TEACHING CONCEPT IN MEASURING SCIENCE FOR APPLIED PHYSICS BACHELORS

V. Sukackas
Physics Department
Faculty of Fundamental Sciences, Kaunas University of Technology
E-mail: vsukack@fmf.ktu.lt

Abstract: Methodics of teaching for students – bachelors of applied physics - in the field of metrology and measurements is discussed. Most students make their first experiment and measurement in general physics laboratory works during the 2nd semester. The PC-simulating of some tools (calipers, micrometers) is used for rapid training. Students learn the principles of computer assisted controlled experiments in the 5th semester. The objectives are analog – digital and digital – analog converting, Fourier transformation, signal sampling, etc. Students create their own programs for computer-controlled experiments at the end of their studies.

Keywords: measurement in applied physics, PC-assisted and controlled experiments.

1 INTRODUCTION

The use of both real and virtual tools in education is the most flexible and the cheapest way for training of skilled person for proper work with high technologies. It is very important for post-soviet Lithuania that Government as the purpose of the future declared creating of the e-community. There are some difficulties typical for the post-soviet countries: a small number of personal computers in students' ownership, very different knowledge of students in informatics, especially at the beginning of studies at the university, strongly limited financial possibilities. In this case, the methodics of the teaching must include bright spectrum of instruments and software products.

2 METHODICS

The computer-assisted teaching tools in physical measurements can be divided into such groups:

- Game-like computer models of different real instruments and processes,
- Computer-assisted experiments,
- Computer-controlled experiments,
- Virtual experiments and phenomena.

2.1 Computer models

We have created and successfully used some computer models of the simplest measuring instruments for many years [1]: slide caliper and micrometer screw gauge. Simple MS-DOS programs generate on the screen the general view of both measurement instruments with different values of length to be set. Student must read and enter the measured value. Such functions as training, self-training, and estimation of knowledge are possible. On the other hand, the PC generates the position of both measurement instruments by given and entered by student length to be measured. It is extremely important measuring with micrometer screw gauge, because reading is complicated and the result consists of whole number of millimeters, half of millimeter, if needed, and some hundredth parts from cylinder scale. The comments on the screen are, of course, different for each routine function. Such programs are extremely effective for learning of the unskilled students at the 1 and 2 semester: no damaging of real instruments, the possibility of self-training by limited conversation with the teacher. Corresponding users manual is given at the appendix. It is useful to remind that the greatest part of the students make their first self-dependent measurement and experiment at the 1 and 2 semester.

We use some other computer-animations of the physical phenomena: oscillations and waves, interference, diffraction during general physics teaching (as a rule for two semesters). The corresponding commercial programs are from the other countries and they have comments in Russian, English or German. The limited language knowledge of students and lectors makes some troubles. On the other hand, the appearance of commercial teaching programs for Lithuanian-speaking students is not expected because of the small market.

2.2 Computer-assisted experiments

We have used PC-assisted investigation of complicated oscillations. The digitized and stored oscillation can be analyzed using Fast Fourier Transform (FFT). Such procedure is quick and makes possible to demonstrate the spectra of coupled and forced oscillations during the lessons and also as laboratory exercises.

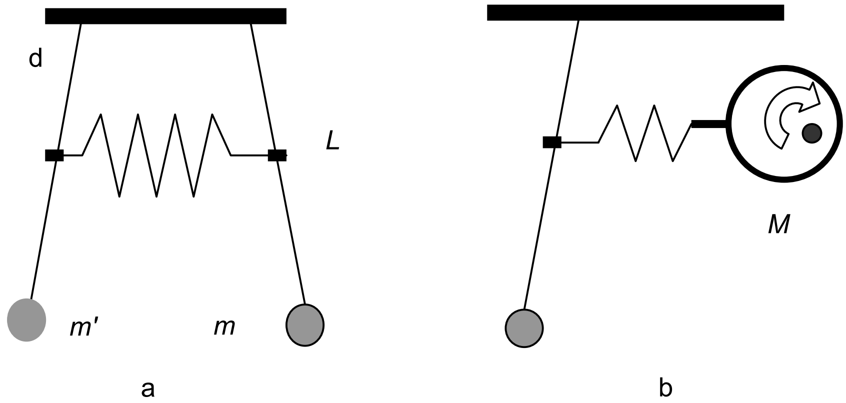

Figure 1. Coupled oscillators (a) and forced oscillator (b).

The laboratory equipment for investigation of coupled and forced oscillations (Fig. 1 a, b), consisting of two physical pendulums, coupling spring and driving motor, was improved by simple angle sensor: lamp and photodiode. The photodiode signal was sampled and stored in PC memory using AD converter μM-4 and commercial package Nextviewlight. An example of PC-assisted investigation of coupled pendulums (fig. 1a) is given in Fig. 2.

