ІІ. ПРОБЛЕМИ МЕТОДИКИ НАВЧАННЯ ФІЗИКИ

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VIRTUAL EXPERIMENT: RESEARCH PHOSPHORESCENCE

Virtual physics experiment for phosphorescence investigation, which can be taken as a basis for developing and improving the software for simulation of physical phenomena and processes in the course "Atomic and nuclear physics", creation of virtual physics laboratory and development of methods for its implementation in an educational process in the secondary and high school have been examined in the article.

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

Formulation of the problem. Physical laboratory practical course is an integral part of the study of physics and plays a key role in familiarization students with experimental basics of fundamental physical laws and phenomena. It plays an important role in university training of specialists in the branch of study "Physics" of educational qualifications "Bachelor" and "Master", future teachers of physics, that is why we have chosen this direction as the major one in our scientific research.

Computerization of laboratory practical course and implementation of off-the-shelf software, as well as custom programs developed at the chair can significantly reduce the time for processing experimental data and expand the practical course, conducting research in computer environment, which is for whatever reason inaccessible for the real experiment.

Moreover, the possibility of comparing of virtual and real data of the same experiment 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 allows not only to provide professional knowledge, but also to create the general culture of personality.

Every educational course is structured in the way that a significant portion of time is devoted to unsupervised activities, which are inextricably connected with lecture, practical and laboratory part of the course. We believe that the opportunity of holding an unsupervised virtual experiment at home with the subsequent execution of some tasks of appropriate real laboratory practical experiment at higher educational institutions allows students to organize, plan and regulate their own learning activities, do a self-assessment and effectively evaluate the results of their actions. All together allows to manage individual activities, stimulates intellectual activity of students, enhances learning motivation, develop learning skills and self-teaching skills, that can be achieved through expansion and deepening of educational technologies and techniques. Therefore virtual physical experiment contributes to better learning material retention, mastering the system of skills necessary for deep understanding of the goals and objectives of school course of physics that helps to effectively transmit knowledge to students and thus forms a reliable substantive competence of future teachers of physics.

We believe that the virtual physical experiments and real laboratory practical course both have a separate value and role for studying physics and should not substitute each other. In our opinion, the reasonable combination of real and virtual physical experiments in teaching physics is a key issue in modern physics didactic and meets an innovation policy in the Ukrainian higher education system.

Another demand of today to have respect while physical education in high school to is a good command of foreign language/-s. The total global trend of nowadays is aimed towards European integration in the educational, economic, cultural and political spheres. Foreign language proficiency allows for access to information in the subject areas, for obtaining the new relevant information on the subject, provides students with more chances to compete in the European market for professionals of the industry.

Analysis of earlier studies. Today we may state that appropriate systems and technologies, which were first introduced into the educational process over 30 years ago, have become to an integral part of teaching process and showed themselves as a highly efficient learning tool. Therefore the problem of the use of information technology in teaching physics is still actively investigated in the wide range 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]; a virtual model of education that best matches 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 the secondary school are quite convincingly demonstrated and proved in the manual of S.P. Velychko 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. Laboratory practical course on quantum physics in the general physics course suggested to the students in the KSPU n.a. Volodymyr 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.

One of the convincing examples is the laboratory work № 9. Study of phosphorescence.

The goal of this work involves representing the phosphorescence decay curve by a diagram and defining a constant in the hyperbolic law.

The lab work is performed on following equipment: a plate, covered with a layer of phosphorus, placed in the lightproof camera; reflecting galvanometer; fluorescent lamp; stopwatch.

At the beginning we want to give some theoretical data: S.I. Vavilov defines luminescence as a propensity of the object to glow, exceeding the thermal radiation of the same object in this part of the spectrum for a given temperature, if this glow has a finite duration (i.e. does not stop immediately after removing the factor that it caused) and much longer than optical vibrations. The difference between the thermal radiation and luminescence is that the energy absorbed by a substance is going to increase the potential energy that is not passing to thermal vibrations of atoms, but is partially or fully released. A substance that absorbs energy does not interact or interacts weakly with the environment.

