Use of Active Demonstrations in General Physics Course at Colleges and Universities

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Abstract. The principles and concepts of IT-related training are laid down in numerous documents (curricula). To make these documents useful for practice, it is necessary to develop a final product for solving applied problems. The essence of the concept of "active demonstration" and the relevance of the use of active demonstrations in physics classes are revealed. It shows the practice of active demonstrations in the course "Physics" at our universities on the example of use when giving lectures, conducting practical and laboratory classes. All stages of development of tools for conducting classes using IT are considered: problem statement, qualitative analysis of the model, mathematical model, software development and computational experiment. A comprehensive research technique is proposed, including natural and computational experiments. The format and implementation of simulators for solving practical problems are proposed. Educators of physical and technical disciplines when organizing lectures, practical, laboratory classes and trainings can use the information presented in the article.

Keywords: physics, active demonstrations, modeling, computational experiment, didactics of educational applications.

1 Introduction

The indisputable success of informatization is the creation of tools as a means of supporting the routine areas of the educational process (management: storage, processing and access to data; performing labor-intensive mathematical calculations, presentations). This toolkit is based on well-established hardware and software platforms. Today there are no problems in finding and obtaining information. A situation arises when access to information and its volume are practically unlimited, and awareness of knowledge in particular of students is inferior to the knowledge of students of the “pre-informatization” period. Despite all the benefits of informatization, the problem formulated by the ancients “to teach, heal, judge ...” remains relevant today. From the point of view of “teach ...” the didactic aspect is the bottleneck in the

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informatization of education. Despite the seemingly broad possibilities of informatization of education, the role of the educator in teaching remains decisive. Variation and modeling in tasks should become their integral part. The requirements for such products include the following: manufacturability, intelligence, motivation and regularization.

In teaching physics as an academic discipline, the requirement for the implementation of the visualization of a physical process or phenomenon as the main factor directly responsible for the effectiveness of perception of the studied material remains unchanged. Therefore, the organization of the educational process requires lecturers to introduce new teaching methods and technologies into the educational process, as well as the transformation of traditional methods that have already proven themselves well in teaching practice. Their synthesis with modern digital and computer technologies will make it possible to bring the educational process to a new level, which will not only increase interest in physics, but will increase the effectiveness of teaching.

One of the main elements providing visual perception of educational material in the learning process is a physical experiment. However, the rapid development of digital and information technologies dictates new requirements for the organization of the experiment. To date, a number of problems hinders this. The main problems include the following:

- the use of outdated devices and installations that do not meet the requirements of the time and the student requirements;
- absence of modern material base, namely digital devices;
- lack of modern methods of using digital equipment in the educational process.

That is why we propose the implementation of active demonstrations using modern digital technologies. What is active demonstration?

By active demonstration, we mean such a demonstration in the course of which one can observe physical processes and phenomena, measure physical quantities, calculate unknown parameters of physical quantities. The main idea of active demonstration is that we gave the trainees the opportunity to personally "control" the experiment (not only natural, but also computational). The results of the experiment can be observed both on a computer screen and on an interactive whiteboard or with the help of multimedia equipment. When using standard demonstrations, many students perceive the experiment as a focus. In our case, when using an active demonstration, it is proposed to solve a number of problems, both qualitative and calculated, to define the parameters of physical quantities during the demonstration in order to “acquire” knowledge ourselves. Work in groups is allowed. In this case, the educator acts as a consultant. The learners manage the demonstration themselves. They can enter parameters and observe the results of the demonstration on the screen, debate them, organize discussions. Thus, knowledge is "acquired" by the trainees independently in the process of their active learning activities.

This most important element of the educational process allows not only to increase its effectiveness, but also to assess the level of sufficiency or insufficiency of the results of the educator's activity in the classroom. Of course, here it is impossible to do without computer modeling of some processes, phenomena and digital equipment, especially if the physical processes under consideration do not have visual features.

The experience of working with models of physical phenomena that are devoid of a visual feature is shown by us on examples of studying the elements of quantum mechanics in the article [1]. No wonder J. Thomson wrote: “It seems to me that the true meaning of the question - whether we understand or not understand a physical phenomenon, comes down to the following: can we build a corresponding model. I remain dissatisfied until I build such a model; if I can do it, I will understand; otherwise, I don’t understand”. We will demonstrate this with examples of use in lectures, practical exercises and laboratory practice.

2 Active lecture demonstrations

Illustrative lecture support can be quite varied. We would like to draw your attention to applications that describe physical processes and allow a deeper understanding of the material. This is especially true for those where a direct solution of the equations of the mathematical model cannot obtain an obvious result. There are many such topics. For example, the movement of a three-body system: the movement of a planet in a two-star system. The problem statement is very simple: these are six equations of motion and initial and boundary conditions. The analytical solution of such problems is either laborious or even impossible. The numerical model of this movement is quite simple and its computer implementation is not difficult [2].

