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**COMPUTER AND MULTIMEDIA TECHNOLOGIES AT PRACTICAL  
CLASSES IN PHYSICS**  
**КОМПЬЮТЕРНЫЕ И МУЛЬТИМЕДИЙНЫЕ ТЕХНОЛОГИИ НА ПРАКТИЧЕСКИХ  
ЗАНЯТИЯХ ПО ФИЗИКЕ**

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**Abstract.** *The paper addresses up to date task of effective introduction of computer-based learning tools into the educational process. Basic principles, features and methods of development and utilization of electronic courses in modern educational institutions are considered. Characteristics that should be inherent in the electronic textbook (manual) are emphasized, so that the e-textbook not only does not yield to traditional textbooks in the quality of comprehension of the educational material, but also employs the digital technology benefits for interactive and dynamic presentation of material, visualization of the studied processes and phenomena.*

*The paper presents the electronic textbook on electrostatics developed by the author for students of technical universities, which corresponds to the current syllabus of the discipline and implements the basic requirements for the technology of creation and use of computer-based learning tools. Brief description of the textbook, its content and principles of operation are given. The e-textbook contains examples of solving problems demonstrated in animated and static way. That allows teacher to control the step-by-step process of solving problem, to demonstrate animated simulation of physical phenomena, followed by discussion and theoretical assessment, which increases interest and motivation of students to study physics. The main purpose of the e-textbook when used in practical classes is to teach students to solve problems on their own. Presentation of tasks in the animated way allows to demonstrate reference solution in the form of algorithmic steps, when each subsequent step appears on the screen after most of the students have completed the previous one. Students who have succeeded to solve the task on their own can check their solution with the reference one, and those who have not can get a hint.*

*Analysis confirms that carrying out practical classes in physics with use of our e-textbook is effective. Results of the research have shown that 68% of students who took part in the experiment have mastered methods of solving problems at the sufficient level. About 80% of students have indicated that the use of electronic and multimedia technologies in physics classes is expedient.*

**Key words:** *computer technologies; electronic textbook; multimedia.*

## **1. INTRODUCTION**

**The problem statement.** In recent years novel information technologies (IT) gain even more and more appreciable role in education. Modern educational process can hardly be imagined without utilization of electronic textbooks, manuals, task-books, simulators, laboratory workshops, catalogs, handbooks, encyclopedias, testing



and control systems and other computer-aided learning tools (CLT).

There are different levels of use of novel information technology in the educational system. At the first level, novel IT serve as tools for solving certain pedagogical tasks within the traditional education framework and supplement traditional teaching methods. CLTs here provide support for the educational process alongside with other (non-computer) learning tools. At this level, CLTs are used in the passive form.

The active role of information technology is exercised at the second level. Now the CLTs provide new opportunities with higher quality, comparing to the traditional educational and methodical tools.

**Analysis of recent studies and publications.** With the literature analysis [1] - [5], we can identify the following main advantages of using CLTs:

- making conditions for independent study of the educational material (self-education, distance education), which allows student to choose a convenient place and time to work with CLTs, as well as the convenient pace of the educational process;
- deeper individualization of training and providing conditions for its variability (in particular, with application of adaptive CLTs, adjustable to the current level of training);
- possibility to train with simulations of the studied objects and processes (including those that are difficult to observe in practice);
- ability to imagine and interact with virtual three-dimensional images of the studied objects;
- ability to present unique information materials in the form of multimedia (paintings, manuscripts, video clips, sound recordings, etc.);
- possibility of the automated control and more objective evaluation of knowledge and skills;
- ability to automatically generate a large number of non-repetitive tasks to control knowledge and skills;
- possibility of more convenient search and access to the information in CLTs (hypertext, hypermedia, bookmarks, automated indexes, keyword search, full-text search, etc.);
- creating conditions for the effective implementation of progressive psychological and pedagogical methods (game forms of learning, experimentation, "immersion" into virtual reality, etc.).

Technological advantages of CLTs include:

- increasing rapidness of development;
- easier updating and development;
- easy duplication;
- easier distribution (especially with internet).

The use of CLTs in the educational process advantages in:

- increasing the quality of education;
- reducing the cost of organizing and carrying out training events;
- redistribution of the teachers' workload from routine to creative activities (work on research and methodological problems, creation of teaching aids



(including CLTs), preparation of non-standard educational tasks, individual work, etc.);

- increasing efficiency of providing the educational process with teaching aids (CLTs) when the structure and content of education is changing (development of new specialties, etc.), which results in increased mobility of the educational system.

