

INTELLIGENT SCHOOL EXPERIMENTAL SYSTEM (ISES) FOR COMPUTER BASED LABORATORIES IN PHYSICS

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Abstract

The laboratories, both real and virtual, start to play the decisive role in new strategies in both teaching and studying natural sciences, including physics. To make the building of real hands-on and real remote experiments easier and user friendly, we have devised the modular system for the measurement in physics, chemistry, biology etc.– Intelligent School Experimental System (ISES). It is an open system working under Windows operating system with all its advantages (OLE and multitasking). The system is composed of an interface card, a set of variable modules and sensing elements (about 40), and a service graphical and evaluation software. We describe the typical experiments and the way they are implemented: Free fall of bodies in vacuum, gasses and liquids, Electrochemical source of electric energy and Change of state of the real gas. The system ISES is used for the constantly built set of remote experiments across the Internet (see http://www.ises.info/default_a.htm). The basic conclusions cope with the general goals the physics laboratory should achieve.

1. Introduction

The physics laboratory plays the central position in the new strategy of education used in the scientific method of cognition of real world [1] or the alternative method of e-LTR (e-Learning, e-Teaching and e-Research) [2]. The main features of these methods are observations, search for proper information, its processing and storing, organization and planning of work, data and results presentation etc., where the experiment and experimentation plays a decisive role. The main goal of the emerging e-laboratory is to strengthen the experimental part of the physics education and to cover the university syllabus of basic physics course by experiments in the direction of Integrated e-Learning [3]. Traditional laboratory work courses do not comply with these trends; therefore it is necessary to redefine the learning targets and to reconsider the learning methods.

The paper presents the motivation, history and the state of the art of the Intelligent School Experimental System (ISES) for laboratory experiments in natural sciences, predominantly in physics. Also, its insemination, experience in physics teaching, and its exploitation in remote experiments across the Internet are given.

2. Reasoning for ISES devise

The main motivation for the device and building of the experimental system for schools was to bring about the change in the physics laboratories in the direction of substituting the “recipe labs” [4] by research laboratories, with the general goals in mind, the physics laboratory should achieve. American Association of Physics Teachers (1977) [5] formulated five goals, the physics laboratory should achieve, with the role of computers already mentioned:

1. **The Art of Experimentation:** The introductory laboratory should engage each student in significant experiences with experimental processes, including some experience designing investigation.

2. **Experimental and Analytical Skills:** The laboratory should help the student develop a broad array of basic skills and tools of experimental physics and data analysis.

Computers, when used as flexible tools in the hands of students for the collection, analysis, and graphical display of data, can accelerate the rate at which student can acquire data, abstract, and generalize from real experience with natural phenomena. The digital computer is an important tool for an inquiry-based course in physics because it has become the most universal tool of inquiry in scientific research. However, computer simulations should not be used as substitutes for direct experience with physics apparatus.

3. **Conceptual Learning:** The laboratory should help students master basic physics concepts. The use of **computers** with laboratory interfaces allows real-time recording and graphing of physical quantities. The qualitative use of real-time graphing in microcomputer-based laboratories (MBL) has increased interest in using the laboratory to enhance conceptual understanding. The combination of two factors — laboratory course design based on an understanding of the preconceptions students bring to the study of physics from their past experience, and the continuing development of MBL and other laboratory technology — has the potential to significantly improve the effectiveness of laboratory instruction.

4. **Understanding the Basis of Knowledge in Physics:** The laboratory should help students understand the role of direct observation in physics and to distinguish between inferences based on theory and the outcomes of experiments.

5. **Developing Collaborative Learning Skills:** The laboratory should help students develop collaborative learning skills that are vital to success in many lifelong endeavours.

Since 1977 till today, the Information communication technology (ICT) and computers have invaded physics laboratory [6]. Our own experience and the golden rule in the introducing the computers into student physics laboratory was the claim for the computer to

remove only the routine and time consuming activities, not encroaching the borders of the physics principles and laws of the examined phenomenon. We formulated the role of a computer in a physics laboratory:

- To collect the data in reasonable time domain range, and present it graphically in real time,
- To give the possibility of simple filtering and analysis of data,
- To export the data to graphical or other processors for further evaluation.

