To the question of the problem of continuity in teaching various branches of physics

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Abstract The aim of the work is a methodology for developing sections of general physics and quantum mechanics on the example of two-body effects in accordance with the principle of continuity using modern computing technologies. A technique by which the diffraction of light, x-rays, electrons and neutrons can be demonstrated from one point of view, i.e. consolidation of knowledge using a questionnaire method of researching a work task .

The purpose of the work is a methodology for developing sections of general physics and quantum mechanics on the example of two-body effects in accordance with the principle of continuity using modern computing technologies. A technique by which the diffraction of light, X-rays, electrons and neutrons can be demonstrated from one point of view, ie the consolidation of knowledge using the questionnaire method of research of the task of work.

Keywords: two-body problem, computer technology, the principle of continuity in pedagogy, the principle of succession, light diffraction, microparticle diffraction.

The degree of knowledge of the problem. Prior to this, many succession studies had been carried out. Of these, in the dissertation of E.N. Ovcharenko "The continuity of education in the system of secondary general and higher vocational education based on innovative didactic technologies" proved that the continuous connection between secondary specialized vocational education and higher education is a big pedagogical problem. And on the electronic resource "Theory and practice of implementing continuity in teaching schoolchildren and students" a retrospective analysis of the conditions for the continuity of education, its implementation in the history of pedagogical thought and teaching practice was carried out, the theoretical foundations of the continuity of education were formulated [No. 8, 2 p.]. In the article by AB Polovnikova "Methodological system of continuity of the course of a physics and technology university" (on the example of the introductory section "mechanics"), it was noted that the implementation of the continuity of the course of physics at the university will be determined by the requirement of continuity of the level of education in the conditions of modernization of universities.

Research Methods and Suggestions . For theoretical study of the problem on this topic, a questionnaire method of research and methods of pedagogical experiment are used. During the performance of the work, the following proposals were made, i.e., the effective use of information technologies along with modern pedagogical technologies in studying the problem of continuity in the transfer of various sections of physics.

Introduction. In our previous works, it was shown that the problem of continuity in the study of various branches of physics is associated with the tasks of implementing within subject relations, determining the content, depth and sequence of presentation of educational material, the levels of increase in its complexity and difficulty, with the search for optimal forms and methods for organizing the learning process on different stages of the educational process . This situation put forward the need for a number of issues that are relevant from the point of view of modern methods of teaching physics, the solution of which, in our opinion, is of considerable interest in teaching both general and theoretical physics for undergraduate and graduate programs in the relevant specialty. It is important to note that continuity plays a special role in the study of all branches of general physics and other branches of theoretical physics. Taking into account the principle of continuity not only saves study time for a deeper study of new material, but also contributes to faster adaptation of each student, which is certainly important for the development of a future qualified generalist.

Main part. First of all, we are talking about more important issues of the connection between optics and quantum mechanics, the effective illumination of which can have a decisive influence on mastering the physical essence of the relationship between macroscopic and microscopic phenomena. It is known that historically one of the sources of quantum mechanics was the parallels established by Hamilton between geometric optics and mechanics. These parallels were brought by de Broglie to Modern Physics and this led to the creation of quantum mechanics, which is one of the foundations of modern physical science. However, even with a more superficial consideration of the issue, it becomes clear and, as experience has shown, this issue causes confusion among many students, that the Schrödinger equation does not coincide with any of the equations for wave propagation. The fact is that the equations describing the propagation of waves contain derivatives of the second order in time, while the Schrödinger equation contains derivatives of the first order in time. Naturally, there are other differences as well.

It is known that the wave equation in its mathematical and physical meaning is a linear hyperbolic partial differential equation that specifies small transverse vibrations of a physical object and is one of the basic equations of mathematical physics . For a multidimensional space and when using the Laplace operator Δ, the homogeneous wave equation is written as

$$\Delta u = \frac{1}{v^2}\frac{\partial^2 u}{\partial t^2}. \qquad (1)$$

Here v, is the wave propagation velocity (the so-called group velocity). In the case of a one-dimensional space, (1) is written as $\frac{1}{v^2}\frac{\partial^2 u}{\partial t^2} = \frac{\partial^2 u}{\partial x^2}$it is called the string vibration equation, gives wave functions similar to the eigenfunctions for particles in potential boxes with permeable walls. On the course "Equations of Mathematical Physics" students get acquainted with the methods of derivation and solution of such linear equations. Currently, guidelines for solving differential equations for various specific cases (for example, an oscillating string, vibrations of a rectangular membrane, and many others) can be found in the WOLFRAM Demonstrations Project at https://demonstrations.wolfram.com/, as well as in [No. 3.17]. This situation provides a convenient opportunity for solving the wave equation for numerous specific cases. However, the demonstration of procedures for solving equations of mathematical physics is a complex and time-consuming task. Therefore, in the courses of optics, quantum mechanics, etc. ready-made mathematical packages for computer demonstration should be used. All such demonstrations should lead to the unambiguous conclusion that the trajectories of particles coincide with the rays of light in the medium, the refractive index is proportional to the factor $\sqrt{2m(E-U)}$, which resembles in appearance the factor present in the stationary Schrödinger equation, and the result of this is that the classical mechanics of a material point is analogous to geometric optics.