Luminescence is generally classified by the type of excitation, mechanism of energy transformation and character of glow. By type of excitation are distinguished photoluminescence – excitation by light; radioluminescence – excitation by ionizing radiation; X-ray luminescence – excitation by X-rays; cathodoluminescence – excitation by an electron beam and others. By duration of the glow are distinguished fluorescence – rapidly decreasing luminescence and phosphorescence – lasting luminescence [7, p. 67].

After the extinction of external exciter the luminescence fades within some time; luminescence is conventionally divided into fluorescence (τ <10-8s) and phosphorescence (τ> 10-8s). This characteristic of the luminescence distinguishes it from reflection, light dissipation, stagnation glow of charged particles or stimulated emission. Substances (solid and liquid), capable to phosphoresce, are called crystal phosphors (CF) or luminophores.

The basic laws of photoluminescence include:

1. Stokes' law: the luminescence wavelength is always greater than the wavelength of light that excites luminescence.

2. The existence of anti-Stokes luminescence resulted in Stokes'-Lommels law: radiation spectrum of luminophores and its maximum are shifted compared to the excitation spectrum and its maximum into the direction of long waves.

3. For complex molecules is valid law (or rule) of reflexive symmetry of Levshin: absorption and radiation spectra, shown as a function of frequency, are reflection symmetric about the line, perpendicular to the frequency axis in the intersection curves of both spectra.

4. Law of constancy of luminescence spectrum: regardless of method of excitation and wavelength of exciting light the spectrum of luminescence remains constant at a given temperature.

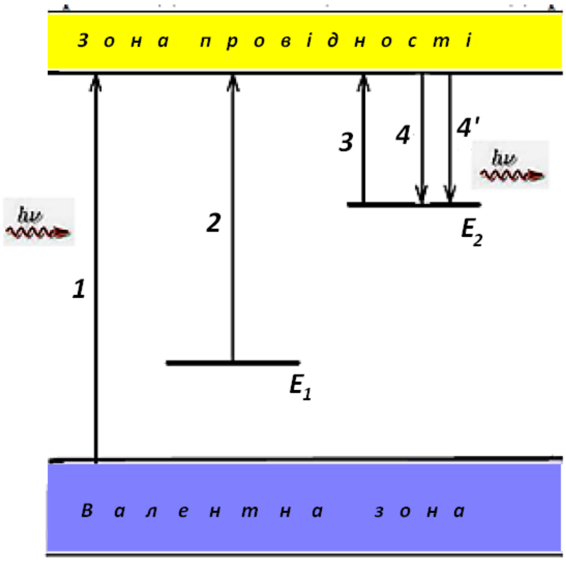
5. The luminescence yield is one of the most important characteristics of luminescence. There are quantum yield and energy yield of luminescence.

Quantum yield is a value that indicates the ratio of the average number of emitted photons to one absorbed: $\varphi = \frac{N_{вип.}}{N_{погл.}}$.

S.I. Vavilov has demonstrated that the quantum yield in solutions does not depend on the wavelength of exciting light. It is connected with high velocity of vibrational relaxation, during which the excited molecule transfers the excess energy to the molecules of the solvent.

Energy yield is the ratio of energy of emitted photons to the energy of absorbed photons: $E = \frac{E_1 N_{\text{âèï.}}}{E_2 N_{\text{ïîãë.}}} = \varphi(\nu_1 / \nu_2)$.

By increasing wavelength of the exciting light the energy yield initially grows in proportion to the wavelength of the exciting light, then remains constant, and after a certain wavelength decreases sharply (Vavilov law) [7, p. 69].



Graph 1. The mechanism of luminescence

Phosphorescence in solids is explained based on the band theory. To explain the mechanisms of luminescence are usually considered two adjacent zones (Graph. 1): the last filled zone is a valence band (PFA) and the first free zone is a conduction band (W). In the energy bandgap between the filled zone and free zone there are local levels caused by defects or impurities in the crystal lattice.

