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ФОРМИРОВАНИЕ ПРЕДМЕТНОЙ КОМПЕТЕНТНОСТИ УЧАЩИХСЯ ОСНОВНОЙ ШКОЛЫ ПУТЕМ РЕШЕНИЯ ФИЗИЧЕСКИХ ЗАДАЧ ГРАФИЧЕСКИМ МЕТОДОМ

В статье рассматривается важность решения задач из разных разделов физики графическим методом. Показано, что решение задач графическим методом увеличивает возможность использования исследовательских задач на уроках физики, которая будет побуждать учеников использовать полученные знания из физики в повседневной жизни, будет содействовать развитию мышления учеников основной школы и формированию их предметной компетентности.

Ключевые слова: графический метод, физическая задача, предметная компетентность, основная школа.

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THE SUBJECT COMPETENCE OF PRIMARY SCHOOL PUPILS THROUGH TO SOLVING PHYSICAL PROBLEMS BY THE GRAPHIC METHOD

The article discusses the importance of solving problems from different areas of physics graphical method. It is shown that the solution of problems of a graphical method increases the ability to use research problems in physics classes, which will encourage students` knowledge of Physics in everyday, will promote the development of basic school pupils thinking and the formation of their subject expertise.

Key words: graphic method, physical problem, subject competence, Primary school.

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ANALYSIS OF THE COVERAGE OF KINEMATIC EFFECT OF THE SPECIAL THEORY OF RELATIVITY IN THE TEXTBOOKS FOR SECONDARY EDUCATIONAL ESTABLISHMENTS

Methodological approaches to covering the basic provisions of the special theory of relativity available in the textbooks on physics for secondary educational institutions are discussed. It is shown that in some textbooks there are physical errors and incorrect formulations and explanations of the consequences of the special theory of relativity. Critical analysis of the peculiarities of implementation of the principle of science during the coverage of the special theory of relativity in the textbooks for secondary educational institutions has been carried out.

Key words: special theory of relativity, principle of science, methodology of teaching, kinematic consequences of Lorentz transformations.

Problem setting. The special theory of relativity (STR) is the branch of physics which plays a critical role in shaping the scientific outlook of students, provides them with modern concepts of space and time, gives them the understanding the limits of the laws of classical physics.

At present in the scientific and methodological literature there is no unified approach to teaching this physical theory in secondary school [1-13].

This is primarily due to the specifics of the STR and its paradoxical consequences, in particular, kinematics one. It is the analysis of the kinematics consequences of the STR which is mainly offered in the textbooks for secondary educational institutions.

Secondly, a relatively complex mathematical apparatus (Lorentz transformations) requires students` high level of development of logical and abstract thinking for the comprehension of the essence of physical phenomena and processes described from the positions of the theory of relativity. And these circumstances also cause a wide range of methodological innovations in the study of the STR in secondary educational establishments (SEE) [1-13].

In our opinion, the tasks facing the teacher in teaching the STR are as follows:

- to create pupils` adequate understanding physical reality that goes beyond their everyday experience (and which is completely described by Newtonian mechanics);
- to help to understand the peculiarities of the laws of relativistic physics (the region of high energies and velocities of particles motion);
- to form the foundations of students` scientific outlook taking into consideration that the essence of the STR as a physical theory is the teaching about properties of space and time;
- to ensure the implementation of the principles of continuity, correspondence and scientific character in studying classical and relativistic mechanics, maintaining at that logical continuity and interconnection.

In accordance with these principles in teaching the special theory of relativity one must adhere to the strict substantiation of all the formulas, conclusions and provisions of relativistic physics that will provide an integral structure of this physical theory.

Analysis of the latest research of solving general problem and selection of unsettled issues. It is well known that classical mechanics is based on Newton's laws, which are invariant relative to Galilean transformations, space and time are considered as independent variables, time itself is absolute. In contrast, in relativistic physics events occur in four-dimensional space-time, it is based on two postulates of special relativity theory formulated by Einstein and Lorentz transformations (LT).

