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Motion study in interactive remote experiments with data collection and transfer across internet

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Summary. — Within the strategy of Integrated e-Learning (INTe-L) we set up several remote interactive mechanics experiments across the Internet studying the linear and curvilinear motion For the purpose, we use the measuring hardware and software -Intelligent School Experimental System (ISES) with sensing units for data collection, recording and evaluation and the software ISES WEB CONTROL kit for establishing the server-client connection. As the first experiment we devised and constructed a new and sophisticated experiment free fall, based on the motion of the permanent magnet in a glass tube with induction pick up coils for position measurement (`http://remotelab4.truni.sk`) To transform the hands-on experiment into a remote one, we have had to move the magnets to their starting position by the magnetic vessel, surrounding the tube. Second experiment, the mathematical pendulum remote experiment (`http://remotelab5.truni.sk`) was created with a unique reconstruction of its instantaneous angle of deflection using two force-sensing elements and an on-line exploited algorithm (ISES supported) for the angle of deflection on line display.

PACS 01.50.-i – Educational aids.
PACS 01.50.F- – Audio and visual aids.

1. – Introduction

The information communication technologies development has made it possible to introduce remote experimentation as an indispensable and missing part of e-Learning. We proposed and realized the new technology of education - Integrated e-Learning (INTe-L) (Schauer 2008a,b, 2009). INTe-L is a new strategy of physics education based on the method sciences use for the cognition of the real world, starting from experiments. In this respect remote experiments will play a decisive role as described by Cooper (2005). The teaching of mechanics is usually a starting point of any basic university physics course, where the support of experiments is decisive and remote experiments are generally missing. The reason is the difficulty in the technical implementation of any mechanical experiments and in the necessity to build the PC controlled actuators that are far beyond the abilities of most university educators. Here, potentially, remote experimentation may help, and we hope for a future network of remote experimentation, created and shared by interested universities (Kolenčík , 2009, Ožvoldová, 2009).

In this article we take one step in the right direction and exploit the possibilities of remote experiments in mechanics. We chose two experiments: First, free fall in a tube, an experiment in the dynamic range of the fractions of seconds with the need of mechanical actuators for teaching of Newtonian mechanics and conservative and dissipative forces. Second, reconstructing the instantaneous deflection angle of a pendulum for teaching kinematics, dynamics and energetics of the oscillatory motion (Schauer 2009) both of these available in the fisrt Slovak e-laboratory on `http://kf.truni.sk/remotelab`.

2. – Remote Experiments Free fall of a body and Mathematical Pendulum

The basis of all our solutions for hands-on experiments is the system Internet School Experimental system (ISES) described elsewhere in detail (Schauer 2008a). It consists of sw and hw solution for the wide range of experiments in physics, chemistry and biology. It offers about 40 modules of sensors and outputs of typical analogues signals, program for data recording, storing and processing. The recent component part of the ISES system is the WEB CONTROL kit for easy building of the remote experiment, a detailed description of which can be found elsewhere (Schauer 2009). It enables the easy construction of remote experiments on the basis of ISES hw by inserting the pre-prepared building blocks into the html programme, formed by the compiled Java applets for typical controls and graphs and setting their parameters.

2˙1. *Experiment Free fall*. – A free fall experiment in a tube is a popular experiment. Based on the motion of a permanent magnet in a tube inducing electromotive force in the coils distributed along the tube and giving corresponding signals, it is one of the most frequently used experiment on free fall (Kingman 2002). It is used in many modifications from a simple recording of the signal to the most sophisticated applications such as the fall in conductive media We have built and present the PC assisted experiment based on the system ISES (ISES tube with coils, signal V-meter module ISES) and software (sw) support (signal recording and data smoothing, processing - recording of chosen typical data, fitting, etc).

In fig. 1 is the view of the hands on experiment used in the laboratory exercises with the data processing and evaluation: a - arrangement of the experiment, b - start of a free fall, c - a typical recorded signal in air. The experiment was performed successfully in both mechanics (Ožvoldová 2009) and as a Faraday law experiment in an electromagnetic theory course (Schauer 2008b).

When we started the transformation of the hands-on experiment to the remote one, the detailed evaluation of the data of the experiment systematically produced differences between the results of other experiments on the free fall and the free fall in a tube, caused by the presence of dissipative forces. We decided to introduce these dissipative forces during the experiment artificially, and then control and measure them. The tube enables us to both eliminate and enhance the friction forces in controlled manner, changing the density of the gas in the tube. This is accomplished by both the rotary pump and controlled gas pressurizing of the tube. In the future the liquids introduced to the tube may serve for experimentation in viscous media.

