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COMPREHENSIVE USE OF CONTINUITY PRINCIPLE AND COMPUTER MODELING IN THE STUDY OF TWO-BODY INTERACTION IN GENERAL PHYSICS AND QUANTUM MECHANICS COURSES

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Abstract. The results of the integrated use of the principle of continuity and computer modeling in the study of two-body interactions in the courses of mechanics (gravitational interaction), molecular physics, optics, atomic physics, and quantum mechanics (electromagnetic effects) from a unified perspective on different in nature physical phenomena during lecture and other types of classes at higher educational institutions are presented. It is shown that by creating a close connection between the principle of continuity and demonstration computer modeling of the phenomena under study, significant success can be achieved in the assimilation of various educational materials. An important component of the application of the principle of educational process continuity, which is conditioned with the visual demonstration of the studied material by means of using the achievements of modern information technologies and the choice of appropriate effective computer programs, was shown. The proprietary system of computer algebra Mathematica, developed by Wolfram Research, was chosen as such a system. The resulting experience showed the advantage of general-purpose computer algebra methods over object-oriented high-level general-purpose programming languages when demonstrating computer experiments. It was shown that the teacher's computer literacy and his virtuoso mastery of the techniques of using computer programs had a significant impact on the students' attitude both to the teacher and to the material being studied. At the same time the teacher's work should follow the principle: the study of any physical phenomenon should be as complete as possible, however, requiring returning to it during the study of subsequent sections on the basis of more general and universal regularities.

1. Introduction

It is known that the continuity of the educational process is a didactic principle, which implies the relationship and the right balance between the parts of the academic subject at different stages of its study. As a necessary condition for organizing and building lifelong education, the continuity applies primarily to educational programs of different levels and orientation. This is due to the fact that continuity provides interconnection of certain stages in the development of

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an educational system in its transition to a new quality. At the same time, currently in Uzbekistan, due to the increasing pace of socio-economic development of the country, the need for continuous development of all levels of the system of public education comes to the fore. The introduction of a credit-module system in educational institutions is a significant example of state support for all educational institutions of the Republic. At the same time, in order to effectively perform the tasks set, higher educational institutions will be empowered to make independent decisions on academic and organizational management. At the same time, as shown in [9] continuity in education is studied both as a pedagogical principle and as a process that ensures the continuity of education. Common problems of continuity for all levels of the educational system are inconsistencies found in the content aspects, forms and technologies of education, and prevent stability and quality in the process of obtaining education.

2. methods used and results obtained

In the light of the above-mentioned requirements, we decided to use the principle of continuity within the framework of six-semester general physics courses when studying the phenomenon of gravitational interaction between two macroscopic bodies in the mechanics course and the chemical bond between atoms and molecules in the molecular physics course, and the electromagnetic interaction between two charged particles (electrons, atomic nuclei) in the optics and atomic physics courses based on a single view of different natural phenomena in terms of general regularities. When considering seemingly quite different phenomena of nature (in the first and second cases subjected to classical mechanics and in the third to quantum mechanics) turned out to be quite common when using the principle of continuity.

When considering the mechanics of motions of space bodies in the course, we usually consider the function

$$V(r) = -G\frac{Mm}{r} + \frac{L^2}{2mr^2},$$

which plays the role of potential energy. In this expression, L stands for the momentum momentum of the planet, other natural or artificial space bodies. G is the gravitational constant. Here both r and L change continuously, and they are related by the formula $L = mvr = mr^2\dot{\varphi}$. At the same time, this formula can also be used for the hydrogen atom or hydrogen-like atoms, where there is quantization of all dynamic quantities by the formulas $r_n = \frac{\hbar^2}{mZe^2}n^2 = r_1 n^2$ and $L_l = \hbar^2\sqrt{l(l+1)}$ (in these expressions n is the principal, l is the orbital quantum numbers, a_0 is the hydrogen atom radius at $n = 1$). The following expression, written in the CGS system, should be used:

$$V(r) = -\frac{Ze^2}{r} + \frac{\hbar^2 l(l+1)}{2m_e r^2}.$$

Here m_e is the mass of the electron, $\hbar$ is the Dirac constant.

