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Applied Questions of Electrodynamics in Physics Course

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ABSTRACT

The article considered the problem of studying applied questions related to “Electrodynamics” course at high school. Teaching the elective course on electronic automatic equipment is provided with regard to the implementation of polytechnic principle. The elective course implies discussion of questions related to the physics of bipolar devices and main carrier devices, and the physics of tunnel effect devices. The considered topics cover automatic regulators, elements of automatic devices, semiconductor diodes, thermistors, transistors, semiconductor triodes trigger, logical elements of digital devices. The study highlighted the problem of wide polytechnic concept development in students. The authors discussed possible introduction of laboratory classes aimed at the development of general concepts related to the structure and the content of modern applied knowledge in students. The offered syllabus of the elective course is intended for fixing and broadening theoretical knowledge, acquaintance with modern technological processes and automated processing equipment for production of integrated electronics and automatic equipment products.

KEYWORDS
Applied knowledge and abilities; elective course; electrodynamics electronic automatic equipment; production automation; semiconductor devices

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Introduction

The intensive nature of the development of the main directions of scientific and technical progress in the modern production, social and economic conditions demands further improvement of physics education. Scientific knowledge received at school carries out not only the informative and worldview function, but also the polytechnical one (Mkrttchian & Stephanova, 2013). Students gain knowledge of technology, economics, organization of production and fundamentals of agriculture, and this process represents a certain system of

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polytechnical preparation at high school. Therefore, “the system of polytechnic knowledge consists of different sciences notions set, the content and logical connection of which reflect the general basis and principles of means of labor and duties in the contemporary industry” (Atutov, 1986).

The efficiency of polytechnic education in a school course is defined by the optimum applied material classified according to the physics contents (Imashev, 2012). In this regard the problems of the development of applied education in physics course in the context of innovative technology are particularly urgent. In the conditions of innovative technology, the task of a school is not only to give a certain amount of knowledge, but also to teach a future expert to think creatively and independently, to improve and develop his or her knowledge (Imashev, 2012). The knowledge of basic physics of the modern and intensively developing society will not only help young people to master a specialty, but also make them professionally demanded and mobile.

Applied education is considered as a process and result of assimilation of the systematized knowledge of the general scientific bases of modern production and formation of skills necessary for practical application in various branches of economics (Imashev et al., 2014).

The applied orientation of education is very important in the field of natural and liberal sciences. The experience has shown that using applied materials in the course of physics is an efficient method in the formation of practical knowledge and skills.

The problem of the applied orientation of education in natural and liberal sciences was studied in many scientific researches. It received theoretical justification in the works by H. Schunk & F. Pajares (2002), T. Ansbacher (2000), J.A. Ross & P. Gray (2006). Certain aspects of knowledge acquisition from training and the prospects of the development thereof are covered in the works by scientists J. Bennett (2003), K. Dobson, J. Holman & M. Roberts (2001). Different methods of modeling and the methodology of teaching activities at schools are reviewed in the researches by D. Hestenes (1997).

In these works, authors revealed the pedagogical nature and educational functions of the applied orientation of the school physics course, reviewed certain methodology issues of this problem and show the way of implementation thereof using concrete material.

S.E. Kamenetskii (2000) notes that the development of intelligence and creativity through theoretical thinking is an important goal of teaching physics. The solution of this problem, in our opinion, contributes to the methodological and applied knowledge development, which is formed in the process of teaching physics.

E.R. Savelsbergh, T. de Jong, & M.G. Ferguson-Hessler (2002) examined how situational knowledge in physics, particularly in electrodynamics, differs across individuals of different competence levels. M. Tseitlin & I. Galili (2005) investigated physics knowledge in the cultural context. They proved that physics could not be represented as a simple dynamic wholeness, but it incorporates several discipline-cultures.

In the research by C. Baily, M. Dubson, & S.L. Pollock (2013) there were investigated some difficulties in advanced undergraduate electrodynamics, and developed course materials and assessments for advanced physics students.