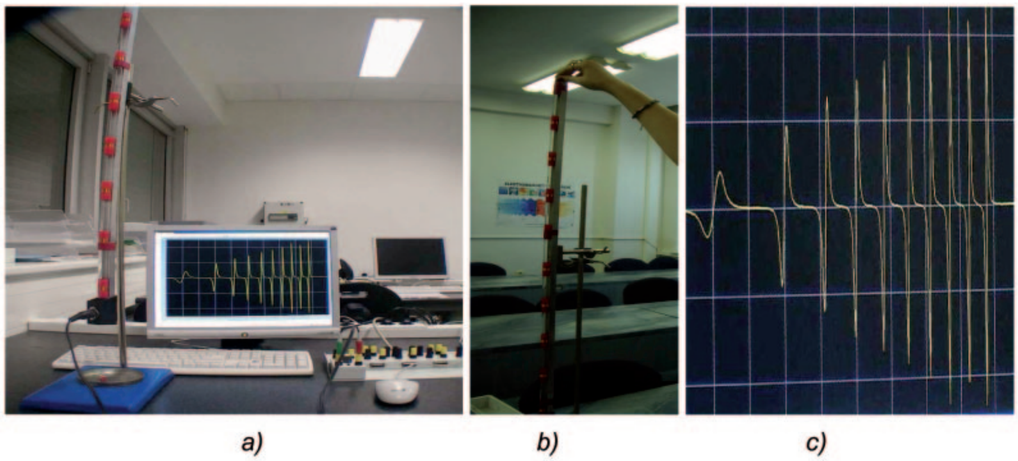

Fig. 1. – Arrangement of the experiment free fall (a), manual start of the magnet (b), a typical signal of the free fall in the air recorded by the ISES system (c).

Once the computer based experiment using the ISES system is built the second step in establishing the remote experiment is needed, *i.e.* the establishing of the classical server-client connection with data transfer from the server to the client and in the reverse direction for the control of the experiment by the client (experimenter). For this purpose, we built the sw kit ISES WEB Control (Schauer 2008b) for the easy transformation of the computeroriented experiment (fig. 2).

To transform the hands-on experiment to the remote one, the most demanding task was to repeatedly lift magnets to their starting position. For this purpose we devised

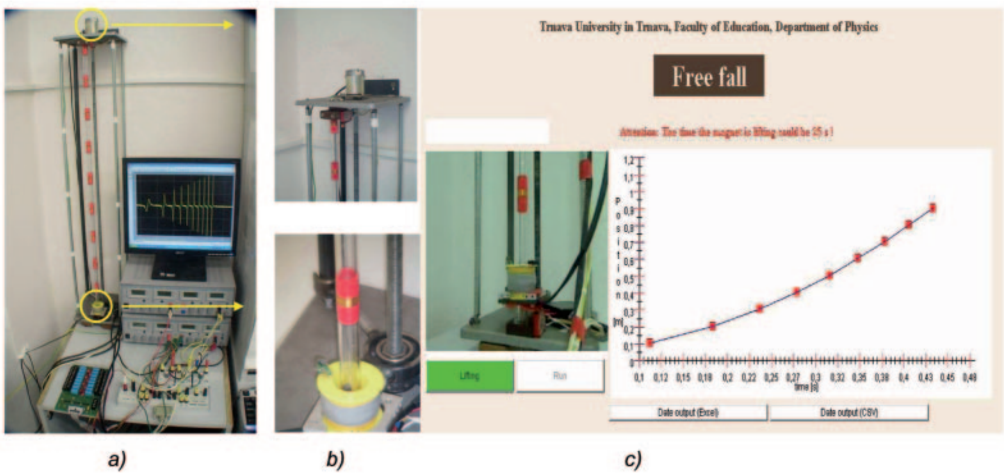

Fig. 2. – The remote experiment free fall. The total arrangement (a), two details: The magnetic vessel lifted by the screw (down), the step motor driving the screw (b), www page of the remote experiment with life camera view, time dependence of the displacement recorded by the experiment, see `http://remotelab4.truni.sk` (c).

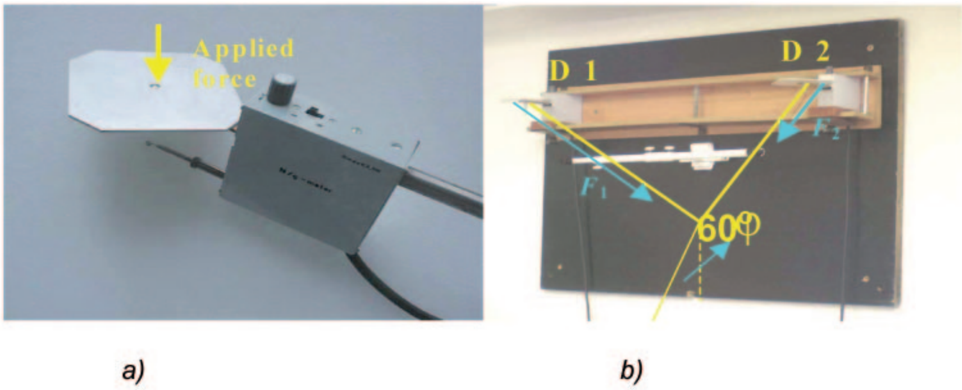

Fig. 3. – ISES dynamometer module (a), board with two dynamometers (D1 and D2) for reconstruction of instantaneous deflection $\varphi(t)$ of the pendulum.

