УДК 378.018.8:373.5.011-051:53](045)

PREPARATION OF FUTURE PHYSICS TEACHERS FOR SOLVING NON-STANDARD PHYSICS PROBLEMS

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The article presents the results of research on the challenges in preparing future physics teachers. It demonstrates that for the effective training of future physics teachers in solving non-standard physics problems, it is essential to shift the focus in the selection of content and educational materials towards the predominance of methods and rules for solving physics problems. While the content of laws and physical theories is important and requires comprehension, it is secondary. This conclusion is illustrated by two methods for solving non-standard physics problems, which are taught to students in the course "Practicum in Solving Non-Standard Physics Problems".
Keywords: *physics problem; physical law; methods of solving; teaching methodology in physics; law of odd numbers; law of conservation of energy; harmonic oscillations; kinematics.*

ПІДГОТОВКА МАЙБУТНІХ ВЧИТЕЛІВ ФІЗИКИ ДО РОЗВ'ЯЗУВАННЯ НЕСТАНДАРТНИХ ФІЗИЧНИХ ЗАДАЧ

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У статті розглянуто результати дослідження щодо підготовки майбутніх учителів фізики. Виявлено, що для успішного навчання майбутніх педагогів розв'язуванню нестандартних задач необхідно переорієнтувати зміст і освітній контент. Зокрема, акцент слід робити на методах і правилах розв'язання фізичних задач, тоді як засвоєння фізичних законів і теорій, хоча й залишається важливим, відіграє другорядну роль. Цей висновок підтверджено прикладами двох методів розв'язання нестандартних фізичних задач, які викладаються студентам під час курсу «Практикум з розв'язування нестандартних фізичних задач».

Запропоновані методи розв'язування нестандартних фізичних задач дозволяють не лише розкрити сутність фізичних законів, а й навчати здобувачів освіти ефективному їх використанню на практиці. Аналіз освітнього процесу свідчить, що ключовим є навчання методам і прийомам розв'язування задач, тоді як засвоєння теоретичного матеріалу може бути організоване у форматі самостійної роботи студентів або в межах змішаного навчання (наприклад, за моделлю «перевернутий клас»). Перспективними виглядають дослідження та впровадження технологій навчання, що враховують підхід, за якого опанування методів розв'язування задач певного типу передує вивченню теоретичного матеріалу, пов'язаного із цими задачами. При цьому важливо враховувати, що здобувачі вищої освіти повинні мати базові знання, які відповідають вимогам шкільної програми.

Запропонований підхід, за якого опанування методів розв'язування задач передує вивченню відповідного теоретичного матеріалу, є особливо актуальним у підготовці майбутніх вчителів фізики. Це дозволяє не лише формувати у студентів навички вирішення задач, але й розвивати їх здатність творчо використовувати сучасні технології навчання для викладання основ фундаментальних фізичних законів.

Для майбутніх вчителів фізики важливо забезпечити комплексну підготовку, яка включає як теоретичні знання, так і практичні навички їх застосування. Застосування описаного підходу може бути реалізоване в курсу «Практикум розв'язування нестандартних фізичних задач». На підставі проведених численних спостережень за освітнім процесом, нами було розроблено технологічну послідовність упровадження розробленого нами методу.

Ключові слова: *фізична задача; фізичний закон; методи розв'язування; методика навчання фізики; закон непарних чисел; закон збереження енергії; гармонічні коливання; кінематика.*

A modern physics teacher must possess a solid foundation in mathematical tools, as well as appropriate methods and techniques for solving advanced-level physics problems. To develop relevant general and professional competencies, the course "Workshop on Solving Non-Standard Physics Problems" was designed. Its primary goal is to familiarize higher education students with methods for solving non-standard physics problems aimed at teaching high school students (grades 10–11).

The purpose of this article is to identify optimal methodological approaches for preparing future physics teachers to train students in solving non-standard physics problems, a critical aspect of teaching gifted youth.

Theoretical foundations for the methodology of teaching problem-solving skills in physics have been explored in the works of O. I. Bugayov, S. U. Goncharenko, O. I. Lyashenko, A. I. Pavlenko, Ye. V. Korshak, M. I. Shut, S. Yu. Voznyuk, H. P. Kobel, and many others.

Traditionally, in the methodology of teaching physics, it is widely recognized that solving physics problems plays a leading role in the educational process. At the same time, educational activities aimed at mastering methods and approaches to solving physics problems have been thoroughly studied by Ukrainian educational researchers. These studies emphasize the dual role of problem-solving: as both a tool and a method for teaching students to operate with scientific knowledge in physics, including a system of scientific concepts [4, p. 4].

