INTERNET FACILITIES FOR VIRTUAL AND HANDS-ON EDUCATIONAL EXPERIMENTS

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ABSTRACT
Real time computer simulators of the standard educational Physics laboratory works were designed in VRML and Java for distant learning and self-studies of University students. Experimental schemes and software were developed of educational hands-on computer-based experiments to be performed by High School and University students out of their physical laboratory.

INTRODUCTION

Development of informational technologies opens up the new possibilities in the sphere of education and fosters design of the novel prospective teaching facilities and methods of learning. Personal computers and computer nets become powerful educational tools making it possible for the student to acquire knowledge and working skills at home any time. It is relatively easy to provide a student with lecture materials and problems for self-instruction via the Internet. Unfortunately, distant students have poor chances to perform laboratory experiments supervised by a qualified instructor. In computer-based learning this problem is traditionally solved through creation of a virtual physics laboratory (Kalinin *et. al*., 2001; Neipp *et. al.,* 2002). There, computer simulators are used instead of real labware.

Pitfalls of substituting the physical reality for its simplified virtual model should be taken into account, though. In our understanding, computer laboratory works in Physics must be regarded as a new and independent type of studies, never meant to discard full-scale course of educational laboratory experiment.

In a previous paper (Kazachkov *et. al*., 2002) we have suggested experimental schemes and software for hands-on computer-supported educational experiments in distant learning to be carried out by the students at home with the simplest materials and equipment engaged.

Also for distant students, a series of qualitative inquiry-oriented experiments and instructive observations (Trowbridge, 2001) were prepared for Internet placement at educational site http://www.khpg.org/vsesvit. Pictures and animated explanations, detailed didactical directions provide for the strong educational impact and creative students' involvement.

DESIGN OF THE VIRTUAL EDUCATIONAL PHYSICAL LABORATORY

Let us itemize the educationally strong features of virtual laboratory work. First, when properly designed, it is perceived by the students as a fascinating computer game appealing to be participated and "won" (solved). Second, such a "game" uses physical values, notions and models to unriddle

natural phenomena and promotes active learning of their essence. Third, virtual laboratory set-up can be used as a good simulator for repeated training of the sequence of experimental operations needed to perform the measurements. Training on a simulator requires no personal tutorship, thus becoming an essential stage of the student's independent work. Fourth, many the devices and processes out of the possibilities of the educational laboratory may be observed, controlled and measured in virtual reality.

Virtual physical laboratory woks are in complete accord with the main idea of distance learning: teaching students without the necessity of their personal class attendance. This goal is achieved by means of the Internet and corresponding languages and technologies like Java and VRML.

Educational laboratory simulators on Mechanics and Molecular Physics are the most advantageous for presentation in three-dimensional virtual space using VRML and Java languages. In the computer labs designed by our group, students investigate translational and rotational motion, oscillations and interactions of moving bodies (examples presented in Figures 1, 2).
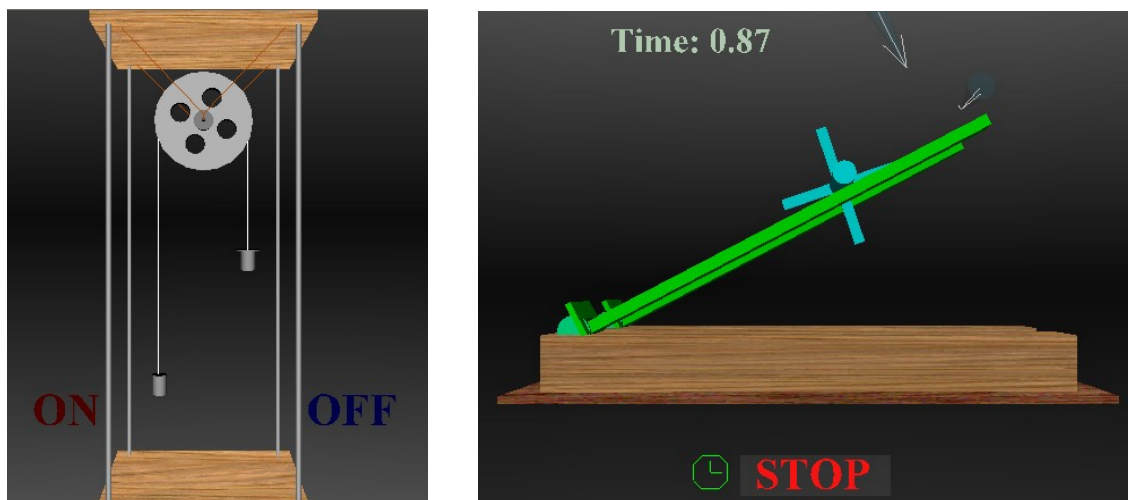