and used the electromagnetic vessel, depicted in fig. 2b, lifted by the screw driven by the step motor. To plan and programme the experiment, a detailed time and logic scheme of experiment is needed, serving for the proper functioning of the experiment. For this purpose a standard flow chart serves nicely, resulting in the corresponding programme and the final form of the experiment available on `http://remotelab4.truni.sk`. www page of the remote experiment with life camera view and time dependence of the displacement recorded by the experiment is in fig. 2c.

2˙2. *Experiment Mathematical Pendulum.* – A mathematical pendulum is a popular and simple demonstration in a class, easy to realize and straightforward for observation. The problems in deeper understanding start when the educator tries to put forward the mathematical formulation of its movement, not speaking about the concepts of its dynamics or energy. Then, the knowledge the students may acquire is limited, in the best case, to its period of oscillations. Especially difficult to explain by chalk only is the concept of small and large deflection cases. On the other hand, it is clear that the pendulum, even a mathematical one, may be a vast source of information, covering the kinematics, dynamics of curved motion and its acceleration, energy - both kinetic and potential - and the role of dissipative forces. The obvious obstacle for this fruitful approach, especially using the strategy of INTe-L, is the missing remote experiment on the pendulum with the data transfer.

We devised the computer-based experiment of a pendulum with reading of its instantaneous angle of deflection, therefore bringing on line information $\varphi = \varphi(t)$. For this purpose we used a couple of ISES dynamometer modules that give information on the forces applied to the platform (see fig. 3a). In fig. 3b is the board with two dynamometer modules that give two time dependent pull forces in the suspenders as the pendulum oscillates. The experiment is depicted in fig. 4.

The measured forces and their time representation give information on the instantaneous deflection angle. The resultant deflection angle φ is to be found in (Schauer 2009b).

Once the computer-based experiment using the ISES system is built, the second step si to transform the hands-on experiment to a remote one. The most demanding task was to give the pendulum the initial preselected deflection. This was accomplished by the module giving the pendulum the initial deflection of the preselected value with step

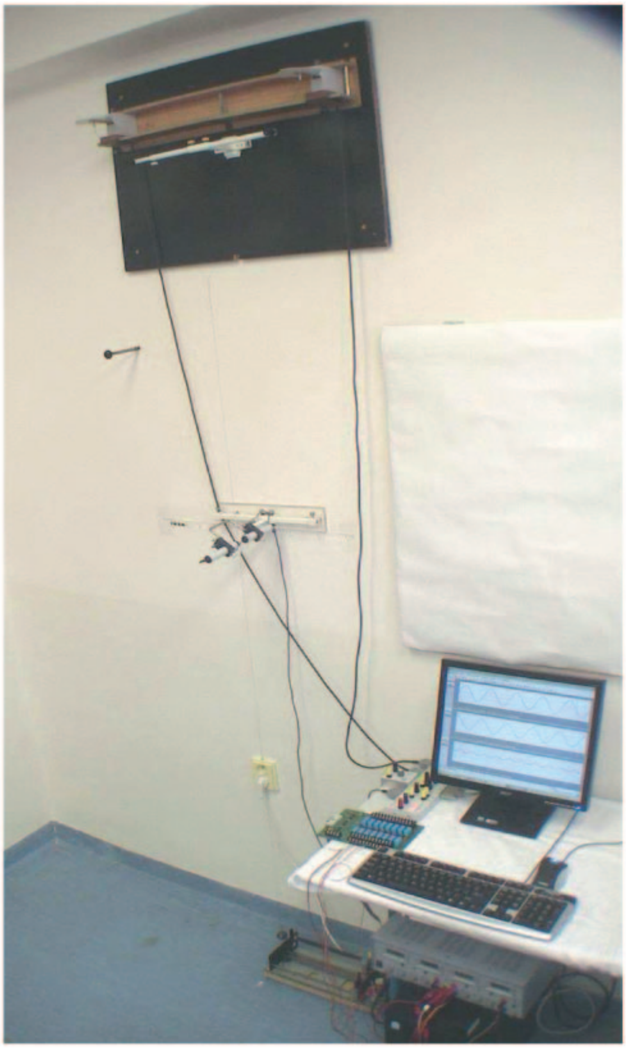

Fig. 4. – Arrangement of the experiment Mathematical pendulum.

motor controlled motion (1), position sensing resistor (2) and electromagnet fixed to the moving trolley (3) in fig. 5.