For the hydrogen atom, $r_1 = \frac{\hbar^2}{me^2} = a_0$. The values of $r_n = a_0 n^2$ allow us to determine the limits of change in the value of r, which is the distance between the central body (nucleus) and

the electron rotating around it. In the case of considering the motion of cosmic bodies, the values of r change from some small r_{min} to infinity.

The next side of the continuity of the educational process connected with the study of different sections of physics is conditioned with the visual demonstration of the studied material by means of the achievements of modern information technologies and the choice of appropriate effective computer programs. As such a system was chosen Mathematica (or Wolfram Mathematica) - a proprietary system of computer algebra, widely used for scientific, engineering, mathematical calculations and developed by Wolfram Research. Its advantage is associated with the fact that it is equipped with both analytical capabilities, and provides numerical calculations, the results are displayed as an alphanumeric form, and in the form of charts [3-8]. The obtained experience showed the advantage of universal methods of computer algebra over, say, object-oriented high-level general-purpose programming languages when demonstrating computer experiments.

To demonstrate the dependence of $V(r)$ on r for hydrogen atoms, we should set the rules for working with the expressions we need. For example, the values of r_n, which take the values $a_0, 4a_0, 9a_0$, etc., are determined in advance to indicate them in the demonstrated graph using the ListLinePlot command. The dependence $V = V(r)$ is plotted according to the command

$$Plot\left[Table\left[-\frac{2^2}{r}+\frac{\hbar^2 l(l+1)}{2\,m\,r^2},\{l,0,3\}\right],(r,10^{-9},2\ 10^{-6}),PlotRange\rightarrow\{-y1,y1\}\right]$$

This results in numerical values expressed in ergs for $V(r)$. To convert to other units, multiply $-\frac{2^2}{r}+\frac{\hbar^2 l(l+1)}{2\,m\,r^2}$ by the appropriate numerical multiplier. A typical result is shown in Figure 1.

The computer demonstration of the above results had a significant impact on the students' mastery of the proposed learning material and, consequently, there was a 15-20 percent increase in performance. At the same time, it was possible to form students' knowledge of numerical values of specific physical quantities and ability to manipulate them when solving various both scientific and applied problems. On the other hand, the presented computer demonstration experiments led to an increase in students' interest directed to the main essence of computer technology.

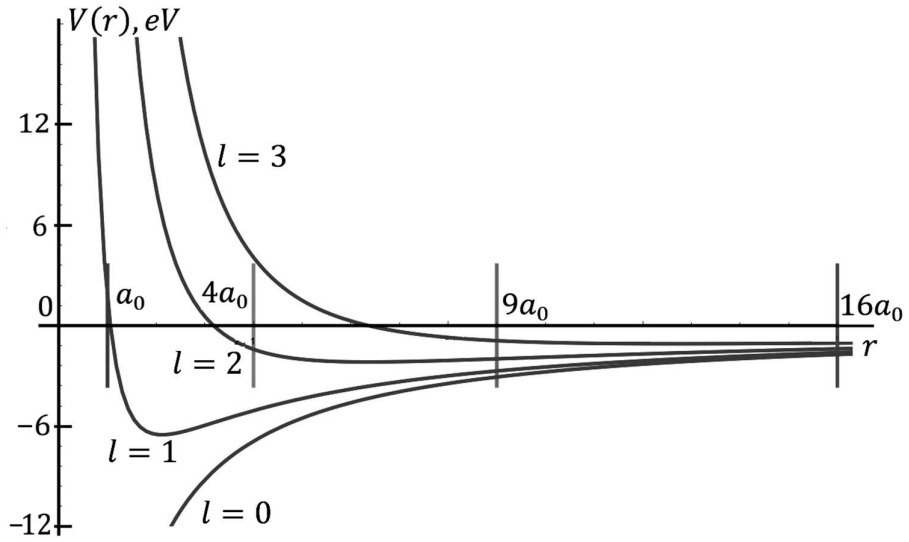

Fig. 1. Dependence of $V(r)$ on r for the hydrogen atom. The horizontal coordinate axis corresponds to r values equal to $a_0, 4a_0, 9a_0, 16a_0$ ($a_0 = 0{,}529$ Å).

