

II. ПРОБЛЕМИ МЕТОДИКИ НАВЧАННЯ ФІЗИКИ

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VIRTUAL EXPERIMENTS IN THE STUDY OF QUANTUM PHYSICS

Some aspect of methods of teaching Physics for development and improvement of educational tools for modeling physical phenomena and processes in the course "Atomic and nuclear physics", creation of a future virtual physics laboratory and development of methods for its implementation in an educational process in the secondary school have been examined in the article.

Keywords: *methods of teaching, quantum physics, virtual physics laboratory, ICT tools, combination of virtual and real experiments.*

Formulation of the problem. Didactics of high school uses a variety of tools and methods to motivate the student audience to study physics, quite common among them are traditional and computer information methods. The said is determined by following factors.

On the one hand computer and information methods get a good “psychological” perception among young people, because students mostly have a good knowledge of computer and tend to use it; due to financial difficulties associated with implementing teaching laboratories with modern equipment and devices and the availability of computers a real physical experiment is often replaced with computer simulations. On the other hand, in the teaching of physics as an experimental science lecturer explanation and real demonstration experiment cannot be fully replaced with computer accompaniment even with good graphics or animation, because no model can completely transfer the full reality of the world. Successful demonstration experiment reflecting the physical phenomenon, which is conducted during the theoretical calculations, allows overcoming of formal approach to physics, promotes better perception and assimilation of theoretical material, forms the gained experience into holistic understanding of the world and promotes the world outlook of students; thanks to the successful demonstrations studying physics becomes more understandable and interesting. That is why real physical experiment and computer educational experiment should complement one another, and the smart combination of real and virtual physics experiment in teaching physics is a key issue in modern physics didactics.

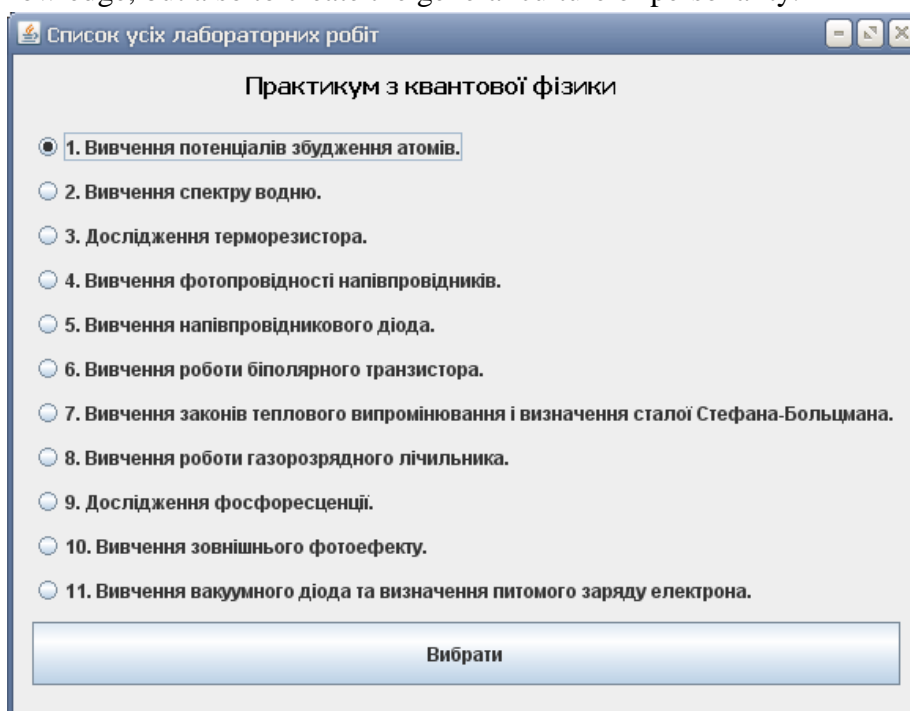
Analysis of earlier studies. Today we may state that appropriate systems and technologies were first introduced into the educational process over 30 years ago, therefore the problem of the use of information technology in teaching physics is considered a lot of scientific and methodological works and researches. The means of information and communication technologies and computer technology are quite well and efficiently integrated in the process of teaching physics in secondary and higher educational institutions as well as into educational physical experiment in atomic and nuclear physics. In particular, didactic and methodological principles of the implementation of computer technology in school physical experiment and educational activities in the computer-oriented learning environment and simulation of physical processes and phenomena by means of computer technology are examined in monographic publications of Y.O. Zhuk, S.P. Velychko, O.N. Sokolyuk and some others [5]; spherical virtual model of education that best match

