PECULIARITIES OF THE ORGANIZATION OF EDUCATIONAL ACTIVITIES OF STUDENTS OF THE AGRICULTURAL HIGHER EDUCATION INSTITUTIONS IN THE CRISIS CONDITIONS

Scientific monograph

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The scientific monograph presents theoretical-methodical and practical aspects of organizing the process of student education in crisis conditions. Using the example of the educational process in agricultural universities, ways to improve independent graphic training are considered, a mathematical model for designing educational resources is proposed, the problems of teaching physics and the methodological foundations of online education in crisis conditions are highlighted.

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CHAPTER 3 "CURRENT ISSUES OF THE ORGANIZATION OF PHYSICS TEACHING IN THE CRISIS CONDITIONS"

Olena Diachynska[1]

Abstract. *The purpose* of the work is to analyze the problems and find the ways to solve them regarding the organization of physics teaching in the crisis conditions. In the conditions of the COVID-19 pandemic, russia's war against Ukraine, additional difficulties arise in the organization of the educational process, in particular, the teaching of physics in the higher educational institutions. To achieve the goal, theoretical research *methods* were used: analysis, synthesis, comparison of information from scientific research to clarify the essence and the role of the methods of conducting lectures, practical, laboratory classes, independent educational and cognitive activities of the students, monitoring the educational achievements of the students in the crisis conditions, and the empirical *methods* of research: conversation, observation and verification of the effectiveness of using one's own approaches during mixed or distance forms of learning of the discipline of physics.

As a result of research, it is substantiated that thanks to a wide variety of interactive information and communication possibilities, it is possible to effectively conduct physics classes in mixed and distance formats, in synchronous and asynchronous modes. *The practical consequences* are the implementation of the various methods of organizing and conducting physics classes in distance training using the resources of the higher education institutions, various services for organizing video conferences, learning management systems, tools for sharing and exchanging information, messengers, websites that offer a wide range of interactive simulations in physics and allow you to study physics in an interactive mode in the crisis conditions. The use of the Mathcad package makes it possible to perform calculations in an automated mode, significantly reducing the time spent on calculations during remote physics classes.

[1] Assistant of the Department of Mathematics,
Physics and Computer Technologies,
Vinnytsia National Agrarian University, Ukraine

Value/originality. The proposed technologies can be applied in the study of the other disciplines. The results of the research can be used to design the content of blended or distance training.

Introduction

Today, the urgent issues of the organization of physics teaching in a higher educational institution in the crisis conditions are related to:

– the need to ensure the safety of teachers and students, including psychological support. If necessary, conduct classes in bomb shelters or organize training using remote technologies;

– availability of educational resources in the crisis conditions. Access to the educational resources such as textbooks, laboratory equipment, and computer programs may be limited. Teachers should be prepared for such situations and have backup plans;

– level of training of students. In the crisis conditions, the level of students' training may be reduced due to stress and difficulties in accessing education. Teachers should take this into account and select appropriate material for teaching;

– psychological condition of students. Crisis conditions can negatively affect the psychological state of students. Teachers must be ready for this and provide students with the necessary support.

In the crisis conditions, it is necessary to be flexible and quickly react to changes. Teachers must be ready for any opportunities and challenges in order to provide a quality educational environment for their students. To do this, it is necessary: to apply innovative technologies to increase the effectiveness of teaching physics; to use various means of communication and interaction with the students to ensure the effective interaction and monitoring of the students' educational achievements; to use various methods and forms of education to keep the students' attention and make learning more interesting and effective; to provide the students with enough time to study the material and complete tasks; regularly check the educational achievements of students to identify gaps in their knowledge and provide them with the necessary assistance; to create an atmosphere of support and cooperation among students so that they can mutually help each other in their studies.

3.1. Methods of Organizing and Conducting Practical Classes in Physics

Physics studies the general laws of nature, it makes a significant contribution to the system of knowledge about the surrounding world, reveals the role of science in the cultural development of society, and contributes to the formation of a modern scientific outlook.

The study of the academic discipline "Physics" gives an idea of the fundamental laws of the movement of matter, its structure, properties and interaction. Knowledge of physics is necessary for successful study of general scientific and special disciplines. While studying the course, students must learn basic laws and theories, master the necessary techniques of mental activity, an important component of which is the ability to conduct experimental research, solve problems of physical content, and model physical phenomena and processes.

Studying the discipline "Physics" gives the student the opportunity:

– to know the basic concepts, laws and theories that explain the physical phenomena, as well as physical quantities that describe the physical phenomena and processes; the essence of the physical phenomena, their mechanisms, cause-and-effect relationships in the physical processes; limits of application of the physical laws and theories of physics; theoretical and experimental methods of the physical research; physical principles of operation of the modern technological equipment and apparatus; the purpose and possibilities of using experimental equipment for conducting the physical research;

– the ability to analyze the relationship of the physical phenomena of various nature; apply physical knowledge to solve practical problems that arise during the development and operation of modern technology; analyze the impact of the physical phenomena on the modes of operation of modern technology; plan and conduct the simplest physical experiments using modern equipment and process the results of these experiments; highlight specific physical content in applied tasks of the future speciality;

– the ability to master the basics of conducting the experimental research and processing their results, to master the methods of evaluating experimental errors.

At the Vinnytsia National Agrarian University, physics is taught in the form of lectures and practical classes. The number of hours allocated for

lectures and practical classes is determined by the curriculum. The list of lesson topics is given in the work program of the academic discipline, syllabus. In the electronic management system of the university the "Socrates" in the personal office, the student gets access to electronic educational materials in physics: the program of the mandatory component, the work program of the academic discipline, the syllabus, lecture presentations, methodological instructions for practical classes, methodological instructions for organizing independent work, individual calculation tasks, physics reference books and trial and the examination tests in Moodle. The full disclosure of scientific and theoretical principles in physics is carried out in practical classes, since the approach to solving typical problems can only be explained in general terms at the lecture.

A practical lesson in physics is an integral part of the educational process, during which the student consolidates theoretical material, develops the skills and abilities of its practical application when solving problems, and develops the cognitive activity. The main tasks of practical classes in physics include: forming of students' scientific outlook; deepening, systematization and consolidation of knowledge obtained at lectures and in the process of independent work; acquiring skills in using theoretical knowledge when solving practical problems; ability to use physical equipment, make measurements and analyze results; forming of intellectual skills and abilities of planning, analysis, generalization; forming the ability to work in a team and effectively interact with the other people. Solving problems is one of the most important tasks in the entire process of learning physics. Consideration of the physical content of problems and the proposed methods of solving them not only contributes to a deeper understanding of the modelling capabilities of the theory, but also develops creative and critical mental activity.

The quality of the student's training depends on the method of practical training. The effectiveness of the practical lesson is determined not only by the content of the information received by the students, but also by the nature of the interaction between the teacher and the student. Active activity of the students brings the best result. It is necessary that each of them works with full loading and gets a good result from their work. Only in this case, it is possible to inculcate in the students the skills and abilities to solve practical problems. The tactics of conducting a practical

lesson depends on the topic and the set goal, the technical equipment of the auditorium where the lesson is held, the level of the theoretical training of the applicants, etc. Practical classes can be conducted in the form of calculations, business games, independent work of students under the guidance of a teacher, etc. At practical classes, visual aids can be used, and demonstrations can be held [1].

It cannot be claimed that there is a single methodology of conducting practical classes. Each scientific and pedagogical worker uses his own developments. But the majority of teachers conduct practical session mainly in the following sequence: formulating the purpose and tasks of the lesson, a short discussion about the theoretical lecture material, solving problems, summarizing what has been learned, summing up, recommendations for the next lesson.

Solving physical problems, as a rule, has a heuristic nature, which does not allow formulating a rule or algorithm by which any physical problem is solved.

However, the following recommendations should be followed when solving problems:

1. Work out the theoretical material in detail.

2. Carefully analyze the condition of the problem, find out the physical essence of processes and phenomena.

3. Familiarize yourself with the methods of solving problems discussed in the practical classes and given in the manual [4]. Find out all the points that are not clear to you and achieve a complete understanding of all stages of the solution. If necessary, consult the teacher.

4. When solving problems independently, you should be guided by the general methodology of solving:

– make a drawing for the task, if necessary;

– find out the physical essence of the processes in question;

– establish the laws that must be used to solve the problem, write down the corresponding equations;

– carry out mathematical transformations, obtain a solution to the problem in a general form, in which the sought for value must be expressed through the values given in the condition of the problem, establish a connection between unknown and known values. At the same time, new unknown values may appear. It should be remembered that the number

of the independent equations should be equal to the total number of the unknown quantities. Not only the quantities given in the condition of the problem, but also the data contained in the reference material of manuals and methodological instructions should be considered known;

– check the final formula obtained by the dimensional method;

– substitute the numerical values of physical quantities in the International System of Physical Quantities (the system is denoted by the symbol SI (System International) in the Ukrainian notation – SI) into the resulting formula and perform calculations. It is recommended to carry out bulky calculations on computers in the following environments: Mathcad, Matlab, Python, C++, MS Excel;

– analyze the obtained solution regarding its compliance with the physical content of the problem [4].

There are various methods of conducting practical classes, in particular: traditional, with elements of problem-based learning, using computer technologies, involving demonstrations. Let's consider their advantages and disadvantages.

With the traditional method, students at home solve problems based on the material studied in the previous practical lesson and prepare for the next lesson, the topic of which is announced in advance. In the classroom, after checking the completion of the homework and monitoring the preparation for the class, problem solving is carried out under the supervision of the teacher. Students are allowed to use any literature or internet sources. This methodical approach allows to activate the work of students. At the same time, the teacher frees up his time and has the opportunity to work individually with students. Students who keep up well can be loaded twice or even three times more given difficult problems or examples. For this, it is necessary to have previously prepared programs and tasks. In the course of the lesson, the teacher evaluates the preparedness and activity of each student, identifies weak points in their preparation. Poorly performing or insufficiently prepared students receive individual homework and are called for consultations. The traditional method does not exclude the work of the students at the blackboard. The need for it arises in those cases when the first lesson is held from a particular section. The teacher needs to deepen some concepts, focus students' attention on the physical essence of the phenomenon, pay attention to the typical mistakes or when the majority of

students in the group have difficulties in solving a certain problem. At the end of the class, the results are summarized with an assessment of the work of each student and homework is given. The considered method solves a number of other important problems: the accumulation of the students' knowledge assessments, their objectivity and the effectiveness of the student knowledge control [1].

