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Methodological Bases for Study Nanotechnology in the General Physics Course of Higher Educational Institutions

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The paper describes methodological aspects of students' knowledge formation about the basic concepts of nanoscience and nanotechnology in General Physics course of higher education. The inclusion of the concepts of nanophysics and nanotechnology in the fundamental physical terms and concepts general list were proposed. Physics aptitude provide formation the graduate competences in the context of nanoscience through progressive systemic administration of certain issues in the General Physics content were shown. Particular attention is paid to the selection of material for nanotechnology in teaching students of different specialties. Proved that the inclusion in the subject material the specific issues associated with nanotechnology allows you to create a culture in the use of terminology; shown the relationship of knowledge gained in the course of physics with the requirements of time; improved targeted training for current production lines universities.

Keywords: Nanoscale, Nanotechnologies, Course of General Physics, Higher education, Nano-objects, Nanoparticles, Method for teaching nanotechnologies.

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1. INTRODUCTION

XX-th century was a turning point in the development of the education system. The goals and tasks that it solves have changed. The rapid development of science and technology has led to major changes in human life. Consequently, there is a need in the reflection of modern advances in education. This is especially true nanotechnology. Awareness of the role of nanotechnologies in the development of each economic sector by the leading countries of the world has led to their recognition as the highest national priorities. Special training programs were approved and substantial funds were allocated for their implementation.

Physics as an academic discipline in higher education has a wide range of opportunities for this task. Physics as a science of the phenomena of nature is the foundation of all modern science. It has an exceptional place in the general system of knowledge accumulated by mankind. Physics demonstrates that we can to construct logical and exact model of the world's construction based on a small number of well-founded experimental principles and a powerful mathematical apparatus.

Physics as a discipline is studied not only by future scientists and teachers of physics, but also by future specialists from various industries. For some, it is a profession, for others, a base for the study of specialized disciplines or has only a worldview. In all cases, its content should reflect the current state of development and achievements of science.

Analysis of the trend of higher pedagogical education in Ukraine in the context of the study revealed some problems contradiction:

- between the need to ensure in teaching the inherent physics unity of the fundamental and applied constituents of the content from one side and the dominant academic teaching of physics, lack of proper interconnection of acquired knowledge with actual practical application from another side;
- between the need to deepen the fundamental training of students on the actual problems of nanoscience and nanotechnology and the significant backlog of educational programs of institutions of higher education from the current state of development of physics;
- between the need of society for the development of the nanotechnological component of the education system at all its levels and the low level of development of the methodology of teaching nano-sciences in higher and secondary schools, the lack of scientific and methodological sources for popularizing knowledge about the current state of development of nanotechnologies and properties of nanoobjects.

Thus, there is need for a comprehensive correction the situation. It is necessary to begin from the training of pedagogical and professional staff in the field of nanotechnology and the inclusion of nanotechnology in the content of disciplines of higher education physics courses.

2. ANALYSIS OF ACTUAL RESEARCH

The problem of studying the basics of nanotechnology has recently been widely discussed by scholars on the pages of pedagogical and methodological works. However, there are no practically studies in the theory and methodology of teaching physics, the result of which is creation of methodological foundations for the formation of students of knowledge about nanotechnology in the general physics course. Only some publications deal briefly with some general issues of nanophysics and nanotechnology. The purpose of this work is to highlight the results of research on teaching methods related to nanotechnology in various sections of the general physics course at higher education institutions.

3. FEATURES OF INNOCENTATION OF NANO-SCIENCE ISSUES IN VARIOUS SECTIONS OF

THE PHYSICS HIGHER EDUCATION COURSE

Particular attention should be paid to the selection of nanotechnological material in teaching students. Future engineeres will study a narrow range of issues in nanoscience, thats why physics will provide basic knowledge that will be necessary for their profession. For future teachers, the breadth of knowledge gained from various fields of science and technology, including nanotechnology, is more important. The physics teacher at school should be equally well-informed in different fields of nanotechnology and in the possibilities of their application. When a teacher knows the basic concepts of nanotechnology, he can to understand the basic relationships and patterns occurring in the nanoscience, and to explain it to the students in accessible form.

