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Applied Aspects of Polytechnic Education in the Physics Course

Gizatulla Imashev[a], Nurgul S. Zhazylbaeva[a], Zhadyra Salykbayeva[a], Zhadyra G. Shimakova[a], Aigul Kh. Yerekeshova[a], Baktygul K. Suleimenova[a] and Shara Zh. Syrbayeva[a]

[a]Atyrau State University Named after Kh. Dosmukhamedov, KAZAKHSTAN.

ABSTRACT

The article deals with the problems of teaching physics in the secondary school according to the tasks of polytechnic education with regard to innovation technologies along with giving brief analysis of studies devoted to improving the polytechnic content of the school physics course. The role and place of applied material given the present conditions of teaching physics at school were considered through the analysis of the social and economic aspect pursuant to the requirements of scientific and technical progress. Upon scientific and pedagogical analysis of the theory and practice of polytechnic teaching of physics in the secondary school, the article shows the necessity to intensify applied training of pupils while studying physical bases of the key areas in the present-day scientific and technical progress. The results develop a new methodological model of the system of polytechnic physics education.

KEYWORDS
Modern production; academic process; personal development; polytechnic education; laws of physics

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Introduction

Given the industrial-innovation development, the school's task is to provide not only a certain amount of knowledge, but also to teach the future specialist creative thinking, for him to accomplish, renovate and develop his own knowledge independently. Knowledge of polytechnic bases of modern, intensively developing production will not only help the youth to master one or another specialty quickly, but also will also make it professionally demanded and mobile. In this regard, the tasks of pupils' polytechnic education development in the process of teaching physics are especially topical in modern production. Polytechnic education is considered here both as the process and as the result of mastering the systematized knowledge of the general scientific bases of modern production, development of skills and abilities, required to work

CORRESPONDENCE Gizatulla Imashev ✉ 77gz5ag@mail.ru

with typical (available) labour instruments, spread in different branches (Bugayev, 1981; Tsichritzis, 1999). The final goal of such education is to develop personal qualities, which allow feeling free in the whole system of public production (Bray, Adamson, & Mason, 2014). One of the aspects related to improving physics study in the secondary school is the problem of polytechnic education in the present-day environment – which this article is dealing with.

To date, some important didactic and methodological recommendations regarding polytechnic training of pupils and the principles of polytechnics in the physics study have been developed.

Development of theoretical and practical problems of polytechnic education was studied in the papers of such scientists and teachers as P.R. Atutov (1985), T.N. Shamalo & A.M. Mekhnin (2012), V.S. Lednev (1991) and others. They revealed functional nature of the polytechnic knowledge, discussed possible approaches towards determination of the content of polytechnic education given the scientific and technological revolution.

The problems of polytechnics were and remain among the most important in pedagogical science and practice of the secondary school. They have been studied in the papers of CIS scholars, such as A.A. Pinskiy & V.G. Razumovskiy (2007), A.T. Glazunov & V.A. Fabrikant (1985), and others. The above-mentioned scholars note that polytechnic education gives students knowledge, which provides them with general scientific bases, common organizational and economic principles of modern production. A.A. Pinskiy & V.G. Razumovskiy (2007), argues that the questions of applied physics are the important component of the physics course content. By and large, this explains the difference in the number of various topics of the course and the difference in time distribution to cover them. This reflects not only the volume of teaching physical theories in the school, but also their relevance for the national economy, and for modern production. A.I. Bugayev (1981) stresses that in order to reach the goals of polytechnic education in physics teaching, one should use more the achievements of modern applied physics. Physics, like other natural sciences, is gradually turning into a direct productive force. Therefore, definition of opportunities and ways to use the laws of nature for the benefit of production appears to evolve as one of its key directions. A.T. Glazunov notes that the polytechnic material of the physics course consists of two parts (Glazunov & Fabrikant, 1985). The first part includes the trends of modern production and their scientific substantiation. While studying the relevant sections the pupils get acquainted with the principles of electrification and industrial heating, mechanization and automation of production. Another part of the polytechnic material encompasses specific technical application of the laws of physics. The most important typical and available technical facilities are also included into the physics course in more or less details.