Thanks to LT transformation of coordinates and time occur at the transition from one inertial reference system (RS) to the other. LT and their consequences are the scientific proof of the existence of space-time as a reality with its specific geometric properties. Therefore, understanding LT and their consequences is a necessary part of forming students` scientific outlook.

We note that the coverage of kinematics effects of the STR on the sufficient methodological level was put into practice in [1; 2; 3; 6; 13].

However, the analysis of modern textbooks and methodical literature shows that the typical summary of relativistic mechanics is the summary in the form of disparate facts and concepts, with fragmentary lighting and not always with a sufficient profundity of analysis and interpretation. In some textbooks and school books [5; 9; 10] there exist physical errors, inaccuracies of definitions, incorrect interpretation of some provisions of the STR.

Purpose of the article. In connection with this the goal of the article in the most general terms is to realize the critical analysis of the peculiarities of the implementation of the principle of science during the coverage of the special theory of relativity in the textbooks for secondary educational institutions.

Summary of the basic material. In many textbooks on physics for secondary schools [1; 3; 12] LT are not mentioned at all, their place and importance in relativistic physics are not explained. This approach to the teaching of the special theory of relativity, in our opinion, does not ensure the principles of science and system in presenting the material. Review of the key provisions of the STR without illuminating LT leaves unsolved the question of the transition from classical to relativistic mechanics, from Galilean transformations to Lorentz transformations.

At that it's unclear to pupils where a new law of addition of velocities is from and so on. This approach does not allow to form a system of knowledge, creates didactic difficulties leading to misunderstanding this physical theory.

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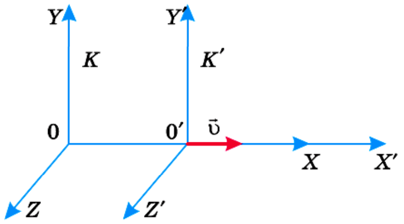
Thus, LT are presented in the textbook [5], and it's emphasized that they are a generalization of Galilean transformations, subject to the relativity of time. However, the presentation of Lorentz transformations is, in our opinion, not systematically verified (and in some places wrong), and it just has the form [5, p. 250]:

«The relationship between variables describing the event in different inertial frames of reference is called the Lorentz transformations:



$$x' = \frac{x \pm \upsilon t}{\sqrt{1-\frac{\upsilon^2}{c^2}}}, y = y', z = z', t' = \frac{t \pm \frac{\upsilon}{c^2}x}{\sqrt{1-\frac{\upsilon^2}{c^2}}} \qquad (1)$$

The sign «+» in the numerator is used during the transition from system *K′* to system *K*, the sign «-» is used when moving from system *K* to system *K′*. This is because system *K′* is moving relative to system *K* at a speed *v*, at the same time one can assume that system *K* is moving relative to system *K′* with speed *v*».

But then in addition it is necessary to explain students that applying the formula in this form in transition from system *K′* to system *K*, and vice versa, except the signs you must also change the corresponding variables *x'* to *x,* and *t'* to *t*. That is the meaning of the expression «The sign «+» in the numerator is used when moving from system *K′* to the system *K*, ...» is an error.

Such volume of additional explanations can only confuse students, so it is advisable to present LT in the form of:

in the transition from system *K* to system *K′*

$$x' = \frac{x - \upsilon t}{\sqrt{1-\frac{\upsilon^2}{c^2}}},\ y' = y,\ z' = z,\ t' = \frac{t - \frac{\upsilon}{c^2}x}{\sqrt{1-\frac{\upsilon^2}{c^2}}}, \qquad (2)$$

and in the transition from system *K′* to system *K*

$$x = \frac{x' + \upsilon t'}{\sqrt{1-\frac{\upsilon^2}{c^2}}},\ y = y',\ z = z',\ t = \frac{t' + \frac{\upsilon}{c^2}x'}{\sqrt{1-\frac{\upsilon^2}{c^2}}}. \qquad (3)$$

It should be noted that the textbook [9, p.128] also contains the formulas of LT, but only for the transition from system *K* to system *K′*.

More detailed analysis of the ways of LT substantiation and methods of using them in teaching physics at SEE will be examined in our further publications.