But, along with the advantages, the use of CLTs has a number of requirements:

- the need to have a computer (with the Internet access) and appropriate software to work with CLTs;
- the need to have computer skills;
- it may be difficult of perceive large amounts of text material from the screen;
- insufficient interactivity of CLTs (which is significantly greater comparing with the book, but less than in full-time education) is the disadvantage;
- also, the disadvantage of CLTs is lack of direct and regular control over the curriculum implementation.

The main reason for conceptual errors in the CLTs design is ignoring the tendency that CLTs should implement all the best from traditional teaching aids and at the same time surely provide new qualities of education. This requirement is the basic rule of conceptual design of CLTs.

Investigations show that even nowadays adaptation of CLTs into the educational process is not sufficient; a lot of digital learning resources available online use static computer screens [6], [7]. In our opinion, there are four main factors that hinder the mass creation and spread of CLTs:

- lack of financial support for the design and widespread implementation of the large number of CLTs in Ukraine;
- the existing education system is not sufficiently prepared for the active use of CLTs, their integration into the educational process and organization on the basis of this technology;
- shortage of qualified developers;
- absence of the developed methodology.

All the aforementioned flaws currently require intense and active improvement in connection with the urgent increase of the role of distance education and CLTs in conditions of complex pandemic situation in the world. The force majeure due to the pandemic has rose a question of immediate integration of CLTs into the traditional educational process and use of advantages of such a combination approach in future.

It is well known that students are the basic category of the electronic textbook users. The role of teachers is to create the necessary conditions for their learning with the use of CLTs and to provide organizational, technical and methodological support.

Application of CLTs also allows teachers to collect statistical data on students' results and learning engagement in order to evaluate their knowledge and estimate quality of education [8]. In order to organize the educational process, the control of students' knowledge, skills and abilities and to analyze the results of evaluation, teachers carry out the following:



- educational testing of students, evaluation of their training and formation of individual tasks, which determine the content and scope of educational material, as well as indicators that reflect the requirements for the formed knowledge;
- adjustment of electronic textbooks in accordance with the prepared tasks;
- check of the electronic textbook functionality taking into account the set adjustments;
- preparation of planned schedules for students;
- organizational and methodological support of activities where electronic textbooks are used;
- control of the students' work with electronic textbooks, analysis and estimation of the results, adjustment of individual tasks and schedules on the basis of these estimations.

Teachers and methodologists choose the types of CLTs and specific learning tools, besides, the design of electronic textbooks should be specialized for the studied discipline. For example, e-textbook in Physics should contain visualizations of physical phenomena, simulation of processes, manipulatable animations, interactive formulas, hints for solving problems, etc [9].

The following conditions are set for design and use of electronic textbooks [1] - [5], [10] - [11]:

1. Electronic textbook is used to present a large amount of educational material, covering in general the theoretical and technological parts of any course (discipline).

2. If the electronic textbook is developed for a relatively wide range of students, then the represented material should not be highly specialized.

3. It is expedient to create electronic textbooks to compensate the lack of educational material sources.

4. When deciding on the introduction of electronic textbooks into the educational process, it should be kept in mind that the greatest effect of its use appears when the bulk of theoretical and technological training is carried out by students independently with electronic textbooks, while the emerging difficulties and issues are addressed during additional practical classes and individual consultations with teachers. If organizers of the educational material set a goal to implement such a technique, then the choice of electronic textbooks as the type of CLTs is justified.

When using electronic textbooks, one can implement the following ways to access the training material:

- by means of a block of content, the elements of which refer to the relevant structural units of the learning material, and means of navigation;
- by means of an index page, reference page and components that contain links to the structural units of the learning material;
- by means of search tools for the learning material;
- by means of user's bookmarks that are associated with the structural units of the learning material.

It should be emphasized that the electronic textbook is not supposed to be analogous to printed textbooks. It should not duplicate a traditional textbook, where texts and illustrations are presented in a static form, as far as it is always more convenient to read printed text from the book than the static text on the monitor



screen. Reading digital texts from the screen takes longer time and is inferior in reading comprehension to the printed ones. However, with the printed textbook readers cannot observe the dynamics of physical process [6].