If equation (1) is considered as an equation of wave optics, then one can easily prove that quantum mechanics is analogous to wave optics. However, at the same time, students should be aware of the Hamilton-Jacobi equation, which is directly related to classical mechanics, which is a single equation that describes the dynamics of a mechanical system with any number of degrees of freedom and is well suited for establishing a connection between classical mechanics and quantum mechanics. This is because it can be obtained almost directly from the Schrödinger equation under conditions of high frequencies (short wavelengths).

It should be emphasized that similar reasoning does not apply directly to undergraduate programs. However, without delving into the details of the derivation and solution methods, and without complicating the studied connection between classical mechanics, optics and quantum mechanics, it is possible by using modern computer simulation methods based on object-oriented programming and computer algebra systems. The experience gained over more than 10 years has shown that in this matter more effective and relatively simple when used directly in the course of the educational process is Mathematica , which is a proprietary computer algebra system widely used for scientific, engineering, mathematical calculations and developed by Wolfram Research [#4, 38] .

When using the computer algebra system Mathematica, the one-dimensional case of the wave equation (1) without boundary conditions is written as follows:

$$DSolve\left[D[u[x,t],x,x] == \frac{1}{v^2}D[u[x,t],t,t],u[x,t],\{x,t\}\right].$$

It should be noted that at present it is possible to solve problems of any type online directly in the educational process by using the site www.wolframalpha.com .

In this case, to solve the problem under consideration, the expression $\frac{d}{dt}\frac{d}{dt}u$[x , t]== $\frac{1}{v^2}\frac{d}{dx}\frac{d}{dx}u$[x , t].

Then one should set the boundary conditions, thereby indicating, say, that the ends of the string during vibrations retain their positions in the form $u[0,t] == 0, u[\pi,t] == 0$. After that, the initial conditions for the motion of the string are introduced, indicating the displacements and velocities of various points of the string at the moment of time $t = 0$: $u[x,0] == x^2(\pi - x), u^{(0,1)}[x,0] == 0$.

Conclusion. Many years of experience have shown that the proposed method of using computer simulation in the educational process in identifying the connection between classical mechanics, optics and quantum mechanics, gave a positive result in deepening students' knowledge of the basic laws of physics. We note that the general-purpose computer algebra system (symbolic computation system) Mathematica used by us is , first of all, a programming language of a relatively high level, approaching in its expressive power to a living language, and it should be studied precisely as a programming language. With its help, you can solve any type of problem in which mathematics occurs in one form or another. It is so easy to use that it is available to schoolchildren and undergraduate students.

It is important to note here that at present there are a large number of computer programs that make it possible to demonstrate the diffraction of electrons and X-rays in various types of crystalline bodies. An interactive program as elegant and easy to use as Single Crystal is designed to visualize and understand the diffraction patterns from single crystals. It allows simulation of electron diffraction patterns and reciprocal lattice cross sections that can be directly compared with observed data. At the same time very easy to use program Ctystal Diffract , designed for the analysis of X-ray and neutron diffraction of powdery and polycrystalline samples on a computer screen, has an interactive control and easily characterizes the obtained experimental data. In all cases, the type of diffraction patterns, as well as the intensity of the spots formed, depend on the nature of specific atoms and their mutual arrangement in the unit cell of the crystal lattice. The demonstration of diffraction patterns obtained using such computer programs aroused great interest among students and undergraduates and formed specific views on wave-particle duality.

At the same time, the skillful use of computer and video equipment directly in the course of the educational process has led to a significant interest of each student in modern pedagogical technologies based on the development of the level of information technology. All this together once again confirms the correctness of our conclusions about the above problems of continuity in the study of various branches of general physics and quantum mechanics. Here it can be noted that continuity in the activities of each teacher should be manifested primarily in the definition of general algorithms for solving the tasks assigned to him, in the systematic use of modern methods and techniques of intellectual and practical activity, in the gradual complication of techniques and methods for transmitting the studied material and, of course, in the systematic introduction of research methods for solving problematic problems. On the basis of this, the course program should be developed or revised, taking into account the requirements of the current stage of the development of society for the training of future specialists, as well as the level of qualification of the teacher and the readiness of students to study the next university sections of physics.

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