A number of theoretical and experimental studies includes the elaboration of the theory and practice of polytechnic education. Namely, they define the essence and structure of polytechnic training of students in secondary schools and clarify didactic framework for the implementation of the polytechnic principle in the study of scientific bases, etc. As A.T. Glazunov & V.A. Fabrikant (1985) rightfully stressed, the organizational forms and methods of work, especially those characterized by the active self-employed students, are important in improving the polytechnic education. In this regard, the

Czechoslovak school pays great attention to various activities of students related to experimentation – large-scale experiments, laboratory works and workshops on physics (Development of Education in Japan: 1984-1986, 1986). Polytechnic orientation is given to the knowledge and skills acquired by pupils.

A.T. Glazunov demonstrated that polytechnic material of the physics course consists of two parts. The first part includes the trends of modern production and their scientific substantiation. Another part of the polytechnic material is presented by concrete technical application of the laws of physics. (Glazunov & Fabrikant, 1985).

Presently, three concepts of the polytechnic principle have been developed in the pedagogical science. According to the first concept, (Atutov, 1986; Epstein, 1979) polytechnic knowledge is functional by nature. This means that it does not differ from the natural sciences, including physics, but differs in their functional orientation towards the object of application. P.R. Atutov (1986) believes that polytechnic knowledge serves as a tool that gives the possibility to master typical, common and perspective features of a certain object, along with production processes and their scientific bases. In this study, the authors used the concept related to the functional nature of polytechnic knowledge. With regard to this concept, this paper studied theoretical and methodological issues related to the development of polytechnic knowledge and skills in the physics study in high school.

According to the second concept, the polytechnic knowledge contains cumulative polytechnic activity of a pupil which provides mobility of labor functions of a working person. This concept is based on the analysis of generalized activity of the working-industrial person, and does not associate it with general subjects (Stavskii, 1983).

Proponents of the third concept during study of the scientific bases of production proceed from the analysis of the general technical knowledge. V.S. Lednev (1991) argues that during development of scientific knowledge of production, one should study specialized courses on general principles of engineering and modern production technology. These include knowledge of the types of machine elements and mechanisms, knowledge of the energy basics, knowledge of technological processes.

In the researches by A.A. Pinskiy & V.G. Razumovskiy (2007) it is noted that the implementation of the principle of polytechnic education, which demonstrates the technological application of physics, is based on the deep and profound learning of the basics of physical science by the pupils. We share the opinion of those authors who believe that during every lesson while pupils learn the basic material, they obtain the required skills.

At the same time the studies by S.V. Volobuyev (2000), A.T. Glazunov & V.A. Fabrikant (1985) identified the main principles of polytechnic training, however they did not consider the organization of polytechnic education in the specialized school. With regard to modernization of the general education system, the result of polytechnic training is considered in terms of polytechnic competence. In addition, domestic pedagogy lacks comprehensive analysis of modern substantive and organizational principles of polytechnic education in high school.

Analysis of theoretical studies and practical developments on the issue of polytechnic education in the modern high school leads to the following conclusions.

Most researchers determine the structure of polytechnic education through specific polytechnic concepts, not systematically. In considering the polytechnic skills, the authors do not pay attention to the study of technical objects and processes with special reference books, as well as to the ability to study polytechnic objects in the manner unknown to students.

The main idea of the research: the creation of a new methodical system of polytechnic training of students in the process of learning physics should increase the quality and effectiveness of teaching and education in secondary schools in line with the level of technological development and modern production.

Method

The set objectives necessitated using the set of complementary research methods, including: study and analysis of special psychological, pedagogical, scientific, and methodological literature on the problems at hand; analysis of academic and methodological literature; general theoretical methods of analysis, synthesis, and theoretical modeling.Effectiveness of the elaborated polytechnic education methods in the process of physics study in the secondary school was checked through the educational experiment.

The research is based on the following hypothesis: if the developed didactic system of teaching physics in a secondary school (including the content, methods and means of polytechnic education) provides effective assimilation of material and corresponds to the level of polytechnic training and professional orientation, the task of teaching physics in high school will be successfully solved, promoting comprehensive development of students.

Overall, this pedagogical experiment involved 970 high school students. This experiment, which met the objectives and tasks of the study, was carried out in 2012/2013 and 2013/2014 academic years, within two stages (School No.3 and School No. 16 in Atyrau).

The stage, which implied experimental verification of the effectiveness of the proposed method of polytechnic education was carried through observation of the learning process and the pupils' independent work in the classroom; conversations with students and a brief survey during the implementation of practical tasks; analysis of the pupils' written assignments and oral answers, recorded on a disc; independent review of the pupils' creative assignments; statistical analysis of results of the pedagogical experiment.