Numerous studies on the methodology of teaching physics provide various methods and approaches for teaching students to solve physics problems [2; 3; 5]. However, these methodological insights typically follow a specific sequence: first, students are expected to acquire the necessary theoretical material, and then develop practical problem-solving skills. While this approach is traditional and well-known, it does not address a crucial methodological challenge – how to teach the practical application of physics laws effectively.

Teaching students to solve advanced-level physics problems involves specific methodological challenges that can reduce the efficiency of the educational process and lead to critical errors in a teacher's future work [1]. It is difficult to describe all methodological issues and solutions in a single article, so we will focus on a few effective methods for solving non-standard physics problems.

The course "Workshop on Solving Non-Standard Physics Problems" aims to train future physics teachers to tackle complex problems. How can the learning process be organized effectively to develop students' skills in solving non-standard problems?

We conducted a survey among students of the Faculty of Physics, Mathematics, and Computer Science at Pavlo Tychyna Uman State Pedagogical University to identify the difficulties they encounter when solving physics problems and to understand what, in their opinion, hinders their ability to master this critical skill. The majority of respondents (82%) noted that simply knowing a physics law is insufficient for solving a physics problem. A follow-up survey revealed that, according to future physics teachers, this is due to two key reasons:

1. Applying physics and mathematics laws requires mental operations that can only be developed through experience (65% of all respondents).
2. The application of physical laws has its limits and depends on the conditions (initial data) stated in the problem's description. Therefore, it is crucial to analyze the problem rather than mindlessly searching for a formula to achieve a numerical result (77% of respondents).

These findings led us to the conclusion that the "Workshop on Solving Non-Standard Physics Problems" course should focus not only on the content of physics laws and their related topics but also on integrating the curriculum around methods and strategies for solving advanced problems.

Teaching students this method means teaching them to use physical laws (principles, rules, etc.), as the foundation of any problem-solving method lies in a physical law.

Thus, it became necessary to select methods for solving advanced physics problems and to search for them in relevant literature. Below, we present two such methods, which are typically absent from school textbooks but can be successfully applied within the school physics and mathematics curriculum.

Method: The Odd Numbers Law

One of these methods is the Odd Numbers Law. Although this law is rarely mentioned in school textbooks, it can serve as an effective tool for solving kinematics problems. The essence of this law is that the distances traveled by a body starting from rest under uniform acceleration over equal time intervals relate to one another as a sequence of odd numbers.

For instance, during uniform acceleration from rest, the distances covered in consecutive equal time intervals are proportional to 1 : 3 : 5 : 7 … . This pattern can simplify the analysis of motion problems and provide a deeper understanding of kinematics:

$$s_1 : s_2 : s_3 \dots s_n = 1 : 3 : 5 : \dots (2n-1)$$

There are examples of problems solved using two approaches below. The first method is based on the equation of motion for uniformly accelerated motion. The second method uses the Odd Numbers Law.

Example 1: What is the displacement of a freely falling body during the \(n\)-th second after it begins to fall?

Method 1: Using the Equation of Motion.

The total displacement is divided into two parts: h_1 and h_2 (see Fig. 1a).

h_2 is the distance the body falls during the *n*-th second (i.e., in 1 second).

h_1 is the distance the body falls in the first $(n-1)$ seconds.

The equation for the displacement h_n in the *n*-th second is derived as follows:

1. The total displacement after *n* seconds is given by:

$$h_{total} = \frac{1}{2}gn^2$$

2. The total displacement after $(n-1)$ seconds is:

$$h_{(n-1)} = \frac{1}{2}g(n-1)^2$$

3. The displacement in the *n*-th second is the difference between these two displacements:

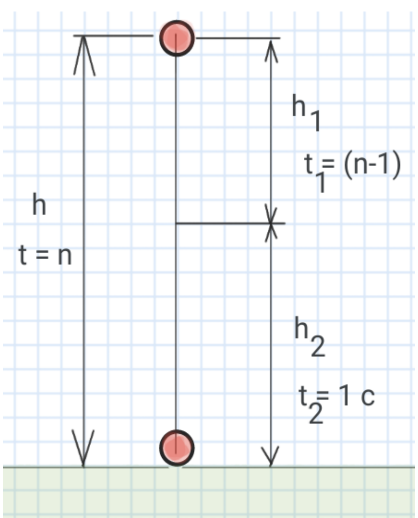
$$h_n = h_{total} - h_{n-1} = \frac{1}{2}gn^2 - \frac{1}{2}g(n-1)^2$$

4. Expanding and simplifying:

$$h_n = \frac{1}{2}g[n^2 - (n^2 - 2n + 1)] = \frac{1}{2}g(2n-1)$$

Thus, the displacement in the *n*-th second is:

$$h_n = \frac{1}{2}g(2n-1)$$



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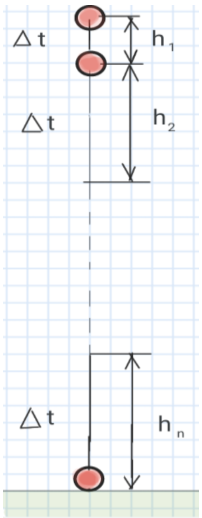

b

Fig. 1

Method 2: Using the Odd Numbers Law.