The question of relativity of events simultaneity is presented differently in modern textbooks, with different degrees of detailing and information.

Unfortunately, highlighting this issue some authors assume physical inaccuracies.

In the reference book [10, p. 86] we read: «Time Δt_0, measured with the clock, moving together with the reference system, is called a proper time. A proper time is the same in all frames of reference.

A moving clock goes slower than a stationary one: $\Delta t = \Delta t_0 \sqrt{1 - u^2 / c^2}$ ».

The text explanation is correct, but the formula $\Delta t = \Delta t_0 \sqrt{1 - u^2 / c^2}$, according to these explanations is wrong (in reality it should be as follows: $\Delta t = \Delta t_0 \Big/ \sqrt{1 - u^2 / c^2}$).

Further, in a rather good, from our point of view, tutorial [5] the following example is considered – the light source is located on the floor of the car and the mirror is on the ceiling. It is proposed to find the time interval during which the light will reach the ceiling, and, reflected from the mirror, turn back. Considering the spread of the light signal relative to the observer moving with the carriage and relatively the stationary observer, the authors of the tutorial [5] indicate incorrectly the direction of the light beam propagation on the illustrations [5, p.249].

Indeed, in *Figure 223, b* ([5, p.249]) it`s mistakenly shown that relative to the stationary observer the light beam will spread towards the broken line *ABC*. In reality, the direction of propagation of light signals is *CBA*.

Fig. 223, a *Spread of the light signal relative to the observer moving with the carriage*
Fig. 223, b *Spread of the light signal relatively the stationary observer*
Fig. 1. *Explanation of the phenomenon of the light signal spread in the "light clock" according to the textbook [5]*

Let us consider this problem in detail.

Regarding system *K′*, related to the observer moving with the carriage, event *A* – switching on the flashlight and event *C* – fixing the light signal have the following spatial and temporal coordinates: event *A*: $x'_A = 0$, $t'_A = 0$; event *C*: $x'_C = 0$, $t'_C = \frac{2l}{c}$ (l – height of the ceiling of the car). Thus, the difference of coordinates and time in system *K′* is equal to: $\Delta x' = x'_C - x'_A = 0$ (the displacement of the beam of light relative to the observer in the train); $\Delta t' = t'_C - t'_A = \frac{2l}{c}$ (the time interval during which the light will reach the ceiling and, reflected from the mirrors, return back according to the clock of the observer in the car).

The time measured by the clock moving with the body in the reference frame *K′* is called a proper time and is marked $\Delta t'$. So the proper time is $\Delta t' = \frac{2l}{c}$.

Now let`s consider the spatial and temporal coordinates of events *A* and *C* in system *K*, related to the stationary observer standing on the platform relative to the car moving with speed $\vec{\upsilon}$.

Event A: $x_A = 0$, $t_A = 0$.

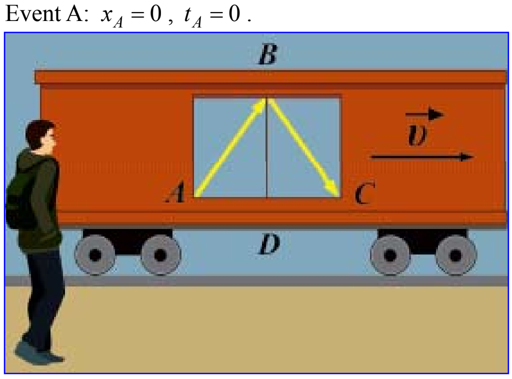


Fig. 2. *Spread of the light signal in the "light clock" in terms of the observer on the platform (in system K)*

From the point of view of the observer on the platform (in system *K*) for a while until the light beam reaches the mirror, the car will shift to the right at the distance *AD*. Correspondingly the mirror on the ceiling of the car will shift to the same distance (see *Fig. 2*). The light beam will reflect from the mirror on the ceiling at point *B* and in accordance with the law of reflection it will begin its movement at the same angle toward the floor of the car. During this time the carriage will shift at the distance *DC* (besides *DC* = *AD*) and the light signal will be fixed on the floor (event C). During the entire period of time during which the light will reach the ceiling and, after reflection, come back the carriage will shift relative to the observer on the platform at the distance of *AC*. A beam of light will pass the distance *AB* + *BC* = 2*AB* (since *AB* = *BC*).