During the pedagogical experiment the experimental and control classes were isolated. The experimental classes were selected by the well-known principles, in accordance with the recommendations related to the representativeness of the sample. In addition, the selected schools represented different regions: cities/towns and villages. The classes, which were close to the experimental classes by their initial data, were selected as the control classes.

In the experimental classes, the teachers conducted their lessons according to the specifically developed guidelines and recommendations, and used traditional teaching methods during tests. During preparation for the

experiment, the authors of this study prepared and distributed guidelines for teachers at different stages of the experiment, developed plans for the experimental lessons, relevant didactic materials, and the texts of assignments, along with the technique of conducting specific lessons.

Assessment of the pilot training was carried out upon quantitative and qualitative analysis of the test results. The systematic analysis of tests gave the possibility to determine gaps in the pupils' knowledge. The coefficient of the obtained knowledge elements was calculated according to the formula:

$$K = \frac{n}{N} \cdot 100\%,$$

where, n indicates the number of correct answers and N – the total number of the knowledge elements.

Processing of results was carried out through comparing the levels of polytechnic training of pupils in the experimental and control classes. In order to obtain reliable information regarding relevant study results, the validity assessment of tests was carried out. The assessment of tests aimed at their validity verification was carried out by expert assessment. In order to determine the effectiveness of tests they were offered to a number of experts, including supervisors and teachers. The authors of this study used a three-tier scale to determine the level of mastering the individual knowledge elements, based on the theory of mental action developed by psychologists, which is widely used in private didactic studies. Besides the systematic analysis of the pilot training, verification was carried out through comparing the results of two independent samples, according to the criterion $\chi 2$, with a view to calculate the differences in the knowledge levels of the pupils from the experimental and control classes. For the statistical processing convenience, the pupils' answers were divided into three categories according to the level of their knowledge and skills: low, medium and high levels. The pilot training was carried out in parallel with verification of the study impact related to applied orientation of the selected "Electrodynamics" sections on the quality of pupils' knowledge and skills.

Data, Analysis, and Results

The intensive character of development of the key areas of scientific and technical progress in the modern production as well as the new socio-economic environment require further improvement of the pupils' polytechnic education in the academic process. The leading role of this work means that creation of the new methodological system of the pupils' polytechnic training in the process of physics study must enhance the quality and effectiveness of education and upbringing in the secondary school in accordance with the level of technique and the development of modern production.

The pedagogical basis of polytechnic education improvement consists in the following:

– the school course of physics must be based upon the last achievements of modern science and technology;

– scientific bases of the new technologies, which reveal the notions, phenomena and laws of physics, must be used in the accessible form while studying the "Electrodynamics" section.

Recently, the following two aspects have become more important in polytechnic teaching of the physics course: socio-economic and ecological. In the school practice, teachers explain to pupils the most important technical and economic problems that matter much for the national economy, along with the social value of modern scientific achievement more frequently with regard to technical purposes and directions of the technical progress in certain branches of technology (Gauron, 2000). Thus, while studying electrodynamics the social value of power industry development, complex approach value of projecting and building the hydro technical constructions, problems of electric power transfer at extra-long distances, etc. are shown (Jain & Verma, 2014).

In a number of places where the systematic physics course is taught, a teacher has the possibility to show that not only physics serves as the foundation of technology, but also the technology itself stimulates research studies, and promotes industrialization of the study of physics (Dykstra, Boyle, & Monarch, 1992). It is possible to show it especially vividly when studying the nuclear physics: regarding the use of accelerators means of registration of elementary particles in the computing machinery. It should be emphasized that such two-way connection of physics and technology is the important result of the scientific and technical revolution (Imashev, 2011).

We consider that in order to determine the polytechnic education content and the ways of its implementation in the process of physics teaching, it is very important to consider the perspective development of the scientific and technical revolution.

The authors attempted to build the structure of polytechnic material as regards physics in compliance with the basic areas of scientific and technical progress. Such system of knowledge provided by the course of physics gives possibility to follow strict order in the development of polytechnic knowledge and abilities. The following study with regard to five basic areas of scientific and technical progress (automation; power engineering; electronics and computer technologies; creation of the materials with required technical properties, and ecology) considers how pupils' polytechnic training is conducted through teaching physics.

