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Inaccuracy that Makes Learning Difficult to Study the Article "On the Electrodynamics of Moving Bodies"

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Abstract

The existence of semantic inaccuracy of 2 articles by A. Einstein "On the electrodynamics of moving bodies", illustrating the principle of the relativity of simultaneity. In a sentence "The observers co-moving with the moving rod would thus find that the two clocks do not run synchronously while the observers in the system at rest would declare them synchronous", the preposition "not" must be moved and placed before the word "synchronous", at the end of the sentence. The criterion for synchronism of the clocks on the rod is the time it takes for the beam to travel from clock A to clock B and back, and for observers on the rod it will be the same both when the rod is at rest and when the rod is moving. Otherwise, observers on the rod would have had at their disposal an experiment that would allow them to determine whether the rod is moving or at rest, which contradicts the first postulate of the Special Theory of Relativity. The inaccuracy is found unchanged in modern editions in English and Russian, and can become a source of difficulties when teaching the basics of the Special Theory of Relativity based on primary sources, as well as make it difficult to understand the author's logic when studying independently. Nobel laureate R. Feynman, having expanded and modified A. Einstein's thought experiment, eliminated the inaccuracy described in the article.

Keywords: Einstein; Relativity of simultaneity; Typos; Special theory of relativity

Introduction

A. Einstein's work "On the Electrodynamics of Moving Bodies" published in 1905, outlining the main provisions of the Special Theory of Relativity, is now deservedly considered classic [1]. It is all the more important to detect and exclude typos and inaccuracies from it. Typos and inaccuracies can be purely stylistic, spelling, factual (dates, proper names, etc.) [2] and semantic [3]. The first three categories, of course, are not of great interest, although they are found both in reprints published during the author's lifetime and in subsequent ones, but correcting them is only a technical task. Of greatest interest are semantic typos concerning inaccuracies in formulas, descriptions of experimental results, etc., since, in addition to correcting them, when discussing them, whole discussions arise that make it possible to determine whether the inaccuracy actually occurs, or whether the author's intention is much deeper than the first glance. In addition, undetected or uncorrected inaccuracies can become a source of difficulties when teaching physics, in particular, the foundations of the Special Theory of Relativity based on primary sources, and also make it difficult to understand the author's logic when studying them independently.

A preliminary search on the Internet, primarily in Russian-language sources, allowed us to find only one known published semantic typo concerning the incorrect indication of the speed at which the frequency, in the formula for the relativistic Doppler effect, reaches infinity [3]. Unfortunately, it is not enough to simply point out a typo, since, despite the passage of more than half a century, the above typo continues to appear in reprints of Einstein's work.

Literature Review

A. Einstein introduces the following procedure (criterion) to determine the synchronism of clocks A and B, located at different points in space A and B:

"For, suppose a ray of light leaves from A towards B at "A-time" t_A, is reflected from B toward A at "B-time" t_B, and arrives back at A at "A-time" t'_A. The two clocks are synchronous by definition if t_B-t_A.

And further, A. Einstein describes the result of a thought experiment demonstrating the relativity of simultaneity:

We further imagine that each clock has an observer co-moving with it, and that these observers apply to the two clocks the criterion for synchronism formulated in §1. Suppose a ray of light starts out from A at time t_A, is reflected from B at time t_B, and arrives back at A at time t'_A. Taking into account the principle of the constancy of the velocity of light, we find that

$$t_B - t_A = \frac{rAB}{(\upsilon - \upsilon)} \; and \; t'_A - t_B = \frac{rAB}{(\upsilon + \upsilon)} .....((1), t_A - t_B != t_B - t_A - D.K.) \quad .... (1)$$

where r_{AB} denotes the length of the moving rod, measured in the system at rest. The observers co-moving with the moving rod would thus find that the two clocks do not run synchronously while the observers in the system at rest would declare them synchronous (Figure 1).