In thesis researches of recent years dedicated to the issues of teaching electrodynamics, quite topical and important aspects of improving the theory and the methodology of teaching are covered, in particular, the work by Y.A. Dyakova (2003) can be mentioned in which, on the example of the "Electrodynamics" section, the problem of generalization of pupils' knowledge in physics in upper secondary school is discussed.

The work by A.Y. Chirkov (2006) are dedicated to the methodology of educational physics experiment, to theoretical methods of introduction of notions and the interrelation of theoretical and empirical methods of research in the course of studying physics in secondary schools, as well as to the system of electrodynamics models in secondary schools and the structure of the section for achievement of efficient acquisition of knowledge.

The work by V.V. Mayer & R.V. Mayer (2006) *Electricity: Educational Experimental Proofs* is dedicated in general to the problem of forming a system of empirical knowledge in electrodynamics with pupils.

The issues related to electrodynamics teaching in general physics courses are reflected in the works by A.L. Nikishina (1998). In this works, the issues related to electrodynamics teaching in general physics, are analyzed, as well as the results of the studies of the problems of theoretical and methodology components in the methodology of teaching physics are presented, and the role and the significance of the practical orientation of school education in physics was studied.

The section "Electrodynamics" is one of the most difficult sections of the school course, which includes electrical and magnetic phenomena, electromagnetic oscillations and waves, wave optics and the elements of special relativity theory.

Physical experiment plays the leading role in teaching physics. The section "Electrodynamics" is not an exception. First and foremost, this refers to the following tests: 1) The Coulomb test aimed at establishing dependence of the interaction forces of two electric charges on the module of these charges and the distance between them; 2) The Oersted test aimed at detecting the effect of electric current on a magnetic needle; 3) The Ampere test related to the interaction of parallel currents; 4) The Ohm test, which shows the nature of relationship between amperage and voltage; 5) The Faraday test related to electromagnetic induction; 6)The Hertz test related to detection and studying the properties of electromagnetic waves; 7) The Rikke test aiming at ascertaining the charge carriers in metals; 8)The tests by Tolman and Stewart, Mandelstam and Papaleksi, which prove electronic conductivity of metals; 9) The tests by Millikan and Joffe, which confirmed the atomistic structure of electricity and provided the possibility to measure the elementary electric charge; 10) The tests by Michelson and Morley, which found no preferred system of reference; 11) The tests by Remer, Fizeau and other scientists to measure the speed of light; 12) The Jung test, which provided the possibility to discover the wave properties of light, etc.

This research topic is making a significant contribution to the world science, complementing the most general laws of nature. It is also making a significant contribution to the knowledge about the world around as a school subject. The authors believe that the school course of physics is the backbone for other natural science subjects, keeping in mind the fact that physical laws determine the content of several courses, such as chemistry, biology, geography and astronomy. Accordingly, the study of applied problems of electrodynamics within the physics course is necessary not only to master the basics of one of the natural sciences, which is a core component of modern culture. Without knowledge of specific features related to electrodynamics, a modernizer will not be able to understand developments related to other components of modern culture, worldview as well as the development of scientific thinking.

Teaching applied aspects of physics course is viewed as an important form of theoretical generalization; "learning fundamental physical theories in the classroom, application of different methods, generalization of applied issues – these are important prerequisites for the worldview formation in schoolchildren". Among the factors that determine the effectiveness of studying applied aspects, one should keep in mind relevance of its content in terms of the theoretical content of material being studied mostly at high school, as well as its scientific significance.

Practical significance of research results lies in the fact that they can be used both in physico-mathematical and in humanitarian classes.

Aim of the Study

The purpose of work is expansion of applied knowledge and abilities of pupils in the course of studying of the section "Electrodynamics" of a course in physics.

Research question

How can one improve polytechnic education when studying physics?