The methodology with elements of problem-based learning is based on the independent preparation of students to solve problems from the new material. For this, the topic of the next lesson and the tasks for it are given in the current lesson. In advance, during the lecture class, students are taught the theoretical material of the next practical class. Students independently solve the proposed problems at home. Since there is no ready-made algorithm, the student must creatively approach such homework. Thus, elements of creativity are introduced into the learning process. The classroom practical session is devoted to the analysis of the homework and checking the assimilation of the new material. At the same time, difficulties are revealed, mistakes are corrected, and the most rational ways of solving the same problem are demonstrated, which increases students' interest in the lesson. Then, more difficult problems are solved under the supervision of the teacher, as in the first method. The end of the lesson is devoted to summarizing the experience of the students' independent work and preparing them for the correct solution of the problematic questions that they will encounter when completing the next homework assignment. For this purpose, instructions are given as to which material must be studied in order to solve certain problems. The considered method activates the search independent work of the students [1].

The method using computer technologies is used in distance training during quarantine. Students must register for Google Classroom in advance. At the beginning of the practical lesson, the teacher updates basic knowledge: the students orally answer theoretical test questions. Then, under the guidance of the teacher, the students solve typical problems. The teacher records the students' activity and the correctness of their answers. As with the first method, it is allowed to use any literature. At the end of the lesson, after considering all the questions, the teacher opens tasks for the students to complete independently – Google forms containing both tasks and test questions. This is the student's homework. The deadline is

regulated by the teacher. The check is carried out outside of school hours, after the student's work has been sent. This organization of the lesson allows the teacher to comment on the students' answers and point out their mistakes. However, unlike previous methods, experience shows that the distance form of education does not make it possible to reliably authenticate the work and check the independence of its execution by one or another student. In addition, distance training requires significant methodical and organizational training, as well as the availability of smartphones, computers or other devices for students and teachers [1].

The method involving demonstrations is used by the authors in conditions of reduced time for studying the discipline. During the lesson, the teacher demonstrates some physical experiment to the students. After that, the students are not asked a final, but an intermediate question, the answer to which is quite simple. After answering the first question, the second question is asked that deepens the understanding of the phenomenon, then the third, etc., until the complete description of the experiment is formed and some practical problem is solved. The main goal of such classes is the formation the ability of the students of higher education to give quantitative, and in some cases, qualitative explanations of the experimental facts that are shown to them. In addition, such classes discuss the adequacy of the chosen theory and the real experiment. There is also an opportunity to draw students' attention to factors that can be discarded to simplify the solution to the problem. For example, to neglect the force of friction when studying the rotational-progressive movement of a body on an inclined plane, or to reject Van der Waals corrections when determining the gas constant of air and to consider air as an ideal gas. Experience shows that practical classes in physics with the use of experiments expand the capabilities of the teacher and increase the efficiency of his work. Phenomena demonstrated and observed by the students make an impression on them and are well remembered. The participation of the students in setting up a demonstration experiment and in its quantitative and qualitative assessments contribute to a more thorough assimilation of the material [1].

Due to the war started by Russia against Ukraine, the educational process in our country's higher educational institutions is carried out in a mixed format or remotely, depending on the security situation, the availability of electricity, and the possibility of connecting the participants

to the Internet. The teacher faces the problem of which method to choose in order to achieve high-quality practical training in conditions of anxiety and limited access to educational resources. The way out of this situation is to use the resources of higher education institutions (at the Vinnytsia National Agrarian University it is the electronic education system Socrates), various services for organizing video conferences (Zoom, Google Meet, Microsoft Teams, Cisco Webex, Blue Jeans), learning management systems (Moodle, Blackboard, Sakai, Canvas), tools for general use and sharing information (Google Drive, Dropbox, Microsoft OneDrive), messengers (Viber, Telegram, WhatsApp), websites that offer a wide range of interactive physics simulations and allow you to study physics in interactive mode (Physics Interactives, PhET Interactive Simulations), programs (Microsoft Office, LibreOffice). Thanks to such a variety of interactive information and communication possibilities, classes can be held both in the classroom (off line) and in a mixed format, and if necessary – in a remote format (on line). In connection with the military operations in Ukraine, distance training can take place both in synchronous and asynchronous modes. In synchronous distance training, the teacher and the students simultaneously interact using video conferencing tools. That is, consideration of the subject topics is conducted in real time in the selected digital environment, approximately as in the usual format (off line). Asynchronous distance training involves working on an individual schedule. This regime can make students feel isolated from their academic group and requires a high degree of self-discipline. Students who have a small stock of knowledge from the school course and who do not succeed in self-study, do not fully master the material of the discipline.

Any of the methods of organizing and conducting a practical lesson in physics can be implemented in the conditions of distance training when the students and the teacher are in safe living conditions, have electricity, the Internet, and have a stationary computer or laptop. Complications arise when students conduct a natural experiment. At the same time, the use of virtual environments or demonstrations of relevant demonstration video fragments cannot form the ability to use real measuring devices, assemble installations and work with them. In the absence of such an opportunity, students can watch video recordings of demonstrations, design a physical experiment at home.

Let's consider our own approach to conducting a practical lesson in physics in the conditions of distance training.

According to the work program of the academic discipline, the teacher develops methodological guidelines for practical classes in physics. The structure of each practical lesson should include: topic, goal, lesson plan, literary sources (with the code in the Socrates repository), a brief overview of theoretical material and basic formulas, examples of problem solving, conditions for solving problems in a practical lesson and independent performance, physical experiments if necessary (with an indication of the e-mail address of the website where you can view the progress of the experiment, or instructions for performing a physical experiment at home), questions for self-control of the studied material, test tasks for final control, topics of scientific research topics, projects, group tasks. Methodical instructions for practical classes in physics are attached by the teacher to the study cards of the disciplines in Socrates. If necessary, they can also be sent to the students by e-mail, Viber or Telegram. As an example, consider the structure of a practical lesson.

<div align="center">Practical lesson № 1</div>

Lesson topic: Kinematics.

Purpose: to learn to describe types of translational and rotational movements of bodies; to form skills and ability to calculate kinematic characteristics of movement; to develop the ability to system thinking, generalization of basic knowledge of mathematics in the extent necessary for mastery of mathematical apparatus in accordance with the given topic of the lesson.

<div align="center">Plan</div>

1. Mechanical movement. Its description and classification.

2. Progressive motion of a rigid body. Movement, path, speed, acceleration. Tangential, normal and total acceleration.

3. Rotational motion of a solid body. Angular velocity and angular acceleration.

4. Motion of a body thrown at an angle to the horizon.

<div align="center">Recommended Books</div>

1. Dzis V. G., Levchuk O. V., Diachynska O. M. Physics. Collection of problems. Part 1. Study guide for training applicants of the first (bachelor) level of higher education in the educational and professional programs

"Industrial Mechanical Engineering", "Power Engineering, Electrical Engineering and Electromechanics", "Agroengineering", "Computer Science". Vinnytsia: VNAU, 2021. 402 p. Repository code 30624.

2. Pogozhykh M. I., Pak A. O., Kupriyanova L. V. Mechanics. Molecular physics and thermodynamics. Electrostatics: practical tasks for independent work: study guide. Kharkiv: KhDUHT, 2019. 103 p.

3. Kovalev L. E., Poberezhets I. I. Physics: a study guide for engineering students. Uman: VOC "Vizavi", 2019. 200 p.

4. Skitsko I. F., Skitsko O. I. Physics. Practicum Education manual. – 2nd edition revised, supplemented. 2020. 614 p.

<center>Information resources</center>

1. Virtual STEM Center of the Small Academy of Sciences of Ukraine. https://stemua.science/

2. Website of the physics teacher. https://fizika.dp.ua/

3. Interactive simulations for natural sciences and mathematics. https://bit.ly/3k2vXb1

4. Ukrainian Journal of Physics. https://ujp.bitp.kiev.ua/index.php/ujp

5. Good physics. https://gutpfusik.blogspot.com/

<center>Basic formulas</center>

1. General kinematic equation of motion

$$S = S(t)$$

where S – is the path, t – time.

2. Kinematic equation of motion in coordinate form

$$x = x(t) \quad y = y(t) \quad z = z(t)$$

3. Kinematic equation of motion in vector form

$$\vec{r} = \vec{r}(t)$$

4. Average road speed

$$\langle v \rangle = \frac{\Delta S}{\Delta t} = \sum_{i=1}^{n} \frac{\Delta S_i}{\Delta t_i} \ .$$

5. Instantaneous velocity vector

$$\vec{v} = \frac{d\vec{r}}{dt} = \vec{r}\,' = v_x \vec{i} + v_y \vec{j} + v_z \vec{k}$$

6. Projections of the velocity vector on the coordinate axis

$$v_x = \frac{dx}{dt} = x'; \ v_y = \frac{dy}{dt} = y'; \ v_z = \frac{dz}{dt} = z'.$$

7. Modulus of the instantaneous velocity vector

$$v = \frac{dS}{dt} = S'.$$

8. Modulus of the instantaneous velocity vector in projections on the coordinate axis

$$v = \sqrt{v_x{}^2 + v_y{}^2 + v_z{}^2}$$

9. The path traveled by the body over a period of time Δt

$$S = \int_{t_1}^{t_2} v(t)\, dt$$

10. Acceleration vector

$$\vec{a} = \frac{d\vec{v}}{dt} = \vec{v}' = \frac{d^2\vec{r}}{dt^2} = \vec{r}\,'',$$

$$\vec{a} = \frac{d\vec{v}}{dt} = \vec{v}' = a_x\vec{i} + a_y\vec{j} + a_z\vec{k}.$$

11. Projections of acceleration onto coordinate axes

$$a_x = \frac{dv_x}{dt} = v_x' = \frac{d^2 x}{dt^2} = x'';$$

$$a_y = \frac{dv_y}{dt} = v_y' = \frac{d^2 y}{dt^2} = y'';$$

$$a_z = \frac{dv_z}{dt} = v_z' = \frac{d^2 z}{dt^2} = z''.$$

12. Acceleration module

$$a = \frac{dv}{dt} = v' = \frac{d^2 S}{dt^2} = s''.$$

13. Module of acceleration due to projections on coordinate axes

$$a = \sqrt{a_x{}^2 + a_y{}^2 + a_z{}^2}$$

14. Module of tangential acceleration

$$a_\tau = \frac{dv_\tau}{dt}$$

15. Modulus of normal (centripetal) acceleration

$$a_n = \frac{v^2}{R},$$

where R – is the radius of curvature of the trajectory.