If we summarized all these requirements and added the demand for the applicability of the emerging computer oriented system in all levels of schools, the simplicity in use and low cost, it all navigated our reasoning to the building of the friendly in use robust modular system with easily interchangeable modules attached to the main panel unit, interfaced to the computer with inputs for modules and outputs for driving signals. The software then should have enabled to connect the experimental system to any type of Windows OS, enable to depict and simply process the acquired data with it straightforward export. On the basis of such and similar considerations emerged the first operating system ISES. Since then, the system have been constantly improved, upgraded and sophisticated, so we can shortly mention the present state of its development.

2. ISES 2007

In our laboratory, the friendly in use hardware and software for easy building of physics experiments ISES - has been constructed in the long period of development starting in 1984 and constantly improving its performance. ISES is an open system working under Windows operating system with all its advantages (OLE and multitasking). The system is composed of an interface card, a set of variable modules and sensing elements, and a service graphical and evaluation software (see the ISES kit with Fig.1).

2.1 ISES Hardware

The computer interface card, with the inputs and outputs and plug-in slots for modules, provides an easy way of interfacing to virtually any PC compatible computer. The card is the 12-bit analog-digital digital-analog, time of conversion- 0.010 ms, DMA, and universal control board and a set of sensors (About 40 for physics, chemistry and biology etc.). The system offers the possibility of simultaneous measuring and data displaying for 8 input channels and process control via two analogue and four binary output channels. The analogue output channels work as programmable voltage sources (DC, AC with 8 kinds of default

signals, manual controlling or user defined signals). Maximum sampling frequency (100 kHz) enables studying of sounds or other high frequency signals.



Fig. 1 ISES: The hardware with the main panel, interface card and incomplete set of modules

The ISES modules are easily interchangeable, the computer, provided with the automatic calibration, automatically senses their presence and adjusted range. The system is equipped with such modules as e.g.: voltage ($\pm 5\text{mV} \div 10\text{V}$, Fig. 2), current ($\pm 0.5\text{mA} \div 1\text{A}$), resistance, capacitance, temperature ($-20^\circ\text{C} \div +120^\circ\text{C}$, Fig. 3), microphone, deviation sensing unit, adjustable preamplifier, light stop, current booster, relay switch, pressure meter, and many others. For chemistry the electromagnet valve for liquids and digital biretta have been developed recently.



Fig. 2 Module for voltage measurement
the range $\pm 5\text{mV} \div 10\text{V}$



Fig. 3 Temperature sensing module
the range $-20^\circ\text{C} \div +120^\circ\text{C}$

The service program enables the measurement of simultaneously 10 different channels (8 analog inputs and 2 analog outputs) and to use 4 binary output channels. All these modules are fully programmable, using the programming panel.

2.2. ISES Software

The data in ISES system is depicted both in analog or digital form, on variable number of panels, with depicted quantities either those measured by modules or their combinations (addition, subtraction, product, quotient etc.). The software provides data processing (integration, differentiation, fitting, approximation etc.). The data export for another graphical processor is straightforward. (Fig. 4).

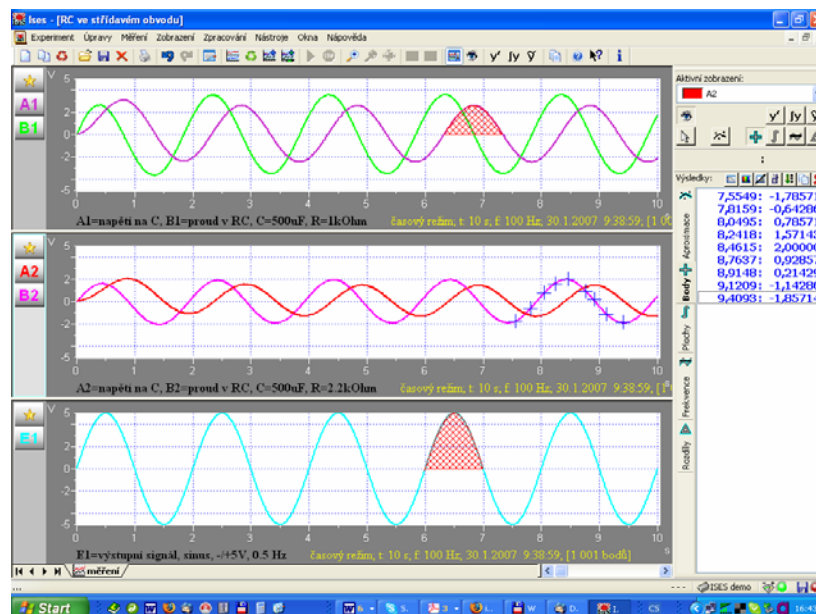


Fig. 4 ISES: data presenting (with the depicted integration - red area and selection of points of interest - blue points and the table)