Computer technology aimed to transfer educational information to students allows to implement the following didactic principles:

- ✓ Principles of scientificity, systematicity and consistency.
- ✓ The principle of clarity.
- ✓ The principle of combination of individual approach to learning with collective forms.
- ✓ The principle of connection between theory and practice.
- ✓ The principle of efficiency.
- ✓ The principle of activity.
- ✓ The principle of independence.
- ✓ The principle of motivation, etc.

The basic psychological principles of human-computer interaction should be taken into account when designing and using electronic textbooks and manuals. Violation of such principles is often manifested in the following:

- Excessive computer assistance to a person in some situations, and insufficient computer assistance in others;
- redundancy of informative dialogue;
- computer "failures", when computer gives answer not on the essence of the considered problem or the asked question;
- insufficient motivation of the computer's help;
- excessive categorical answers, etc.

All of the above may lead to the increase in time required to study the material, instead of its expected decrease, and to lowering in motivation to learn, etc.

That's why it is important to develop electronic textbooks which take advantages of digital technologies and present information in the interactive and dynamic form instead of the static reading. In that case, users of e-textbooks have high efficiency of cognitive learning and increased interest and involvement in the study [6].

**The research goal.** Considering the basic requirements for the technology of creation and use of CLTs, we have developed the electronic textbook for students of technical universities, which corresponds to the current syllabus of the General physics course. The main goal of the textbook is to serve students in training to solve problems on their own.

## 2. THE RESULTS AND DISCUSSION

In order to program the textbook we have used:

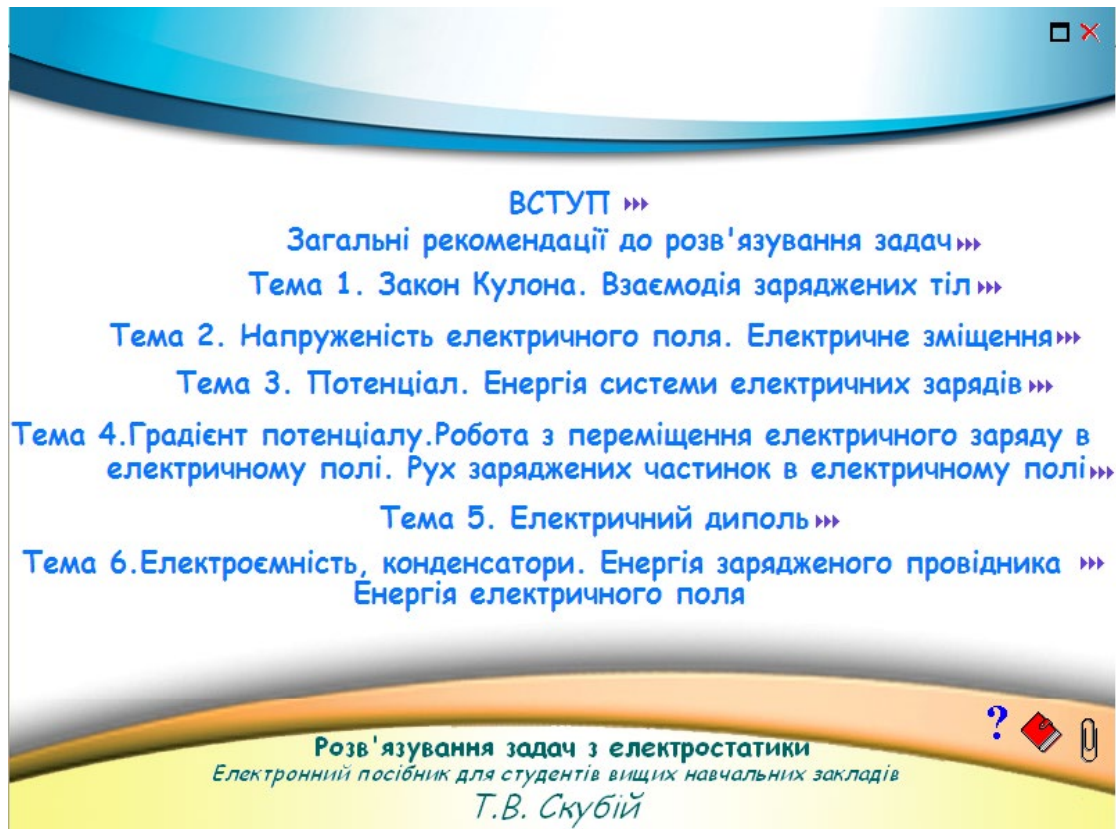
- Delphi software for programming interface (main menu);
- Multimedia software (Flash, SWISHmax) for producing animation;
- HTML.