Methods

The authors used the following research methods:

a. theoretical: theoretical analysis of the psychological, pedagogical and methodical literature, methods of theoretical study of the problems based on the methodology of system approach and of the pedagogical science; the analysis the draft of the standard of school education in physics, the concept of school education in physics, the existing recommended and experimental programs; the analysis of experience of training in various educational institutions, the synthesis of experience of teachers of physics using the ideas set forth in this research;

b. diagnostic: testing, questionnaire surveys, interviewing, inquiries, observations, conversation, and the export evaluation method;

c. pedagogic experiment connected with introduction in practice of training in physics of the developed educational and methodical materials on applied issues of physics: ascertaining and educating, statistical processing of the results of pedagogic experiment.

The research is based on the following hypothesis: if the elaborated scheme of teaching physics at the secondary school (including the content, methods and means of polytechnic education) provides efficient acquisition of polytechnic knowledge and meets the standard of polytechnic training and vocational guidance, the task of teaching physics at secondary school will be successfully fulfilled, contributing to the comprehensive development of students.

When holding the pedagogical experiment, experimental and control classes were set aside. Experimental classes were selected according to the known principles and according to recommendation in respect of representativeness of sample. S control classes, such classes were selected which according to basic were close to experimental classes. The research was carried out in Atyrau secondary schools No. 3, 16, 19, 35. 235 students from the experimental and 232 students from the control classes participated in the experiment. Along with element-by-element analysis of the pupils' knowledge, the math statistics method was used: comparison of the results of the two independent samples using the χ^2 (chi-square) method for computation of the significance of the difference in the nature of the answers of pupils from experimental and control classes. As one of the indicators of efficiency of formation of applied knowledge when studying electrodynamics, the results of the "Electrodynamics" test by pupils from experimental and control classes. In order to obtain reliable data about the state of the result of teaching interesting for us, the evaluation of the test works in terms of efficacy or validity was made. The valuation of the problems of the test work in terms of validity was carried out using the expert evaluation method. In order to obtain the data in terms of the efficacy of the work, it was offered for examination to a number of experts: supervisors, teachers. In the period of study of each topic, all pupils made test works with applied content by levels. In our study, a three-level rating scale was used for diagnostics of acquisition of separate elements of knowledge based on the theory of formation of intellectual activities developed by scientists in psychology and widely used in private didactic studies.

Data, Analysis, and Results

The current physics course taught in the secondary and high schools of Kazakhstan corresponds to the world best practices in terms of teaching content and methodology. However, there are some areas in foreign methodology of teaching physics, which need a detailed study, in particular: strengthening cognitive activity of schoolchildren by means of teaching motivation; development of cognitive abilities of students (especially those studying at high school) by describing scientific research methods; development of pupil interest in physics and enhancement of its educational possibilities through humanization of its content; development of student creative abilities through modeling and the use of computers in the classroom; intellectual development of schoolboys by means of laboratory research work.

Results from the analysis of numerous studies on the problems of teaching physics in foreign countries would be best divided into the following major components: the content of elements of physical knowledge at different stages of schooling; forms and methods of teaching physics; educational technology.

The applied orientation of a physics course is defined by the following principles:

a. disclosure of the value of theoretical material as the scientific basis of the modern industry;

b. providing coverage of physical fundamentals of the major directions of scientific and technological progress;

c. giving specific examples of application of achievements in physics in economy;

d. giving the pupils practical abilities and training them for work in industries;

e. development of inventive and design abilities of school students.

According to Y.B. Altshuler & A.A. Chervova (2008), in preparing for a school research experiment in physics students learn the essence and practical application of a number of methods of physical science. The experiment must be preceded by setting up a model of the studied object or process. It is accompanied by isolation of essential and inessential factors, which use abstraction and idealization to build a mathematical model. Qualitative analysis of mathematics as well as direct or parametric calculations allow making an estimate of the experiment results.

The model related to the proven teaching methods regarding electrodynamics was implemented with due regard to a number of studies (Altshuler & Chervova, 2008).

Its rationale was based on the synthesis of methodological and applied knowledge that can significantly reduce the gap between the school discipline and science. In particular, organization of the educational process is based on training approaches, which involve activation of mental activity of students.