16. Total acceleration vector

$$\vec{a} = \vec{a}_n + \vec{a}_\tau = \vec{a}_d + \vec{a}_\tau$$

17. Full acceleration module

$$a = \sqrt{a_n^2 + a_\tau^2} = \sqrt{a_d^2 + a_\tau^2}\ .$$

18. Average acceleration

$$\langle a \rangle = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}.$$

19. Speed with uniformly accelerated (decelerated) motion

$$v_t = v_0 \pm at.$$

20. Path with uniformly accelerated (decelerated) movement

$$S = v_0 t \pm \frac{at^2}{2}.$$

21. Average angular velocity

$$\langle \omega \rangle = \frac{\varphi_2 - \varphi_1}{t_2 - t_1}$$

22. Instantaneous angular velocity

$$\omega = \frac{d\varphi}{dt}\ .$$

23. Angular acceleration module

$$\varepsilon = \frac{d\omega}{dt} = \omega' = \frac{d^2\varphi}{dt^2} = \varphi''\ .$$

24. Kinematic equation of uniformly accelerated rotational motion

$$\varphi = \varphi_0 + \omega t \pm \frac{\varepsilon t^2}{2}$$

25. Rotation period

$$T = \frac{2\pi}{\omega}.$$

26. Frequency of rotation

$$v = \frac{1}{T}, v = \frac{\omega}{2\pi}.$$

27. Linear (tangential) speed

$$v = \omega R.$$

28. Tangential acceleration

$$a_\tau = \varepsilon R.$$

29. Normal (centripetal) acceleration

$$a_n = \omega^2 R.$$

30. Full acceleration module

$$a = \sqrt{a_n^2 + a_\tau^2} = R\sqrt{\omega^4 + \varepsilon^2}$$

Problems to be solved in a practical lesson

1. The movement of a material point is given by the equations: $S = At^3 + Bt^2 + \sqrt{Ct + D}$, where $A = 0,1\dfrac{m}{s^3}; B = 0,5\dfrac{m}{s^2}; C = 5m^2 / s; D = 1m^2$. Determine the average speed and average acceleration of the material point during the first $5s$ of movement.

2. The movement of the material point is given by the equations: $S = At^2 + Bt + \dfrac{C}{t + D} + E$, where $A = 0,2\dfrac{m}{s^2}; B = 4\dfrac{m}{s}; C = 4m \cdot s; D = 2s; E = 4m$. Determine the speed and acceleration of the material point at the time $t = 3s$.

3. The equation of motion of a material point has the form: $V(t) = A + Bt - C \cdot ln(D \cdot t^2 + E)$, where $A = 5m/s, B = 0,8$ m/s², $C = 1,8$ m/s, $D = 21/$s2, $E = 1$. Find the path traveled by the body in the first $20s$ of movement. Plot graphs: $S = S(t)$, $V = V(t)$, $a = a(t)$ for the first $20s$ of movement.

4. The disk rotates according to the equation $\varphi = A + Bt + Ct^2 + Dt^3$, where $A = 1rad$, $B = 1rad/s$, $C = 0,8rad/s^2$, $D = 0,4rad/s^3$. Determine the angular velocity ω and angular acceleration ε at the moment of time $t = 2s$, the average angular velocity $\langle\omega\rangle$ and the average angular acceleration $\langle\varepsilon\rangle$ during the time interval from $t_1 = 1s$ to $t_2 = 4s$.

5. The body rotates around a fixed axis according to the law $\varphi = A + Bt + Ct^2$, where $A = 4rad$, $B = 5rad/s$, $C = 1rad/s^2$. Determine the normal, tangential and total acceleration of a point located at a distance of $R = 5cm$ from the axis of rotation at the time $t = 2s$.

6. The dependence of the path on time for a point moving in a circle with a radius of $R = 3m$ is described by the equation $S = Dt^3$, where $D = 0,01m/s^3$. Determine the moment of time t, when the linear speed of the point $v = 3m/s$. Find the normal a_n, the tangential a_τ and the total a acceleration of the point at that instant of time.

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Test tasks

1. The material point covered the first part of the path of $20\,m$ in $10\,s$, the second part of the path of $30\,m$ in $6\,s$, and the third part of the path of $70\,m$ in $14\,s$. Find the average speed of movement of a material point.

2. During the first $4\,s$ of uniformly accelerated motion, a material point travels a distance of $12\,m$. Find the linear acceleration if the initial speed is $1\,m/s$.

3. The equation of motion of a material point is $S = 2t^2 + 3t + 5$. Determine the speed of the material point for the moment of time $t = 2\,s$.

4. The equation of motion of a material point is $S = 0,2t^3 + 2t + 4$. Determine the acceleration of a material point for the instant of time $t = 3\,s$.

5. The linear speed of a point on the edge of a disk with a diameter of $60\,cm$ is $18\,m/s$. What is the angular velocity of the disk?

6. The equation of motion of a material point is $\varphi = t^3 + 2t + 10$.. Determine the angular acceleration of the material point for the moment of time $t = 4\,s$.

Problems for independent solving

1. The movement of a material point is given by the equation: $S = At^2 + Bt + C$, where $A = 2\dfrac{m}{s^2}; B = 3\dfrac{m}{s}; C = 4m$. Determine the average speed and average acceleration of a material point during the time interval from $t_1 = 2\,s$ of $t_2 = 5\,s$.

2. The material point rotates according to the equation $\varphi = A + Bt^2 + Ct^3$, where $A = 5\,rad$, $B = 2\,rad/s^2$, $C = 1\,rad/s^3$. Determine the angular velocity ω and angular acceleration ε at the time $t = 3$ s.

3. The body was thrown at an angle of 60^0 to the horizon with an initial speed of $30\,m/s$. Determine the flight time, the flight range and the maximum height to which the body will rise.

A question of self-control

1. Define mechanical motion.

2. What is the main task of mechanics?

3. Under what conditions can a body be considered a material point?

4. What basic kinematic quantities characterize the movement of a material point in space?

5. Define speed, acceleration?

6. Write down the formulas for determining the average and instantaneous speed, average and instantaneous acceleration, centripetal, tangential, total

acceleration, average and instantaneous values of angular velocity and angular acceleration.

According to the class schedule and by invitation sent in advance, students join a practical lesson in physics in Zoom video conference mode. During the class, all participants are recommended to work with the cameras turned on, which improves the interaction between the teacher and the students, and the students among themselves. After the welcome speech and the announcement of the topic, all participants are actively involved in the educational activity. Depending on the topic of the lesson, the achievement of its goal and according to the student-centered approach to learning, the most optimal training methods are chosen: explanation, method of problem-based training, conversation, integrated training [2]. Therefore, the class can be started with a discussion on the studied lecture material or an explanation of the theoretical material not covered in the lecture, with a review of a physical experiment followed by the formulation of thematic questions that lead to solving problems. After a short discussion-survey, you can start solving physical problems. After reading and analyzing the condition of the problem, the teacher or the student writes on the Zoom Whiteboard an abbreviated record of the condition of the problem and the subsequent solution, using a regular tablet or graphic (Figure 1).

**Figure 1. The record of solving a physics problem
in Zoom using a whiteboard and a graphics tablet**

While solving problems, students discuss among themselves and with the teacher. Although the class takes place remotely, no student is limited in attention, everyone can ask questions, answer, write on the board, which creates a positive atmosphere of cooperation. We solved the third problem of the practical lesson using Mathcad (see example 1). After solving the problems of the practical session, we analyze the obtained results, then we practise solving the problems that will be included in the test tasks, we summarize what we have learned and answer the questions for self-control. At the end of the lesson, the teacher advises the students on the performance of individual calculation tasks.

Solving professionally oriented problems in physics often causes difficulties, as it requires the use of complex mathematical apparatus. The use of the Mathcad package makes it possible to perform calculations in an automated mode, significantly reducing the time spent on the calculations.

The expediency of the widespread use of Mathcad for solving physical problems can be motivated as follows:

– Mathcad makes the study of physics easier, as it reduces the time to perform computational work;

– Mathcad makes the study of physics more interesting, as it allows you to consider many interesting and previously inaccessible issues at a very high, close to professional level;

– Mathcad is intuitive, easy to learn in practice, has a graphical interface for entering information, does not require programming skills.

Solving a physical problem in the educational process is a powerful means of combining theory and practice. A physical problem is, in fact, a physical model of a certain real phenomenon, while physical modelling actually takes place at the stage of analyzing the content of the problem and realizing those physical laws that are discussed in the problem. When solving a problem, the processes of building a physical and mathematical model of the problem are interconnected. During the derivation of the final working formula describing the physical model of the problem, mathematical modelling is already taking place [4].