At the same time, the result is impressive. Using a dynamic model, one can demonstrate the most complex nature of the planet's motion in the system of two stars in Fig. 1.

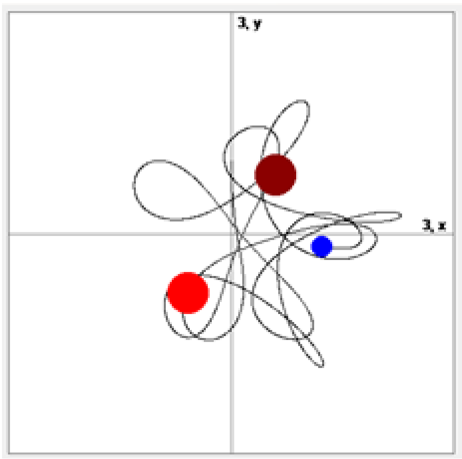

Fig. 1. The trajectory of the planet in the system of two stars

Another example of a deeper understanding of the physical process using a computer model can be demonstrated by the example of “maxwellization” of an ideal gas.

Having considered a system of N particles, setting their initial conditions, numerically realizing the motion, one can obtain the velocity distribution at any time instant and make sure that even the unidirectional motion of particles at the initial moment of time with the same velocities will ultimately lead to the Maxwell distribution.

This model (gas of disks) is deterministic, but the result is statistical. The ideal gas model can also be described statistically (Monte Carlo method) by choosing randomly colliding particles. The result will be similar - "maxwellization" of velocities.

Dynamically all this can be demonstrated only with the help of computer models shown in Fig. 2. These and a large number of other models are presented in [2, 3], which describes the full cycle of development of various models of physical processes (problem statement, qualitative analysis of the problem, mathematical model, development of program code, computational experiment) and allow complement lecture presentations more effectively.

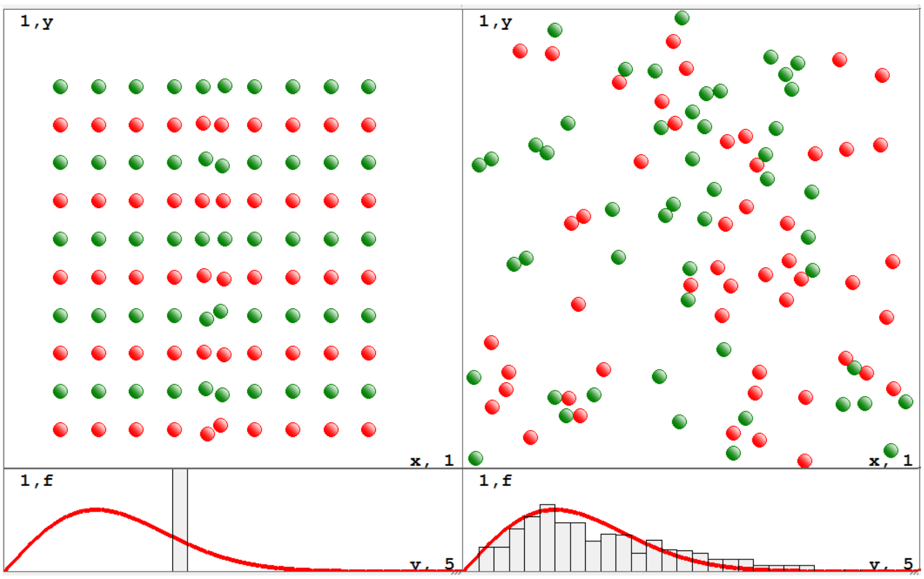

Fig.2. "Maxwellization" of ideal gas molecules. On the left - the initial state of the particles, on the right - after collisions, the solid line - the Maxwell velocity distribution. Speeds are in shares of the most probable speed

3 Active demonstrations in practical sessions

Practical exercises are primarily associated with solving specific problems. The forms of their implementation can be varied. Since we focus on the active use of information technologies, we will present our version.

Using a computer allows you to generate, almost unlimited, variants of the initial data. Graphic capabilities allow not only dynamic illustrations, but also interactivity - this significantly expands the method of solving the problem.

The task interface has three fields (Fig. 3): 1 - the field of initial data and numerical answers, 2 - the statement of the problem and all the formulas necessary for solving, 3 - the graphic field of dynamic illustrations and interactive actions. According to the considered scheme, we have developed a recitation book for a general physics course, which can also be used as a simulator.