2.3. Support for ISES

We have concentrated in the course of the ISES development on the support both for teachers using the system at schools and also for other users. The organization of schooling for teachers of ISES in computer laboratory is a regular event, as well as the transferring of news in development of the system ISES. For these ends, the detailed instruction book is available, the database of a great number of experiments, some of them with the measured typical data and instructions for measurements, covering different levels of schools, different syllabi have been devised and published [7]. These experiments are constantly collected and disseminated.

The support with written texts, software, news in hardware is to be found on www page (http://www.ises.info/default_a.htm).

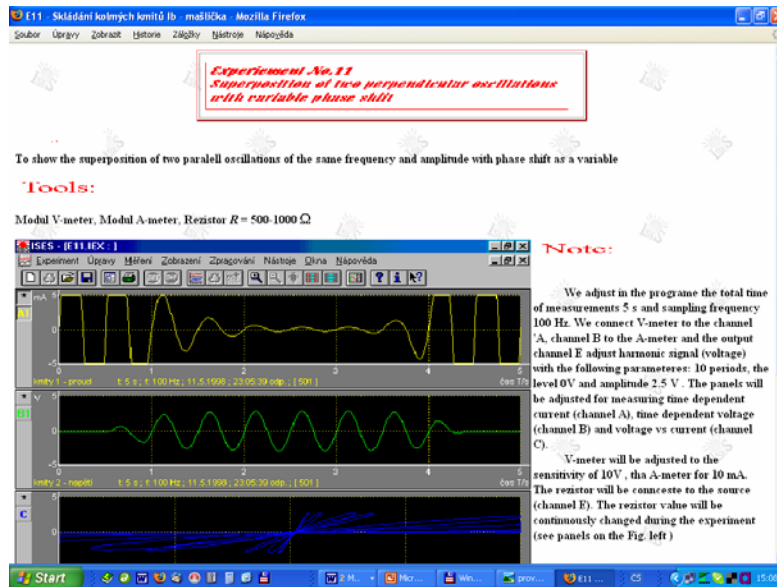


Fig. 5 Example of the database element of the experiment of Superposition of two perpendicular oscillations

for computer based laboratories both on secondary schools, but also in some universities. Fig. 6. shows the physics laboratory at the Faculty of Chemistry, Brno University of Technology for two term basic physics course with 24 experiments with 15 with ISES covering Mechanics, Oscillations and Waves, Thermodynamics, Optics, but also some typical experiments from Solid state physics.



Fig. 6 Undergraduate university physics laboratory equipped with ISES

3. ISES in physics, chemistry, engineering and science

Here we want to present only sample examples of the laboratory exercise from two participating university Faculty of Pedagogy in Trnava and Faculty of Chemistry in Brno.

Mechanics - Free fall of a body

The measurement of the free fall of a body in gasses and liquids is an important, but difficult for the recording experiment. The experimental setup with ISES is in Fig. 7a. The apparatus consists of the tube with the coils attached in regular distances. A permanent magnet falling in the tube induces electromotive voltage that is recorded and evaluated as instantaneous velocity. In Fig. 7b is recorded the free fall in a gas.