The choice is also due to the fact that a significant number of interesting physical problems is reduced to transcendental equations, integrals that do not have an original function, differential equations that do not

have analytical solutions. Some physical tasks are quite cumbersome. For example, solving problems from the sections "Alternating current", "Statistical physics", error estimation. The Mathcad system has a complete set of tools for successfully solving such problems. Therefore, the use of the Mathcad mathematical package opens up the opportunity to expand the range of tasks, reduce the time for performing cumbersome mathematical calculations, focusing the student's attention on the physical essence of the process. The use of the Mathcad mathematical package when solving problems is an effective tool for improving the quality of vocational education as a whole. Facilitating learning due to the automation of calculations increases the level of students' mastery of the physical essence of the tasks, the meaningfulness of their activities. Let's consider several examples of solving problems from different sections of physics in Mathcad [4].

Example 1. The equation of motion of a material point has the form: $V(t) = A + Bt - C \cdot ln(D \cdot t^2 + E)$, where $A = 5\,m/s$, $B = 0,8$ m/s², $C = 1,8\,m/s$, $D = 21/$ s², $E = 1$. Find the path traveled by the body in the first $20\,s$ of movement. Plot graphs: $S = S(t)$, $V = V(t)$, $a = a(t)$ for the first $20\,s$ of movement.

Let's prepare a problem for solving in Mathcad. We will derive and write working formulas. The path traveled by the body in the first $20\,s$ of movement

$$S = \int_0^t \left(A + Bt - C \cdot ln(D \cdot t^2 + E) \right) dt,$$

Body acceleration $a = \dfrac{dV}{dt}$.

We record numerical data and working formulas in Mathcad (Listing 1). When writing formulas in the worksheet, we follow the grammar of the Mathcad system.

Example 2. Calculate the moment of inertia of a non-uniform rod with a radius of $1,5\,m$ relative to an axis passing through its center perpendicular to the plane of the disk. The surface density of the disk

$\sigma(x) = 0,05x^2 + \sqrt{\dfrac{x^2 + 5x + 2}{x^2 + 1}}$, kg/m^2, where x – the distance from the center of the disk.

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Listing 1

Condition of the problem

The value of the coefficients of the equation of motion of a material point

$A := 5$ $B := 0.8$ $C := 1.8$ $D := 2$ $E := 1$

The equation of motion of a material point $v(t) := A + B \cdot t - C \cdot \ln\left(D \cdot t^2 + E\right)$

The solution

$a(t) := \dfrac{d}{dt} v(t) \rightarrow 0.8 - \dfrac{7.2 \cdot t}{2 \cdot t^2 + 1}$ <== A function for calculating the acceleration of a material point

$S(t) := \displaystyle\int_0^t \left(A + B \cdot t - C \cdot \ln\left(D \cdot t^2 + E\right)\right) dt$ <== Function to calculate the path (the function is given in integral form)

$v(20) = 8.965$ <== The speed of a material point at the moment of time t=20s, m/s

$a(20) = 0.62$ <== Acceleration of a material point at the moment of time t=20s, m/s^2

$S(20) = 87.4$ <== The path traveled by a material point during the first t=20s of movement, m

Let's set a period of time for drawing graphs $t := 0, 1.1 .. 20$

The graph of the dependence of the path on time

Time, s
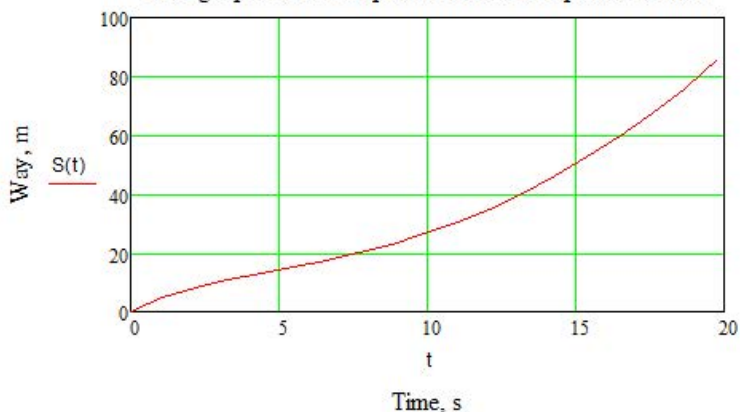
Graph of the dependence of speed on time

Speed, m/s

$v(t)$

10
8
6
4
2
0

0   5   10   15   20

t

Time, s
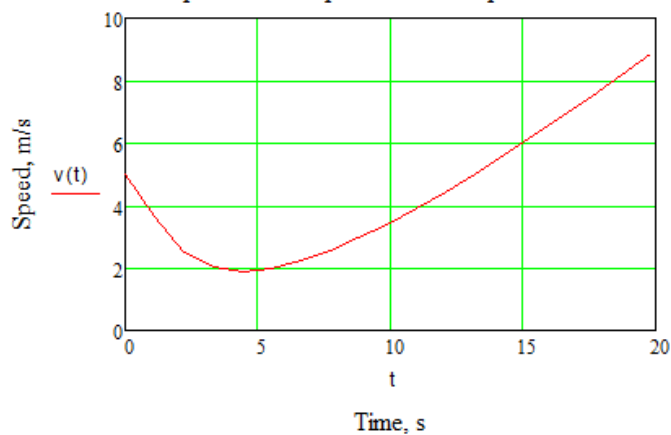
Graph of acceleration versus time

Acceleration, m/s2

$a(t)$

0   5   10   15   20

t

Time, s
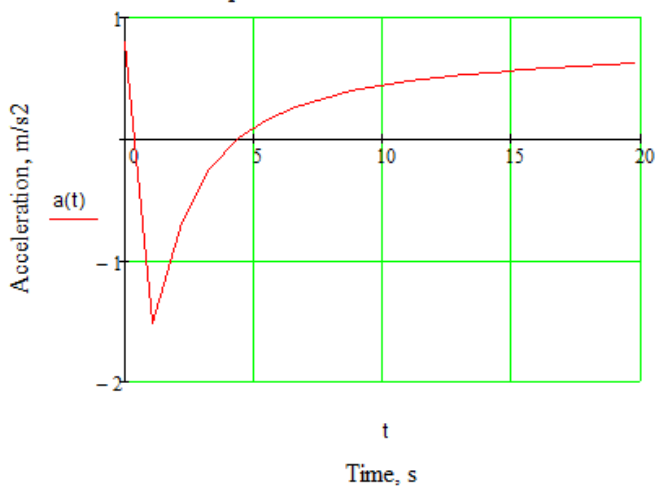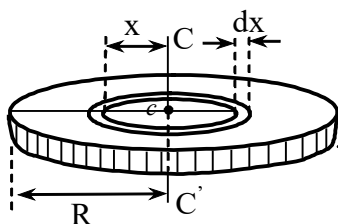
Figure 2. Determination of the moment of inertia of an inhomogeneous disk

Solving

At a distance x from the center of the disk (Figure 2), we select an infinitely thin hoop of thickness dx, whose elementary moment of inertia is equal to $dI_d = x^2 dm$.

Determine the elementary mass dm of the selected elementary volume in the form of a thin ring, taking into account that the surface density $\sigma = \sigma(x)$ depends on the distance to the axis of rotation

$$dm = \sigma(x)ds,$$

where $\sigma(x) = 0,05x^2 + \sqrt{\dfrac{x^2 + 5x + 2}{x^2 + 1}}$ is the surface density, $dS = 2\pi x dx$ — the surface area of the selected belt.

Therefore, the elementary moment of inertia of the selected element on the disk is:

$$dI_d = 2\pi x \left(0,05x^2 + \sqrt{\dfrac{x^2 + 5x + 2}{x^2 + 1}} \right) dx.$$

To calculate the moment of inertia of the entire disc, it is necessary to integrate the expression:

$$I_d = \int_0^{R=1.5} 2\pi x \left(0,05x^2 + \sqrt{\dfrac{x^2 + 5x + 2}{x^2 + 1}} \right) dx.$$

This integral does not have an origin, so we will calculate it numerically in Mathcad:

$$R := 1.5 \qquad I_d := \int_0^R 2\pi \cdot x \cdot \left(0.05 \cdot x^2 + \sqrt{\dfrac{x^2 + 5 \cdot x + 2}{x^2 + 1}} \right) dx = 14.21$$

Answer: 14,21 $kg \cdot m^2$.

Example 3. The specific heat capacity of the body in the temperature range of 250 – 350 K varies according to the empirical dependence $C = 300 \cdot e^{\frac{T+20}{T-75}} \; J/(kg \cdot K)$. How much heat is required to heat a 6 kg body from 250 to 320 K?

Solving

The elementary amount of heat that must be expended to increase the body temperature by dT is equal to: $dQ = c(T)mdT = 300e^{\frac{T+20}{T-75}}mdT$, where T the absolute body temperature. The total amount of heat is

$$Q = \int_{T_1=250}^{T_2=320} 30e^{\frac{T+20}{T-75}}mdT \ .$$

We record numerical data and working formulas in Mathcad. When writing formulas in the worksheet, we follow the grammar of the Mathcad system.

$$T_1 := 250 \quad T_2 := 320 \quad m := 6 \quad Q := \int_{T_1}^{T_2} 30 \cdot e^{\frac{T+20}{T-75}} \cdot m \, dT = 5.413 \times 10^4$$

Answer: $5{,}413 \cdot 10^4 \ J.$

Example 4. Find the work of stretching a rubber cord for 5 m, if the coefficient of elasticity is $k(x) = 5x^2 + 3\sqrt{\dfrac{x^2 + 25x + 2}{x^2 + 1}}, \ N\!\!\diagup\!\! m^2 \ .$

Solving

Elementary work during deformation of the cord is equal to: $dA = Fdx = kxdx$.