Proceeding from the analysis, we systematized the polytechnic material related to physics in compliance with the main areas of scientific and technical revolution. The study specifies links between the course sections and key areas of scientific and technical progress in the economy with regard to the developed system of polytechnic material, and gives the applied material, which can be used by the teacher while studying this or that topic. Such systematization of applied physical issues determines the content of polytechnic material and reinforces the professional direction of studying this course of physics in the secondary school (Mias, 2005).

The mechanisms of realizing the polytechnic principle in the course of physics include:

– studying physical bases of using concrete technical device;

– pupils' understanding of the technical principle, which forms the basis of constructive properties of the device;

– teaching the ability to use specific technical devices, which realize the studied physic-technical principle.

Due to the purposeful interaction between a teacher and a pupil, upon the use of the specified mechanism, the polytechnic knowledge, abilities and skills are formed (Volobuyev, 2000).

The conducted study showed that application of concrete methods and means of education, forms of organization of the academic classes was finally predetermined by the goals and tasks of polytechnic education.

The specific methods and means of teaching, forms of organization of the academic classes are directed, as a rule, at the solution of one goal (task) of polytechnic training of pupils (Dewey, 1990). Therefore, the application of the combination of methods and means of teaching, as well as forms of organization of academic classes is required for solving the studied problem in general. At different investigational levels the following methods were used: theoretical analysis of literature on the research problem; studying the synthesis of the best pedagogical practices; modeling of the educational systems and processes; pedagogical experiment with statistical processing of its results.

The Tables 1, 2, 3, the pupils from the experimental class most successfully mastered the polytechnic material related to electrostatics - 61%, direct electric current - 59%, the magnetic field - 63%, and the pupils from the control classes, - - 49%, 47% and 51% respectively. Students learnt the laws of the electric field (61% - in the experimental and 48% - in the control classes), they are able to consider processes in the electrical circuit (60% - in the experimental and 47% - in the control classes), can explain the phenomenon of magnetic field and its technical use (63% - in the experimental and 51% - in the control classes). Correct answers make on average 61% in the experimental and 49% in the control classes.

Table 1. Results for section “Electrostatics”

Elements defining knowledge and skills	*Number of correct answers, %*	
	Control class	Experimental class
Electric charge. Electrification. The law of electric charge conservation	49	60
Charged bodies. The electrification of bodies	48	61
Interference of electrical charges. Coulomb's law	47	59
Capacitors	50	59
Summing up on “Electrostatics”	51	63
Examination on the “Electrostatics” section	50	62

Table 2. Results for section “Direct Electric Current”

Elements defining knowledge and skills	*Number of correct answers, %*	
	Control class	Experimental class
Ohm's law for subcircuit	45	58
Work and power supply	46	57
Independent work on the section of a constant electric current	50	62
Repetition. Section “Constant Electric Current”	49	60
Anchoring. Section “Constant Electric Current”	45	57

Table 3. Results for section "Magnetic Field"

Elements defining knowledge and skills	*Number of correct answers, %*	
	Control class	Experimental class
Magnetic field. Ampere's law	51	63

Discussion

The analysis of results presented in Tables 1, 2, 3 shows that the number of pupils from the experimental classes, who successfully solved all the tasks, significantly exceeds the relevant number of pupils from the control classes. The obtained results testify to the fact that the elements of knowledge and skills, which were formed using the experimental procedure, are characterized by significant increase (11 - 13%) in the knowledge difference as compared with the control classes, where teaching was conducted pursuant to the traditional system.

The results of the pedagogical experiment show that the suggested system of teaching physics for the 10 grades and methods of its application are sufficiently effective and can be successfully used in the mass school. The present study was conducted using the example of electrodynamics; however, the authors believe that the developed technique of polytechnic education in the physics course can be applied in the process of polytechnic training developed for students, both for other branches of physics, and in any other subject of natural sciences.

Consequently, the problem is raised in the following way: polytechnic education must be considered as the organic part of continuing education, which has its own complex educational subject, and which is characterized by the subject of study, specific contribution into the development and upbringing of pupils. Polytechnic education has its own transparent structural components and their own consecutive stages (Imashev, 2012).

