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Teaching students the equations of mathematical physics using educational electronic resources

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Abstract. *Problem and goal.* Currently, information and telecommunications technologies are widely used in the professional activities of most specialists in various subject areas. This circumstance initiates the training of students in higher education institutions, who must have not only deep subject knowledge, but also be able to master modern information and telecommunications technologies and be able to apply them in their activities. One of the fundamental disciplines that is included in the university curricula for preparing students of physical and mathematical fields of study is "Equations of mathematical physics". In the process of teaching students the equations of mathematical physics, the goals are set not only to form students' solid subject knowledge, but also to acquire the skills and abilities to apply modern information technologies in the study of mathematical models based on the equations of mathematical physics. *Methodology.* Educational electronic resources are used in training sessions on mathematical physics equations. Such training sessions with students take place in the form of laboratory classes, where modern computer technologies are used to find solutions to equations of mathematical physics and then analyze them. *Results*. The implementation of didactic principles of teaching mathematical physics equations in laboratory classes using educational electronic resources allows students to achieve good results in the methods of studying mathematical physics equations. *Conclusion.* The use of educational electronic resources in the classroom on the equations of mathematical physics allows students, in addition to deep subject knowledge, to acquire the skills and abilities to use modern computer technologies to solve mathematical problems.

Keywords: equations of mathematical physics, educational electronic resources, training, student, informatization of education

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Обучение студентов уравнениям математической физики с использованием образовательных электронных ресурсов

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Аннотация. *Проблема и цель.* В настоящее время информационные и телекоммуникационные технологии повсеместно используются в профессиональной деятельности большинства специалистов разных предметных областей. Это обстоятельство инициирует подготовку в вузах студентов, которые должны иметь не только глубокие предметные знания, но и способных овладевать современными информационными и телекоммуникационными технологиями и уметь их применять в своей деятельности. Одной из фундаментальных, входящих в вузовские учебные планы подготовки студентов физико-математических направлений, является дисциплина «Уравнения математической физики». В процессе обучения студентов уравнениям математической физики ставятся цели не только формирования у них прочных предметных знаний, но и приобретения умений и навыков использования современных информационных технологий при исследовании математических моделей, в основе которых лежат уравнения математической физики. *Методология.* На учебных занятиях по уравнениям математической физики используются образовательные электронные ресурсы. Такие учебные занятия со студентами проходят в форме лабораторных, на которых применяются современные компьютерные технологии для поиска решений уравнений математической физики и их последующего анализа. *Результаты.* Реализация на лабораторных занятиях дидактических принципов обучения уравнениям математической физики с использованием образовательных электронных ресурсов позволяет студентам достичь хороших результатов по методам исследования уравнений математической физики. *Заключение.* Применение образовательных электронных ресурсов на учебных занятиях по уравнениям математической физики позволяет студентам помимо глубоких предметных знаний приобрести умения и навыки использования современных компьютерных технологий для решения математических задач.

Ключевые слова: уравнения математической физики, образовательные электронные ресурсы, обучение, студент, информатизация образования

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Problem statement. The theory of equations of mathematical physics arose on the basis of specific physical problems that lead to the study of individual partial differential equations (see, for example, [1–12]). The study of mathematical models of physical problems led to the creation in the middle of the 18th century of a new branch of analysis, which is called the equations of mathematical physics and is the science of mathematical models of physical phenomena. In the 19th century, applied problems of electrodynamics, thermal conductivity, optics and other applied problems were investigated, as a result of which new equations of mathematical physics were constructed and studied. In the 20th century, applied problems of quantum physics, plasma physics and other applied problems began to be studied, as well as the theory of relativity developed. Therefore, new equations of mathematical physics appeared.

The foundations of the theory of equations of mathematical physics were laid by J. Herman, B. Taylor, D. Bernoulli, L. Euler, J. Dalembert, J. Lagrange, G. Monge, P. Laplace, A. Legendre, S. Poisson, N.E. Zernov, G. Riemann, V.G. Imshenetsky, J. Fourier, O. Cauchy, M.V. Ostrogradsky, P. Dirichlet and other authors. Further development of the theory of equations of mathematical physics is found in the research of N.E. Zhukovsky, S.V. Kovalevskaya, A.N. Krylov, O. Lyava, A.M. Lyapunov, V.A. Steklov, N.M. Gunter, L. Prandtl, E. Schrodinger, R. Courant, M.A. Lavrentiev, S.L. Sobolev, A.N. Tikhonov, M.V. Keldysh and other authors.