Accordingly, full work

$$A = \int_0^x kxdx = \int_0^x \left(5x^2 + 3\sqrt{\frac{x^2 + 25x + 2}{x^2 + 1}} \right) xdx \ .$$

This integral does not have an origin, so we will calculate it using numerical methods in Mathcad:

$$A := \int_0^5 \left(5 \cdot x^2 + 3\sqrt{\frac{x^2 + 25 \cdot x + 2}{x^2 + 1}} \right) \cdot x \, dx = 888.889$$

Answer: $315{,}972 J.$

Example 5. For an unbranched electric circuit of alternating current (Figure 3), develop a program – a document for determining: full Z, active

R, reactive X_L, X_C, X resistances, phase shift between current and voltage, voltage on the elements of the electric circuit, total, active and reactive power, construction of vector diagram of current and voltage, graph of phase relations between current and voltage, determination of resonance frequency ν_{res}, construction of resonance curve for the range of operating frequencies $0{,}05\nu_{res} \le \nu \le 5\nu_{res}$.
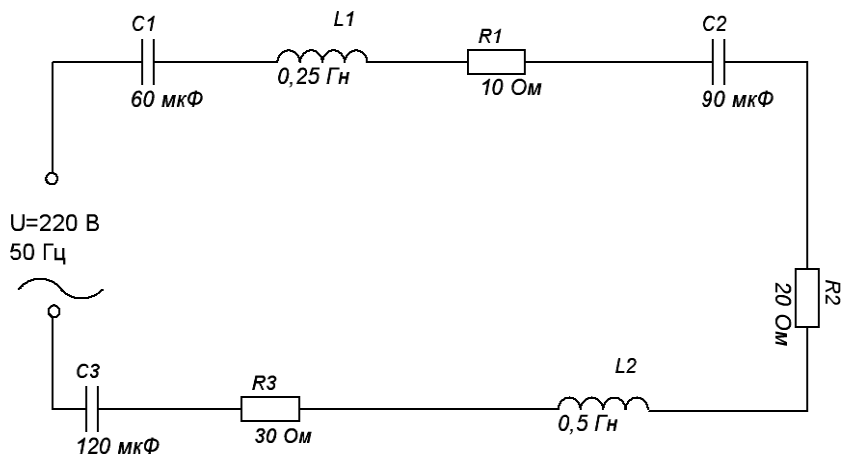

Figure 3. Electrical diagram

The solution of the given problem by means of the Mathcad system is given in Listing 2, the developed program makes it possible to calculate arbitrary unbranched AC circuits.
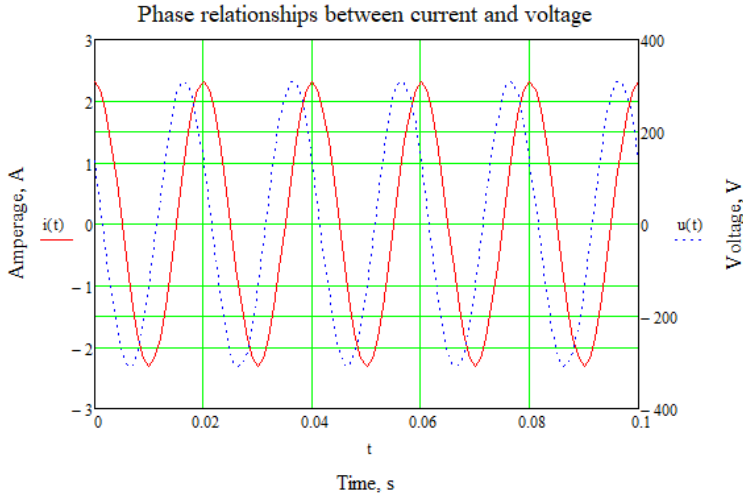
Listing 2

$$\text{ORIGIN} := 1$$

Incoming data:

$$R := \begin{pmatrix} 10 \\ 20 \\ 30 \end{pmatrix} \qquad C := \begin{pmatrix} 60 \cdot 10^{-6} \\ 90 \cdot 10^{-6} \\ 120 \cdot 10^{-6} \end{pmatrix} \qquad L := \begin{pmatrix} 0.25 \\ 0.5 \end{pmatrix} \qquad f := 50 \qquad U := 220$$

Total active resistance, Ohm:

$$R_\Sigma := \sum R \qquad\qquad R_\Sigma = 60$$

Reactive resistance of inductors, Ohm:

$$X_L := 2 \cdot \pi \cdot f \cdot L \qquad X_L = \begin{pmatrix} 78.54 \\ 157.08 \end{pmatrix}$$

The total reactance of the inductors, Ohm:

$$X_{L\Sigma} := \sum X_L \qquad X_{L\Sigma} = 235.619$$

Reactive resistance of capacitors, Ohm:

$$X_C := \overrightarrow{\left(\frac{1}{2\pi \cdot f \cdot C} \right)} \qquad X_C = \begin{pmatrix} 53.052 \\ 35.368 \\ 26.526 \end{pmatrix}$$

Total reactance of capacitors, Ohm:

$$X_{C\Sigma} := \sum X_C \qquad X_{C\Sigma} = 114.945$$

Total reactive resistance of the circuit, Ohm:

$$X := (X_{L\Sigma} - X_{C\Sigma}) \qquad X = 120.674$$

Total circuit resistance, Ohm:

$$Z := \sqrt{R_\Sigma^2 + (X_{L\Sigma} - X_{C\Sigma})^2} \qquad Z = 134.767$$

Current strength in an electric circuit, A:

$$I := \frac{U}{Z} \qquad I = 1.632$$

Voltage on active resistors, V:

$$U_R := I \cdot R \qquad U_R = \begin{pmatrix} 16.324 \\ 32.649 \\ 48.973 \end{pmatrix}$$

Voltage on the inductor coils, V:

$$U_L := I \cdot X_L \qquad U_L = \begin{pmatrix} 128.212 \\ 256.423 \end{pmatrix}$$

Voltage on capacitors, V:

$$U_C := I \cdot X_C \qquad U_C = \begin{pmatrix} 86.604 \\ 57.736 \\ 43.302 \end{pmatrix}$$

Phase shift between current and voltage, deg:

$$\varphi := \frac{180}{\pi} \cdot \text{acos}\left(\frac{R_\Sigma}{Z} \right) \qquad \varphi = 63.563$$

Active power, W:

$$P := U \cdot I \cdot \cos\left(\varphi \cdot \frac{\pi}{180} \right) \qquad P = 159.892$$

Reactive power, VAR:

$$Q := U \cdot I \cdot \sin\left(\varphi \cdot \frac{\pi}{180} \right) \qquad Q = 321.581$$

Full power, VA:

$$S := U \cdot I \qquad S = 359.137$$

+

Amplitude values of current and voltage: $I_0 := \sqrt{2} \cdot I$ $I_0 = 2.309$ $U_0 := \sqrt{2} \cdot U$ $U_0 = 311.127$

Instantaneous values of current and voltage: $i(t) := I_0 \cdot \cos(2 \cdot \pi \cdot f \cdot t)$ $u(t) := U_0 \cdot \cos\left(2 \cdot \pi \cdot f \cdot t + \varphi \cdot \dfrac{\pi}{180}\right)$

The time period for constructing a schedule, s: $t := 0, 0.001 .. 0.1$

Phase relationships between current and voltage

Amperage, A

i(t)

u(t)

Voltage, V

t

Time, s

Construction of a vector diagram of current and voltage

The coordinates of the beginnings and ends of the voltage vectors (current)

$$UC1 := \begin{pmatrix} 0 & 0 \\ 0 & -U_{C_1} \end{pmatrix} \qquad UR1 := \begin{pmatrix} 0 & -U_{C_1} \\ U_{R_1} & -U_{C_1} \end{pmatrix} \qquad UL1 := \begin{pmatrix} U_{R_1} & -U_{C_1} \\ U_{R_1} & U_{L_1} - U_{C_1} \end{pmatrix}$$

$$UR2 := \begin{pmatrix} U_{R_1} & U_{L_1} - U_{C_1} \\ U_{R_1} + U_{R_2} & U_{L_1} - U_{C_1} \end{pmatrix} \qquad UC2 := \begin{pmatrix} U_{R_1} + U_{R_2} & U_{L_1} - U_{C_1} \\ U_{R_1} + U_{R_2} & U_{L_1} - U_{C_1} - U_{C_2} \end{pmatrix}$$

$$UL2 := \begin{pmatrix} U_{R_1} + U_{R_2} & U_{L_1} - U_{C_1} - U_{C_2} \\ U_{R_1} + U_{R_2} & U_{L_1} - U_{C_1} - U_{C_2} + U_{L_2} \end{pmatrix} \qquad UR3 := \begin{pmatrix} U_{R_1} + U_{R_2} & U_{L_1} - U_{C_1} - U_{C_2} + U_{L_2} \\ U_{R_1} + U_{R_2} + U_{R_3} & U_{L_1} - U_{C_1} - U_{C_2} + U_{L_2} \end{pmatrix}$$

$$UC3 := \begin{pmatrix} U_{R_1} + U_{R_2} + U_{R_3} & U_{L_1} - U_{C_1} - U_{C_2} + U_{L_2} \\ U_{R_1} + U_{R_2} + U_{R_3} & U_{L_1} - U_{C_1} - U_{C_2} + U_{L_2} - U_{C_3} \end{pmatrix}$$

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Continuation of listing 2

$$Uz := \begin{pmatrix} 0 & 0 \\ U_{R_1} + U_{R_2} + U_{R_3} & U_{L_1} - U_{C_1} - U_{C_2} + U_{L_2} - U_{C_3} \end{pmatrix} \qquad Id := \begin{pmatrix} 0 & 0 \\ 50 \cdot I & 0 \end{pmatrix}$$