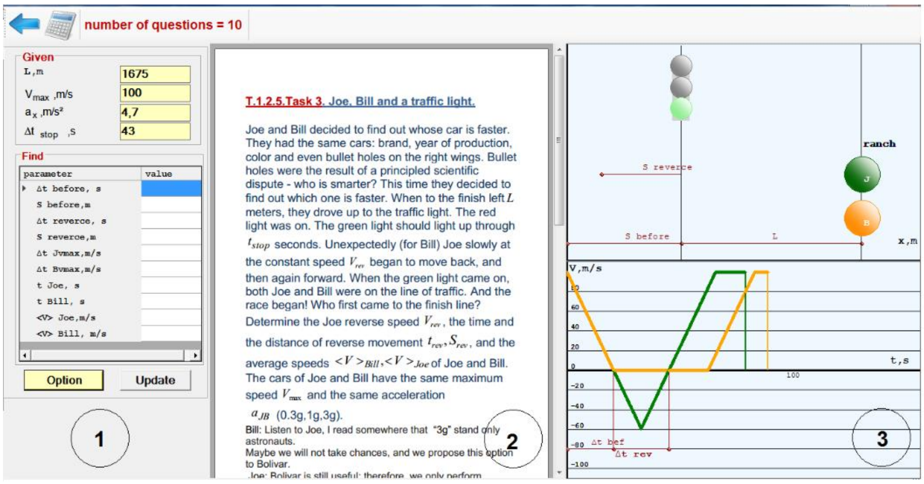

Fig. 3. Application task interface and structure

4 Active demonstrations in laboratory exercises

Consider the use of computer modeling in a laboratory practice, the implementation of which is possible on a unified installation. On the one hand, this makes it possible to reduce the cost of equipment, on the other, to show the connection between physical phenomena of various nature. We used the phenomenon of electromagnetic induction, both for diagnosing the process parameters and for studying the phenomenon itself.

We analyze natural and computational experiments in the study of the phenomenon of electromagnetic induction and its application to study the resonant oscillations of a spring pendulum [4]. In this laboratory practice, the phenomenon of electromagnetic induction is studied with the relative motion of a magnet and a coil. In the theoretical part of the work two mechanisms of induction phenomena are considered, the concept of a vortex electric field, the phenomenon of electromagnetic induction in moving conductors and its Maxwellian interpretation. A mathematical and computer model of the studied processes has been developed. Comparison of natural and computational experiments demonstrating the principle of mutual electromagnetic interaction of a magnet and a conductor with their relative motion is performed. It is shown that the final expression for the EMF of induction does not depend on the choice of a frame of reference connected with either a coil or a magnet. An expression for the EMF is obtained, which linearly depends on the number of turns of the coil, the speed of the magnet's flight and its magnetic moment. A magnetic dipole model is used to describe the magnetic field of a permanent magnet, and its magnetic moment is measured. The computer program interface allows you to change geometric, dynamic and magnetic parameters. Based on a computational experiment, a range of parameters for carrying out a natural experiment was selected.

A distinctive feature of the proposed laboratory work is excitation, imitation of dissipative forces and registration of oscillation resonances in a unified way - only due to electromagnetic induction. Theoretical models (analytical and numerical), as well as computer modeling of data obtained by theoretical and experimental methods are considered.

The workshop describes the theory and schematic diagrams of experimental installations used in the study of free, forced, and coupled oscillations of spring pendulums. In the study of free vibrations, the calculated and experimental data of undamped and damped vibrations are presented at various initial displacements of the center of the magnet relative to the equilibrium position and the center of the coil. When studying forced oscillations of a spring pendulum, excitation, imitation of dissipative forces and registration of oscillation resonances are experimentally realized. To study the oscillations and resonances of two coupled spring pendulums, the phenomenon of electromagnetic induction is used, which makes it quite simple to carry out such an experiment. Based on a computational experiment, a range of parameters for a natural experiment was selected.

As an example, illustrating the proposed technique, let us consider the laboratory work “Study of nonlinear oscillations and resonances of a spring pendulum”.
In some particular case, the Duffing oscillator can describe nonlinear oscillations [5]. The oscillation equation has the form:

$$\ddot{x} + 2\beta\dot{x} + \omega_1^2 x = -\gamma x^3 + f_0 \cos\omega t \qquad (1)$$

β is the attenuation coefficient, 1/s;

ω_1 is the cyclic frequency of free harmonic oscillations, 1/s;

ω is the driving force frequency, 1/s.

The coefficients of equation (1): $\beta, \gamma, f_0, \omega_1$ are set by the parameters of the experimental setup.

