REAL INTERACTIVE PENDULUM EXPERIMENT WITH DATA COLLECTION AND TRANSFER ACROSS INTERNET

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Abstract
Within a set of remote interactive mechanics experiments across the Internet, we devised and built several mechanics experiments, controlled by web services (such as a web browser), using measuring hardware and software -Intelligent School Experimental System (ISES) with sensing units for data collection, recording and evaluation. We used the software ISES WEB CONTROL kit for establishing the server-client connection. 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 display. The exploitation of the pendulum in kinematics, dynamics and work – energy relations is shown, based on the INTe-L strategy.

1. Introduction
The development of information communication technologies has made it possible to introduce remote experimentation as the indispensable and missing part of e-Learning leading to Integrated e-Learning (INTe-L) (Schauer, 2009), a new strategy of education in physics 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 for different reasons described in a concise way in a recent paper (Cooper, 2005, 2009).
The teaching of mechanics is usually a starting point of any basic university science course, where the support of experiments is important and where remote experiments are generally missing. The reason for this 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 strive for a future network of remote experiments, created and shared by interested universities (Ožvoldová, 2009).

2. Experiment "Pendulum "

2.1 Hands on experiment 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 Figure 1a). The parameters of the device are the following:

2 Parameter	Value
Maximal load	± 9.81 N (1 kg)
Differential load	± 0.98 N
Sensitivity	± 0.01 N (1g)
Range	Two 1x and 5x

(more about Internet School Experimental System (ISES) see (Schauer, 2009).

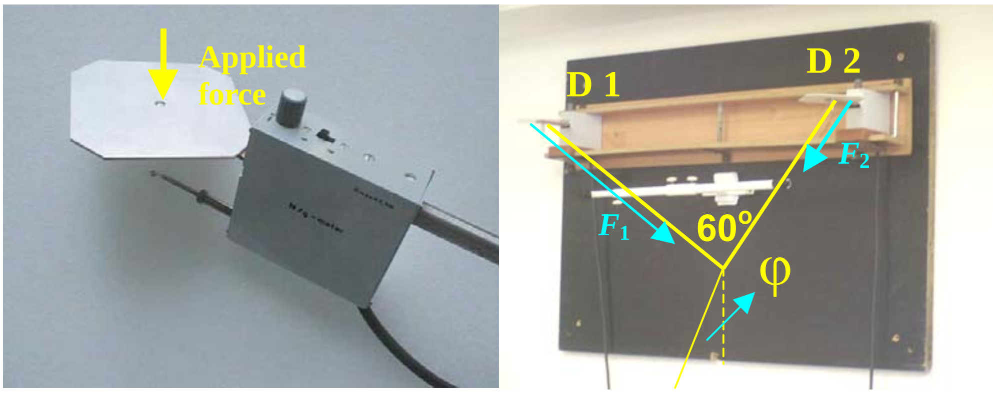

Figure 1: ISES dynamometer module (left), board with two dynamometers (D1 and D2) for reconstruction of instantaneous deflection φ(t) of te pendulum

We built the PC based experiment with the system ISES, enabling both hw and sw solutions (signal recording and data smoothing, processing - recording of chosen typical data, fitting, etc). In Figure 1b is the board with two dynamometer modules that give two time dependent pull forces in the suspenders as the pendulum oscillates. The forces and their time representation give information on the instantaneous deflection angle. After some geometry, the resultant deflection angle φ is (Schauer 2009b)

$$\varphi = \left[\frac{\alpha}{2} - \arcsin\left(\frac{F_2 \sin(\pi - \alpha)}{F_1 + F_2} \right) \right], \quad (1)$$

This operation is executed by ISES on line. The record of the typical forces F1, F2 and the resulting deflection φ is in Figure 2a.