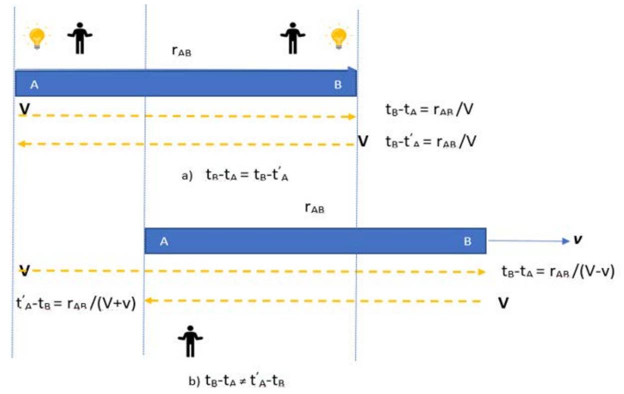

Figure 1: Explanation of the result of a thought experiment demonstrating the relativity of simultaneity: a) fulfillment of Einstein's synchronicity criterion for observers on a rod b) the same for observers at rest.

In our opinion, in the above quote there is a semantic inaccuracy; the preposition "not" is placed in the wrong place where it should be in meaning. The sentence in the quotation should read like this: "The observers co-moving with the moving rod would thus find that the two clocks do run synchronously while the observers in the system at rest would declare them not synchronous."

Rationale and proof

To substantiate and prove the above, one should turn to the meaning of formula (1), which determine how much time it takes for a ray of light to travel from the clock A installed at one end of the moving rod to the clock B installed at the other end of this rod and back.

If these times are equal, the clocks are considered to be running synchronously, that is, showing the same time, or having the same clock hands. Since the denominators of expressions (1) use the value of the rod speed v relative to a stationary reference frame, this speed cannot be determined by observers on the rod; for them, the time of passage of the rays from clocks A to B and back must always be equal, regardless of whether the observers move with the rod or the rod is at rest.

If it were possible for observers on the rod, by conducting one or another experiment, to determine whether the rod is moving translationally and uniformly, or at rest, this would be a violation of the 1st postulate of the Special Theory of Relativity, according to which there is no experiment that would show the difference between a system at rest and moving uniformly and rectilinearly. In other words, for observers on the rod, formula (1) will always look like:

$$t_B - t_A = \frac{rAB}{(\mathrm{IN})} \qquad t'_A - t_B = \frac{rAB}{(\mathrm{IN})} \qquad t_B - t_A != t_A - t_B$$

$$t_B - t_A = t'_A - t_B \qquad \text{………… (2)}$$

Consequently, only observers in a fixed, at rest coordinate system can calculate time using formulas (1).

It is they, and only they, who will be able to see how a beam of light from a source in clock A "catch up" with those moving away from it at the speed of movement of the rod v clock B, and will be able to notice the inequality in the time of the reverse movement of the beam from clock B to clock A, since in the latter case, clock A moves towards the ray of light released from clock B.

And, having clarified the inequality of these times, only observers from a system at rest will be able to draw a conclusion about the non-synchronism of the clock on the moving rod.

In the lectures on physics by R. Feynman, a description of a similar thought experiment is given:

"Suppose that a man moving in a spaceship (system S') has placed a clock at each end of the ship and is interested in making sure that the two clocks are in synchronism. How can the clocks be synchronized? There are many ways. One way, involving very little calculation, would be first to locate exactly the midpoint between the clocks. Then from this station we send out a light signal which will go both ways at the same speed and will arrive at both clocks, clearly, at the same time. This simultaneous arrival of the signals can be used to synchronize the clocks. Let us then suppose that the man in S' synchronizes his clocks by this particular method. Let us see whether an observer in system S would agree that the two clocks are synchronous. The man in S' has a right to believe they are, because he does not know that he is moving. But the man in S reasons that since the ship is moving forward, the clock in the front end was running away from the light signal, hence the light had to go more than halfway in order to catch up; the rear clock, however, was advancing to meet the light signal, so this distance was shorter. Therefore, the signal reached the rear clock first, although the man in S′ thought that the signals arrived simultaneously. We thus see that when a man in a spaceship thinks the times at two locations are simultaneous, equal values of t′ in his coordinate system must correspond to different values of t in the other coordinate system!" [4,5].