Therefore, the learning process should be organized with a view to learn the basics of physics and scientific methods should become both an object and a means of academic knowledge. This principle is implemented in the originally developed conceptual content of "Electrodynamics" section (Figure 1).

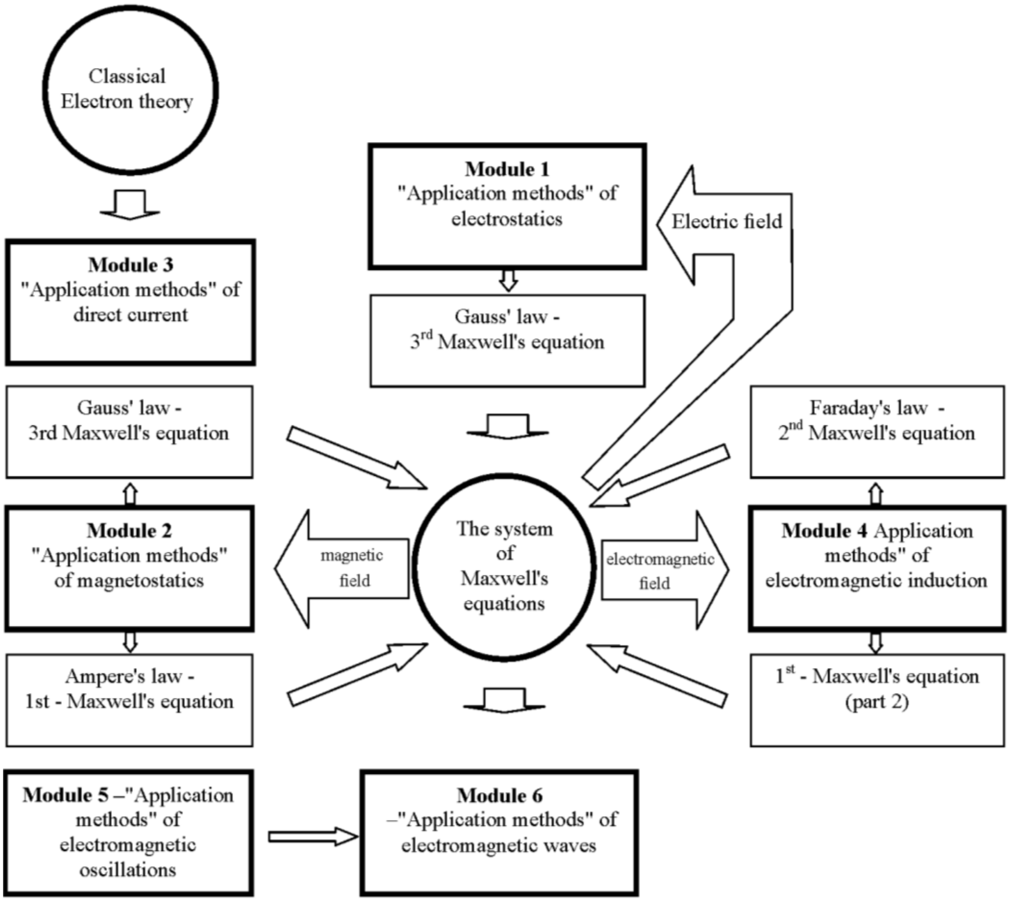

Figure 1. The structure of "Electrodynamics" section

The elective course "Elements of Electronic Automatic Equipment" gives the chance to familiarize students with some fundamentals of manufacturing techniques of integrated circuits and the principle of functioning of elements of microprocessors.

This course gives a teacher a good chance to show the main stages of development of automatic equipment, to point out the predominating automation role in modern production, covers the most important directions of scientific technical progress.

Based on the above, the authors recommend the following scheme of the elective course "Elements of Electronic Automatic Equipment", designed for 34 academic hours.

I. Introduction (1 h).

Development and use of automatic equipment. Production automation. History of development of electronic computer devices.

II. General information about automatic devices (2 h).

Automatic regulators, their types and kinds. Concept about the design of robots.