There are various ways to receive the information in the field of nanotechnology for students. First of all, the sources of such information are materials presented on the Internet and in periodicals. But the main source is the physics course at the university. The selection of material from nanotechnology should be determined by professional orientation.

The concepts and formulations of the laws of the nanoscience can be equally well used in the study of various sections of general physic course. As illustrations of a number of physical phenomena and processes, it is possible to discuss relevant phenomena and processes that are important for the development of nanotechnology. The concepts and principles of nanotechnology are necessary to consider the prospects for development of various branches of modern science: molecular technology, the transition from microelectronics to nanoelectronics, the study of quantum phenomena and processes, etc.

When planning the courses of general and theoretical physics, it is necessary to include elements of nanotechnology in different sections.

Integration of nanoscience and nanotechnology into the course of general physics of higher educational institutions is presented in the block diagram (Fig. 1). It shows sections of the general physics course and suggests topics for studying each section.

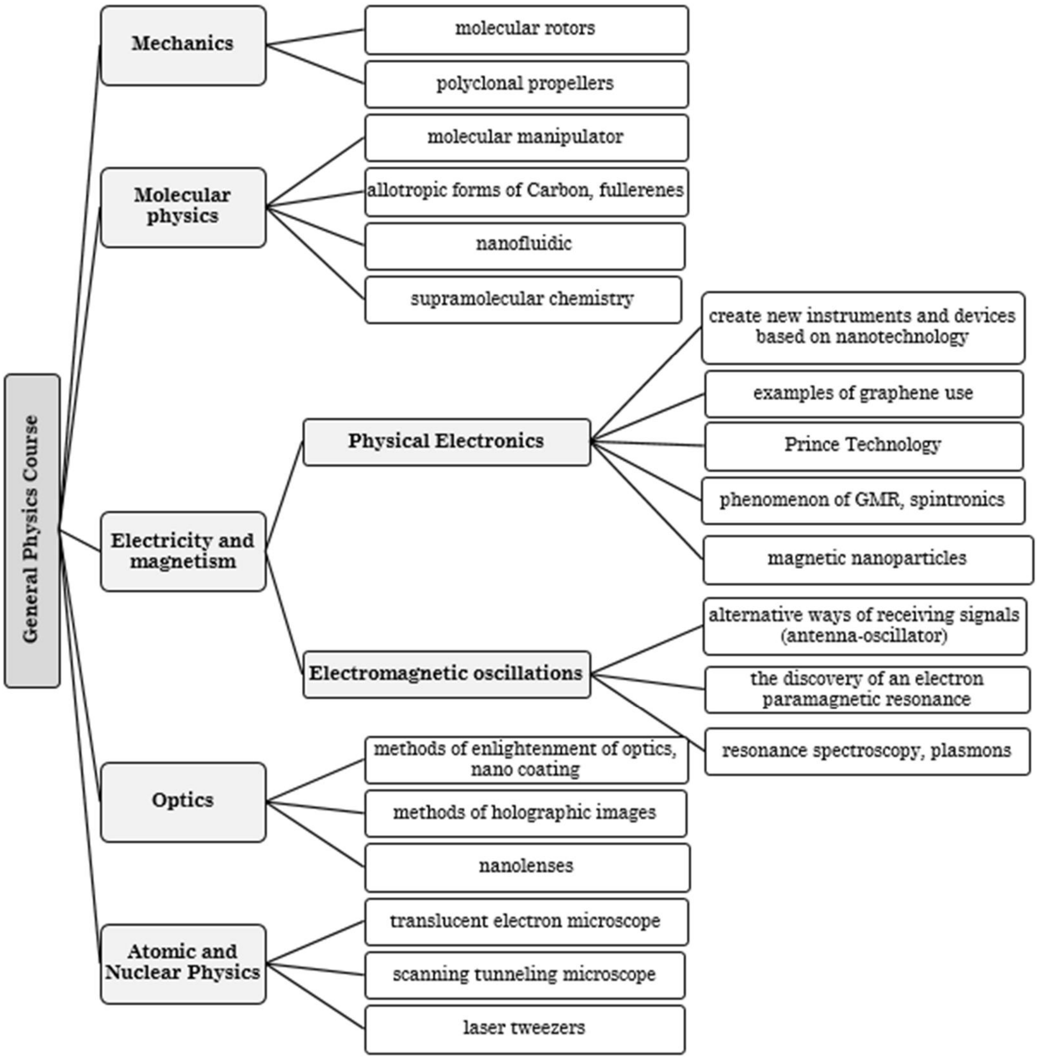

Fig. 1 – Inclusion of nanoscience issues in different sections of the physics course