If the measurement of the time of passage of light from the middle of the spacecraft to the clocks at the bow and stern is replaced by a comparison of the time of passage of light from the clocks at the ends A and B of the moving rod, we will obtain an exact description of A. Einstein's experiment.

But R. Feynman, in contrast to the inaccuracy in A. Einstein's article, makes the correct conclusion that it is for an observer "in a different coordinate system" that the times of light will be different, and the synchronicity of the clocks will be disrupted.

Objections

In our opinion, the presence of inaccuracy is quite obvious, however, we can briefly touch on possible objections [2]:

The clock on the rod is set by the clock in a stationary, resting frame of reference, so it always shows the time of the frame at rest, and since the rod moves relative to this frame, observers on the rod will see the non-synchronism of their clocks, just as observers in a frame at rest would see the non-synchronism the progress of the clock on the rod.

However, when illustrating the relativity of simultaneity, Einstein does not touch upon the question of what exactly the hands of a clock show-especially since the hands of all clocks, both those located on a rod and those at rest, always show the same thing-this is directly stated in the article: "...to both ends of the rod (A and B) a clock is attached that is synchronous with the clock of the system at rest, that is, its readings correspond to the "time of the system at rest" in those places in which these clocks are located; therefore, these clocks are "synchronous in a system at rest".

And we are talking only about whether the criterion of clock synchronicity is fulfilled according to the procedure proposed by Einstein during the movement of the rod, and the obligatory nature of its fulfillment for observers on the rod clearly follows from the first postulate of the Special Theory of Relativity.

Since the rod is moving, time slows down for observers on the rod, and the clock on the rod is set to the time of the system at rest, so observers on the rod can see that the clocks are not synchronous.

This does not correspond to the thought experiment proposed in the article, since to illustrate the relativity of simultaneity, A. Einstein does not use any concepts specific to the special theory of relativity (does not consider the dilation of time on a moving rod, the shortening of its length for stationary observers, etc.), the situation is considered in ordinary Euclidean space.

Discussion

In Feynman's description, the moving clocks are synchronized "according to Einstein." Therefore, in each place they fly past, they do not give the same readings as the readings of stationary clocks installed in the same places, synchronized "according to Einstein" in their stationary state.

And in Einstein's description there is a moving clock Not synchronized according to Einstein. Einstein specially synchronized the moving clocks in that description differently (he synchronized them to the same readings for all clocks, just as it was always assumed in non-relativistic physics) they give in every place they fly past exactly the same readings as the readings stationary clocks installed in the same places, synchronized "according to Einstein" in their stationary state.

For Einstein, synchronous clocks are those clocks that are synchronized according to Einstein, that is, if the time of passage of a ray of light between the clocks and back is equal, the clocks are synchronous, otherwise they are asynchronous. It doesn't matter what time the clock hands show, their synchronicity is not determined by the hands. And on the rod, always and in any circumstances, performing clock synchronization according to Einstein (measuring the time of passage of a light beam between one to the other and back) will always give a positive result. In the description of the thought experiment in the article, A. Einstein specifically indicated that all clocks are set according to the clock of the system at rest-therefore, all time stamps are made in the system at rest.

Let us note once again that synchronization according to Einstein is not about setting the clock hands, but about comparing the time it takes for a beam of light to travel from one to the other and back. This is quite obvious from Einstein's description: The two clocks are synchronous by definition if $t_B - t_A = t'_A - t_B$.

Feynman's scientific experiment uses exactly the same clock synchronization mechanism [6-10].

Conclusion

In our opinion, the presence of inaccuracy proved above is quite obvious. The more interesting question is why, for more than 100 years since the publication of A. Einstein's seminal work, no one has yet paid attention to this inaccuracy and proposed to correct it, perhaps saving students and students studying primary sources from headaches and the impossibility of constructing a logically consistent presentation of one of the fundamental principles of the special theory of relativity.

As said over 50 years ago, "It seems appropriate with this letter to draw the attention of readers and, in particular, editors to the fact that reverence for the classics of science should not be extended to obvious typos made in the first publications of their works".

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