The solution to equation (1) can be obtained in the form [5]:

$$\omega_2 = \omega_1 + \delta A^2 \mp \sqrt{\left(\frac{f_0}{2A\omega_1}\right)^2 - \beta^2}, \qquad (2)$$

where $\omega_2 = \omega$ is the cyclical frequency of nonlinear oscillations, 1 s; $\delta = \frac{3\gamma}{8\omega_1}$ and A is the nonlinear oscillation amplitude.

The laboratory work is supported by a computer application containing all the necessary information, data processing tools, a computer model for imitating the process. The work consists of two types of experiment: natural and computational. The first is traditionally associated with setting up laboratory equipment, obtaining experimental data and processing them. The second - computer simulation allows you to vary a large number of initial parameters and observe the dynamic change in other parameters (Fig. 4).

The solution of equations and, in particular, (1) is not always possible to obtain in an analytical form. In our case, solution (2) is valid only for the steady state. The numerical solution in most cases (at least in the educational process) is not very difficult. In Fig. 4, using a numerical model, snapshots of the dynamic change of individual components-addends of equation (1) are presented. This allows you to analyze the influence on the oscillation process of the damped force component, elastic force, excitation force, nonlinear force component (Figure 4.1), to present a dynamic phase diagram of motion (Figure 4.2), change in the amplitude of oscillations (Figure 4.3).

Thus, with the help of computer technologies, it is possible to significantly expand the methods of experimentation, which make it possible to study systems with a large number of degrees of freedom.

The use of information technology is not an end in itself. Computer support, in particular a laboratory workshop, should be simple, convenient and not complicate the process of acquiring new knowledge. The development of computer models, with seeming simplicity, is a laborious task. Even with an understandable traditional learning algorithm, building a computer model is not easy. The example we have described is our experience and vision of the application of computer technology in education. The learning process cannot be simplified, however, it is also unacceptable to overload. As elsewhere, the optimum is needed, especially when computer technology is used.

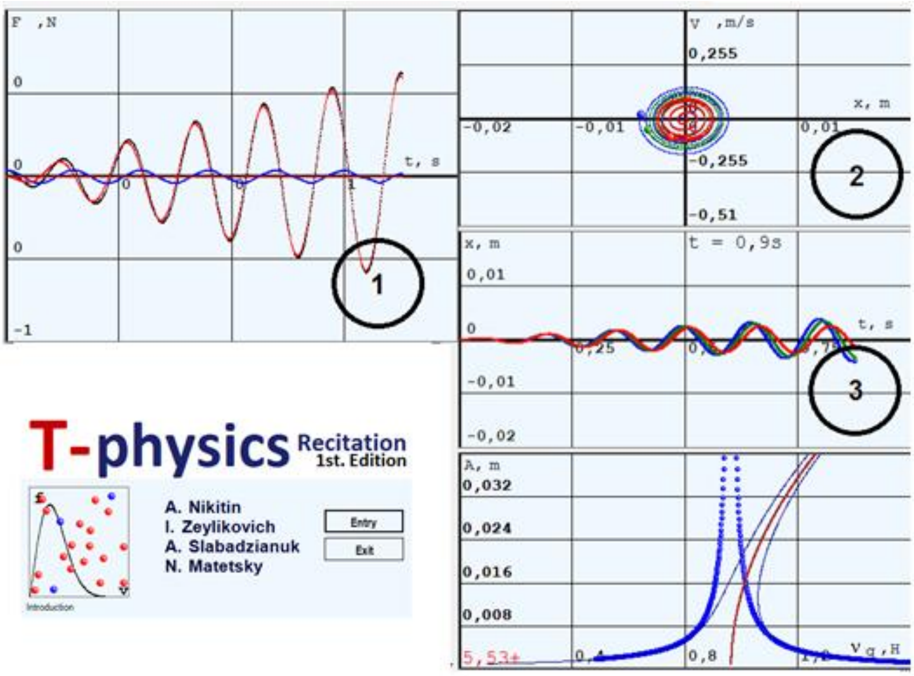

Fig. 4. Results of the computational experiment

5 Conclusion

Modern hardware and software platforms can be as complex as desired. Numerous curricula are certainly necessary, but they by themselves will not solve any problem of education, since they only declare "slogans-competence". The final element of the application of information technologies in education should be technologies that implement the function of obtaining subject knowledge. It is necessary to develop specific educational resources filled with subject knowledge. The field of education is conservative enough to quickly embrace the new information paradigm. To avoid the problem of the ability to perceive information at the speed that information technologies impose, changes should probably occur at the genetic level. This will take time. "Learn ... ... Life will do the rest" (F. Dostoevsky).

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