The first in essence introductory lecture is devoted to the beginning of studying the course of general physics. In explaining the significance of mechanics laws, the teacher can show how the simplest laws of classical mechanics applied to different objects of the macro world are also important for the microcosm. The scale changes the functional purpose of many objects, which are used both in everyday life and with the production purpose.

In subsequent lectures, for example, in the study of energy, should tell about a Nano Engine - a molecular device capable of converting energy into motion (Fig. 2)[1]. The attention of students is fixed not only on the new device of the microworld, but also on the units of measurement of the molecular motors forces of proteins measured in piconeton. For example, the protein engine can move "cargo" - various molecules through the channels of micro tubes inside the cells. This allows students to focus on the fact that knowledge of the mechanisms of movement is studied within the various technical disciplines, and acquire a new relevance in the context of new technologies.

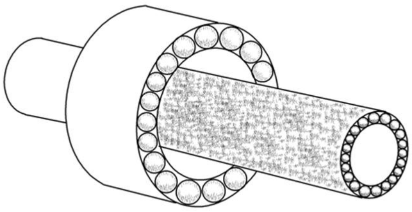

Fig. 2 – Schematic view of the nanoengine

When studying the rotational motion in the section "Mechanics", it is extremely important to talk about molecular rotors [2]. These are synthetic nanoscale engines that generate torque when feeding enough energy. Interesting and useful information is about molecular propellers – nanosized screw-shaped molecules. They are capable of making rotational motion due to their special spatial shape, which is a similar form of macroscopic screw [3].

Possibilities of using examples related to nanotechnology are significantly expanded in the study of the main provisions of Molecular Physics.

When substantiating the basic provisions of the molecular-kinetic theory, it should be pointed that the modern research base provides not only to see the atoms but also to assemble ones.

When comparing models of ideal and real gas, one can cite an example of creating a molecular manipulator [4]. It should be emphasized that in this case the gravitational interactions are less important and the influence of intermolecular interactions and Van der Waals forces become significant.

Note that the same combination of atoms in various forms leads to new materials. Here you can give an example with carbon fiber. Until recently, it was known that carbon forms three allotropic forms: diamond, graphite and carbine. The fourth allotropic form of carbon, the so-called fullerene, is already known today. This discovery (1985) allowed to extend the range of newly synthesized materials with extraordinary physical and chemical properties. In the late 80's and early 90's, after the development of a technique for obtaining fullerenes in macroscopic quantities, a number of other than lighter and heavier fullerenes were found: from C20 to C70, C82, C96, etc. [5,6]. Fullerenes are empty inside. Such cavity can contain any third party atom. When the fullerene molecule introduced metal atoms, such complexes called metallo-fullerenes. They are promising for application in nanotechnology and Nano chemistry.

When considering physical models of liquids, we can talk about Nano fluidics. This is a section of the hydrodynamics of nanostructured liquids. It studies non-typical properties of liquids such as a sharp increase or decrease in the viscosity of nano-capillary walls, a change in the thermodynamic parameters of the liquid, and also atypical chemical activity at the interface between the solid and liquid phases [7].

To emphasize the importance of studying intermolecular interactions can be mentioned about such a new science as supramolecular chemistry [8]. It includes chemical, physical and biological aspects of the study of more complex molecules than conventional, chemical systems connected into a whole by means of intermolecular (non-covalent) interactions, forming a kind of blocks. For example, Chinese scientists have developed a nanocontainer for hydrogen storage. Such molecular structure (Fig. 3) is a single-carbon nanotube blocked by fullerene molecules. Its ends are closed by fullerene half-spheres.