the modern educational paradigm based on the synergetic approach to teaching physics in the context of the effective functioning of educational experiment is proposed and described in the monograph of I.V. Salnyk [6]. The continuity in the study of main principles and physical properties of liquid crystals in high school are quite convincingly demonstrated and proved in the manual of S.P. Velichko and V.V. Nelipovych [3], based on the creation of the system of virtual experiment that fully reflects all phenomena and processes of liquid crystals studied in high school according to the manual of M.I. Hryshchenko [4] and others.

The main material. So, based on the fact, that physical laboratory practical course plays an important role in university training of bachelors and masters, future teachers of physics, it is an integral part of the study of physics, playing a key role in familiarization students with experimental basics of fundamental physical laws and phenomena, we chose this direction as a major one in our scientific research. Laboratory practical course allows students to master the abilities and skills necessary for deep understanding of the goals and objectives of the school physics course, helps to effectively transmit knowledge to students and thus forms a reliable substantive competence [1, 2].

The students who will carry out laboratory work of a (real or virtual) physical practical course should process educational material according to theoretical data, scrutinize the suggested devices, methodology of investigation and measurement, calculation and determination of appropriate measurement errors.

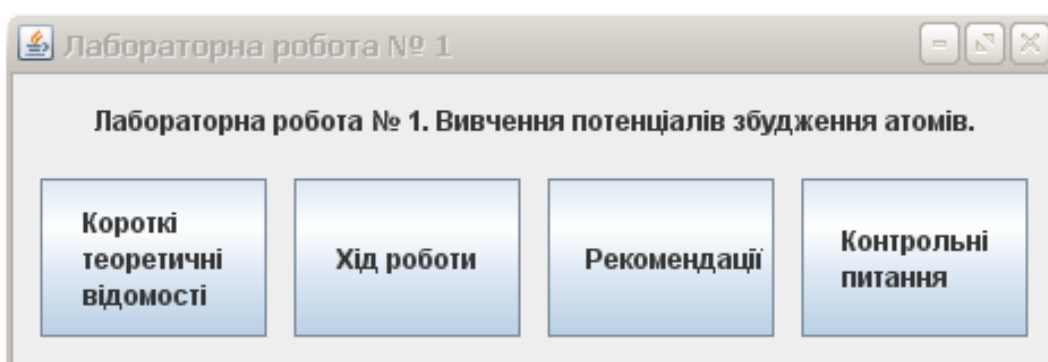
If the experiment is virtual, it is necessary to evaluate the reliability of the results by comparing them with the known results. So an optimal variant of laboratory investigations is combination of implementation of each laboratory work in virtual form (to examine the essence of a physical process) with the following check of the obtained results in the real experiment where possible. Moreover, the possibility of comparing of virtual and real experimental data of the same test allows making conclusions about the relevance of the analogy between the real processes and their simulation on the one hand and the effectiveness of pedagogical software tool development on the other. Thus, the combination of traditional and virtual experiment allow not only to provide professional knowledge, but also to create the general culture of personality.



Graph 1. List of laboratory works in quantum physics

Laboratory practical course on quantum physics in the general physics course suggested to the students in the KSPU n.a. Vynnychenko unites eleven independent laboratory tests. Subjects and content of laboratory works are coordinated with the branch standards of higher education in the training program of Physics and course curriculum of general physics. For each laboratory work students get instructional materials and guidelines including the theme and purpose of the laboratory work, a list of equipment and materials, brief theoretical information, analysis of circuit installation, course of work, objectives and test questions. Simultaneously, the description of laboratory work includes the summary about the structure, operational principles of major devices and proposals to the implementation of additional tasks.

In main program window on the left there are buttons that allow you to select one of the eleven laboratory work and the button “Select” (Graph 1). After clicking the button appears a window with the selected laboratory work, which contains four bookmarks as follows (Graph 2):



Graph 2. Bookmarks for each laboratory work

After selecting the first bookmark appears a new window (while previous windows are still opened; you can move them on the screen so that they don't cover each other, or if necessary minimize the window using the “minus” in the upper right corner of the program, unfold it in full screen (maximize) or close it with help of “cross”). This window contains brief theoretical information for laboratory work; use the sliders to scroll through the contents and read the text.