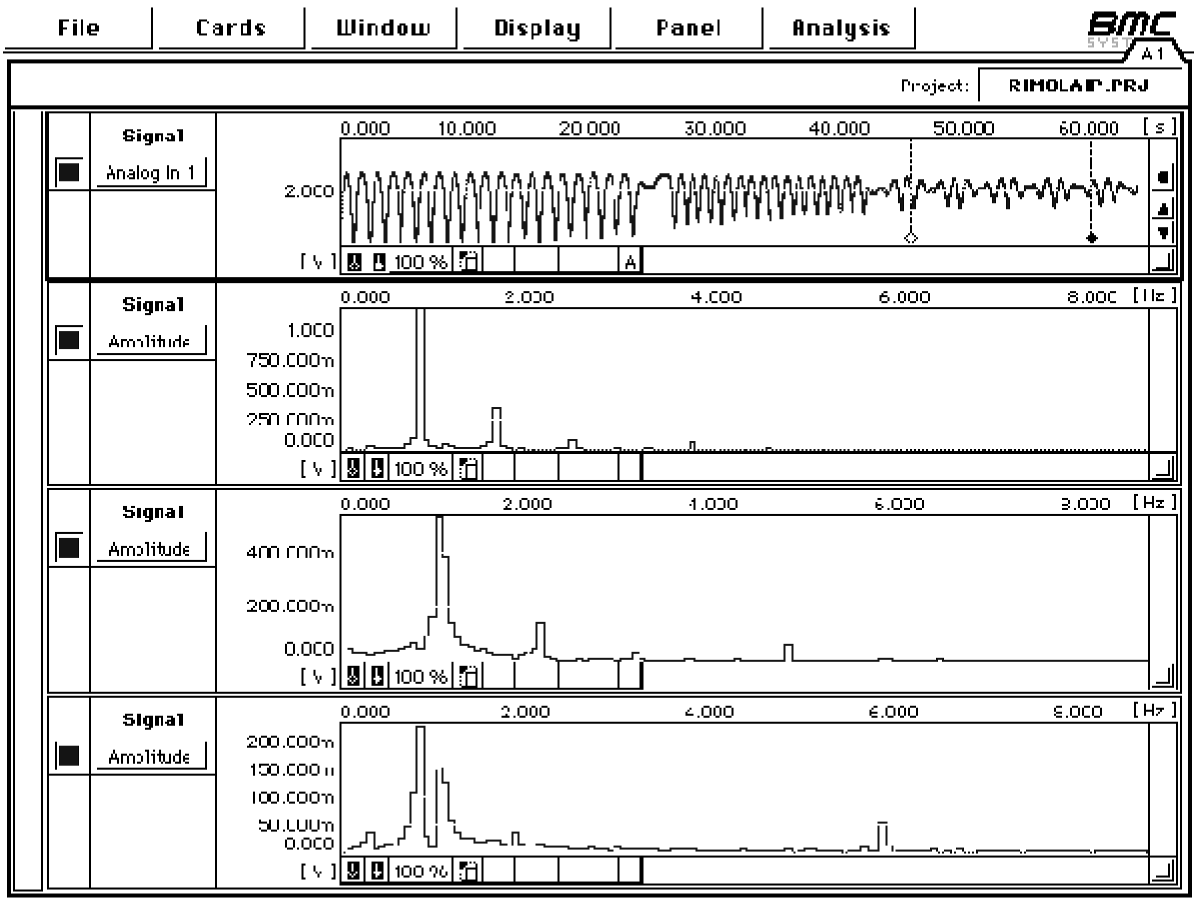

Figure 2. Oscillations of coupled pendulums (top graph from the left: synchronic, in opposite phases, in any phases), its corresponding spectra (other graphs from the top to the bottom).

The angle of one pendulum was sampled and stored in PC in three routines about 20 sec each (top graph from the left to the right): both pendulums oscillate synchronically, in opposite phases and in any phases. The system of two coupled pendulums has 2 degrees of freedom and each oscillation is the superposition of two harmonic oscillations having self-frequencies - beating. The FFT allows finding these simple components of resultant oscillation, what is difficult to do without PC. Corresponding spectra (synchronic, in opposite phases and in any phases) are shown in other graphs from the top to the bottom. It is clear that the complicated third oscillation consists of two oscillations: synchronic and with opposite phases. Such physical pendulums with period ca 1-second are picturesque but exact analysis of resultant oscillation is impossible without PC. This experiment is prepared for the 5th semester students.