The nanocontainer can hold hydrogen at pressure equivalent to several gigapascals (GPa).

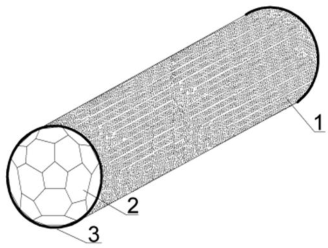

Fig. 3 – Schematic view of the nanocontainer: 1 is a single-carbon carbon nanotube, 2 is a fullerene molecule, 3 is the fullerene semispheric

The above topics can be offered to students as subjects of mini-research tasks of their independent work or preparation for practical classes and seminars.

When considering surface tension, capillary phenomena, wetting so special attention should be paid to the fact that the totality of these phenomena is caused by specific surface interactions. Increasing the contribution of surface energy leads to change in properties. This is because, when the size of the particles is reduced, the proportion of atoms on the surface is increases. Consequently, the properties of surface atoms differ from the properties of atoms in volume.

Since the number of surface atoms increases sharply in nanosobjects, their contribution to the properties of such objects becomes determinative and increases with subsequent diminishing sizes. This is one of the reasons for the emergence of new properties at the nanoscale.

The feature of nanomaterials is their specific electrical and magnetic properties. So the study sections "Electricity" and "Magnetism" of general physics course are great opportunities to illustrate the application of nanotechnology to create new instruments and devices.

In studying the conductivity of insulators, semiconductors and conductors in the course of general physics formed a basic knowledge about models and laws of the microworld. The use of physical models as a basis conduction band theory allows to show students how to explain the position of the only classification of materials based on differences in their ability to pass electrical current.

Section "Physical Electronics" is a synthesis of ideas vacuum and solid state electronics and it describes the development of physical and technological bases of creation of integrated electronic circuits with characteristic dimensions topological elements smaller than 100 nm.

Reducing the size of devices has become a natural process of modern electronics. At the same time, economic costs are increasing. Their reduction is the most important task. It can solvethe development of nanotechnology within the electronics. The use of graphene (a monolayer of carbon atoms) is vivid example that demonstrates the capabilities of nanomaterials within this theme. He was received in 2004 by A. K. Geim and K. S. Novoselov (Nobel Prize in Physics, 2010). If the question of forming a "bandgap" graphene is resolved it will replace silicon in this material integrated circuits. In addition, graphene can be effectively used to form supercapacitor electrodes – the equivalent capacitor extra large capacity (specific capacity supercapacitor 10 F / cm^2 at a nominal voltage of 2.4 V) and light emitting diodes (see, for example, [9]).

Examples of graphene, characterized monolayers can be supplemented by another example which is no less spectacular. This is Prince Technology (proposed by V. Ya. Prince 1995) - formation of three-dimensional micro- and nanostructures based on branch strained semiconductor films on a substrate, followed by phasing them into spatial object [10].

In the study of electromagnetic oscillations in electrical circuits, as an example, we can consider alternative methods of obtaining signals. Here it is appropriate to tell about an oscillator antenna about 1 μm in size, created in 2005 at the Boston University Laboratory. This device has 5000 million atoms and is capable of oscillating at 1.49 GHz. It allows to transmission of large volumes of information.

In this topic, as a rule, the phenomenon of resonance is also considered. It is appropriate here to report the discovery of electronic paramagnetic resonance, to tell about resonance spectroscopy and plasmons. Plasmons are collective vibrations of free electrons in a metal. At the beginning of 2000 had given impetus to the development of a new branch of nanoplasmony based on nanosize particle technology [11]. As a result, it was possible to transmit electromagnetic radiation along a chain of metallic nanoparticles by excitement of plasmon oscillations.