Thus, the spatial and temporal coordinates of event *C* in system *K* are equal to: event *C*: $x_C = AC = AD + DC = 2AD$, $t_C = \frac{2AB}{c}$.

The differences of coordinates and time between events *A* and *C* in the system *K* are equal: $\Delta x = x_C - x_A = 2AD$ (the displacement of the beam of light relative to the observer on the platform); $\Delta t = t_C - t_A = \frac{2AB}{c}$ (the interval of time during which the light will reach the ceiling and, reflected from the mirrors, come back according to the clock of the observer on the platform).

Let`s set the mathematical dependence between $\Delta t$ and $\Delta t'$. For this we`ll express the corresponding distances: $BD = l = \frac{c\Delta t'}{2}$, $AB = \frac{c\Delta t}{2}$. Taking into consideration that the car moves at a constant velocity $\vec{\upsilon}$, we`ll have: $\Delta x = 2AD = \upsilon\Delta t$, hence we get $AD = \frac{\upsilon\Delta t}{2}$. By the Pythagorean theorem, we find: $AB^2 = AD^2 + BD^2$, substituting the appropriate values, we get: $\left(\frac{c\Delta t}{2}\right)^2 = \left(\frac{\upsilon\Delta t}{2}\right)^2 + \left(\frac{c\Delta t'}{2}\right)^2$.

Let`s do elementary transformations: $(c^2 - \upsilon^2)\Delta t^2 = c^2(\Delta t')^2$, hence we have:

$$\Delta t = \frac{\Delta t'}{\sqrt{1 - \frac{\upsilon^2}{c^2}}}. \qquad (4)$$

Proceeding from this, we can conclude that relative to the stationary observer (reference system *K*) the event occurring in the mobile reference system K' lasts longer. Or, in other words, the moving clock goes slower than the stationary one.

Equation (4), in our opinion, should be understood as follows:

Duration of the physical process in the reference frame, where it is immovable, always less than the duration of it in terms of any other inertial system of reference.

One can also say that the physical process in the frame of reference with respect to which it is moved, is slower than in terms of the system of reference in which it is at rest.

Only the measurements of periods of time are different.

Connection of period of time between two events occurring in some reference system in the same point of space (and hence this period of time $\Delta t'$ *is fixed with one clock) with the interval of time between those events, but which is measured with two clocks in the other reference system according to which these two events take place in two different points in space is given by the formula (4).*

Summing up, it can be stressed that in relativistic mechanics, in contrast to classical mechanics, time is not absolute, it depends on the choice of reference system.

In the textbook on physics [9, p.129] in considering this issue the authors admit a bad error, giving the ratio for determining the duration of physical process in different reference systems in the form of:

$$\Delta t' = \frac{\Delta t}{\sqrt{1 - \frac{\upsilon^2}{c^2}}}.$$

Thus, according to [9, p.128-129], the authors note: «A. Einstein found that in transition from one reference system to another coordinate transformations coincide with the formulas of Lorentz transformations:

$$x' = \frac{x - \upsilon t}{\sqrt{1 - \frac{\upsilon^2}{c^2}}}, \; y' = y, \; z' = z, \; t' = \frac{t - \frac{x\upsilon}{c^2}}{\sqrt{1 - \frac{\upsilon^2}{c^2}}} \Bigg\},$$

where *x, y, z, t* are coordinates and time in the fixed reference system, and *z', t'x', y'* are respectively the same ones in the moving system of reference.

In the STR it has been also found *that measured in the different inertial systems of reference duration of the event will be unequal*. This is because of non synchronism of the events occurring in the different reference systems.