During excitation of a crystal (irradiation with light, X-ray or γ-rays, electron bombardment, etc.) electrons can be moved in the conduction band from valence states or local levels of point defects (Graph 1, transitions 1, 2, 3). In the latter case takes place the ionization of point defects (transitions 2, 3).

An electron that got into conduction band loses contact with the atom to which it belonged before, and is moved by a crystal until it reaches a defect in the crystal lattice, for example, an activator formed defect that also lost its electron – an ionized one. Recombinating with the ionized center, the electron transmits an excess energy in the form of photon (radiative transition 4') or heat (non-radiative transition 4). The process accompanied by ionization (collapse) of electron-trapping centers with the following radiative recombination is called *recombination luminescence*. Luminescence that is not accompanied by the transfer of charge carriers is called *non-recombination*.

Luminescence decay law in the idealized case, where crystal phosphors (CF) have only luminescence centers and no electron-trapping centers, can be derived as follows. If the number of ionized luminescence centers N and electrons in the conduction band n stay the same at any point of time, and β – probability of recombination of the electron with luminescence center, then reduction in the number of ionized luminescence centers in time dt can be expressed in the following way:

$$-dN = \beta N n dt = \beta N^2 dt \quad (1)$$

Having taken the integral (1), we get: $1/N = \beta t + const.$ (2)

If the stopwatch timing is lead since the deexcitation moment and assign N_0 as the number of ionized luminescence centers at the time t, then $const = 1/N_0$ and $1/N = \beta t + 1/N_0$;

from which $$N=N_0/(1+\beta N_0 t). \quad (3)$$

If neglected the probability of non-radiative transitions of excited luminescence centers into the basic one, the intensity of luminescence can be considered proportional $-dN/dt$. That is why $I \sim$

$dN / dt = \beta N^2$ or $I = \beta N_0^2/ (1 + \beta N_0\, t)^2$, when $t = 0$ $I = I_0 = \beta N_0^2$, thus the finite expression is:

$$I = I_0/(1+(\beta I_0)^{1/2}t)^2 \text{ or } I = I_0/(1+\alpha t)^2. \qquad (4)$$

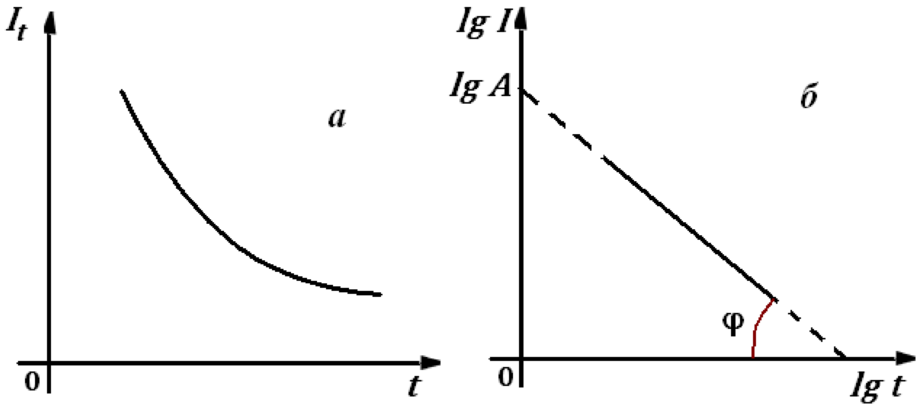
Thus, for CF with no electron-trapping centers the luminescence decay law is hyperbole of the second kind. Experience suggests that in some cases the luminescence decay of CF is really described by a hyperbole of the second kind.

But more often, as was proved by Becquerel (1868), experimentally observed decay laws are the hyperbole with an exponent less than two:

$$I = I_0 / (1 + \alpha t)^n, \qquad (5)$$

where $1\leq n \leq 2$, α – constant, which lies in rather wide range (from fractions of c^{-1} to many thousands c^{-1}).