Development of electronics in further will be associated mainly with the spintronics - an electronics industry that uses the quantum properties of the electron spin: two quantum states (spin-up, spin-down). Changing the orientation of the spins occurs at the impact of high current density passing through the ultrathin ferromagnetic structure. The orientation of the spins remains unchanged if the source of the polarized current is turned off. So the spintronic devices are widely used in information storage devices such as alternating voltage generators and field effect transistors, and so on. Spintronics emerged on the basis of study of the phenomenon of spin-dependent scattering of electrons in solid-state devices. These were studies of the injection of spin-polarized electrons from ferromagnetic metal into ordinary metal by Johnson and Silsby (1985) and the discovery by Albert Fertom and Peter Grünberg (1988) of their colleagues of the phenomenon of giant magnetoresistive resistance (GMR) in multi-layers $[Fe/Cr]_n/S$ (S – substrate) (see, for example, [12]). The use of semiconductors in spintronics was started in 1990 in connection with the invention of the Dutta and Das spin field effect transistor (Spin-FET). In a film structure ferromagnet / no ferromagnet / ferromagnet has detected a spin-valve magnetoresistive effect, which allows a magnetic field of about 1.6 kA/m to change the resistance on 5-10 %.

The history of the GMR-effect clearly demonstrates how a totally unexpected scientific discovery can give impetus to the development of entirely new technologies and the creation of new commercial products. Magnetic properties of nanoparticles can also be very useful when creating quantum computers.

Currently, intensive studies of the properties of materials sensitive elements GMR devices as multi-layers, granular alloy film and spin-valves in terms of their practical zastovuvannya in electronic and sensor technology (see, for example, works [13-16]).

There are several groups of physical phenomena that can be used in spintronics:

- dependence of the electrical resistance of homogeneous materials on the external magnetic field: an anisotropic magnetoresistance in thin ferromagnetic films, a colossal magnetoresistance in manganites;
- giant magnetoresistance in layered structures with sequential layers of ferromagnetic and paramagnetic (or antiferromagnetic) metals, as well as in granular structures;
- tunneling magnetoresistance in layered structures containing a paramagnetic (or antiferromagnetic) dielectric between layers of ferromagnetic metal;
- injection of spin polarized charge carriers in ferromagnetic material with a nonmagnetic.

Recently, a special interest is the study of the properties of magnetic nanoparticles [17]. They are found in many biological structures. Magnetic properties of nanoparticles are determined by many factors. Among of them should be the chemical composition, the type of crystal lattice and the degree of its defect, the size and shape of particles, morphology (for particles with complex structure), the interaction between adjacent particles [18]. If you change the size, shape, composition and structure of the nanoparticles can be controlled magnetic characteristics of materials based on them. Magnetic nanoparticles are effectively used in systems for storing information, magnetic nanopillers, medical diagnostics and for the creation of nanorobots..

Particular properties are found in particles embedded in different matrices: polymeric, zeolite, and others.

For the first time, the magnetic properties of a material consisting of a non-magnetic dielectric solid matrix and magnetic nanoparticles distributed in it (3-10 nm) were described in 1980. In recent years, the development of magnetic nanomaterials have been changes which, without exaggeration, be called revolutionary. It is related to the development of effective methods of obtaining and stabilizing the magnetic particles of nanometer size and the development of physical methods of research such particles.

Upon completion of the review section "Magnetism" can provide students with modern scientific global project. Its purpose is the purposeful synthesis of specially designed magnetic molecules based on quantum mechanical modeling using the Monte Carlo method (Metropolis algorithm). The results of this method can be directly compared with the experiment [19]. At the same time, the concept of molecular magnetism is expanding and the search for possibilities of use in applied branches continues. The promising field of practical application of this project is the creation of high-integrated memory modules and miniature magnetic switches. Prognosis and application in medicine with local chemotherapy of tumors.

In the section "Optics" and "Atomic and nuclear physics" describes a material that is integrative in nature. When studying the classical topics of wave optics such as interference, diffraction and polarization of light, when considering the phenomena occurring in thin films, on diffraction gratings, in crystals and solutions of salt, sugar, emphasis should be placed on the coexistence of physical objects whose dimensions are determined nanometers with wavelengths of electromagnetic radiation. Thus, the teacher has opportunity to show the importance of physical conclusions for modern applications.