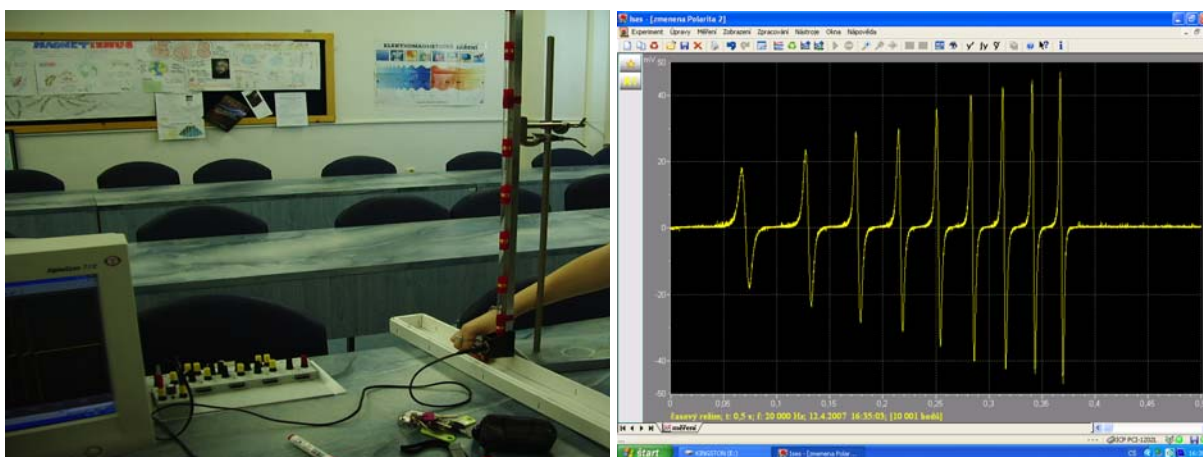


Fig.7a Apparatus for free fall in vacuum, gasses and liquids with ISES

Fig. 7b The signal of the free fall of a body is recorded with ISES reflecting the instantaneous velocity of a body in a tube

Electrochemistry - Electrochemical source of electric energy

Computer oriented experiments in chemistry are infrequent [8]. We devised the experiment, useful also in physics in explanation of the function of electrochemical source of electromotive force, using the Nernst equation. The standard electrochemical source consisting of two vessels filled with electrolytes and two metallic electrodes separated by the membrane bridge is in Fig. 8. Changing the concentration of the electrolyte by the computer controlled burette and measuring the electromotive force of the cell together with conductivity

and pH factor of the electrolyte enables to elucidate the function of electrochemical cell and prove /disapprove the corresponding Nernst equation.

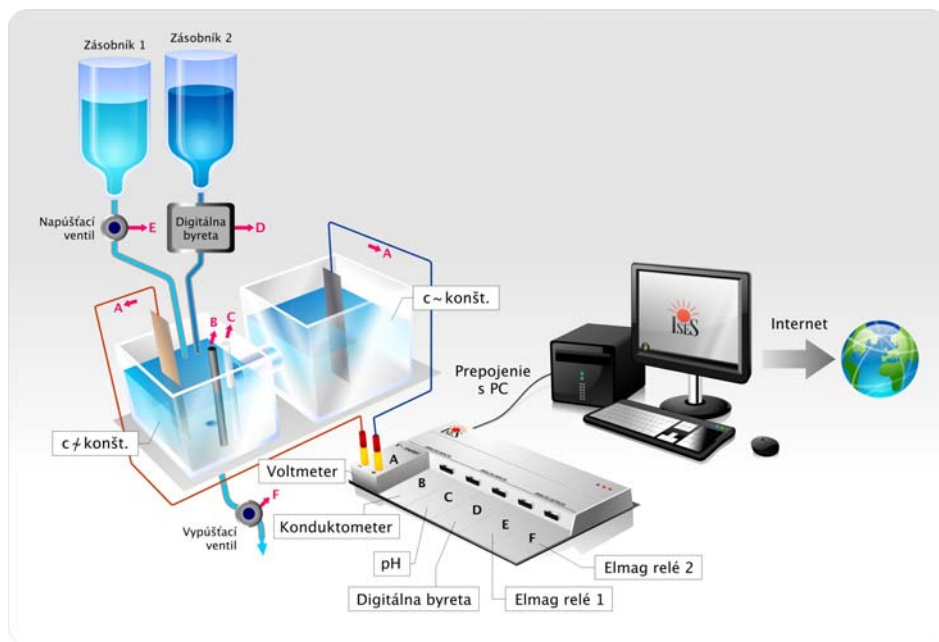


Fig. 8 The electrochemical cell characterization using ISES, the variables are the concentration of electrolytes, metals and measured quantities are resulting electromotive voltage, conductivity of the electrolyte and its pH factor (not depicted)