The discrepancy between the conclusions of the foregoing theoretical analysis with experiment is understandable, because the reception of luminescence decay law was held for an idealized case where phosphor has luminescence centers and no electron-trapping centers. In a real CF there is a lot of electron-trapping centers next to luminescence centers. Furthermore, there are CFs containing luminescence centers of two or more kinds. So the problem of theoretical finding of luminescence decay for real CF is quite complicated.



Graph 2. Graphical dependencies $I_t = f(t)$, $\lg I_t = f(\lg t)$

Let's transverse (5) (taking α off the table) and receive $I_t = \dfrac{A}{(B+t)^n}$. (6)

So long as $t>>B$ we get $I_t = \dfrac{A}{t^n}$. (6′)

We take the integral of (6′): $\lg I_t = \lg A - n \lg t$. (7)

Graphs 2,*a* and 2,*б* reflect graphical dependencies $I_t = f(t)$, $\lg I_t = f(\lg t)$.

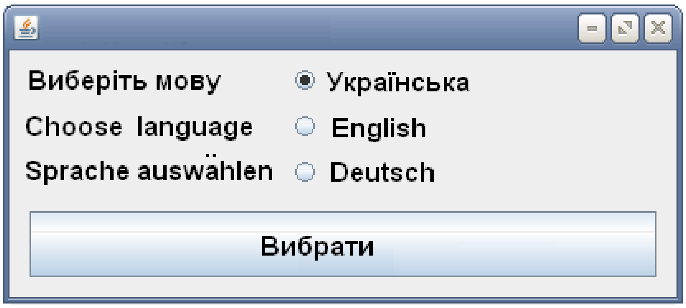
From graph (Graph 2,*б*) we can find the hyperbolic index $n = \text{tg}\varphi$, (8)

as well as the constant ***A***.

representing the phosphorescence decay curve by a diagram and defining a constant in the hyperbolic law

To represent the phosphorescence decay curve and find the constant *A* in the hyperbolic law we have created educational software in Java programming language. The interface of the created program for virtual laboratory works in quantum physics is designed in uniform style, intuitive and easy to use.

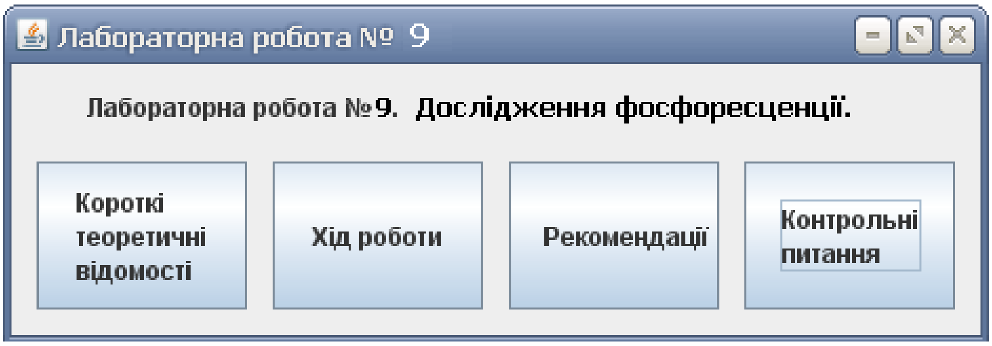
Taking into account the needs of educational process you can select one of three languages buttons in the first window, so it looks (Graph 3):



Graph 3. Choice of language

After pressing the button "Select" there appears a new window with the catalog of laboratory works in quantum physics, previous windows are still opened; you can move them on the screen so that they don't cover each other. If necessary you can minimize the window using the "minus" button in the upper right corner of the program, unfold it in full screen (maximize) or close it with help of "cross".