The section "Interference and diffraction of light" is much better understanded by students, if accompanied by teaching the material with examples of the practical use of this phenomenon. Examples include the application of a certain thickness of nano-coatings on the windshield of cars or the glass of automobile lamps that reduce the risk of roadblock blindness, and the methods of enlightenment of optics. In the study of diffraction should pay attention to methods of holographic images (or as they are now called 3*D* image). They focus students on the rapid process of introducing fundamental knowledge about the application of nanotechnologies in everyday life. It is important for students to know about the physical principles underlying fiber-optic technologies, without which it is impossible to imagine a modern high-quality transmission of large volumes of information.

In the study of topics related to geometrical optics should pay attention nanolinzam, produced for military, civilian purposes and television screens are based on Fresnel lenses [20].

The curriculum of the final course of general physics "Physics of Atom and Atomic Nucleus" includes the following topics: experimental foundations of quantum concepts, wave-particle duality, quantum-mechanical description of atomic, hydrogen atom, multi-electron atoms and molecules, quantum properties of solids. Throughout the course, there is an opportunity to demonstrate to students the connection between atomic physics and modern advances in nanotechnology.

According to the hypothesis of French physicist Louis de Broglie wave nature of microscopic wavelength for microparticles is determined by the formula:

$$\lambda = \frac{h}{m\upsilon}, \tag{1}$$

here h is a Planck's constant, m is the mass of the particle, υ is its velocity.

The hypothesis was experimentally confirmed by C. Davison, L. Jermer in the USA and J. Thomson (1927). They demonstrated the analogy that enables us to construct an electron microscope under the laws of optics.

For electrons accelerated by an electric field with a potential difference U in the non-relativistic case ($\upsilon << c$), taking into account the energy conservation law the equality is fulfilled

$$\frac{m\upsilon^2}{2} = eU , \tag{2}$$

here e is the electron charge, m is the mass of the electron.

On the basis of conjunctions (1) and (2) we obtain

$$\lambda = \frac{h}{\sqrt{2meU}} = \sqrt{\frac{150}{U}} , \tag{3}$$

here λ – вmeasured in angstroms (Å), U – in volts (В), and taking into account the relativistic mass effect:

$$\lambda = \frac{h\sqrt{1-\upsilon^2/c^2}}{\sqrt{2m_0eU}} = \sqrt{\frac{150\left(1-\upsilon^2/c^2\right)}{U}}. \tag{4}$$

When $U = 50$ кВ the difference between the exact values and the approximate ones is only 2%, and at $U = 200$ кВ – at least 10%.

Derivation of formulas (3) and (4) evaluation and de Broglie wavelength of electrons can be considered together with students on practical lesson.

In 1931, R. Rudenberg filed a patent application for a translucent electron microscope, and in 1932, M. Knoll and E. Ruska built the first such microscope. In it, scientists used magnetic lenses to focus electrons (E. Ruska – laureate of the Nobel Prize in Physics, 1986). In 1934, L. Marton (USA) received the first electron microscopic images. Electron-probe devices have become one of the main and indispensable tools for conducting research in the field of physics, materials science, engineering, electronics, sensory engineering, medicine, biology, etc. for the last decades. Historically, the largest spread among electron microscopes was raster and translucent microscopes with electromagnetic lenses (see, for example, [21]). Since the 1980s, new types of microscopes – scanning, atomic-force and tunnel-are beginning to be used.

In studying the tunneling effect, it should be noted that on the basis of it were explained previously unknown processes that were observed experimentally: alpha decay of nuclei, cold electronic emission from metal, etc. It became the basis of atomic science and technology, including nanotechnology.

The coefficient of transparency of the potential barrier of rectangular shape is determined by the ratio

$$D = D_0 \exp\left(-\frac{2l}{\hbar}\sqrt{2m\left(U_0 - E\right)}\right).$$

It depends on the mass *m* чof the particle, the difference between the potential and total energies ($U_0 - E$) of the particle and the width of the barrier *l*. Thus, with a constant difference ($U_0 - E$) for electrons, which is 5 eB та $l = 0.1$ nm – $D = 0.1$. Increase of *l* to 0.5 leads to a sharp decrease in the coefficient *D* to $5{\cdot}10^{-7}$, which makes the effect insignificant.