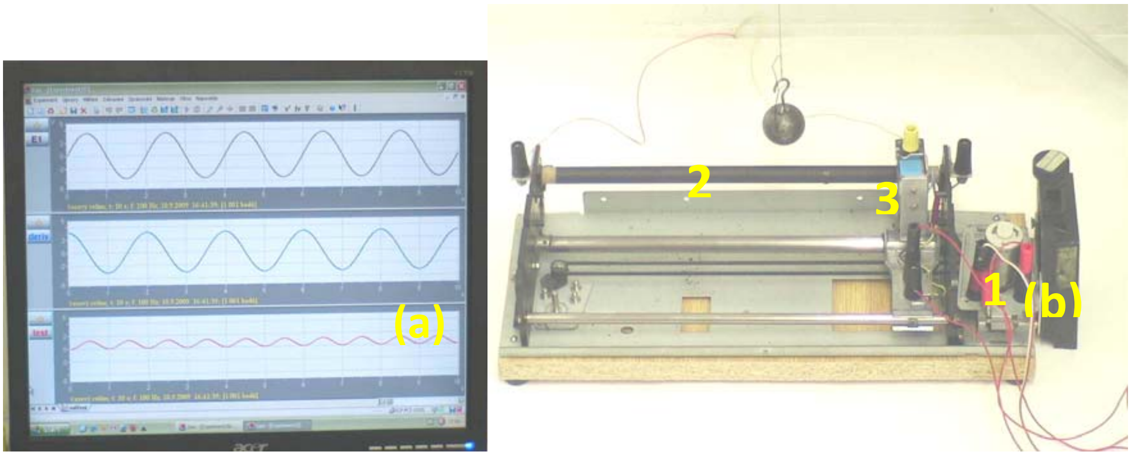

Figure 2: The signals corresponding to the forces F_1, F_2 and deflection φ (a), the unit for remote experiment giving the pendulum the initial deflection of the preselected value with step motor controlled motion (1), position sensing rezistor (2) and electromagnet (3) (b)

2.2. Technical means of remote experiments

The basis of our solution for the hands-on experiment is the system Internet School Experimental system (ISES) described elsewhere in detail (Schauer, 2008a, 2008b), consisting of sw and hw solutions for a wide range of experiments in physics, chemistry and biology. It consists of inputs

from about 40 modules of sensors and outputs of typical analogue signals, program sw for data recording, storing and processing.
The recent component part of the ISES system is the WEB CONTROL kit for easy building of any remote experiment, a detailed description of which can be found elsewhere (Schauer, 2009a). It enables the easy construction of remote experiments on the basis of ISES hw by inserting the pre-prepared building blocks into the html program, formed by the compiled Java applets for typical controls and graphs, and setting their parameters.

2.3 Remote experiment Pendulum

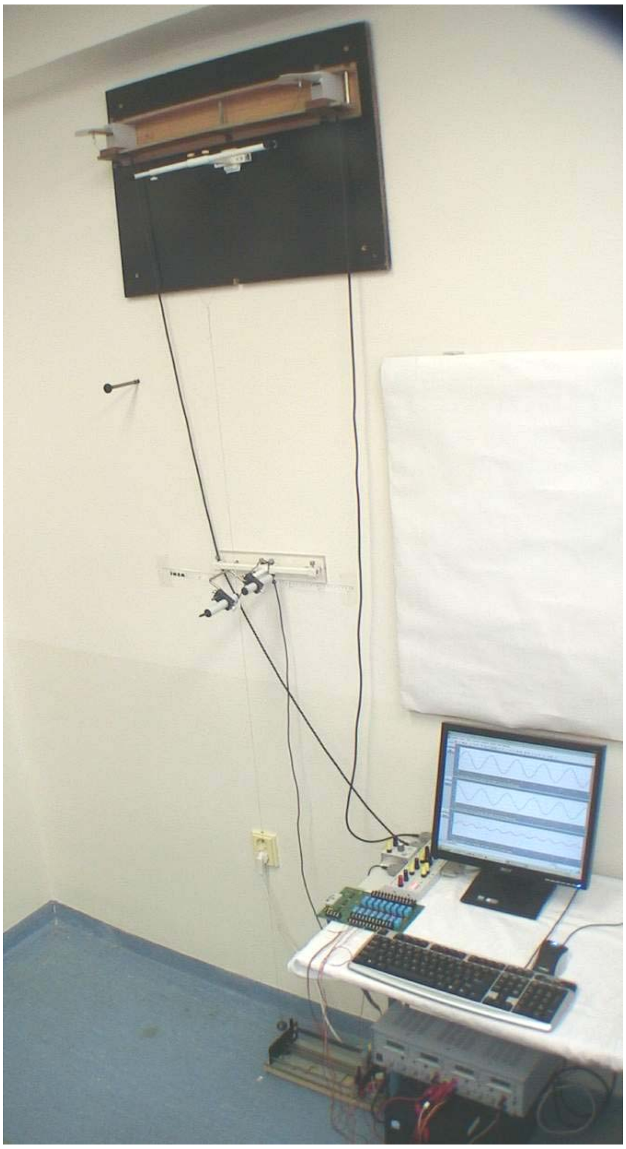

Figure 3: Arrangement of the experiment Pendulum

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 the 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 software kit ISES WEB Control (Schauer, 2008c) for the easy transformation of the computer oriented experiment based on the ISES system to RE (with server-client approach), using only the web services, web pages and Java support on the client side based on the copy-paste principle of the prefabricated applets as building blocks of the control programme. 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 motor controlled motion (1), position sensing resistor (2) and electromagnet fixed to the moving trolley (3) in Figure 2b.
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 is neded. The arrangement of the experiment is in Figure 3.