Let some event in the fixed reference system last for time $\Delta t = t_2 - t_1$. Then in the moving system of reference its duration will be determined by time interval $\Delta t' = t_2' - t_1'$. From Lorentz transformations formulas after mathematical simplifications we have:

$$\Delta t' = \frac{\Delta t}{\sqrt{1 - \frac{\upsilon^2}{c^2}}}.$$

This ratio indicates that in the different inertial systems of reference the measured duration of the event will be different*: in the moving reference system the event lasts longer than the fixed one* $(\Delta t' > \Delta t)$. I.e. for the same observer in the different reference systems time flows differently: the observer in the fixed reference system will notice that the clock slows down its speed in the reference systems, moving relative to him».

The last two sentences of this quotation contain conflicting statements.

In addition, if, according to [9, p.128], the moving system of reference is SR *K'*, then the formula $\Delta t' = \frac{\Delta t}{\sqrt{1 - \frac{\upsilon^2}{c^2}}}$ ([9, p.129]) is incorrect.

Then, the authors of the textbook use the concept of «duration of event». But the term «event» can not be used in correlation with the concept of «time», because according to the definition of an event it has no duration in time. Obviously, one should use the notion «duration of process», or « interval between events».

Perhaps when writing formulas the group of authors made a mistake by putting strokes in expressions exactly the opposite.

In addition to that they make the same error in the relation for relativistic length contraction coming to a wrong conclusion as for reducing the length in the moving reference frame [9, p.128]: «$l' = l\sqrt{1 - \frac{\upsilon^2}{c^2}}$. This means that $l' < l$ that is the length measured in the moving frame of reference is less than the length in the system relative to which it moves, and because the multiplier $\sqrt{1 - \frac{\upsilon^2}{c^2}}$ is always less than 1». And further in the text [9, p.128]: «The rod which length is 1m in the frame of reference moving at the speed close to the speed of light in vacuum, e. g. 0.9 s, has a length of approximately 87 sm».

The above-mentioned quotations indicate incomplete explanations and incorrect wording regarding these kinematics effects. We think that such inaccuracies contradicting the principle of scientific character are unacceptable for the textbook of such level.

In connection with this it is appropriate to notice that the «Implementation of the principle of scientific learning requires students` arming with methods of scientific knowledge, not only giving them the system of finished scientific verities» [4, p.228].

As an illustration, proving (4) one can offer the students the following physical problem.

Problem. It is experimentally established that in the upper layers of atmosphere as a result of interaction of cosmic radiation with atoms of gases that form the Earth's atmosphere, moons, the weight of which are 207 times greater than the mass of the electron, are born. Moving with speed $\upsilon = 0{,}995c$, they manage to fly to the collapse of S = 6 km. Determine the lifetime of moon for the observer on the Earth, the proper lifetime of moon, the integrated path of moon in the reference frame associated with it.

Solution.

In the stationary frame of reference associated with the observer on the Earth's surface moon lifetime probably is $\Delta t = \frac{S}{\upsilon}$. Substituting the numerical data we obtain $\Delta t = \frac{6 \cdot 10^3 m}{0.995 \cdot 3 \cdot 10^8 m/s} \approx 2 \cdot 10^{-5} \mathbf{s}$.

The proper lifetime $\Delta t'$ of moon can be found from the equation (4):

$$\Delta t' = \Delta t \cdot \sqrt{1 - \frac{\upsilon^2}{c^2}} = 2 \cdot 10^{-5} \cdot \sqrt{1 - \frac{(0.995c)^2}{c^2}} \approx 2 \cdot 10^{-6} s.$$

In the frame of reference, connected with moon, its traversed path is

$$S' = \upsilon \cdot \Delta t' = 0.995 \cdot 3 \cdot 10^8 m / s \cdot 2 \cdot 10^{-6} s = 597m .$$

So, relative to the stationary observer moon lives 10 times longer than in its own reference frame. It is this relativistic effect thanks to which moon travels the distance of 6 km.

Conclusions. Thus, the analysis of the notional component of the STR proposed in some textbooks and manuals for secondary educational establishments, testifies to its incomplete conformity to the principle of scientific character. Taking into account the universality of the principle of scientific character, we think it is appropriate to wish the authors of the existing and future textbooks on physics to be more careful when covering the fundamental postulates of modern physics and, in particular, the special theory of relativity.