Theory gives us an expression for the oscillations $\varphi = \varphi(t)$ of each pendulum:

$$\varphi = \Phi_1 e^{-\beta t} \cos(2\pi f_1 t + \alpha_1) + \Phi_2 e^{-\beta t} \cos(2\pi f_2 t + \alpha_2), \tag{1}$$

where Φ_1, Φ_2 - amplitudes, f_1, f_2 – frequencies, α_1, α_2 – initial phases, $\beta_1 = \beta_2 = \beta$ – attenuation factors of synchronous oscillations and oscillations with opposite phases. The amplitudes have an exponent factor because of attenuation. The frequencies are equal to:

$$f_1^2 = \frac{g}{4\pi^2 L}, \tag{2}$$

$$f_2^2 = \frac{g}{4\pi^2}\left(\frac{1}{L} + \frac{Kd^2}{mL^2}\right), \tag{3}$$

where: g – free fall acceleration, L – length of the pendulums (we consider both pendulums being mathematical and identical), K – coupling spring constant (Kg = force/deformation of spring), d – distance between pivot and coupling spring fix points, m – pendulum's mass.

The transient process of forced oscillations occurs by switching on the driving harmonic force to physical pendulum. The transient response consists of two oscillations with frequencies corresponding free and forced oscillations when the frequency of force is not equal the pendulum's resonance frequency. The equation (1) may be written in such form:

$$\varphi = \Phi_f e^{-\beta t} \cos(2\pi f_f t + \alpha_f) + \Phi_d \cos(2\pi f_d t + \alpha_d), \tag{4}$$

where quantities with index *"f"* correspond free and with index *"d"* – forced oscillation.

The transient process can be analyzed in the given above manner. The angle as a time function was stored immediately after switching-on the driving force (transient process). Free oscillation was sampled and stored immediately after switching-off the driving motor M and forced oscillation - after a longer time (when the free oscillation goes to zero).

The used angle sensor (lamp and photodiode) has a square-form characteristic. It is a question for the students: how to make it linear?

By the way, students must learn the principles of spectral analysis, quantisation, sampling, reconstruction, aliasing phenomenon, etc.

2.3 Computer-controlled experiments

Computer-controlled experiments are the most complicated objectives for students, because [1]:

Dynamics of the controlled object does not allow using common means for the adjusting programs ("debugging", tracing, printing of intermediate results),

It is difficult to use the traditional means for adjusting analog circuits in object under control,

Some phenomena connected with analog – digital (AD) and digital – analog (DA) converting occurs (e. g. pulse-form noises after DA converting),

There is a need for new, not typical software and hardware (anti-aliasing and digital filtering),

There is a need for not typical knowledge (e. g. about interface systems).

Simulating of the temperature control in a mini-thermostat is one of such tasks. Students must create a program for the changing of temperature according to the given law, e.g. sinus or triangle. The heater has only two positions: full – zero and the program must switch-on the heater periodically but for variable and controllable time. The heat capacity is simulated with RC-circuit.

Another example – radar model for measuring of reflecting objects angle-coordinates in horizontal plane.

A semiconductor laser is placed in the point *O* (Fig.3). The diverging laser beam is scanned in a given sector by means of motor driving. The beam symmetry axle *OO'* coincides with the direction of maximum intensity. Laser light reflected from target *T* gets into a photodiode, its signal after converting into digital form and calculating controls the direction of the laser beam. The signal from photodiode increases by adjusting direct to target, reaches the maximum when the symmetry axle *OO'* goes through *T* and begins to decrease. The maximum signal is stored and the criterion for reverse of laser-beam moving is the given (e.g. 50 percent) increasing of signal. In such a way the laser beam follows the object in dynamics. Maximal photo signal is the criterion of right laser beam direction. The finding routine may be turned out and again turned on by each change of the signal.

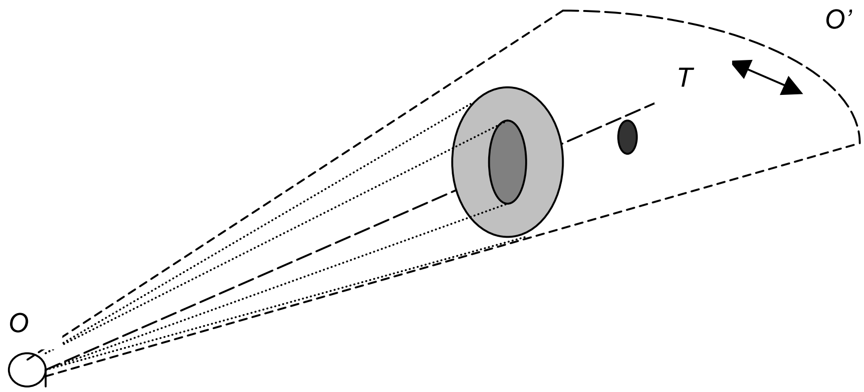

Figure 3. Principle of radar model.