The presented electronic textbook contains:

- Animated intro;
- Main menu (Fig. 1);
- Didactic material for carrying out practical classes on the main topics of



Electrostatics (the list of topics is presented in Fig. 1):



**Figure 1. The main menu**

The following didactic material is presented for elaboration of each topic of practical lesson:

1. List of theoretical questions that the student should know. It is used to adjust successive stages of learning theory and solving problems;
2. Brief theoretical information;
3. Methodical recommendations for solving problems. During work with this material, the software allows to go to other pages of the electronic textbook, where students can find formulas, definitions, methods of solving problems, etc., by clicking the links (underlined);
4. Examples of solving basic typical problems;
5. Problems for independent work with different types of tasks and various levels of complexity;
  - a) a list of concepts, laws, principles and methods required to solve problems;
  - b) list of the literature to study;
  - c) numbers of tasks that students have to solve in order to master the normative level of knowledge and skills;
  - d) tables of homework options. The programming of each table allows student to go to the text of the problem and to go to the answer for any table number by clicking the underlined number or the word "answer", respectively.

Examples of solving problems are presented in two ways in the electronic textbook:




1. Animated method. It reveals dynamics of the physical phenomenon, which is described in the text of the problem; builds a physical model of the situation; writes mathematical stage of solving the problem, presents numerical calculations (arithmetic or graphical). The software allows to pause the animation at any moment by clicking anywhere on it. To continue viewing the animation, one should click the “run” icon.

2. Static method. There is a static demonstration of solving problem at the same page, and user should scroll the page to view it. The static method gives a complete solution to the problem in traditional way. Clicking hyperlinks (underlined) allows users to go to other pages of the electronic textbook, where formulas, definitions, methods for solving problems, etc., are presented.

Each page of the electronic textbook has function buttons on the left (Table 1).

**Table 1 - Function buttons of the electronic textbook**

<b>Головна</b>	- to go to the main menu from any page of the textbook;
<b>Попередня</b>	- to return to the previous page;
<b>Наступна</b>	- to go to the next page;
<b>Про посібник</b>	- to get acquainted with the summary of the electronic textbook
	- to run the animation

When carrying out practical classes, utilization of our electronic textbook allows to implement the following:

- to see computer simulations of physical situation mentioned in the task;
- to manage students' activities on the way of solving problem with the help of heuristic means (a developed system of teacher-to-students questions);
- to manage the step-by-step process of solving problem;
- to see the reference solution of the problem on the screen (that is, it is recommended not to demonstrate solutions of all problems at once, but to give students opportunity to solve the problem individually and then compare their solution with the reference).

Practical classes with the use of our e-textbook have been carried out as follows.

The first stage is the stage of acquaintance with the text of the problem. A brief record of the data is the stage of its formalization, coding, creation of a symbolic model of the problem, formulation of the problem in physical language. At this stage, students have studied the text of the problem appearing on the screen, thoroughly imagining phenomenon or process described in the problem formulation. After getting acquainted with the text of the problem, students have recorded the abbreviated data using the accepted physical symbols.

The second stage is the stage of analysis of the physical model, that is, a comprehensive consideration of physical phenomena and processes related to the problem. At this stage, a physical model of the situation, which is described in the text of the problem, has been built on the screen. Teacher can stop the animation any



time to consider comprehensively in details physical phenomena and processes mentioned in the problem. Such an approach provides success of using problems as one of the tools for learning physics.

At this stage, students' attention has been drawn to the fact that it is necessary to determine the initial and final states of the process and parameters that characterize them. That allows to clarify the conditions, to put appropriate subscripts for the variables, and so on.

When clicking the "run" icon, the animation is continued and students can observe "live" models of physical phenomena, which are described in the text of the problem, with following discussion and theoretical assessment. That has aroused students' interest and created an atmosphere of collective creativity. Observation of building of a physical model allows:

- a) to identify the main elements of the physical model;
- b) to determine how the state of objects changes and what is the reason for that change;
- c) to establish physical quantities that can characterize the properties of objects and the conditions of their interaction.

The third stage is the stage of solving problems. This is the key stage in the process of consideration of educational task. The patterns (laws, formulas, rules, methods) that describe the phenomenon or process are found, that is, extracted from students' memory, during discussion of the data of the problem with students.