Vector diagram of current and voltage

$UC1^{(2)}$
$UR1^{(2)}$
$UL1^{(2)}$
$UR2^{(2)}$
$UC2^{(2)}$
$UL2^{(2)}$
$UR3^{(2)}$
$UC3^{(2)}$
$Uz^{(2)}$
$Id^{(2)}$

Voltage, V

$UC1^{(1)}, UR1^{(1)}, UL1^{(1)}, UR2^{(1)}, UC2^{(1)}, UL2^{(1)}, UR3^{(1)}, UC3^{(1)}, Uz^{(1)}, Id^{(1)}$

Voltage, V; Current, I*50 A
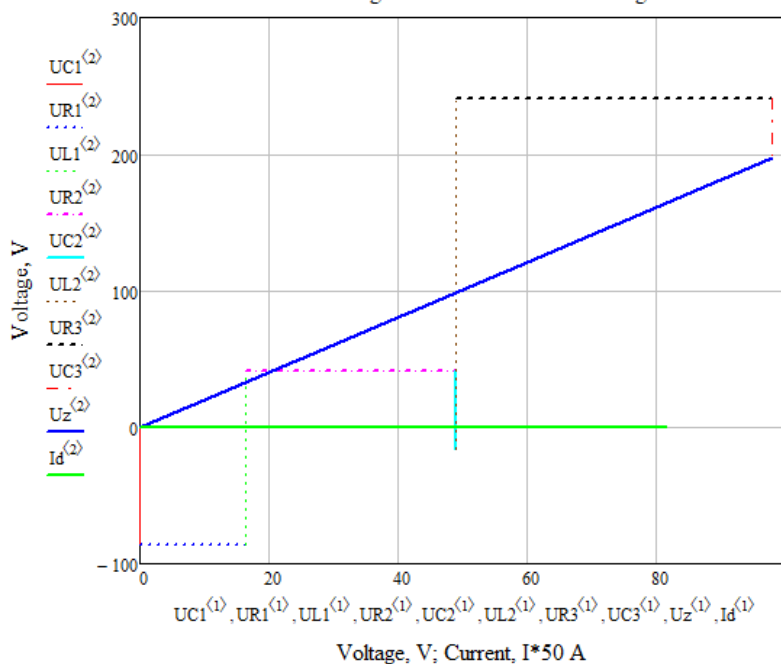
— Voltage vector on C1
···· The voltage vector on R1
···· Voltage vector on L1
·—·· The voltage vector on R2
— The voltage vector on C2
···· Voltage vector on L2
·-·- The voltage vector on R3
— · Voltage vector on C3
— The total voltage vector
— Current vector

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Continuation of listing 2

Study of the frequency characteristics of an electric circuit

Construction of resonance curve

A function for calculating the current strength in an electric circuit depending on the frequency ν

$$I(\nu) := \frac{U}{\sqrt{\left(R_1 + R_2 + R_3\right)^2 + \left[2\cdot\pi\cdot\nu\left(L_1 + L_2\right) - \left[\dfrac{1}{2\cdot\pi\cdot\nu}\cdot\left(\dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}\right)\right]\right]^2}}$$

Resonant frequency ν_r, Hz

$$2\cdot\pi\cdot\nu_p\left(L_1 + L_2\right) - \left[\frac{1}{2\cdot\pi\cdot\nu_p}\cdot\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)\right] = 0 \text{ solve } \rightarrow \begin{pmatrix} -34.922869872609996491 \\ 34.922869872609996491 \end{pmatrix}$$

$$+$$

$$\nu_r := 34.92$$

Interval of operating frequencies for building a resonance curve: $\quad \nu := 0.05\cdot\nu_r, 0.05\cdot\nu_r + 0.1 .. 5\cdot\nu_r$

Resonance curve

Frequency, Hz
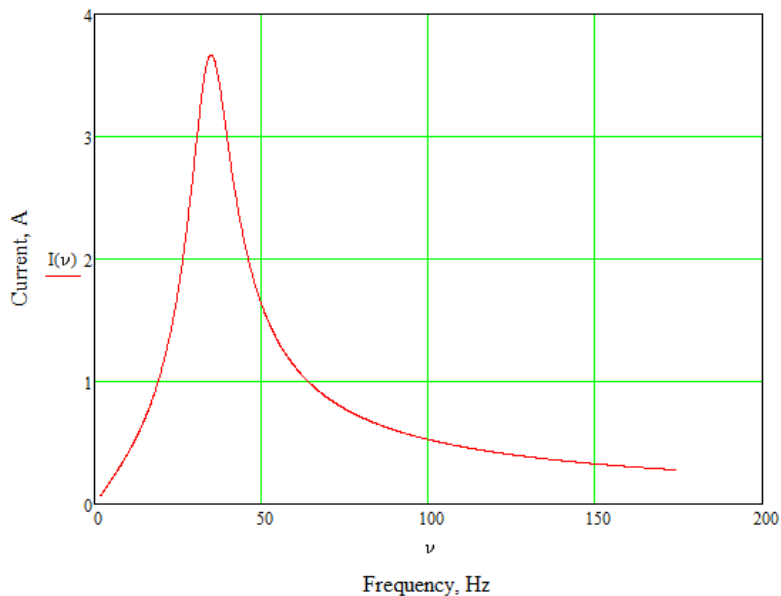
3.2. Methods of Organizing and Conducting Laboratory Classes in Physics

Laboratory work in physics is small in scope and content of the student's initial scientific research, an effective form of organization of the educational process in physics in the institutions of higher education, during which the student conducts natural, simulation experiments, experiments using laboratory equipment, measuring equipment, computing equipment. In the process of performing laboratory work, the student acquires the skills of applying theoretical knowledge in practice, practical skills of working with the methodology of experimental research, learns to process and analyze the results of the experiment. The main tasks of laboratory classes include: deepening the theoretical knowledge that the student has acquired in lectures and during independent work, thanks to their practical application; formation of the skills of working with measuring equipment, the ability to calculate errors; acquisition of skills and practical decision-making skills in real production conditions.

In a laboratory class, the number of students should not exceed half of the academic group, if the group has more than 15 students. Each student must independently perform all laboratory work and issue their results. At the introductory lesson, the teacher must acquaint the students with the general rules of work in the laboratory and safety rules that they must follow. The following requirements have been developed for students, the observance of which is important for the education of students in a responsible attitude to their duties. Students who did not show up for the laboratory work or were not allowed to do it due to poor preparation, perform work on an additional schedule at the expense of personal time. The procedure for performing the laboratory work is determined by the schedule, which is published at the beginning of the laboratory classes and posted on the bulletin board in the laboratory [3].

When performing a laboratory work, students should pay great attention to studying the essence of physical phenomena, mastering the technique and methodology of conducting a physical experiment. It is irrational to start performing laboratory work without mastering the theoretical material, without having clear ideas about the purpose of the

experiment, the methodology and the procedure for its implementation. The teacher checks the student's preparation for the laboratory work during an interview with the student at the beginning of each lesson. Students who have mastered the theoretical material and have a blank for the report (brief synopsis) are allowed to perform the work. The report contains the following items:

1. The name of the laboratory work, its number and the set goal.

2. A brief synopsis of the theoretical foundations of the measurement method and a diagram of the installation.

3. Procedure for performing work.

4. Control questions.

5. Table blanks for entering the results of the experiment and the results of its processing.

6. Processing the results of the experiment (calculation of physical quantities and estimation of their errors, construction of graphs).

7. Conclusions.

A student who came to a laboratory class without preparations, or who did not master the basic theoretical principles of laboratory work, is not allowed to the class. Having received permission to perform laboratory work, the student begins experimental research, in the process of which he conducts measurements of physical quantities. To increase the accuracy, it is necessary to measure each physical quantity at least three times. The results of the experiment should be clearly recorded in the table. After completing the experiments, the results of the experiment must be submitted to the teacher for signature and start filling out the second part of the report. It is desirable to process the results on a computer or calculator, having developed programs for this.

Working documents (programs) of the Mathcad system for processing the results of the experiment are embedded in the electronic textbook [5], the texts of some program samples are given in the appendix. To start the working document, you need to activate the hyperlink "Processing the results of the experiment in Mathcad" in the corresponding section of the laboratory work. At the same time, the Mathcad system is launched and the corresponding working document is opened. In the working document of the Mathcad system, it is necessary to replace the experimental ones with their respective values in the templates. Templates (matrices

and constants) that need to be changed are highlighted in yellow. Read the results in the areas highlighted in green. Graphs must be built on a separate sheet of paper (format not less than 14x20 cm) observing the scale. When maintaining the work, the student must submit a full report on the performance of the laboratory work and give full answers to the theoretical questions posed by the teacher.

Since 2019, due to the coronavirus pandemic, and then since February 24, 2022, with the start of russia's war against Ukraine, the higher educational institutions of our country switched to distance education. This kind of teaching load in physics, such as laboratory work, turned out to be incompatible with distance training. After all, their main implementation is a full-scale experiment, the conduct of which requires special equipment that is fundamentally not available at home. Initially, to solve this problem, the teachers made a video recording of the step-by-step performance of laboratory work in the physical laboratory of VNAU, then uploaded it to the Google Drive of the VNAU Socrates system, and the access link to them was sent to students. Measurements of physical quantities were carried out from 3-5 times (for each team, in each of which there were 2 students), then protocols of the obtained measurements were created in MS Excel, in which the values of the measured quantities were entered opposite the names of the students. After gaining access to the video recording of the laboratory work, the students reviewed and performed calculations in the received MS Excel protocols with subsequent formulation and recording of the conclusion. Joining the video conference in Zoom during laboratory work, the teacher and students debated, discussed the progress of the work, demonstrated their calculations, conclusions and answered the questions. It was a difficult, time-consuming approach to the organization, implementation, and carrying out of the laboratory work at the beginning of distance training. The disadvantage of this process was not accepting the direct participation of the students in carrying out measurements during the execution of the work. At the same time, a part of the competencies provided by the educational and professional program in the speciality may be lost for the future specialist with such an approach. For example, consider an example of performing one of the laboratories works in the distance form of education from the "Optics" section.

Laboratory work № 7

Topic: Determination of the wavelength of light using the "Laser – diffraction grating" system.

Devices and materials: optical bench; diffraction grating; screen; line; laser.