It was recommended for students to display the echoes in polar system: amplitude of echo - angle. Each target movement reflects as the circular spot movement on the screen.

Such radar model is a very simplified copy of well-known radar sight in warplanes. The beam movement in radar sight is more complicated – the beam rotates on the axis, not coinciding with the direction of maximal intensity. The amplitude of reflecting waves is constant by the right adjusting of the axis to the target and a periodic time function in other cases. Of course, the comments about practical use in planes since the Second World War and modern uses in the navigation of spaceships, given in laboratory exercises manual, can increase the students', especially boys', interest [3].

The interruption of program (by printing, tracing, etc) destroys the normal running of the system in both cases. Students were taught to use the programs – imitators of real blocks - with possibility to stop it ("freeze").

2.4 Virtual experiments and phenomena

Such program packages are used when there is no possibility to illustrate pictorially physics phenomena by common means. It is typical for the quantum mechanic. We used the commercial program package IQ 2.1 [4] for illustration of the processes on the microscopic scale (Ψ-function, Schrödinger's wave equation etc).

Another experiment is the investigation of the frequency responses of RC or LC circuit in virtual laboratory. It is too expensive to buy the modern measurement equipments, e.g. Hewlett-Packard, for teaching laboratories. Students can be skilled to work with such devices using the Agilent Technologies program package given in Educator's Corner CD - ROM.

3 CONCLUSION

The use of combined (virtual and real) tools for teaching of measurements in applied physics is the most flexible and cheapest teaching version. This quality is determinant for post-soviet countries.

REFERENCES

[1] S. Tamulevičius, V. Sukackas, Computer aided teaching of physics in Book of Abstract of the fifth Nordic Conference on Computer aided teaching (Stockholm, 13-16 August 1995), Karolinska Institute, Sweden 1995, p. 28.

[2] H. Schumny, Meßtechnik mit dem Personal Computer, Springer-Verlag, Berlin Heidelberg New York, 1993, 330 p.

[3] J.Holub, R. Smid, J. Vedral , How to exercise complex measurements, 1st Virtual Workshop on Tools for Education in Measurement, 2001.06.1-15, http://imeko.mit.tut.fi .

[4] S. Brandt, H. D. Damen, Quantenmechanik auf dem Personalcomputer, Springer-Verlag, Berlin Heidelberg, 1993, 500 p.

APPENDIX

There are two directories attached to the paper:
- Slankmat.v11 – simulation of slide caliper,
- Mikr – simulation of micrometric screw gauge.

System hardware requirements:
- System – 486 or Pentium IBM compatible PC,
- Monitor – VGA or higher,
- OS – MS-DOS 5.0 or higher, Windows 3.1 or higher.

Installing the simulating programs: copy both directories to any drive.
To start the programs:
- Start the files slankmat.exe or mikromtr. exe,
- Select the functions from menu.

There are 3 functions:
- Treniravimasis - training,
- Kontrolé - estimation of knowledge,
- Mokymasis - self-training.

During the training the student must enter the "measured" length till he enters the right answer. His answers are commented a little. By estimation of knowledge the PC offers the student 3 or 10 different readings. The right answers are demanded and the statistics (how many attempts needs the student for each reading) is displayed. Most "friendly" is the self-training function. The PC displays the length corresponding each wrong answer of the student; so he can see and correct his mistakes.
The main questions and comments in Lithuanian have such meanings in English:
"Pagalba" – help,
"Išrinkti" – select,
"Baigti darbą" or "Nutraukti" – escape,
"(Perskaitę) spauskite bet kurį klavišą" – press any key,
"Ar tikrai Jūs norite nutraukti darbą" – do you really want to escape,
"Kiek milimetrų rodo mikrometras (slankmatis)?" – readings of the micrometer (caliper) in millimeters.
"Labai klystate" – it's a great mistake
"Klystate" – a mistake
"Vos atspėjote, reikia dar mokytis" – about right, but you must learn
"Neblogai atspėjote" – not bad, you are right
"Labai neblogai, bet vis tiek netiksliai" – not so bad, but with mistake
"Puikiai atspėjote" – excellently right
"Puiku! Atspėjote" – excellent! You are right
"…mm atspėjote per …. kartų" – …mm you have read from … time
"…mm atrodytų taip –" …mm seems like so
"…mm! Ne šis slankmatis tiek negali parodyti" - …mm! No, it is out of limit for this caliper.