Figure 1. Virtual Atwood machine (left); symmetrical body rolling down an incline, computer simulation (right)
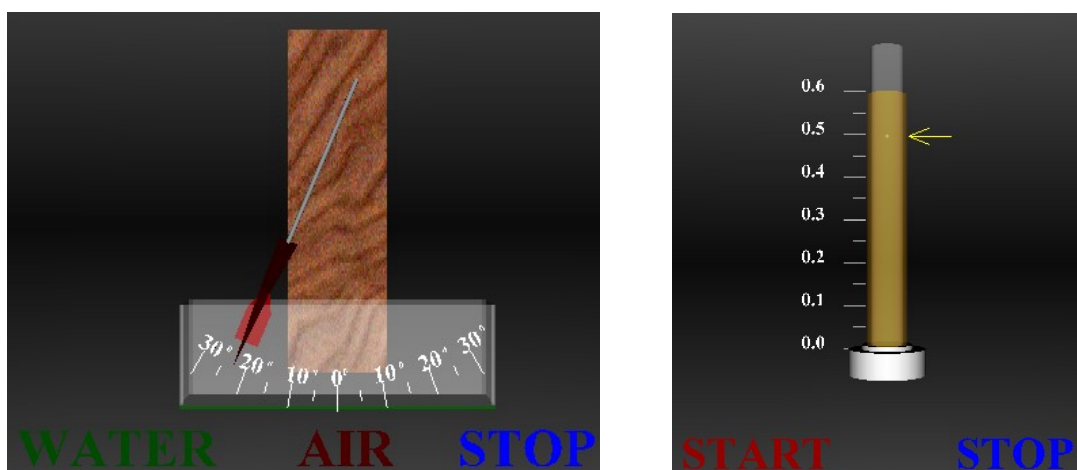

Figure 2. Investigation of damped oscillations in virtual experiment (left); measuring of fluid viscosity by Stokes method, computer simulation (right)

Construction of the mathematical model of the designed setup
At this stage it is necessary to define the basic factors affecting the behavior of the system and key parameters of an experiment. Omitting important factors oversimplifies the model and reduces its educational impact. Overloading the system with objects and interactions dramatically complicates computer calculations.

In a virtual laboratory, teachers have an opportunity to alter several parameters of an experiment. Determining the set of these parameters is also an important problem to be solved at the designing stage. We tried to avoid simple models (such as "harmonic oscillations of a pendulum") simulating non-linear response of the virtual objects to external action. Used calculative methods (Euler's integration) allowed deliberately introducing "experimental" errors. Random-number generators were also helpful in this connection.

Aspects of user's interaction with the virtual laboratory world
It is vital to determine which false steps and deviations from the optimum work plan should be prohibited without decreasing an educational value of the lab work and its interactive nature.

Even with no special need in reproducing of all the details of the prototype laboratory set-ups in the created virtual world, we generally simulated their realistic appearance.

We allowed for the maximum freedom of students' actions. The user can just pull the string or slightly deflect the virtual pendulum without starting the experiment as a whole. The simulated worlds are designed to adequately respond to such the actions.

The values of all the physical parameters used in the labs are displayed on the computer monitor with the prescribed accuracy by means of Java-applets. They can be divided into three categories:
- adjustable parameters (acceleration of gravity, frictional force, etc.);
- results of direct virtual measurements (travel time, distances, etc.);
- results of indirect measurements (acceleration, moment of inertia, net force, etc.).

In our experience, direct measurements should be carried out in conditions as close to real ones as possible. Thus, in virtual measurement of distances, "Start" and "Finish" marks are set with a certain deliberate inaccuracy. Stopwatch are switched on and off by the students manually. That causes errors in time measurement. Such a simulation of random and systematic experimental errors brings the virtual lab close to a real time hands-on practice. Learning how to estimate errors of measurements is an essential part of our training program.