III. Use of properties of the electric condenser in elements of automatic devices (4 h).

Dependence of capacity of the condenser as a part of integrated circuits. Use of properties of the electric condenser in automatic devices.

Laboratory classes

1. Research of dependence of capacity of the condenser from the area of facings.

2. Calculation, assembly and test of the capacitor sensor of periods.

IV. Conductivity of metals and semiconductors (12 h).

Use of the property of conductivity of metals and semiconductor substances. Thermistors. Semiconductor diodes and their use for strengthening of a signal. Field transistors. Trigger on semiconductor triodes.

Laboratory classes

3. Research of parametrical stabilizers.

4. Research of key circuits on diodes.

5. Assembly and test of the voltage amplifier on the semiconductor triode.

6. Studying static characteristics of transistor.

V. Magnetic properties of substance in automatic equipment elements (10 h).

General information about relay and its designation. Electromagnetic relays: neutral and polarized. Conditions of operation and dropout of electromagnetic relays. Magneto electric and electrodynamics relays. Pulse steam room scheme. Electromagnetic and electromachine bodies.

Laboratory classes

7. Studying of ways of measurement of reaction time and dropout of the relay.

8. Studying of the polarized relay.

9. Studying and testing of pulse couple.

10. Studying of collector electric motors.

VI. Logical elements of digital devices (5 h).

The main logical operations, which are carried out by the COMPUTER. Laws of logic algebra. Idea of binary system of calculation. The trigger in the COMPUTER. Electronic logical elements and their application in the adder.

Laboratory classes

11. Research of a semiconductor diodes logical element "I".

12. Assembly and test of the semiconductor diodes logical OR element.

13. Assembly and test of the semiconductor triode logical NOT element.

VII. Guided tours (2 h). In laboratory of computer center; PPTUS-manufacturing-Caspian technical management of communication.

The elective course promotes formation and development of student abilities related to creative use of physical fundamentals of electronic computer facilities. The program of the course allows profound study of applied questions related to the section "Electrodynamics" and assumes further development of abilities of pupils. To increase interest of children in profession, it is expedient to give classes in the form of conversation with pupils, seminars, discussions, supplementing with examples from life and equipment, using additional literature (Levinshtein, Kostamovaara, & Vainshtein, 2005).

At the elective course "Elements of Electronic Automatic Equipment", the program includes 13 laboratory classes, and each of them includes tasks of research of automatic equipment elements. We will describe some laboratory classes developed by us.

I. Studying static characteristics of a transistor

During the introductory conversation, the teacher repeats all characteristics of the transistor together with pupils.

The input characteristic of the transistor creates the dependence of input current from input voltage at constant input voltage:

$$Yinp = f\,(Uinp) \mid Uinp = const \quad (1)$$

The output characteristic creates the dependence of output current from output voltage at constant value of input current:

$$Youtp = f\,(Uoutp) \mid Uoutp = const \quad (2)$$

Then choose a transistor and determine transistor terminals using the reference book. Choose a common-base transistor and define its characteristics. Function will be the input characteristic:

$$Ie = f\,(Ue) \text{ at } Uk = const \quad (3)$$

Output characteristic: $Ik = F\,(Uk)$ at $Ue = const$ (4)

Work course explanation:

1. Connect the transistor to the measuring stand. Select the Uk voltage equal to zero. By means of the R1 resistor change the voltage of Ue and read the value of Ie current at the microampermeter.

Draw the input characteristic of $Ie = f\,(Ue)$ at $Uk1 = 0V$ (5)

2. Do similar measurements at $Uk2 = 2V$, (6)

and $Uk3 = 5V$ (7)

and draw input characteristics on the same drawing.

3. By means of the R1 resistor set the Ie value = 0.5 mA (8)

and take readings of Ik, changing the value of voltage of Uk.

Draw the output characteristic of $Ik = F(Uk)$ at $Ie1 = 0.5mA$ (9)

4. Do the same at

$Ie2 = 1$ mA, (10)

$Ie3 = 2$ mA, (11)

$Ie4 = 4$ mA, (12)

$Ie5 = 6$ mA (13)

and draw the output characteristics of the transistor.