The purpose of the work: to study the diffraction of light on a diffraction grating and the principle of laser operation, to master the method of determining the wavelength of light.

Theoretical information and description of devices

A diffraction grating, as a dispersing system, can be used in a spectral device instead of a prism. It provides greater resolution and light intensity compared to prism spectrometers of the same size. Like the prism, the diffraction grating is installed in parallel beams. The position of the main diffraction maxima is determined by the equation (Figure 4):

$$d \sin \varphi_k = 2k \frac{\lambda}{2}, \tag{1}$$

where d – the period (or period) of the lattice; φ_k – diffraction angle, that is, the angle between the normal to the grating and the direction of the diffraction maximum; λ – the length of the light wave; k – the order of the maximum $k = \pm 0, 1, 2, 3...$. If a stream of white light falls on the grid, then with the same value k the diffraction angles will be different for different wavelengths, that is, the decomposition of white light into a spectrum will be observed. When $k = 0$ the maximum condition is satisfied for all wavelengths, i.e. when $\varphi = 0$ a central light band is observed.

Most often, a diffraction grating is used to determine the length of light waves. If the slit is illuminated by monochromatic light with a known wavelength, then according to (1) the length of the light wavelength is:

$$\lambda = \frac{d \sin \varphi_k}{k} \tag{2}$$

The sine of the angle at which the k – th order spectrum is observed can be determined from Figure 4:

$$\sin \varphi_k = \frac{x_k}{\sqrt{L^2 + x_k^2}}, \tag{3}$$

where x_k – is the distance from the center of the maximum of the zeroth order to the center of the maximum of the k-th order; L – distance from the screen to the diffraction grating. Then on the basis of (1) taking into account (3) we have:
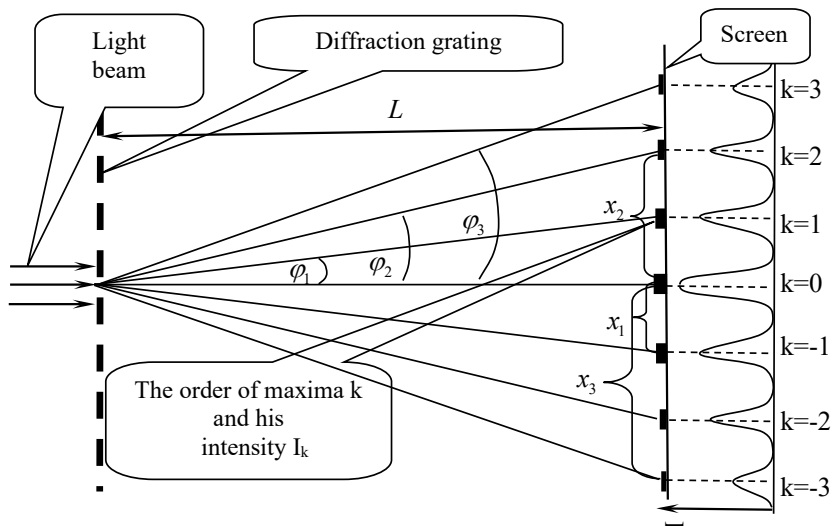
Figure 4. The diffraction pattern obtained from t he grating

$$\lambda = \frac{d \cdot x_k}{k \cdot \sqrt{L^2 + x_k^2}} \qquad (4)$$

The order of work

1. Turn on the laser, illuminate the diffraction grating. While observing the diffraction pattern on the screen, measure the distances between the diffraction maxima of the same order.

2. Place the diffraction grating and the slit at a distance of 5-10 cm from each other. Measure the distance L between the grid and the screen.

3. Measure the distances between the centers of maxima of the same order. Divide the measurement results by 2 and determine the distance x_k between the center of zero and the centers k-th of their orders. Enter the measurement data into the table (develop the table yourself).

4. For each value according k to formula (4), calculate the wavelength of light and estimate the measurement error.

Control questions

1. Explain the Huygens-Fresnel principle.
2. What is diffraction of light.

3. Fresnel diffraction phenomena.

4. Fraunhofer diffraction. Diffraction from a slit. Diffraction from a diffraction grating.

5. What is the difference between a diffraction spectrum and a dispersion (prismatic) spectrum?

6. What is affected by the value of a permanent diffraction grating and how?

After processing the material and recording the workpiece in a notebook, the students watched the video recording of the step-by-step performance of the laboratory work sent by the teacher (the video recordings of the performance of each laboratory work were saved on the Google Drive of the Socrates system of VNAU) and performed calculations according to the protocol of the measured values. The students made calculations in Excel (Figure 5).

When further overcoming difficulties during laboratory work, whenever possible, the experiment was replaced by its mathematical modelling in Mathcad. This replacement of real-life modelling with mathematical modelling during laboratory work allows to compensate to a large extent the decrease in the quality of the educational process due to the disadvantages of distance training.

The practice of distance training of physics in higher education shows that special attention should be paid to laboratory classes in physics, since they are the key means of forming a range of practical skills and abilities in students, which form the basis of the professional competence of future specialists. It is important that, during distance training, students independently or under the guidance of a teacher conduct simulation experiments and experiments, during which they reinforce the theoretical knowledge acquired in lectures and acquire practical skills. At the same time, the main means of implementing laboratory classes are specialized software simulation environments, as well as virtual digital laboratories. In cases where, for objective reasons, a real physical experiment cannot be simulated by a student in a virtual laboratory, it is advisable to use a demonstration of the corresponding phenomenon or process by the teacher in synchronous or asynchronous mode (video broadcasting of the experiment process from the laboratory or use of an appropriate video recording). Modern means of video communication make it possible to record not only

**Figure 5. A fragment from the video recording of the laboratory work
"Determining the length of the light wave using the system "Laser – diffraction grating"
and the protocol of the values of the measured values**

the progress of the experiment, but also the real results of measurements of physical quantities used by the students for calculations and formulation of relevant conclusions and generalizations. Note that these two areas of physical experiment implementation in higher education in the absence of the possibility of full-time or mixed education have become widespread and have provided this extremely important complex training of future specialists. In particular, a wide range of video fragments of both traditional and specialized physical experiments are available on digital educational resources [7].

3.3. Organization of Students' Independent Activities

All forms of classes in physics involve significant independent extracurricular work of the student. Due to the lack of time in lectures, practical and laboratory classes, it is not possible to consider all theoretical questions, all basic methods of conducting physical experiments and all types of problems and methods of solving them, therefore, within the framework of the educational process, it is important to organize independent educational and cognitive activities of students.

The volume of independent work of students for the bachelor's level of higher education should be within $1/3 – 2/3$ of the total number of hours. This number of hours makes it possible to develop cognitive activity, to form independence as a personality trait, the ability to creatively solve tasks, and the ability to make decisions. It is necessary to focus attention on the following aspects of independent educational and cognitive activity of the students: 1) Independent educational and cognitive activity of a student is an organized activity that includes the following components: awareness of the goal and set educational task; clear and systematic planning of independent work; search for necessary educational and scientific information; assimilation of own information and its logical processing; the use of methods of research and the scientific research work to solve the tasks; development of one's own position regarding the assigned task; presentation, justification and maintaining of the received decision; conducting self-analysis and self-control. 2) Educational and cognitive activity differs in some ways from ordinary educational activity. It is exploratory in nature, several cognitive tasks are solved during its implementation, and its result is a solution to problem situations. 3) In the case of the optimal variant, the student's

educational and cognitive activity is self-regulated, self-directed, internally motivated, selective in nature [2].

The content of the independent educational and cognitive activity of students in physics is determined by the work program of the academic discipline, methodical instructions for practical classes and methodical instructions for independent work. Independent work of students is provided by a complex of educational and methodological tools: lecture notes, study aids, textbooks, methodological developments, electronic resources. After a certain period of time, a lecturer checks the theoretical material, submitted for the student's independent study and evaluated the results of the student's independent work. The teacher of practical classes in physics advises students, if necessary, on solving independent tasks, individual tasks, writing a project, after completing the tasks, analyzes and evaluates the results of the independent educational work of each student. In the student's personal office in Socrates, individual physics tasks are attached to each section, which the student completes independently. The general requirements for the performance of individual tasks are described:

1. During the study of the physics course, the student must complete independent (individual) tasks for each section of physics. Each task includes 6-8 problems.

2. The numbers of tasks that the student must include in his work are determined by the table of variants. The number of the assignment variant corresponds to the last two digits of the score book (login in the Socrates system, student card), for example, if the number of the student's score book is m21563, then the number of the assignment variant will be 63. The numbers of the tasks are listed according to the variants in the table.

3. Independent tasks are performed in handwritten or electronic version at the choice of the student. On the cover of the independent work, information about the student should be given in the following format: Vinnytsia National Agrarian University, Individual tasks No., in physics, student of the first year (indicate the faculty), group (indicate the group), full name, variant № (indicate the variant), Vinnytsia 2024 year. The handwritten version of the work is drawn up on the separate sheets of paper or in the separate notebooks and handed over to the teacher for checking. The electronic version of the work is performed in MS Word or Power Point (presentation) and must contain a table of contents (the table of contents is

recommended to be created using MS Word in the automatic mode with the hyperlinks), a list of references. To insert working documents with calculations (Mathcad listings, fragments of MS Excel book sheets), it is recommended to use the "Insert" menu command, the "Screenshot" or "Screenshot" function of MS Word. If desired, the student can also attach electronic versions of working documents with calculations to the work (Mathcad working documents, sheets of MS Excel books or program listings written in an arbitrary programming language). All individual tasks № 1, № 2, etc. are inserted into one MS Word or Power Point working document. The MS Word working document has the format: A4 sheet format, Times New Roman text font, size – 14 pt, spacing 1,5, paragraph indent 1,25, mathematical formulas are typed in the formula editor. The MS Word document (file) is signed according to the sample: for example: group AI-3 task №1, student login M20099, file name.docx. The presentation in Power Point is signed according to the same sample but has the extension pptx: for example: group EO-2 task № 2, student login a21015 file name. pptx). For the electronic version of the work, the student is additionally awarded 40% of points, for example, if the student will be awarded 5 points for the handwritten version of the work. For the same work, but performed in the electronic version, the student will receive: $5 + 0.4 \cdot 5 = 7$ points.