Let us conditionally divide the entire path into segments $h_1, h_2, \dots, h_n$, which the body covers in equal time intervals $\Delta t = 1s$ (Fig. 1b). For this case, we write the law of odd numbers as:

$$h_1 : h_n = 1 : (2n - 1) \text{ or } \frac{h_1}{h_n} = \frac{1}{2n-1},$$

h_1 – movement in the first second $\Delta t_1 = 1c$, h_n– movement in n-th second (Fig. 1b), that is, $\Delta t_n = 1\ c$.

Ago $h_1 = \frac{g\Delta t^2}{2} = \frac{g\cdot 1^2}{2} = \frac{g}{2}$. Therefore, $\frac{h_1}{h_n} = \frac{g/2}{h_2} = \frac{1}{2n-1}$,

$$h_n = \frac{g}{2}(2n - 1) = g(n - \frac{1}{2})$$

The answer is the same for both methods: $h_n = g(n - \frac{1}{2})$.

Example 2. A body is freely falling from a height of 80 m. What is its displacement during the last second of the fall?

Method 1: Using the Equation of Motion.

Let h_2 be the distance the body travels in the last second, and h_1 be the distance it travels in $(n - 1)$ seconds. Then the total distance is $h = h_1 + h_2 = 80\ m$.

Let us find the total time \(t\) during which the body was falling:

$$h = \frac{gt^2}{2},\ t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2\cdot 80}{10}} = 4\ s.$$

Let's find the displacement during the last second:

$$h_2 = h - h_1 = h - \frac{g(t-1)^2}{2} = 80 - \frac{10\cdot(4-1)^2}{2} = 80 - 45 = 35\ m.$$

Method 2: Using the Odd Numbers Law.

Let's divide the entire path into segments that the body travels during equal time intervals of Δt = 1 s. How many such segments will there be?

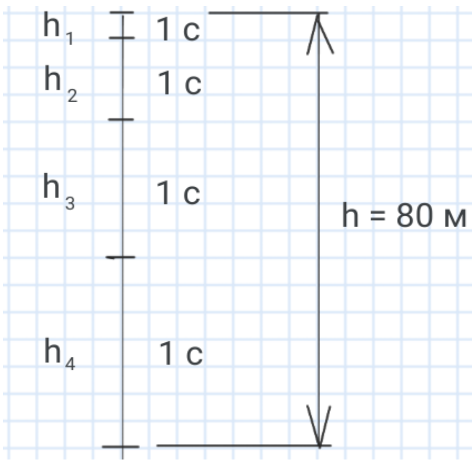

Fig. 2

The object was in free fall $t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2\cdot 80}{10}} = 4\ s.$

Therefore, there will be four segments of Δt = 1 s. (***Fig.*** 2).

Thus, according to the law of odd numbers:

$$h_1 : h_2 : h_3 : h_4 = 1 : 3 : 5 : 7$$

$$\frac{h_1}{h_4} = \frac{g\Delta t^2/2}{h_4} = \frac{g/2}{h_4} = \frac{1}{7},$$
$$h_4 = \frac{7g}{2} = \frac{70}{2} = 35\ m.$$

The answer is the same for both methods: 35 m.

Example 3. How long did the body fall if, during the last 2 seconds, it traveled 60 meters?

Method 1: Using the Equation of Motion.

Let t be the time during which the body fell from the height h. Then h_1 is the distance that the body traveled in the time $(t - 2)$, while $h_2 = 60\ m$ is the distance that the body traveled during the last Δt = 2 s. Therefore,

$$h = h_1 + h_2$$
$$h_2 = h - h_1$$
$$h_2 = \frac{gt^2}{2} - \frac{g(t-2)^2}{2}$$
$$h_2 = \frac{gt^2}{2} - \frac{g}{2}(t^2 - 4t + 4) = \frac{gt^2}{2} - \frac{gt^2}{2} + 2gt - 2g$$
$$h_2 = 2gt - 2g$$

From the last equation, we will express the time:

$$h_2 = 2gt - 2g \Rightarrow 2gt = h_2 + 2g \Rightarrow t = \frac{h_2}{2g} + 1$$
$$t = \frac{h_2}{2g} + 1 = \frac{60}{20} + 1 = 4\ s$$

Method 2: Using the Odd Numbers Law. We will conditionally divide the entire path into segments (the number of segments n) that the body travels over equal time intervals $\Delta t = 2\ s$. The falling time can be found using the formula $= n \cdot \Delta t$. To find the number of segments n, we will use the law of odd numbers: $h_1 : h_n = 1 : (2n - 1)$, where $h_1 = \frac{g\Delta t^2}{2} = 20м$, $h_n = 60$ м (according to the problem conditions). Then,

$$\frac{h_1}{h_n} = \frac{1}{2n-1} = \frac{20}{60} = \frac{1}{3}$$
$$2n - 1 = 3$$
$$n = 2$$

So, $t = n \cdot \Delta t = 2 \cdot 2c = 4\ s$

The answer is the same for both methods: 4 s.