Analytical methods for solving equations of mathematical physics include methods such as the method of characteristics, the Fourier method, the Dalembert method, the method of integral transformations, the Laplace transform, and other methods. Approximate methods for solving equations of mathematical physics include finite-difference methods. Among the fundamental scientific results that have a major role in the development of finite-difference methods for solving partial differential equations are: the necessary condition for the stability of an explicit numerical solution of some partial differential equations, set out in a 1928 article by R. Courant, K. Friedrichs and G. Levy [13].

Important results in the theory of difference schemes were obtained on the basis of the energy method developed by R. Courant, O.A. Ladyzhenskaya, G. Levy, L.A. Lusternik, K. Friedrichs and other authors. Studies of approximation, stability, and convergence have created the necessary basis for a broad search for effective difference schemes designed to solve partial differential equations.

To study a particular process or phenomenon, a corresponding mathematical model is constructed. There are no general ways to build mathematical models. In each specific case, the model is selected taking into account the application problem under study. The mathematical model should reflect the most important features of the phenomenon, all the essential factors on which the success of the operation mainly depends.

Specialists from different subject areas take part in the construction of mathematical models. The mathematical model must be examined for its correctness. Creating a mathematical model is the most important and responsible part of the research, which requires a deep knowledge not so much of mathematics as of the essence of the simulated phenomena.

In the process of teaching mathematical physics equations, students use subject knowledge in such disciplines of applied mathematics as “Ordinary differential equations”, “Integral equations”, “Numerical methods”, “Optimization Methods” and other disciplines of applied mathematics, in special courses of applied mathematics devoted to mathematical modeling, inverse and conditionally correct problems [14–20]. In the process of such training, computer technologies are used, which allow for mobile research of various applied tasks [21].

The process of informatization of education imposes new requirements on future specialists. The importance of the information competence of the future specialist increases. It is considered in connection with the categories "computer literacy", "information culture" and characterizing the level of personal development in modern society.

Specialists who will use a wide range of computer technology tools in the educational process must have the necessary level of fundamental training in the field of information and telecommunications technologies.

Research methods. Computer algebra systems are widely used in teaching the disciplines of applied mathematics, such as "Equations of mathematical physics", "Ordinary differential equations", "Numerical methods", "Optimization methods" and other disciplines of applied mathematics. Among them are Mathcad, Matlab, Mathematica, Maple, and others, which are also called computer math packages.

Scientific and methodological aspects of the use of computer algebra systems in solving mathematical problems are developed in the works of such authors as I.V. Belenkova, D.P. Goloskokov, E.A. Daher, S.A. Dyachenko, E.V. Klimenko, P.P. Mashkov, S.N. Medvedev, M.I. Ragulin, E.A. Ryabukhin, M.G. Semenenko, Yu.Yu. Tarasevich, etc. (see, for example, [22–25]).

According to E.A. Daher, such systems of computer algebra from the point of view of pedagogy is a didactic means of teaching, which, if there is an appropriate teaching methodology, allows you to optimize the educational process, to intensify it. And from the point of view of computer science, such computer algebra systems are an information technology that is designed to automate the solution of mathematical problems in various fields of science, technology and education [23]. Computer algebra systems have an easy-to-use interface, include analytical and numerical methods for solving various mathematical problems, and tools for visualizing the results of calculations.

The use of computer algebra systems in teaching mathematical physics equations allows us to implement didactic principles of teaching. Let us analyze a number of such principles.

The principle of scientific learning is implemented, since it becomes possible to use them to reflect fundamental scientific achievements in the field of applied mathematics in the content of teaching mathematical physics equations, to form knowledge about general scientific methods of cognition and methods of research of mathematical models based on the equations of mathematical physics.

The principle of scientific learning is close to the principle of fundamental education, which includes the aspect of strengthening the general education component. The use of computer algebra systems in teaching mathematical physics equations contributes to the formation of the ability to interpret and analyze the results of activities, use databases and data banks, use a computer, which refers to the general education training of students.