After selecting the second bookmark opens the window “Course of work” with two active tabs that looks like following (Graph 3):



Graph 3. Course of work

By selecting “Description of installation” the student prepares and checks the equipment integrity and gets ready for the experiment. After choosing “Experiment” the student must select options of the experiment and the task that should be fulfilled (Graphs 4, 5).

Опис установки

Хід роботи

Завдання 1. Зняття вольт-амперної характеристики установки

1. Зібрати схему згідно з рис. 1, строго дотримуючись полярності джерел ϵ_1 та ϵ_2 .

Рис. 1

2. З допомогою Π_1 виставити $U_{K-C} = 0$.

3. Замкнути ключ K і перевірити справність установки. Для цього слід плавно збільшувати U_{K-C} з допомогою Π_1 та спостерігати за показами гальванометра. Якщо при деякому значенні напруги має місце порушення монотонності $\mathcal{J} = f(U_{K-C})$, то установка працює нормально.

Введіть покази U_{K-C}

$U_{K-C}, \text{В}$ $\mathcal{J}, \text{мкА}$

А В

Graph 4. Course of work

It should be noted that this program allows you to perform a virtual experiment with thyatron THZ – 0.1/1.3, filled with xenon and krypton, and compare the results with those of the real physical experiment with the same thyatron. It is also possible to perform a virtual physical experiment with thyatron filled with other inert gases or with mercury vapor (Graph 5).

Опції досліджу

Виберіть наповнення тиратрону

Kr+Xe

Ne

Ar

Hg

Виберіть завдання

Завдання 1

Завдання 2

Вибрати

Graph 5. Options for work with different thyratrons

Experimental basis for Bohr postulates are experiments of Frank and Hertz. Graph 4 (bookmark “Description of installation”) shows a schematic diagram of the installation. The studied atoms (atoms of mercury in experiments of Frank and Hertz) in a state of vapor or gas fill the vacuum tube 1. Mercury atoms receive the required energy from the electrons emanating from the hot cathode 2 and become accelerated by an electric field between the cathode and the grid 3.

On the basis of the law of conservation of energy the following can be written down: $\frac{mv^2}{2} = eU_{K-C}$, where m, v, e, U_{K-C} correspond to mass, speed, module of electronic charge and accelerating voltage between the cathode and the grid, which can be changes with the help of P1 potentiometer (6) and measured by voltmeter V (4). The braking voltage eU_{K-A} between the grid (3) and anode (5) appears with help of the current supply ε_2 of potentiometer (6') (Π_2). Some electrons, the energy of which is higher than eU_{K-A} , overcome the braking (holding) voltage, reach the anode and create anode current I, which is measured by a galvanometer G (7). Varying U_{K-C} from zero to a certain value and measuring the current I, we can construct the current-voltage characteristic. If Bohr postulates are incorrect, then $I = f(U_{K-C})$ should take the form of steadily rising curve. If Bohr postulates are true, then given nature of dependence is violated when $U_{K-C} = U_1; U_2; \dots; U_K, \dots$ etc., when the energy of the electrons equals to $\frac{mv^2}{2} = eU_K = (E_m - E_n)k = khv$, where k is an integer. This energy is sufficient for excitation of atoms in case of collision with electrons. After this first inelastic collision electrons lose their kinetic energy and cannot reach the anode. As a result, the current decreases sharply at U_1 . At further increase of U_{K-C} the current increases again steadily until electrons regain the necessary energy $\frac{mv^2}{2} = eU_2 = e \cdot 2U_1$, when the secondary excitation of atoms will take place and so on [7].

After installation fault check the student performs the task 1 (Graph 5), determines the voltage U_1 at which the current decreases sharply, fills in the table and constructs a dependency graph of the current on accelerating voltage $I = f(U_{K-C})$.

Завдання 1. Зняття вольт-амперної характеристики установки

1. Повернути потенціометр Π_1 у початкове положення $U_{K-C} = 0$.
2. Збільшуючи послідовно на 0,2 В, записати покази мікроамперметра.

Результати вимірювань записати в таблицю 1.

Таблиця 1.

U_{K-C}, B	0	0,2	0,4	0,6	0,8	1,0	1,2	1,4	...
$I, \mu A$									

3. Побудувати графік залежності на міліметровому папері.