The analysis of the state of the polytechnic education in high school allowed justifying the need for effective didactic and organizational - pedagogical approaches to the polytechnic training of pupils with regard to modern requirements. Polytechnic training of pupils today has some essential features keeping in mind the current rate of scientific and technological progress. Physics course at school provides wide opportunities for the implementation of the polytechnic education principle.

Polytechnic education should be based on the study of the main directions of scientific and technical progress, the physical foundations of modern production, based on the concepts, laws and theories in the process of physics study. Getting the polytechnic knowledge by pupils in the process of physics study is realized through development of their scientific thinking with content (Lipman, 1991). The content of polytechnic material and the principles of its selection for the physics course at school should meet modern teaching requirements; reflect the most important branches of engineering, manufacturing technologies and ecology.

Achieving the unified level of polytechnic education of the secondary school pupils is possible if its implementation is realized with regard to the functional nature of the polytechnic knowledge (Shamalo & Mekhnin, 2012).

To date, some theoretical problems of polytechnic education have been developed, but at the same time there are some unsolved questions that require specific attention and study. With regard to our model of methodical system of polytechnic training of pupils the content of polytechnic training was determined and the model of the pupils' polytechnic knowledge and skills development was constructed. Implementing this model into the educational process resulted in the polytechnic knowledge and skills of pupils, which allowed to use physical and technical material in the process of physics study within interaction of the teacher and students.

In the present study, the following specific conclusions were reached:

1. Elaboration and implementation of the scientifically founded methodological system of physics teaching based on the polytechnic principle reflecting the applied character of study, into the academic process will improve the quality of polytechnic training of pupils, and in particular, will increase the level of practical training of students and the development of their polytechnic skills. The content, tools, methods and forms of organizing the polytechnic education at every stage in accordance with specific purposes represent a single entity; the interconnection between the joint activity of teachers and pupils are established.

2. The experiment showed that the elaborated methodology of polytechnic education in physics teaching at the secondary school differs from previous ones as regards:

– the content of the selected material;

– consideration of specific technical objects and technological processes of the modern industrial and agricultural production;

– development of the socio-economic development and scientific and technological progress;

– creation of the new methodological system of polytechnic training of pupils;

– use of tools and techniques of active transformation of polytechnic knowledge in the course of their use in different situations.

3. Pedagogical possibilities of the physics course in polytechnic education of pupils will be the most effective if the character of assignments for pupils is systematic and has different directions, and if the order of steps aimed at giving students the technical knowledge and skills, is followed.

4. We suggested the innovative approach for the polytechnic training of pupils during the physics study, including the approximate content of the material applied in physics, the content of lessons, workshops, seminars and labs, which provided physical and technical questions and tasks, and the system of tasks for independent and creative work.

5. The elaborated guidelines for the study of physical and technical materials on the basis of systematization and generalization promote polytechnic training of pupils. Organizational forms of generalizing lessons of physics having physical and technological content may be different. We described the development and implementation of such active forms of polytechnic training as seminars, optional lessons, specialized courses, academic conferences.

6. The idea that laid the foundation of the scientific and methodological research regarding the possibility of strengthening the polytechnic orientation of teaching physics through studying the physical bases of the main directions of scientific and technical progress was fully confirmed.

The general approach to the implementation of the polytechnic principle into the physics course taught at the secondary school elaborated on the model basis with regard to the latest achievements in pedagogy, psychology and methodology of physics teaching proved to be very fruitful. The assumption regarding the increase of effectiveness of physics teaching and the improvement of polytechnic training of pupils during the study of the physical bases of the major directions of scientific and technical progress was confirmed by results of quality control of the students' polytechnic knowledge.

7. The study founded that the proposed method of studying the applied materials did not lead to overload of pupils and enhances their polytechnic training. The main time reserve allocated for the pupils to study physical bases of electric power, automation, instrumentation and development of new materials with desired properties lies in the part of the lesson, given at the stage of learning new material; to conduct laboratory work; to consolidate the material; to solve problems.

8. The proposed didactic system of polytechnic training opens up new possibilities to improve the modeling of organizational and pedagogical forms and methods of physics teaching in modern production. Experimental study of polytechnic education of pupils in the physics study gives reasons to assert that the polytechnic training, based on the new methodology with regard to manufacture environment will effectively influence the educational process and personal development through all factors.