Prospects for further research. We stress that the existence of inaccurate definitions, incorrect interpretations of certain provisions of the STR initiate the need of further systematic research in methods of teaching the STR in secondary educational establishments.

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АНАЛИЗ СОДЕРЖАНИЯ СПЕЦИАЛЬНОЙ ТЕОРИИ ОТНОСИТЕЛЬНОСТИ В УЧЕБНИКАХ ФИЗИКИ ДЛЯ СРЕДНИХ УЧЕБНЫХ ЗАВЕДЕНИЙ

Обсуждаются имеющиеся в учебниках по физике для средних учебных заведений методические подходы к освещению основных положений специальной теории относительности. Показано, что в некоторых учебниках имеют место физические ошибки и некорректные формулировки и объяснения последствий специальной теории относительности. Осуществлен критический анализ особенностей реализации принципа научности при освещении специальной теории относительности в учебниках для средних учебных заведений.

Ключевые слова: специальная теория относительности, принцип научности, методика обучения, кинематические последствия преобразований Лоренца.

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АНАЛІЗ ЗМІСТУ СПЕЦІАЛЬНОЇ ТЕОРІЇ ВІДНОСНОСТІ В ПІДРУЧНИКАХ ФІЗИКИ ДЛЯ СЕРЕДНІХ НАВЧАЛЬНИХ ЗАКЛАДІВ

Обговорюються наявні в підручниках з фізики для середніх навчальних закладів методичні підходи до висвітлення основних положень спеціальної теорії відносності. Показано, що в деяких підручниках мають місце фізичні помилки та некоректні формулювання і пояснення наслідків спеціальної теорії відносності. Здійснено критичний аналіз особливостей реалізації принципу науковості при висвітленні спеціальної теорії відносності в підручниках для середніх навчальних закладів.

Ключові слова: спеціальна теорія відносності, принцип науковості, методика навчання, кінематичні наслідки перетворень Лоренца.

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ФОРМИРОВАНИЕ КОМПЕТЕНЦИЙ ПРИ ИЗУЧЕНИИ ФИЗИКИ ПУТЕМ ПРОФЕССИОНАЛЬНОЙ НАПРАВЛЕННОСТИ УЧЕБНОГО МАТЕРИАЛА

В статье дается оценка использованию компетентносного подхода при изучении физики в сфере профессионального образования. Автор предлагает пути решения проблемы профессиональной ориентации при обучении физики и представляет анализ результатов на примере трех академических групп. Статья может стать полезна преподавателям колледжей с техническим профилем.

Ключевые слова: компетентносный подход, физика, колледж, профессиональная направленность.

... Если ты даешь человеку одну рыбу,
То он будет сыт раз в году.
Если ты его научишь ловить рыбу,
То он будет сыт всю жизнь…
Из древней восточной поэзии

В образовательную сферу понятие компетенции пришло из профессионально-технической области. Это понятие было введено американским психолингвистом Авраамом Ноамом Хомским в 1965 году и было определено как «способность создавать и понимать бесконечное число высказываний, правил, принципов, действий, способов или моделей поведения, предпочтительных стратегий или производственных стилей в профессии» [1].

Компетентносный подход – это приоритетная ориентация на цели, которые ставятся, исходя из результата, при этом необходимо, чтобы цели и результаты были направлены на повышение компетентности учащихся. Причем в качестве результата рассматривается не сумма усвоенной информации, а способность человека действовать в различных проблемных ситуациях. Преподаватель реализует новую функцию сопроводителя учащегося в деле приобретения им тех или иных компетенций. Наряду с сохранением прежнего ролевого статуса преподаватель призван обеспечить более высокие уровни консультирования и мотивирования. В свою очередь образовательный процесс потребует от учащихся большей степени вовлеченности, развития своих умений работать с информацией. Подростковый период – период активного накопления знаний, благодаря интеллектуализации памяти информация запоминается и воспроизводится, широко используется мышление [2]. Таким образом, у

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