2.4. Kinematics, Dynamics and Energetics of Oscillations

The representations for kinematics, dynamics and energy of the pendulum is in Figure 4a,b. All of these quantities are expressed in terms of the instantaneous deflection e.g. tangential and normal acceleration (Ožvoldová M 2009)

$$a_t = l\varepsilon = l\left(\frac{d^2}{dt^2}\right) = -l(\varphi_o\Omega^2 \sin\Omega t), \quad (2) \qquad a_n = l\omega^2 = l\left(\frac{d\varphi}{dt}\right)^2 = l(\varphi_o\Omega\cos\Omega t), \, (3)$$

or the force of the pull T

$$T = mg\cos(\varphi_o \sin\Omega t) + ml(\varphi_o \Omega \cos\Omega t)^2. \quad (4)$$

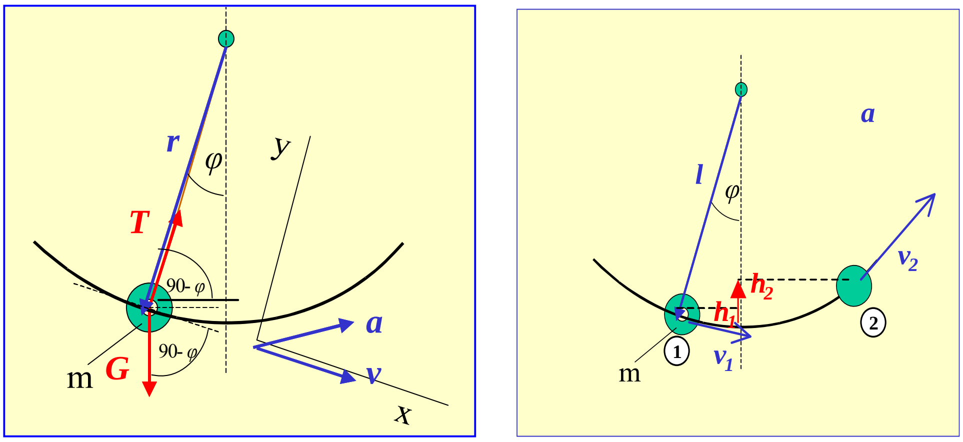

Figure 4: The representation of pendulum - kinematics and dynamics (left) and energetics (right)

2.5 Conclusions

The main conclusions of the remote experiment mathematical pendulum are as follows:

1. The remote experiment from mechanics with mechanical actuators was devised and successfully brought into operation (Figure 4) within the INTe-L strategy of education (Schauer 2009).
2. The pendulum with adjustable initial deflections, both in small and large signals, was constructed bringing the instantaneous deflection of the pendulum for further processing in kinematics, dynamics and energetics of oscillatory motion.
3. The study of dissipative forces is thus enabled with a high precision.
4. The technical and financial requirements to build such experiments call for the establishing of a European university network of remote experiments, covering a basic course of physics based on nearly identical syllabi.

References

Cooper,M., 2005. Remote Laboratories in Teaching and Learning – Issues Impinging on Widespread Adoption in Science and Engineering Education. iJOE International Journal of Online Engineering, Vol. 1,No. 1, 1-7

Cooper, M., Ferreira J.M.M., 2009. Remote Laboratories Extending Access to Science and Engineering Curriculae. IEEE Transaction on Education 2009, Vol. 2, No. 4, 342-353

Ožvoldová, M., 2009. Integrated E-learning Freshmen of Engineering Education. Proceeding of 2009 International Symposium on Total Engineering Education, Shanghai China, 23-25 October 2009.

Schauer, F., Lustig, F., Dvořák, J. and Ožvoldová, M., 2008a. Easy to Build Remote Laboratory with Data Transfer using ISES – Internet School Experimental System. European Journal of Physics, Vol. 29, No. 4, 753-765

Schauer, .F, Lustig, F., Ozvoldova, M., 2008b. e-laboratory Project, Url: www.ises.info, accessed 2009 July

Schauer, F., Ozvoldova, M., Lustig, F., 2008c. Real Remote Physics Experiments across Internet – Inherent Part of Integrated E-Learning. iJOE – International Journal of Online Engineering, Vol. 4, No. 2, 52 – 55

Schauer, F., Ožvoldová, M. and Lustig, F., 2009a Integrated e-Learning – New Strategy of Cognition of Real World in Teaching Physics, Innovation 2009, World Innovations in Engineering Education and Research,USA, iNEER Special Volume 2009, chapter 11, 119 –135