Students taking the course of distant learning send final results of the work performed via the Internet for evaluation by their instructor. To get their grades, the students also submit an account in the form of programmed tests of knowledge control. On-line sessions are making distant learning and evaluation close to the real laboratory classes.

HANDS-ON COMPUTER-SUPPORTED EXPERIMENTS FOR DISTANT LEARNING

Recently, we have developed quantitative experimental problems for distant learning Physics, first suggested earlier (Kazachkov *et. al.*, 2002). Research schemes already tested in educational practice propose the students to determine a coefficient of sliding friction μ in a series of simple experiments and computer-based calculations. In the home-performed lab work small object like a coin or a nut is set sliding down (van den Berg and Burbank, 2002) or across (Kazachkov *et. al.*, 2002) a fixed incline: table's lid, a sheet of plywood or plastic (Figure 3).

Figure 3. Throwing coins across and down an incline

As it is seen in the photo (Figure 4), coins thrown at random across an inclined plane, have stopped along the straight line – as predicted by the theory (Kazachkov *et. al.*, 2002). Right picture of Figure 4 presents resting positions of bodies thrown horizontally, a final stage of computer simulation based on the exact solution of equations of motion on an incline with friction. To calculate μ, the following cubic equation should be solved:

$$8k\mu^3 – 4\mu^2\, tg\alpha\ - 8k\,\mu\, tg^2\alpha + tg^3\alpha = 0.$$

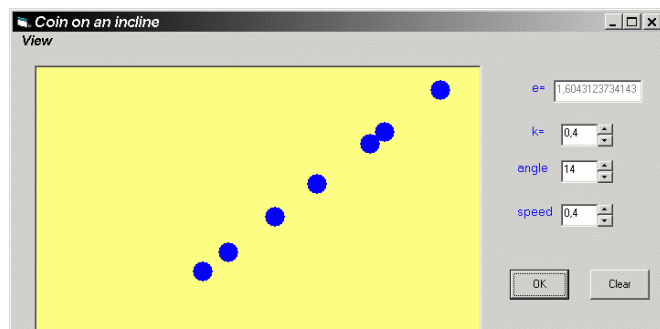There $k = y_{stop} / x_{stop}$, and α is the plane's angle of inclination.

Figure 4. Coins at rest after sliding along an incline, hands-on experiment (left) and computer simulation (right)

Students are instructed to throw about a dozen of coins the described fashion, to mark the stop-points, to determine their positions on an incline and to graph them by means of personal computer. A series of throwing should be performed to diminish experimental errors. The value of k is obtained from the

slope of graphed $y_{stop} = f(x_{stop})$ dependence by the least mean squares fitting. With α measured preliminary students have enough experimental data to determine a coefficient of sliding friction.

After a series of measurements and calculations, an angle of a plane's inclination could be changed and new experiments performed. All the measurements are done by ordinary ruler and protractor, while computer-based procession of results involves computer fitting of experimental curves by the theoretical dependencies.

CONCLUSIONS AND FUTURE AIMS

Our activities on creation of a virtual physical laboratory for class studies and distant education and building of an Internet site of educational hands-on experiments has evidenced that computer-based approach towards learning may strongly enforce an educational experiment – the core part of any course Physics (High School, University). Significantly, students' motivation of learning Physics has noticeable increased. Moreover, students of Kharkov National University of Radioelectronics, Kharkov National University, and of #27 Physical-Mathematical Lyceum (Kharkov) have creatively contributed into the development of both physical and software parts of the project.

That encourages further development of facilities for real-time and virtual educational experiments in Physics. In particular, calculative experimental problems on gas laws and hydrodynamics (Stone and Siegel, 1967; Dieffenbach, 2003; Carpenter, 2003), equally amusing and instructive, should be developed into a class and distant computer-based laboratory work (preliminary studies under way at the Kharkov National University and #27 Physical-Mathematical Lyceum).

Some physics toys and tricks: spinning tops (Soodak, 2002), amazing balances (White, 1970; Kimler), always attractive for students, are planned to be computer-simulated for inquiry-oriented University and High School studies.

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