After choosing the laboratory work appears a new window with the selected laboratory work that contains four bookmarks, corresponding to real laboratory practical stages (Graph 4):

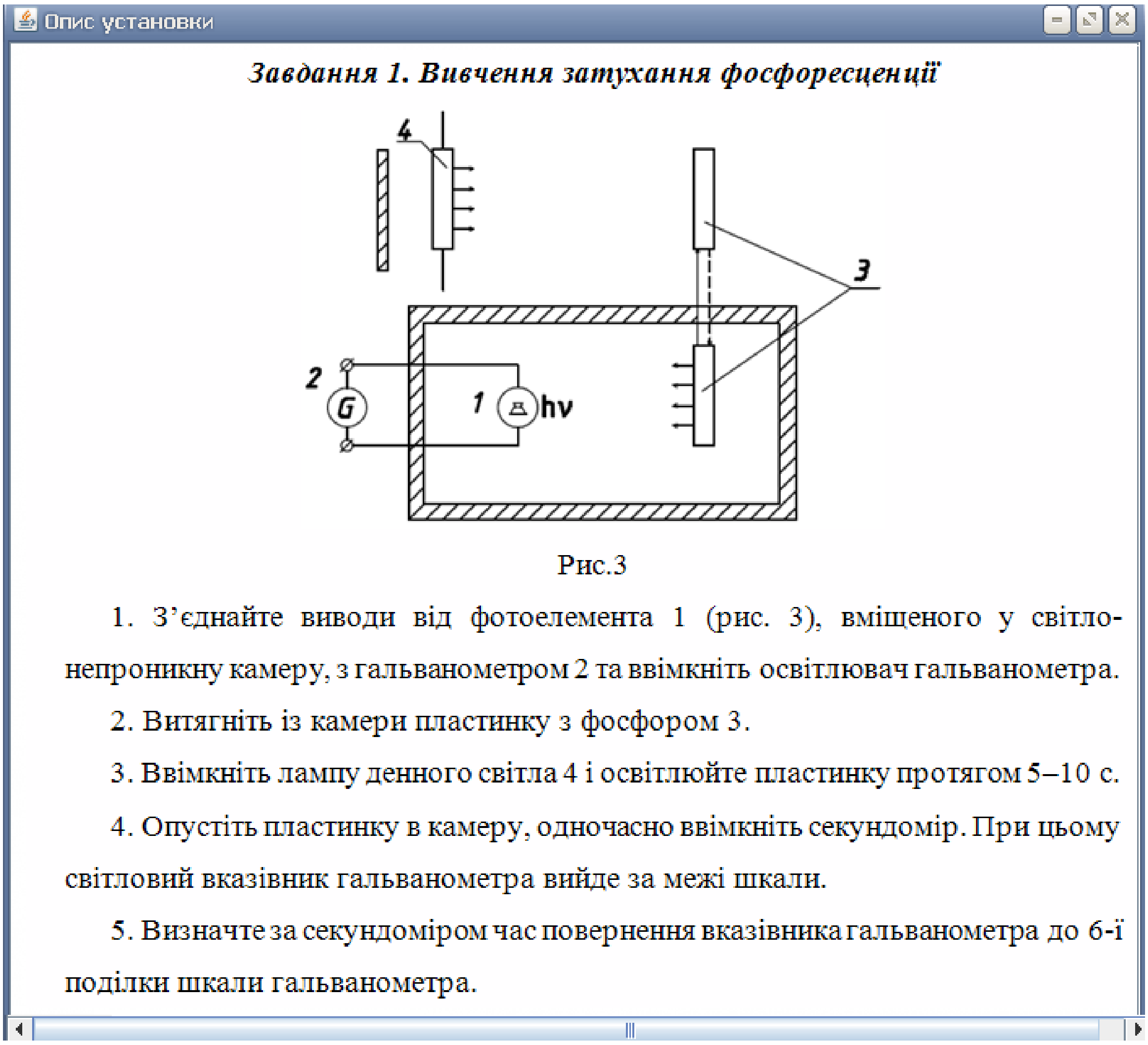


Graph 4. Bookmarks to the laboratory work

After choosing the first bookmark we get a new window containing 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 5):

Graph 5. 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 according to the instructions and guidance requirements (Graph 6):



Graph 6. Task 1. Study of phosphorescence decay

The student repeats the experiment paragraphs 2-5 3 times recording all measurements to the table; then he runs the experiment again for paragraphs 2-6 with 5, 4, 3, 2, 1 galvanometer ticks. All the results are recorded to the table as well and are used during constructing the graph $I_t = f(t_{cep})$.