5. Define the coefficient of transmission of the emitter current.

Perform and register the work as pupils.

Analysis of the received results.

3. Research of the logical element "I" on semiconductor diodes.

At the beginning of work, acquaint pupils with the device and the electronic scheme of logical multiplication with the element "I". The logical element has some inputs and only one output. The signal at the output appears only in presence of signals on all inputs. This signal at the output is result of repetition of an input signal as composed so many times, as how many inputs are available. Therefore, such device is called the device of logical multiplication.

Work course explanation:

1. Assemble a logical element "I" with two inputs, as shown in Figure 2.

2. Assemble an installation for receiving positive impulses.

3. Connect a source of positive impulses to one of inputs, and connect a neon lamp to its output.

4. To make observations of appearance of a signal at the output: in the absence of impulses on inputs and in the presence of an impulse on one of inputs.

5. Connect a source of positive impulses to both inputs.

6. Feeding at the same time positive impulses on both inputs, make observation of appearance of a positive impulse at the output. Enter the results to the Table 1.

Table 1. Appearance of a positive impulse at the output

Input 1	*Input 2*	*Output*
0	0	
0	I	
I	0	
I	I	

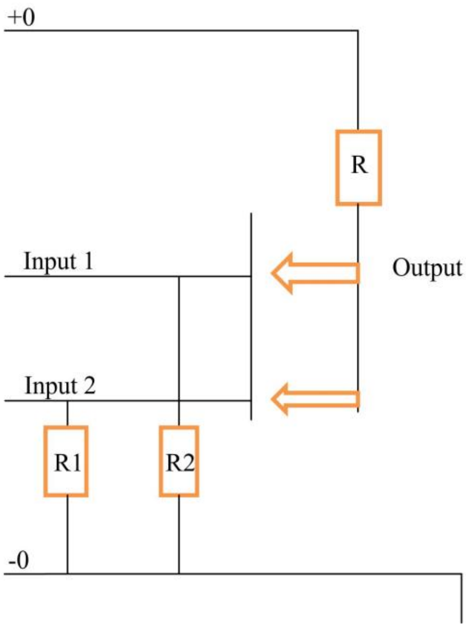

Figure 2. Logical element "I" with two inputs. Main bus

The comparative characteristic of quantitative indices of levels of formation of applied abilities with pupils of experimental and control classes at this course is presented in Table 2. The represented data has shown that the test work was successfully performed by pupils from experimental classes. The number of pupils having low level of formation of applied abilities in experimental classes is 3-fold less than in the control class. In the experimental classes, the high and the average level was 84 % as compared to 57 % in control classes, which is the evidence of a higher level of formation of applied knowledge and abilities. The obtained results are statistically valid and they may be regarded as an actual proof of the efficiency of formation of applied pupils' knowledge in the process of studying electrodynamics.

Table 2. Level of Formation of Applied Abilities in the Elective Course "Elements of Electronic Automatic Equipment"

Class	*Experimental*		*Control*	
Level	Number of pupils	%	Number of pupils	%
High	61	26	21	9
Average	136	58	100	43
Low	37	16	111	48
Total	235	100.0	232	100.0

Discussion and Conclusion

Research results confirmed, in particular, the hypothesis expressed by Y.B. Altshuler & A.A. Chervova (2008), who noted the following: "The teaching research experiment in contrast to the majority of demonstration experiments related to the physics course taught in high school, stands among the most effective methods of cognition, thus exerting influence on the formation of methodological and applied knowledge of students. Such research experiments may accompany teaching of applied problems of electrodynamics in the 11^{th} grade - partially for public demonstrations, but mainly - during physical practical and research activities in the student scientific society" (Altshuler & Chervova, 2008).