3. Conclusions.

Experience has shown that the computer literacy of the teacher and his virtuoso possession of the methods of using computer programs, especially the ability to write mathematical programs during lectures, practical and other types of classes had a significant impact on the attitude of students both to the teacher and to the material under study. It is clearly seen that the problem of continuity in the study of different sections of physics is associated with the tasks of implementing intrasubject links, determining the content, depth and sequence of presentation of the teaching material, levels of increasing complexity and difficulty, with the search for optimal forms and methods of organizing the learning process at different stages of the educational process. In the case under consideration, connections between sections or parts of one relatively large subject are realized in the study of one important physical phenomenon - the motion of bodies in the field of central forces. As one of the optimal methods of teaching, the use of computer technology in all types of classes comes to the fore. At the same time, the teacher's work should follow the principle: the study of any physical phenomenon should be as complete as possible, however, requiring a return to it during the study of subsequent sections on the basis of more general and universal regularities.

Thus, the use of the principle of continuity with the constant and close application of computer simulation led to an increase of students' interest in the materials studied. This led to the formation of unified views on physical processes taking place in different sections of modern physical science.

Literature

1. Матвеев А. Н. М33 Атомная физика: Учеб. пособие для студентов вузов.-М.: Высш. шк., 1989.-439 с.: ил. ISBN 5-06-000056-7

2. Курс теоретической физики, Том 3, Квантовая механика, Ландау Л.Д., Лифшиц Е.М., 2004.
3. В.П.Дяконов. Mathematica 5/6/7. Полное руководство. Издательство ДМК Пресс. Москва. 2010. 624 с.
4. David J. Griffiths, Darrell F. Schroeter. Introduction to Quantum Mechanics. Pearson Education. Cambridge University Press. 2018. 644 p.
5. Nouredine Zettili. Quantum Mechanics. Concepts and Applications. Second Edition. WILEY. A John Wiley and Sons, Ltd., Publication. 2009. 674 p.

Veb site

6. www.wolfram.com
7. http://demonstrations.wolfram.com
8. Stephen Wolfram. An Elementary Introduction to the Wolfram Language. Second Edition. Champaign, IL, USA : Wolfram Media, Inc. 2017. 339 p.

References

9. М.В.Бывшева. Теоретические аспекты преемственности в системе образования. Психология и педагогика: методика практического применения. Научный журнал на тему: Психологические науки, Науки об образовании. 2011. № 22. 259-263 стр.
10. Joraev M., Abdikamalov B., Khozhanazarova R. Methodologocal aspects of using a quantum-mechanical potential well with impermeable walls to explain the Rayleigh-Jeans law using a computer experiment // Academicia An International Multidisciplinary Research Journal. – Affiliated to Kurukshetra University, Kurukshetra, India, Vol.10, Issue 7, July 2020, 116-120p. ISSN:2249-7137. Impact Factor: SJIF 2020=7,13. DOI: 10.5958/2249-7137/2020/00879.4. (13 00 00 № 5)
11. Джораев М., Абдикамалов Б.А., Хожаназарова Р.М. Интерферометр Майкельсона как универсальный физический прибор для демонстрации интерференции света при преподавании курса оптики в высших учебных заведениях// ISSN 2181-1296. Самаркандский государственный университет, Научный Вестник -2021 №2 (126) стр. 189-194.
12. Джораев М., Абдикамалов Б., Хожаназарова Р. Методические вопросы проведения компьютерного эксперимента для демонстрации оптического аналога движения частицы в области потенциального порога // Путь наука, ISSN 2311-2158 Международный научный журнал, №5 (75), 2020, Импакт-фактор 0.543. Волгаград 2020, стр 68-70.
13. Khozhanazarova R.M. Methodology for solving the radiation problem proposed by planck in physics on the basis of the principle of consistency. // Karakalpak Scientific Journal, 2021. Vol. 4. Iss3