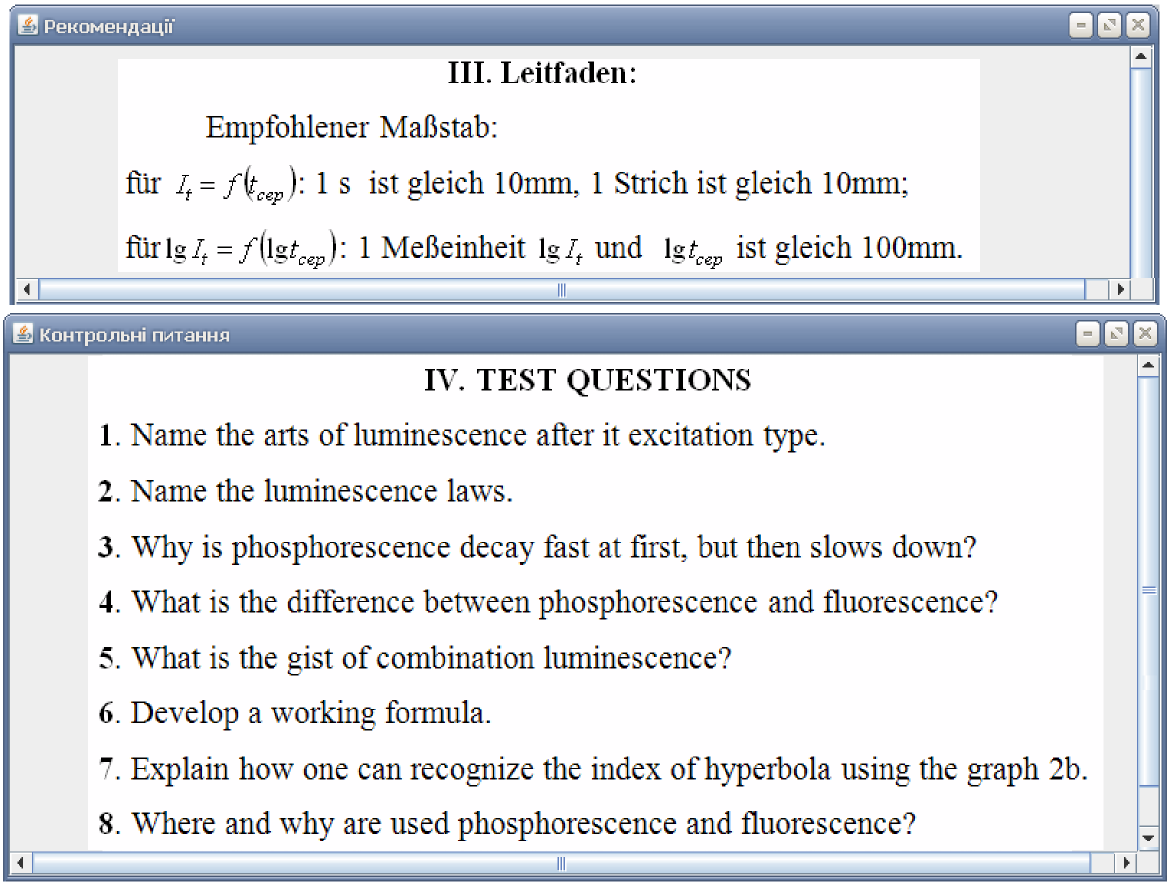
Galvanometer indications in divisions, s	*I*, A	*t*, s	$t_{cep.}$, s	$lg\ I_t$	$lg\ t_{cep.}$
6					
…					

The second task foresees the definition of the hyperbole index and constant A through approximation of the received function: the student must determine the decimal logarithms of the average time and galvanometer indications; construct a dependence plot $\lg I_t = f(\lg t_{cep})$; extrapolate the obtained direct to its intersection with coordinate axes; find *lg A* on the graph and then determine *A*.