Based on the accomplished work, the elective course “Elements of Electronic Automatic Equipment” designated for the pupils of senior classes of high school was developed. The elective course consists of six modules, and each of them includes theoretical and practical training telling the pupils about physical fundamentals of modern electronic automatic equipment. The influence of studying of applied questions of electrodynamics over the increase of the level of knowledge of pupils in the field of receiving physical and polytechnic education is defined. Practical work of pupils in the course of studying at this elective course consists in research activity and testing. In connection with that, laboratory researches are developed and approximate work progress, for the purpose of formation of applied knowledge and abilities in each module, is prepared.

Studying of this material introduces school students into a wide range of social and economic problems, shows the ways of their solution, and acquaints pupils with the role of physics in development of the fields of equipment and production. In the practice of teaching, it is possible to strengthen the applied orientation of the studied course questions in such a systematic way to reveal their value and application in the industry, agriculture, and construction. Along with the main components, the elective course contents included laboratory classes, which provided the possibility to change the applied material depending on the pupils’ level of training.

In the study, laboratory classes of the applied physics and technology contents for improving polytechnical training of pupils in the course of studying of physical fundamentals of automatic equipment have been developed. Models of studying of an elective course of electronic automatic equipment were elaborated with regard to the fact that realization of the polytechnic principle serves as an important condition of increase of the efficiency of teaching and of the education process. This elective course gives the chance to reflect modern achievements of science and technology in school education in a fuller way; A more important place in training which is given to performance by pupils of creative tasks, development of skills of independent retrieval of knowledge, allows to bring pupils closer to the modern level of development of science, to acquaint them with the main directions of scientific and technical progress, and with the methods of carrying out physical researches. Experimental data on formation of applied abilities with students was obtained.

The curriculum of theoretical physics taught at secondary schools should combine the simplicity of exposition of the material with the rigorousness of proof of the main theories. It is necessary to include material that is accessible to students and which forms the core of basic knowledge and promotes the development of scientific outlook, formation of the modern concepts of physical phenomena.

Aspects of applied electrodynamics in the physics course should be represented by topics that may be useful to students in their practical activities. However, the existing courses on theoretical physics do not consider their application aspects, since they represent university-based courses of physics adapted for schools.

Elective courses promote to a more successful solution of problems of applied education, formation of higher levels of applied knowledge and abilities, which is especially topical for modern school.

Implications and Recommendations

Therefore, the authors analyzed the scientific and methodological literature and requirements for the development of elective courses. The relevantly structured models of studying elective course on electronic automation based on the polytechnic principle serve as an important factor in terms of raising the efficiency of the training process. This approach provides comprehensive involvement of the latest scientific and technological achievements in school education, reveals the importance of creative tasks in training, develops independent research skills, allows getting closer to the current level of scientific development and provides the possibility to familiarize students with basic directions of scientific and technical progress, as well as with the methods of physical research.

The authors obtained experimental data related to the development of applied skills in students.

The authors of this paper developed the elective course "Elements of electronic automation", designed for high school students. This course consists of six modules; each of them includes theoretical and practical classes, devoted to the physical basis of modern electronic automation. The paper determined the impact of studying applied problems of electrodynamics related to the improved level of student knowledge in terms of getting further physical and polytechnic education.

During laboratory classes, it is possible to offer such assignments in which students should prepare the theoretical part, using additional literature to make work plans.

Research analysis showed that teaching electrodynamics in high school faced with numerous unsolved questions. The proposed methodology cannot ensure the effective assimilation of knowledge and skills in physics and electrodynamics, in particular, most of them are not aimed at the development of student skills of independent work, and this methodology practically does not implement the individual learning principle, poor attention is paid to the personality-oriented technologies. Thus, the research problem has not been solved to date.

Teaching electrodynamics in high school has the following challenges:

– Low level of knowledge and skills in high school students, which does not meet the requirements of the Federal component of the state standard of secondary (full) general education on the basic level of physics;

– Low interest in the study of physics in general, and electrodynamics in particular;

– Lack of mathematical skills and abilities in students;

– Lack of academic hors to consolidate the studied material.

Disclosure statement

No potential conflict of interest was reported by the authors.

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