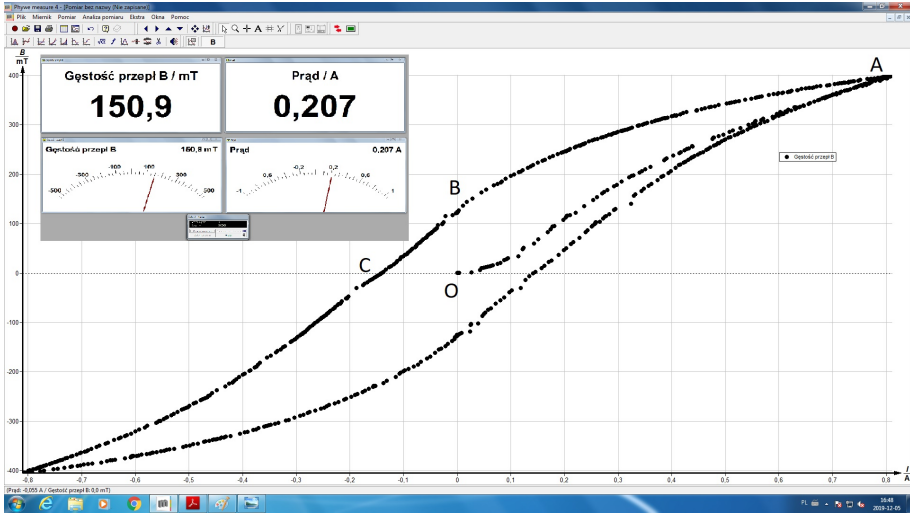


Fig. 2. The hysteresis loop obtained in the Cobra3 experiment.

### 3.3. Dulong–Petit law

The internal energy in solids is mainly associated with a crystal lattice vibrations resulting from the temperature changes. According to Debye's theory, which takes into account vibrations of the crystal lattice up to a certain limit frequency  $\nu_D$ , the heat capacity is expressed by the relationship  $C_V(T) = 3Nk_B D(T/T_D)$ , where  $k_B$  is Boltzmann constant,  $N$  is number of atoms in given volume,  $T_D$  is Debye temperature, and  $D(T/T_D)$  is Debye function [1]. For high  $T/T_D$ , the Dulong–Petit law is obtained

$$C_m = 3N_A k_B = 3R, \quad (2)$$

where  $N_A$  is Avogadro number,  $R$  a gas constant and  $C_m = 24.94 \text{ J}/(\text{mol} \cdot \text{K})$ . Figure 3 shows an example of the measurement result for a zinc metal block (Zn) immersed in water. The observed temperature jump visible in Fig. 3 exhibits the process of equalizing temperatures in time between water and Zn. The molar heat capacity for Zn calculated on the basis of the heat balance in the tested system is equal to  $C_m = 24.43 \text{ J}/(\text{mol} \cdot \text{K})$ . The obtained result with relative measurement uncertainty of about 3% is with good agreement with a table value for Zn ( $25.2 \text{ J}/(\text{mol} \cdot \text{K})$ ) and theoretical prediction of the Dulong–Petit law (relative uncertainty is less than 2%).

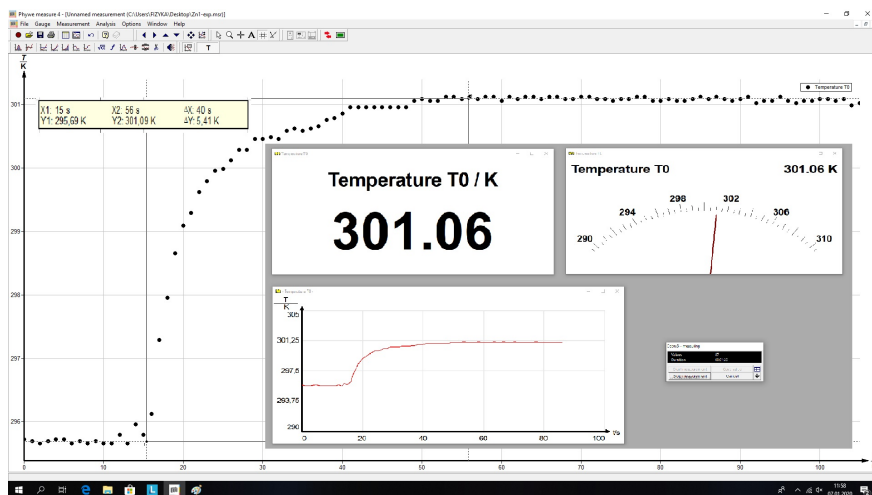


Fig. 3. The process of heat exchange between the water and zinc metal block.

#### 4. Conclusions

The presented description of selected computer-aided experiments shows the didactic possibilities of using this type of solutions in a student physics laboratory. From our many years of experience, it can be concluded that after acquiring the skill in performing computer-aided experiments, students are better at methods of data processing, presentation of measurement results, modeling, and in applying modern theories in the interpretation of physical phenomena. In addition, an increase of interest in measuring methods used in scientific and industrial laboratories is observed.

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