4. The conditions of tasks in the independent work must be completely rewritten without abbreviations. After that, write down their short conditions and transfer all the data specified in the conditions to the SI system.

5. It is necessary to solve the problems in a general form, that is, to express the sought quantity in the letter designations of the quantities specified in the condition of the task. With this method of solving, there is no need to calculate intermediate values.

6. Solving problems should be accompanied by short but comprehensive explanations; in those cases, when necessary, add drawings or provide drawings. Graphs are built to the appropriate scale manually or on a computer (Mathcad, Matlab, MS Excel), drawings are built manually or using MS Word, or in any graphic editor of the student's choice.

7. After receiving the final calculation formula, it should be checked by the dimensional method, instead of the symbols of the values, the units of measurement of these values in the International System of Units (SI) should be substituted in the right part of the formula, carry out the

necessary actions with them and make sure that the unit obtained at the same time corresponds to the desired physical quantity. If there is no such correspondence, it means that the problem is solved incorrectly.

8. Numerical values of quantities when substituting them into the calculation formula should be expressed only in SI units. As an exception, it is allowed to express the numerical values of homogeneous quantities that are in the numerator and denominator of the fraction and have the same degrees in any but the same units.

9. When substituting into the calculation formula, as well as when writing the answer, the numerical values of the quantities should be written as a product of a decimal fraction with one significant figure before the comma to the corresponding power of ten. For example, instead of 984000, you should write $9{,}84 \cdot 10^5$, instead of 0,000647, write $6{,}47 \cdot 10^{-4}$, etc.

10. Calculations can be performed manually, on a calculator or on a computer (Mathcad, Matlab, MS Excel or any package of applied mathematical programs or any programming language). When performing calculations on a computer, the working document should have detailed comments. A listing of the program or a working document with the results of the calculations must be attached to the solutions of the problems. Calculations according to the calculation formula must be carried out in compliance with the rules of approximate calculations. As a general rule, the final answer should be written to three significant figures. This also applies to the case when the result is obtained using a calculator or computer.

11. The independent work completed in a handwritten mode is submitted to the lecturer for verification (in the case of distance training, photocopies of handwritten works are inserted into an MS Word document and sent to the teacher's email address.

12. The independent work done in electronic version in MS Word or Power Point format is sent to the e-mail address of the teacher (it is not necessary to print the work).

13. The deadline for submitting independent works for verification is no later than a week before the certification. If the work during the verification is not passed, the student is obliged to correct the shortcomings and present it for re-verification, including those tasks the solutions turned out to be incorrect.

A student can receive an advice or explanations on solving individual problems in physics during distance training through a video conference in

Zoom, Viber or Telegram messengers, by sending a link to a video recorded on Google. If students, after receiving timely consultation and support from the teacher, will be able to independently solve problems, analyze the obtained solutions, will actively work in classes, then in this case it is possible to inculcate in students the skills and abilities of independent work.

3.4. Organization and Control of the Students' Knowledge

Knowledge control allows the teacher to determine how well students have mastered the educational material and identify gaps in their knowledge, evaluate the effectiveness of teaching and identify shortcomings in the educational process, the ability to effectively influence the formation of competencies, the development of students' abilities creates a sense of responsibility in students for their academic success, helps them to engage in self-training more actively and learn the material better.

The choice of forms of control depends on the purpose, methods, content of training, place and time of classes. According to the forms of training, the following forms of control are distinguished: individual, group, frontal and self-control. During individual control, the individual knowledge, abilities and capabilities of individual students are revealed. During individual supervision, each student receives his task, which he must complete without outside help. Individual control is planned in advance. The group form of organization of control is used during repetition for the purpose of systematization and generalization of the educational material. For such control, the group is temporarily divided into several subgroups (from 2 to 10 students). Depending on the purpose of control, the groups are offered the same or different tasks. During frontal control, tasks are offered to the whole group and the correctness of perception and understanding of the educational material, the degree of memory retention is checked. Self-control is especially important for the development of students. For the organization of self-control in the process of studying physical and mathematical disciplines, it is the provision of answers to the assigned tasks. Then it is enough for students to check the final result [3].

The monitoring of students' educational achievements is divided into the following types according to the time of its implementation: preliminary, current, boundary and final. Preliminary control (diagnostics of students' initial level of knowledge) is used as a prerequisite for successful planning

and management of the educational process. Current control of knowledge is an organic part of the entire pedagogical process and serves as a means of detecting the degree of perception (assimilation) of the educational material. Boundary (thematic, modular, block) control of knowledge is an indicator of the quality of studying individual sections, topics and related cognitive, methodical, psychological and organizational qualities of students. Boundary control can be carried out verbally and in writing, in the form of a control work, individually or in a group. The final control is the assessment of students for the purpose of assessing their knowledge and skills in accordance with the requirements of the professional qualifications [3].

Control of knowledge in physics is carried out during lectures, practical classes, tests and exams. During face-to-face education, we mainly use the following forms of control: survey, writing independent work, control work, colloquium, testing. Surveys with the camera turned on and testing turned out to be the most effective in distance training.

The content of test tasks must meet the following requirements: 1) clarity of wording; 2) optimal level of complexity; 3) reliability; 4) validity. Reliability is the resistance of the test results to the influence of various random factors-obstacles, that is, immunity to interference. It means the probability of students obtaining the same test results in various testing situations. Reliability is one of the most important characteristics of the test. The test program should allow to determine and evaluate knowledge, skills and abilities with maximum accuracy. Validity is a concept that tells us what exactly a test measure and how well it does it. Validity covers a wide range of test information. Various categories of this information form types of validity. The test should include a set of tasks of various types in order to comprehensively assess the level of assimilation of educational information: understanding, cognition, reproduction, application, creativity [3].

In order to carry out intermediate, current or boundary control of knowledge in physics in practical classes in remote form, electronic testing was first compiled and conducted using the cloud-based Google Forms service, then using the Vseosvit platform, which allows you to create tests of various types, including multiple-choice tests with one or more correct answers, free-response tests, matching tests, drag-and-drop tests, sequencing tests, etc. With the introduction of Moodle at VNAU in 2022, tests were already developed in it. First, for the final knowledge

control (credit, exam), and later for the current stages of knowledge control (attestation, modular). Testing in Moodle is an effective way of evaluating students' educational achievements, which meets modern requirements for the quality of education.

To test theoretical knowledge, you can use testing with the choice of one or more correct answers, testing with multiple choices, testing to establish compliance. Practical work, laboratory work, project activity can be used to test practical skills. And to test creative abilities – creative tasks, such as creating a physical model, presentation, essay.

The choice of the form of knowledge control depends on the specific goals of assessment, the educational achievements of students and other factors. In any case, the teacher's possession of various forms of knowledge control is an important condition for effective assessment of students' educational achievements and contributes to increasing students' interest in studying the discipline.

Tests are used to monitor students' educational achievements in physics. Questions in the test can be closed or open. In closed tests, the student is offered several answer variants and chooses the correct ones from them. In open tests, the student independently calculates the answer and enters it from the computer keyboard.

Tests can be final, thematic, tests for self-control and self-education. The final tests are intended to objectively confirm the student's level of knowledge during attestation and when passing the exam (credit). The thematic test is designed to contribute to the improvement of the educational process itself, it is used in maintaining of laboratory works and in practical classes. Tests for self-control and self-education are important for the learning process. They are often called "practice tests". They should be freely available.

Final tests in the discipline "Physics" include 15 questions and 5 mini-problems from different sections of physics. From 3 to 5 minutes are allocated for solving one problem. Final tests are attached in Moodle. They are passed with mandatory registration and entering a password.

Tests for self-control and independent preparation contain 15-30 tasks, which will include theoretical questions and test mini-tasks. They can be of open, closed or combined form. Tests for self-control and self-training are attached in Moodle for free access.

Conclusions

The pandemic and russia's armed invasion of Ukraine led to the rapid development of distance training educational trends. Taking into account the priority of a safe educational environment, the availability of electricity, the ability to connect to the Internet for participants in the educational process, a mixed and distance form of education is used in higher educational institutions of our country. The teacher is faced with the problem of which method to choose, so that in conditions of anxiety and limited access to educational resources to achieve high-quality teaching of the discipline "Physics". The way out of this situation is to use the resources of higher education institutions, various services for organizing video conferences, learning management systems, tools for sharing and exchanging information, messengers, websites that offer a wide range of interactive physics simulations and allow you to study physics in an interactive mode and programs. Thanks to such a variety of interactive information and communication opportunities, classes can be held both in the classroom and in a mixed format, and if necessary, in a remote format. In connection with the military operations in Ukraine, distance training can take place both in synchronous and asynchronous modes.

Any of the methods of organizing and conducting a practical lesson in physics can be implemented in the conditions of distance training when the students and the teacher are in safe living conditions, have electricity, the Internet and a stationary computer or laptop. Complications arise when students conduct experimental research. At the same time, they use virtual environments or watch video clips that do not develop the ability to use real measuring devices, assemble installations and work with them. Replacing natural modelling with mathematical modelling in Mathcad makes it possible to largely compensate for the decrease in the quality of the educational process due to the disadvantages of distance training.

Effective means of the technology implementation are: Moodle learning management system, Socrates electronic management system, Zoom service, Viber messengers, Telegram, electronic board (Whiteboard), math package Mathcad.

The effectiveness of the practical lesson is determined not only by the content of the information received by the students, but also by the nature of the interaction between the teacher and the student. Active activity of

the students brings the best result. It is necessary that each of them works with full load and get a good result from their work. Only in this case, it is possible to inculcate in students the skills and abilities to solve practical problems.

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