9. Our study was carried out on the example of electrodynamics but, in our view, the elaborated methodology of polytechnic education in the physics course could be applied during the development of polytechnic training of pupils both with regard to other sections of the physics course and with regard to any other subject of natural science. In order to determine the levels of polytechnic skills, the pupils were offered the specially designed tasks. The experiment showed that many pupils in experimental classes were able to find the essential features of the machines in action, to collect and customize settings, to perform troubleshooting, to use the skill of meter reading from one object to another, to draw conclusions and to generalize. Students control the formation of classes Development of polytechnic skills of the medium and high levels of the control class pupils is going more slowly. This is explained by the fact that the

traditional method of the polytechnic skills development in the physics study has no tools to increase pupils' rating.

10. Insufficient development of the body of physical and technical knowledge and skills in the majority of students, lack of clear objective related to purposeful formation of polytechnic knowledge, lack of polytechnic competence development system in the secondary school;

11. As a result, the student activity is largely based on the empirical knowledge; it is weakly associated with the use of scientific achievements that impedes the development of their initiative, and independence.

Conclusion

In this study, the following specific results were achieved:

1. The role and place of polytechnic education in the case of physics teaching improvement in the secondary public school were detected, and the basic pedagogical requirements to students' polytechnic training at the present stage were determined.

2. The content of polytechnic material in the present environment of teaching physics course at school, based upon estimation of socio-economic aspect in compliance with the requirements of scientific and technical progress, was determined.

3. The specific methods of studying the physical bases of modern production and the model of methodological system of polytechnic education in the process of studying physics were developed.

The practical value of the study consists in the following:

– Creation of the new methodological system model of polytechnic physics teaching given the modern production environment;

– Development of the methodological complex with a view to solve the problem of polytechnic education improvement in the process of studying physical bases of the key areas of scientific and technical progress;

– Implementation of the methodological recommendations regarding the improvement of the pupils' polytechnic education while studying the "Electrodynamics" section.

The study confirmed the hypothesis regarding the importance of scientific and theoretical foundations of polytechnic education at the present stage of physics teaching in secondary school;

– development of methodical system of polytechnic training for high school students.

– identification and justification of the most important trends in the development of polytechnic education in the process of teaching physics in high school;

– determination of the indicative content of polytechnic education, the development and substantiation of polytechnic knowledge and skills in the process of teaching physics in high school.

The contribution of the article implies the following: the development of the conceptual framework of improving polytechnic education during the study of physics in high school at the present stage; identification and substantiation of the most important trends which specify modern development of polytechnic education; creation of the polytechnic education model of physics study along with definition of its criteria, indicators and levels; development of the methodical system of polytechnic training for students in the study of physics; organization and conduct of the pedagogical experiment.

The perspective studies as regards polytechnic education of the pupils in the process of physics teaching can be conducted within the following directions:

– development of polytechnic means of thinking through initiative and creative approach towards solution of the polytechnic education problems;

– fostering the interconnection of physics teaching with the pupils' industrial labour;

– promotion of world outlook and scientific-technical thinking of pupils.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Gizatulla Imashev is a Doctor of Pedagogy, Professor at Physics and Technical Disciplines Department, Atyrau State University named after Kh. Dosmukhamedov, Atyrau, Kazakhstan.

Nurgul S. Zhazylbaeva is a Lecturer at Physics and Technical Disciplines Department, Atyrau State University named after Kh. Dosmukhamedov, Atyrau, Kazakhstan.

Zhadyra Salykbayeva is a Lecturer at Physics and Technical Disciplines Department, Atyrau State University named after Kh. Dosmukhamedov, Atyrau, Kazakhstan.

Zhadyra G. Shimakova Holds a Master Degree at Physics and Technical Disciplines Department, Atyrau State University named after Kh. Dosmukhamedov, Atyrau, Kazakhstan.

Aigul Kh. Yerekeshova Holds a Master Degree at Physics and Technical Disciplines Department, Atyrau State University named after Kh. Dosmukhamedov, Atyrau, Kazakhstan.

Baktygul K. Suleimenova Holds a Master Degree at Physics and TECHNICAL disciplines Department, Atyrau State University named after Kh. Dosmukhamedov, Atyrau, Kazakhstan.

Shara Zh. Syrbayeva is a Associate Professor, Head of the Physics and Technical Disciplines Department, Atyrau State University named after Kh. Dosmukhamedov, Atyrau, Kazakhstan.

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