The fourth stage is the stage of obtaining the calculation formula. At this stage, students check if the system of obtained equations is defined or if the number of equations corresponds to the number of unknowns; otherwise, the data of the problem is used to compile additional equations if necessary; then the system of equations is solved in general, that is the calculation formula is obtained. At the first stages of learning, the solution to the problem has appeared on the screen, but with time students have been solving the problems by themselves and comparing their solution with the reference, which appears on the screen.

The final stage is the stage of calculating and obtaining the magnitude of the desired value. After completing this step, the reference calculations and the answer appear on the screen for comparison.

The fourth and final stages are the stages of understanding the relation and correspondence of physical and mathematical models of the solved problem.

In the solution mode, the task of managing students' individual work has been implemented as follows: the teacher manages the independent work of students with the help of questions – "algorithmic steps". First, the time is given to the students to perform a step of this algorithm on their own. Then, after the most of the students have completed the task, the teacher opens the reference solution of this algorithmic step on the screen. That is, a kind of "hint" is displayed on the screen for those students who could not complete the task correctly, and those students who have solved the task on their own now can check it with the reference solution.

Our electronic textbook also contains tables of options for homework. The teacher can use them to carry out classes, tests or control work of students.

The electronic textbook contains: 10 animated examples of solving problems; 24





static examples; 27 illustrations and 100 pages of text.

The developed electronic textbook can be used during practical classes, as well as in distance education and during self-preparation of students at home.

### 3. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

Analysis of the practical classes implemented with utilization of the developed electronic textbook has shown that 68% of students who took part in the experiment have mastered methods and ways of solving problems in the section "Electrostatics" at the sufficient level. The survey of students has confirmed the effectiveness of this learning tool (about 80% of students consider it expedient to use electronic and multimedia technologies).

Basing on the practical application of the electronic textbook in the educational process, the following is revealed:

1. Animated simulation of physical situations described in the problem helps students to understand the text and imagine the processes more completely and clearly.

2. Students gain the opportunity to get acquainted with rational methods of solving problems, and at the same time with modern innovative learning technologies.

3. The electronic textbook purposefully demonstrates the main stages of solving the problem.

Prospects for further research and exploration include:

1. Development of computer games as tools for diagnosing knowledge, skills and abilities to solve problems in physics.

2. Introduction of such games into the educational process.

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**Аннотация.** Статья обращена к актуальной задаче эффективного внедрения компьютерных средств обучения в образовательный процесс. Рассмотрены основные принципы, особенности и методы создания и использования электронных курсов в современных образовательных учреждениях. Выделены характеристики, которые должны быть присущи электронному учебнику (пособию) для того, чтобы он не только не уступал традиционным учебникам по качеству восприятия образовательного материала, но и использовал преимущества цифровых технологий для интерактивного и динамического представления материала, визуализации процессов и явлений, которые изучаются.

В статье представлено разработанное автором электронное учебное пособие по электростатике для студентов технических университетов, которое соответствует действующим программам дисциплины и учитывает основные требования к технологии создания и использования компьютерных средств обучения. Дано краткое описание пособия, его содержание и особенности работы. Электронное средство содержит примеры решения задач, демонстрируемые анимационным и статическим способом. Это позволяет преподавателю управлять пошаговым процессом решения задачи, демонстрировать на экране анимированную визуализацию физических явлений с последующим обсуждением и теоретической оценкой, что повышает интерес и мотивацию студентов к изучению физики. Основной целью пособия при использовании на практических занятиях является научить студентов решать задачи самостоятельно. Анимационный способ представления задач позволяет демонстрировать эталонное решение в виде алгоритмических шагов, когда каждый следующий шаг появляется на экране после того, как большинство студентов выполнили предыдущий. Студенты, которые самостоятельно справились с заданием, могут сверить свое решение с эталонным, а те, которые не справились, получить подсказку.

Проанализировано, что проведение практических занятий по физике с использованием разработанного нами электронного пособия является эффективным. Результаты исследований показали, что 68% студентов, принимавших участие в эксперименте, усвоили на достаточном уровне методы решения задач. Около 80% студентов отметили целесообразным использование электронных и мультимедийных технологий на занятиях по физике, что подтверждает эффективность такого способа обучения.

**Ключевые слова:** компьютерные технологии; электронный учебник; мультимедиа.

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