The proposed methods for solving non-standard physics problems not only reveal the essence of physical laws but also teach students to use them effectively in practice. An analysis of the educational process indicates that the key aspect is teaching methods and techniques for solving problems, while mastering theoretical material can be organized in the format of independent student work or within blended learning models (e.g., the “flipped classroom” model). Research and implementation which include learning technologies that prioritize mastering problem-solving methods for specific types of problems before studying the theoretical material related to these problems look promising. At the same time, it is important to ensure that higher education students possess basic knowledge aligned with the requirements of the school curriculum.

The proposed approach, in which mastering problem-solving methods precedes the study of the corresponding theoretical material, is particularly relevant for training future physics teachers. This approach not only develops students’ problem-solving skills but also enhances their ability to creatively use modern teaching technologies to explain the fundamentals of key physical laws.

For future physics teachers, it is essential to ensure comprehensive preparation, which includes both theoretical knowledge and practical application skills. The described approach can be implemented within the framework of the course "Workshop on Solving Non-Standard Physics Problems".

Based on numerous observations of the educational process, we have developed a technological sequence for implementing our proposed method:

1. **Organizing Lessons Using Problem-Based Learning:**

– The instructor presents a problem to the students without prior explanation of the theoretical material.
– Students analyze the problem's conditions, formulate hypotheses, and propose solutions.
– During the discussion of results, the theoretical material is introduced to explain the solution and clarify the associated physical laws.

2. **Utilizing the "Flipped Classroom" Model in Blended Learning:**

– Students independently study theoretical material using video lectures, textbooks, or interactive platforms.
– During class sessions, students work on problems designed to apply the studied laws in practice.
– This approach encourages deeper understanding of the material and enhances students' motivation.

3. **Developing and Using Educational Cases:**

– For example, creating a case where future teachers are asked to model a physics lesson scenario. Students must explain a non-standard problem solution to a class, supporting all explanations with physical laws.
– "Explain Clearly" Method:
– Students are divided into two groups: "teachers" and "students".
– The instructor provides a non-standard problem (ideally qualitative, requiring proof of a statement or leading to an unexpected conclusion).
– The "student" group explains the solution and justifies their perspective, while the "teacher" group critiques the explanation, identifies errors, and seeks clarification if the explanation is unclear.
– The groups then switch roles. This helps future educators practice explaining complex material in an accessible way.

4. **Developing Professional Competencies:**

Mastering problem-solving methods at the early stages of training fosters the development of the following key competencies:

– Analytical Thinking:
– Students learn to analyze problem conditions, identify key parameters, and build logical sequences essential for understanding physical processes.
– Methodological Preparation:
– Familiarity with problem-solving methods enables future teachers to design clear and effective lessons tailored to the needs of diverse students.
– Creative Approach:

– Working with non-standard problems cultivates the ability to find unconventional solutions, which is crucial in teaching practice.

5. Implementing the Approach in Teaching Practice

To reinforce problem-solving skills, the following components should be incorporated into educational programs:

1. Teaching Practice in Schools:
– Students conduct lessons using a methodology based on the problem-solving approach.
– During lesson reviews, instructors provide feedback on the effectiveness of the applied methods.
2. Workshops and Seminars:
– Training sessions where students learn to explain problems of varying complexity to students of different age groups.
– Integration of modern technologies (e.g. simulations, interactive platforms) to visualize solutions.
3. Creation of Educational Materials:
– Future teachers develop problem collections with detailed explanations, promoting a deeper understanding of the subject matter.
– The use of an approach where problem-solving methods precede the study of theory requires proper organization of the educational process. Key challenges include:
– Providing students with a sufficient number of high-quality problems of varying complexity.
– Training instructors equipped with the necessary teaching methodologies and expertise in solving non-standard physics problems.
– Motivating students to independently master theoretical foundations.

Promising directions include the development of digital tools to help students engage with problems interactively and the creation of methodological guidelines for instructors on implementing this approach in the educational process.

Overall, this approach helps future physics teachers acquire not only solid professional knowledge but also flexible thinking skills and readiness to integrate innovations into their teaching practices.

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