In 1981, Gerd Binnig and Heinrich Rohrer (Nobel Prize winners, 1986), scientists from the Swiss department of the IBM company, created a scanning tunneling microscope, a device that allows you to act on a substance at the atomic level. With the help of tunneling microscope it was possible to move atoms from one place to another, manipulate them and, theoretically, to collect from them any object. Later Gerd Binnih proposed design of the instrument by which to further explore the surface in more detail – the atomic force microscope (AFM). AFM works in several operating modes, each of which has its own features. Table 1 presents AFM modes and their capabilities.

Table 1 – AFM operating modes and their capabilities

Working modes of AFM	Possibilities of operating modes
Contact mode	topography
	measurement of forces
	local hardness measurement
	measurement of propagation resistance
Resonance mode	topography
	phase contrast
	magneto-strength microscopy
	electrostatic microscopy
Contactless mode	mechanical lithography
	electric lithography

In the study of lasers students should pay attention to examples of their use. It is advisable to consider laser tweezers. This optical device allows you to hold and move in space micro and nano-sized objects, captured in the constriction (focus) of laser beam [22].

The phenomenon of retention of microscopic particles in the laser beam was first described in 1970 by Arthur Ashkin, employee of Bell Telephone Laboratories in USA. He studied light pressure on microobjects.

Later, Ashkin and his colleagues demonstrated the possibility of optical trap based on infrared laser. It can capture, hold and move in space different biological structures, such as viral particles, single bacterial and yeast cells, and organelles in living cells of algae. The cells that were captured in the optical trap went on to share. This indicated a lack of harmful influence of infrared laser radiation on biological objects. Subsequently, Steven Chu (1997), one of the co-authors A. Ashkin was awarded the Nobel Prize in Physics for works on capturing and cooling atoms with the help of the optical trap.

Students should not only take into account new information, but also in each case to understand the physical nature of the phenomenon being investigated or the principle of the work of a device.

When studying the phenomena occurring at the molecular and atomic levels, students receive the initial information about the mathematical apparatus of quantum mechanics. Mathematical methods of quantum mechanics are widely used in quantum chemistry, in quantum electronics, when processing data of X-ray diffraction analysis in crystallography. It is difficult to deny its relevance in modern instrument making, oriented on the use of liquid crystals, semiconductor materials and other nanoobjects. In the study of these topics it is appropriate to mention the achievements of the pharmaceutical industry. Drugs are currently being developed that have an effect on the body precisely on the molecular or on the nanoscale, on the so-called "nano-drugs", "nano-patches", "nano-jackets".

The last lecture on the course of general physics is usually devoted to the review of modern science achievements. It should also pay attention to issues related to nanotechnology.

In order to provide logistical, scientific and methodological basis for teaching the foundations of nanotechnology it is advisable to create educational and scientific centers of nanotechnology at the leading universities of the region.

Educational and Scientific Center of Nanotechnologies is an educational and advisory and information-coordination association. It carries out work on maintenance of educational and research activity in higher and secondary educational establishments of the region. Another important task is to transfer the results of research work in the socio-economic field.

The main tasks of the activity of such educational and scientific centers of nanotechnology should be:

- creation the base of scientific and methodological resources for studying the foundations of nanotechnologies, ensuring their accessibility for subjects of educational activity;
- ensuring the opportunity for secondary schools and universities of the region to conduct physical experiment during the teaching of the foundations of nanotechnology;
- increase of the level of commercialization of scientific and scientific-methodical products and services, management of objects of intellectual property;
- transfer of innovative scientific and scientific-methodical product created by the Center's employees in the socio-economic sphere of the region and country.

The main directions of the Center's work are: - studying and generalizing the domestic, European and world experience in nanotechnology studies in educational institutions; formation of information, educational methodological and scientific sources in accordance with the profile of the Center's activities; development and testing of innovative teaching and methodological support for the study of the bases of nanotechnology in secondary and high school; provision of transfer of results of research activities of university staff to the educational process; attraction of research grants, preparation of project proposals, submission of inquiries for the purpose of obtaining individual (collective) grants by the Center's staff, including for scientific research, internship; creation of conditions for effective interaction of the Center with the education authorities of the region and partner institutions; organizing and conducting conferences, seminars and workshops for teachers of secondary schools, university teachers and other events scientific and methodological various levels; organization and implementation of information and explanatory work among the academic community, educators, and local community in accordance with the profile of the Center on the need for training in the field of nanotechnology.