Введіть покази U_{K-C}

U_{K-C}, B В $I, \mu A$ А

Graph 6. The results obtained in the task 1

Using the obtained dependency graph, the student determines the maximum voltage at which the current decreased sharply and proceeds to the second task.

Завдання 2. Визначення першого потенціалу збудження

1. За графіком визначити максимальну напругу U_1 , після якої починається спадання струму.
2. Перевірити експериментально результат. Для цього потенціометром Π_1 одержати покази вольтметра U_1 . Потім, збільшуючи та зменшуючи напругу в околі значення U_1 , спостерігаючи за показами гальванометра, виміряти кілька разів U_1 . Результати вимірювань записати в таблицю 2.

Таблиця 2.

$\mathcal{J}_{max}, \mu A$								$\mathcal{J}_{maxexp}, \mu A$
U_1, B								U_{1exp}, B

3. Розрахувати середнє значення першого потенціалу збудження $U_{1\text{сєр}}$ та середнє значення струму $\mathcal{J}_{\text{сєр}}$.
4. Порівняти перший потенціал збудження, одержаний експериментально, з табличним значенням. Знайти абсолютну похибку випромінювання, яку дав даний метод на даній установці.

Введіть покази \mathcal{J}_{max}

$\mathcal{J}_{max}, \mu A$ U_1, B

А В

Graph 7. The results obtained in the task 2

For the self-control students can answer test questions for each laboratory work, as well as open the tabs “Recommendations” and “Control questions” as presented on the graph 8.

Контрольні питання

1. У чому суть моделі атома Резерфорда–Бора?
2. Сформулюйте основні положення квантової теорії будови атома за Бором.
3. Назвіть переваги та недоліки теорії атома за Бором.
4. Чому досліди Франка і Герца вважають експериментальною основою квантової теорії будови атома за Бором?
5. Поясніть принцип роботи установки (за схемою).
6. Чому струм на графіку $\mathcal{J}=f(U_{к-с})$ не спадає до 0 при $U > U_1$, $U > U_2$ і т.д.?
7. Поясніть, у чому причина похибки при вимірюванні U_1 ? Які шляхи зменшення похибки?
8. При якій умові поле між сіткою та анодом буде гальмівним для електронів? Чи одержимо такі ж результати, якщо газ криптон у досліджуваній лампі замінити на інший?

Graph 8. Questions for self-control

Conclusions. The advantage of a computer model of laboratory work is the ability to change the parameters of the experiment (e.g., filling of the thyatron) during its implementation; enhanced

safety; students can perform such work remotely. However, the virtual laboratory work should not be a formal replacement for real physical objects and processes, it should also provide possibility for obtaining new results under modified options of investigated objects that stimulate creative thinking of the student.

The next stage of work is, in our opinion, the further development and improvement of software tools for the simulation of physical phenomena and processes in the course “Atomic and nuclear physics”, widening the virtual physics laboratory and developing methods of its implementation in the educational process.

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Кіровоградський державний педагогічний університет імені Володимира Винниченка
ВІРТУАЛЬНИЙ ЕКСПЕРИМЕНТ У ПРОЦЕСІ ВИВЧЕННЯ КВАНТОВОЇ ФІЗИКИ

У статті розглянуто окремі аспекти методики фізики, які можуть бути покладені в основу розробки та удосконалення програмних засобів для моделювання фізичних явищ та процесів з розділу «Атомна і ядерна фізика», створення віртуальної фізичної лабораторії та вироблення методики її впровадження у навчальний процес як середньої, так і вищої школи.

Ключові слова: методика навчання, квантова фізика, віртуальна фізична лабораторія, засоби ІКТ, поєднання віртуального і реального експерименту.

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ВІРТУАЛЬНИЙ ЕКСПЕРИМЕНТ В ПРОЦЕСЕ ИЗУЧЕНИЯ КВАНТОВОЙ ФИЗИКИ

В статье рассмотрены отдельные аспекты методики физики, которые могут быть положены в основу разработки и усовершенствования программных средств для моделирования физических явлений и процессов с раздела «Атомная и ядерная физика», создание виртуальной физической лаборатории и выработки методики ее внедрения в учебный процесс, как средней, так и высшей школы.

Ключевые слова: методика обучения, квантовая физика, виртуальная физическая лаборатория, средства ИКТ, сочетание виртуального и реального эксперимента.

ВІДОМОСТІ ПРО АВТОРІВ

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