Using the graph, the student finds *n*; *tg*φ; selecting three arbitrary values $t_{cep.}$ and I_{cep}, calculates by (2) the value *B*. At the end of work the student has to record the luminescence decay law (2) with the calculated values of *A*, *B* and *n*.

The developed software provides an opportunity to represent all the content in Ukrainian, German and/or English.

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 7 in German/English.


Рекомендації

III. Leitfaden:

Empfohlener Maßstab:

für $I_t = f(t_{cep})$: 1 s ist gleich 10mm, 1 Strich ist gleich 10mm;

für $\lg I_t = f(\lg t_{cep})$: 1 Meßeinheit $\lg I_t$ und $\lg t_{cep}$ ist gleich 100mm.

Контрольні питання

IV. TEST QUESTIONS

1. Name the arts of luminescence after it excitation type.
2. Name the luminescence laws.
3. Why is phosphorescence decay fast at first, but then slows down?
4. What is the difference between phosphorescence and fluorescence?
5. What is the gist of combination luminescence?
6. Develop a working formula.
7. Explain how one can recognize the index of hyperbola using the graph 2b.
8. Where and why are used phosphorescence and fluorescence?

Graph 7. Recommendations and Control questions

Conclusions. The present level of development of computer technology and software enables great opportunities to modernize and improve the efficiency of the educational process. Using the best traditional and innovative means and forms in education diversifies it and improves the quality of learning. 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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ІННОВАЦІЇ В УПРАВЛІННІ НАВЧАЛЬНО-ПІЗНАВАЛЬНОЮ ДІЯЛЬНІСТЮ УЧНІВ З ФІЗИКИ

Стаття присвячена дослідженню проблеми управління результативною навчально-пізнавальною діяльністю учнів з фізики. Доведено, що завдяки цілеспрямованому управлінню процесом навчання гарантовано забезпечується можливість формування прогнозованих компетентнісно-світоглядних якостей школяра. В статті наведено фрагменти веб-квесту «Енергозбереження – крок до майбутнього!».

Ключові слова: *фізика,парадигма, інновації, управління навчанням, теорія, веб-квест, компетентність, світогляд, старша школа.*

Постановка проблеми. Дослідження та розв'язання проблеми управління навчальною діяльністю зумовлена потребами сучасності.

Вимоги сучасної освітньої парадигми орієнтують науковців на створення та обґрунтування наукової теорії управління навчанням, методології освітнього прогнозу й сценаріїв інноваційних технологій результативного навчання [3].

Аналіз актуальних досліджень. Активними пошуками відповіді на питання про удосконалення змісту і якості фізичної освіти займались і займаються багато учених: П.С. Атаманчук, Л.Ю. Благодаренко, С.П. Величко, О.І. Іваніцький, О.І. Ляшенко, М.Т. Мартинюк, В.Ф. Савченко, М.І. Садовий, В.Д. Сиротюк, В.Д. Шарко, М.І. Шут та інші.

Проблема управліннянавчально-пізнавальною діяльністю багатоаспектна, тому широко представлена в педагогічних, психологічних і філософських дослідженнях. Результати наукових пошуків і досліджень П.С.Атаманчука (докторська дисертація «Теорія і методика управління пізнавальною діяльністю старшокласників у навчанні фізики») та узагальнені наслідки колективного доробку науковців кафедри методики викладання фізики і дисциплін технологічної освітньої галузі Кам'янець-Подільського національного університету імені Івана Огієнка засвідчують факт існування науково обґрунтованої концепції (теорії) навчання студента (учня) [1 -3].

Метою статті є обґрунтування наукової теорії управління навчанням, детальне розкриття передумов створення теорії, а також висвітлення одного із сценаріїв інноваційних технологій результативного навчання.