The use of computer algebra systems in teaching mathematical physics equations implements the principle of systematic learning, which is closely related to the principle of scientific knowledge, forming the quality of knowledge that characterizes the presence in the minds of students of structural connections that are adequate to existing, both intra-subject and inter-subject, connections and reflects the content-logical connections, taking into account the cognitive capabilities of students, previous training and the content of other disciplines of applied mathematics.

In procedural terms, the use of computer algebra systems makes it possible to use various forms and methods that activate the cognitive activity of students.

The use of computer algebra systems in teaching the equations of mathematical physics contributes to the students' awareness of a wide range of connections between the theory and practice of studying the equations of mathematical physics. Inter-subject relations play a crucial role here.

The implementation of the principle of inter-subject connections in teaching students the equations of mathematical physics using computer algebra systems contributes to the reflection in the content of the training of the variety of cause-and-effect relationships that operate in nature and are known by the methods of modern world science. At the same time, interdisciplinary connections act as an equivalent of inter-scientific connections, the methodological basis of which is the process of integration and differentiation of scientific knowledge.

The use of computer algebra systems in teaching mathematical physics equations allows us to consider a large number of examples of the application of mathematical models in various fields of scientific knowledge, including electrodynamics, geoelectrics, geophysics, seismology, astrophysics, photometry, economics, etc., the consideration of which would be impossible without their application due to the complexity of the objects presented and the limited educational time.

The novelty of the educational material presented with the help of computer algebra systems in the discipline “Equations of mathematical physics”, the illustrativeness and practical significance of the studied material contributes to the activation of learning, which is closely related to the formation of a stable cognitive interest.

The implementation of the principle of professional orientation of training when teaching students the equations of mathematical physics using computer algebra systems allows students to develop professionally significant skills and abilities to analyze the role and degree of influence of various factors and conditions on the nature of the studied properties of processes and phenomena.

Students acquire the skills and abilities to interpret the obtained solutions of mathematical physics equations presented in the form of graphs and surfaces.

As a result, students master fundamental knowledge in the disciplines of applied mathematics, such as “Equations of mathematical physics”, "Ordinary differential equations”, “Mathematical modeling”, “Computer modeling”, “Numerical methods”, “Information technologies in mathematics” and other disciplines of applied mathematics. The use of computer algebra systems in the process of teaching mathematical physics equations allows students to realize creativity and initiative in combination with pedagogical guidance, shifting the focus from formal reproduction to active learning.

Results and discussion. An essential characteristic of computer algebra systems is the performance of learning functions by this system. Its application implements the main didactic functions, such as compensatory, informative, integrative, instrumental.

The inclusion of laboratory classes in the process of teaching mathematical physics equations allows, with the use of educational electronic resources, to achieve a high level of knowledge assimilation, mastering the necessary applied mathematical apparatus by activating the educational and cognitive activities of students and makes it advisable to use this form of training organization.

Providing the teacher and students with their extensive opportunities, educational electronic resources become a learning environment in which, as a result of the interaction of the teacher and students, educational, cognitive, creative activities are carried out, this is a mathematical laboratory that allows you to solve a wide range of educational, scientific and professional tasks.

In the laboratory classes, students master computer modeling as one of the modern information technologies in the development of the theory and practice of mathematical model research. It is possible for students to identify certain properties of a mathematical model; to draw appropriate conclusions about the properties of the physical phenomenon under study, which can then be justified, and in the future-to serve as a foundation for theoretical research.

Students acquire the skills and abilities to explore mathematical models by computer means and realize that computer modeling is indispensable in cases where a physical experiment is difficult or impossible to implement due to various circumstances. As a result of such training, students develop an applied mathematical culture and an information culture.

In teaching equations of mathematical physics, in the content of which there is a complex conceptual apparatus, complex mathematical methods, the implementation of such a form of training as laboratory classes using educational electronic resources is justified. Such laboratory classes integrate fundamental knowledge in the field of equations of mathematical physics, develop practical skills and skills of using educational electronic resources in solving mathematical models based on the equations of mathematical physics.

Conclusion. Modern requirements for university graduates require strong subject knowledge, the ability to know about new information technologies and be able to choose the most effective one for solving a professional problem. Also, a modern graduate should have an information mindset.

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