To plan and program the experiment, a detailed time and logic scheme of experiment is needed, serving the proper functioning of the experiment. For this purpose a standard flow chart of the experiment was needed.

2˙3. *Kinematics, Dynamics and Energy of Motion.* – On the basis of the measured date one can study kinematic, dynamic, as well as energy aspect of the motion. The theory of the free fall in dissipative media is starting from the differential equation with the general solution for the motion in low pressure gasses (neglecting the buoyancy force)

$$m\frac{\mathbf{d}^2y}{\mathbf{d}t^2} = mg - \mathbf{k}_1\nu \quad \Rightarrow \quad \nu(t) = \frac{mg}{\mathbf{k}_1}\left(1 - \mathbf{e}^{-\frac{k_1 t}{m}}\right). \tag{1}$$

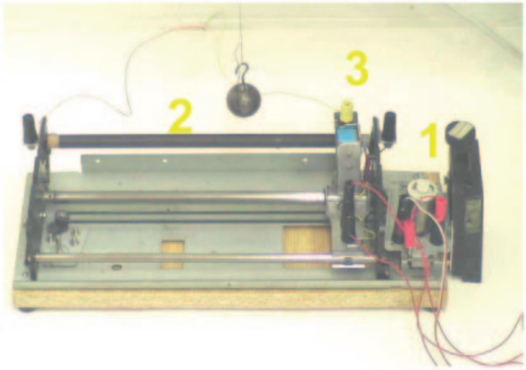

Fig. 5. – The unit for remote experiment giving the pendulum the initial deflection of the preselected value with step motor controlled motion (1), position sensing resistor (2) and electromagnet (3).

The pendulum representation of its kinematics, dynamics and energy is in fig. 6. These quantities may be expressed in terms of its instantaneous deflection $\varphi = \varphi_o \sin(\Omega t)$, *e.g.* tangential and normal acceleration (Ožvoldová M 2009).

$$a_t = l\varepsilon = l\left(\frac{\mathrm{d}^2}{\mathrm{d}t^2}\right) = -l(\varphi_o\Omega^2 \sin\Omega t), \tag{2}$$

$$a_n = l\omega^2 = l\left(\frac{\mathrm{d}\varphi}{\mathrm{d}t}\right)^2 = l(\varphi_o\Omega\cos\Omega t), \tag{3}$$

or the force of the pull T

$$T = mg\cos\left(\varphi_o \sin\Omega t\right) + ml\left(\varphi_o\Omega\cos\Omega t\right)^2. \tag{4}$$

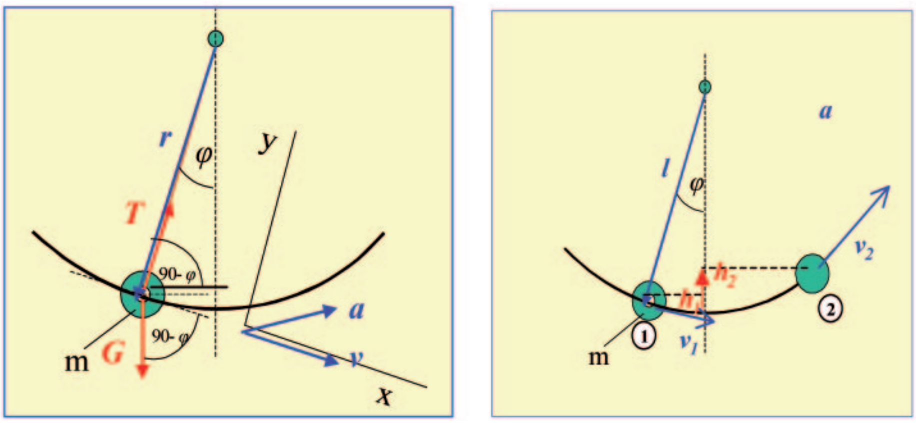

Fig. 6. – representation of pendulum - kinematics and dynamics (left) and energy (right).

2·4. *Conclusions with implications for INTe-L.* – The main conclusions of the remote mechanics experiments may be formulated as follows:

- The remote experiments from mechanics with mechanical actuators were devised and successfully brought into operation and used in the education process via INTe-L strategy rate across the Internet with 100 kHz sampling rate was successfully mastered,

- The pendulum with adjustable initial deflections, both in the small and large signal case, was constructed giving the date of the instantaneous deflection of the pendulum for further processing in kinematics, dynamics and energetics of oscillatory motion.

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