4. CONCLUSIONS

1. The state of teaching natural sciences in higher educational institutions and educational standards and programs in the context of the world development of the nanoindustry are analyzed. It is shown that solving the problem of improving the quality of disciplines in the natural-mathematical cycle in high school is related to the development of nanotechnologies and the inclusion in the corresponding educational programs of elements of nanoscience.

2. Ascertained the need to introduce the concepts of nanoscience and nanotechnology in general list of fundamental physical terms and concepts. The main source of relevant information should be courses in physics, chemistry and biology. They form the appropriate professional competence of graduates in the context of nanoscience through the gradual introduction of a system of individual on the content of general courses and in-depth study of them – in special courses.

3. It is proved that the inclusion in the subject matter the specific questions related to nanotechnology allows us to solve several of problems: popular for the students word "nanotechnology" is filled with specific content, thus forming a technology culture in the use of terminology; specific models that are fundamental in the course of general physics and illustrate the physical meaning of these physical phenomena acquire increased importance as show the connection of knowledge gained within the discipline of study with the time requirements; the targeted training of personnel for the actual directions of production is being improved by higher educational institutions involved in the development of priority scientific areas identified by the state programs.

4. In the course of the study, it was found that universities should create and develop regional centers of nanoscience at universities. Their goal is to provide a material and technical and scientific and methodological basis for teaching the fundamentals of nanotechnology in secondary and higher educational institutions of different levels.

ACKNOWLEDGMENTS

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Методичні засади вивчення питань нанотехнологій у курсі загальної фізики вищих навчальних закладів

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Робота присвячена висвітленню методичних аспектів формування у студентів знань про основні поняття нанонауки та нанотехнології у курсі загальної фізики вищих навчальних закладів. Запропоновано включення понять нанофізики і нанотехнологій у загальний перелік фундаментальних фізичних термінів і уявлень. Показано, що саме фізика може забезпечити формування відповідних компетенцій випускника у контексті розвитку нанонауки шляхом поступового системного введення окремих питань у зміст загального курсу. Особливу увагу приділено відбору матеріалу з нанотехнологій при навчанні студентів різних спеціальностей. Доведено, що включення у предметний матеріал конкретних питань, пов'язаних з нанотехнологіями дозволяє сформувати культуру у використанні термінології; показати зв'язок знань, отриманих в рамках курсу фізики з вимогами часу; поліпшити цільову підготовку кадрів для актуальних напрямків виробництва вищими навчальними закладами.

Ключові слова: Нанонаука, Нанотехнології, Курс загальної фізики, Вищі навчальні заклади, Нанооб’єкт, Наночастинка, Методика навчання нанотехнологій.

Методические основы изучения вопросов нанотехнологий в курсе общей физики высших учебных заведений

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Работа посвящена методическим аспектам формирования у студентов знаний об основных понятиях нанонауки и нанотехнологии в курсе общей физики высших учебных заведений. Предложено включение понятий нанофизики и нанотехнологий в общий перечень фундаментальных физических терминов и представлений. Показано, что именно физика может обеспечить формирование соответствующих компетенций выпускника в контексте развития нанонауки путем постепенного системного введения отдельных вопросов в содержание общего курса. Особое внимание уделено отбору материала по нанотехнологиям при обучении студентов различных специальностей. Доказано, что включение в предметный материал конкретных вопросов, связанных с нанотехнологиями позволяет сформировать культуру в использовании терминологии; показать связь знаний, полученных в рамках курса физики с требованиями времени; улучшить целевую подготовку кадров для актуальных направлений производства высшими учебными заведениями.

Ключевые слова: Нанонаука, Нанотехнологии, Курс общей физики, Высшие учебные заведения, Нанообъект, Наночастицы Методика обучения нанотехнологиям.

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