Thermodynamics - Change of state of the real gas

The adiabatic change occurs when no exchange of energy between examined gas and the surrounding exists. It is rather difficult condition to fulfil in a real experiment. One way is to carry out the change quickly enough so the energy exchange could be neglected. On the other hand the isothermal process is carried out moving the piston very slowly and the temperature remains nearly constant. Isochoric process may be then observed after the adiabatic compression, when the piston is kept in a stable position. An experimental apparatus for such school laboratory experiment was developed on the basis of ISES system. The equipment (Fig. 9) consists of a cylindrical vessel with piston. It enables to press the gas inside the cylinder in 0.1 s. The movement of the piston (volume change) is scanned by a slide potentiometer and module ohmmeter. The module barometer picks up the pressure and the temperature is measured by the thin thermocouple inside the cylinder and by the ISES module voltmeter. The response of state variables is recorded and displayed on the monitor of the supporting computer (Fig. 10). The upper trace is the pressure change; the middle one is the volume record and the bottom one shows the temperature development. The scales and

sampling frequency are adjusted so that some tens of points in region of adiabatic change can be plotted. The measured data can be easily exported into Excel for further processing.



Fig. 9 Experimental setup with ISES for the measurement of the change of the state of the real gas

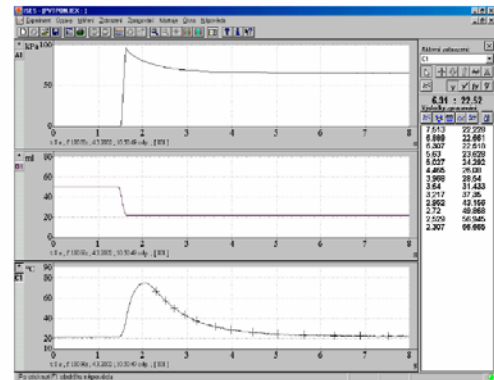


Fig.10 ISES: State quantities of the real gas during the change of the state: upper trace-gas pressure, the middle trace – volume and the bottom – temperature

4. Outlook and future developments

The system ISES is constantly improved, the present step is the development the ISES interfaced to the USB input (e.g. for notebooks) and the ISES experiments sharing by directly remotely control from a distant computer. At present, both the web page [7] and corresponding written helping written texts are translated into English and German.

The development of the remote experiments in our laboratories was logically bound to the development and refinement of the ISES experimental system. The start of the program of the remote experiments based on ISES dates from 2000 with the simple experiment controlling the liquid level in a vessel and till now has developed to the present state, we report elsewhere. Till present above 7000 connections have been recorded. [9]. The present state of the ICT in the region of measurements, data collection and transfer using web services is rather complicated and not clearly arranged for the physics teacher to think about building the remote real physics experiment. Missing standards lead to many individual solutions, and therefore to unnecessary hurdles for hosts and users [10]. With our contribution towards the remote experiments with ISES we intended to bring the unifying solution and help for those being interested in construction of remote experiments using our software ISES web control CD [9].

5. Conclusions

In the search for new strategy of education and for the strengthening of the role of experiment and experimentation in physics education and teaching the system ISES for hands-on computer based laboratory and remote experiments has been built. The experiences gained from computer based laboratories and experiments based on the system ISES enable to formulate the conclusions:

- ISES supports the art of experimentation by its utmost simplicity without any programming and its prime feature to remove only the routine work in experimentation not to conceal the real world phenomena or underneath physics laws,
- ISES cultivates experimental and analytical skills by the possibility to collect the data in a well arranged way, to depict them, make possible their simple evaluation and transfer to other evaluation processors or programs,
- Conceptual learning by the possibility to record the experiment data in different ways and thus gives the possibility to change the parameters of the phenomenon and so to elucidate quickly the phenomenon in question, and consequently to understanding the basis of knowledge in physics:
- Developing collaborative learning skills; this is especially remarkable in computer based laboratories and remote laboratories with students interconnected by the net. They are encouraged to draw the resources and discuss the achieved results with the colleagues and teachers.

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