# ABOUT THE TIME OF THE CLOCKS OF SATELLITE NAVIGATION SYSTEMS

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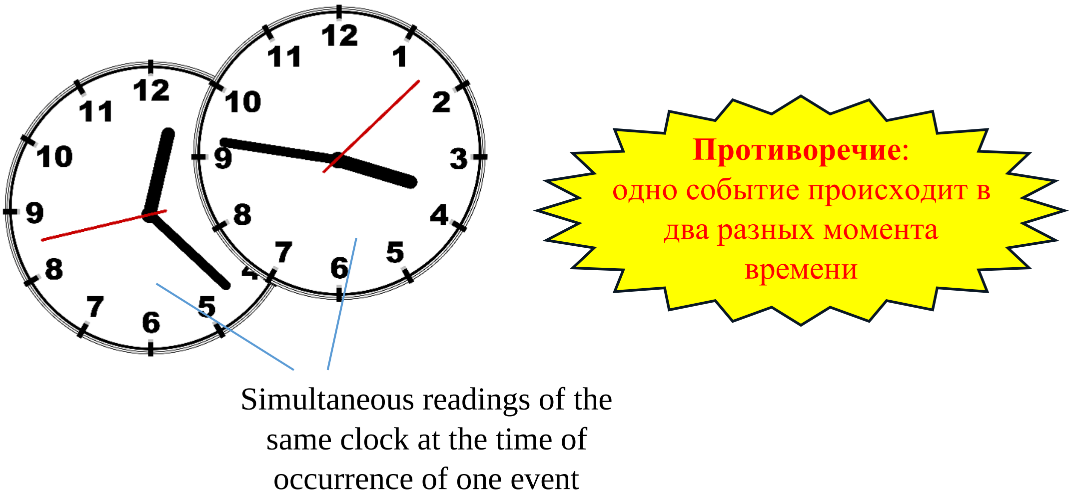
***Abstract.*** *The paper presents a seemingly simple problem about clocks moving towards each other. The speed of the relative movement of the clock and the time that will pass until the first clock meets is known. Using the special theory of relativity (SRT) using a well-known formula, you need to determine the time that the second clock will show at the moment of meeting. The problem is that solving the problem using SRT leads to three contradictions that cannot be resolved within the framework of formal logic. The first contradiction: one event occurs simultaneously at two completely different points in time using the same clock. The second contradiction: the same clock at the same moment in time (the moment of occurrence of one event) shows two completely different times. Third contradiction: calculations of the same physical quantity in different ways with the same initial data lead to completely different values that are absolutely incompatible with each other.*

*The resolution of these contradictions is urgently needed in the technical sciences, since the so-called relativistic "time dilation" of high-precision clocks on navigation satellites of satellite navigation systems during the day is thousands of times higher than the required accuracy of the state primary time standard.*

***Graphic annotation***

*The contradiction that the "relativistic time dilation" of SRT leads to: at the same time the same clock shows two completely different values of time.*




***Keywords:*** *thought experiment, scientific problem, special theory of relativity, special relativity, speed of light, relativistic effect, theory of aberration, running of a moving clock.*

**Introduction**

The paper presents the problem of clocks moving towards each other and its solution using STR. The decision leads to contradictions that require resolution. These contradictions indicate that the value of clock loss due to this effect when solving practical problems, for example, in satellite navigation, can be calculated with relatively large errors that are unacceptable in modern satellite navigation systems.

The problem was discussed many times with various scientists, among whom were doctors and candidates of technical sciences, but the contradictions that arose during the discussions were not resolved.

**Relevance**. Relativistic time dilation, according to calculations, leads to a daily clock error of the GLONASS and GPS satellite navigation systems greater than 7000 ns (nanoseconds, 1 ns = 10-9 s). The value of the daily lag of the satellite clock compared to the stationary clock on Earth due to relativistic "time dilation" $v$ for 86400 seconds, that is, per day, is calculated by the formula [1, p.19]

$$\Delta t = 86400 \times \left(1 - \sqrt{1 - (v/c)^2}\right) \text{ seconds.}$$

where $v$ and $c$ – are the speed of movement of the navigation satellite and the speed of light, respectively.

GLONASS and GPS satellites move at approximately 3,900 m/s. The speed of light is 299,792,458 m/s. Moreover, in accordance with existing requirements, the limits of permissible shifts of the national time scale UTC(SU) relative to the UTC coordinated universal time scale are +/- 3.0 ns [2]. Thus, the accuracy of the modern state primary standard of units of time, frequency and national time scale is thousands of times higher than the value of the calculated daily "relativistic" clock drift of these satellite navigation systems. The contradictions that arise when calculating the relativistic effect of "time dilation" are an expression of a serious scientific problem, since the magnitude of the error that arises when calculating the deviation of satellite clocks due to this effect is so large that it cannot be neglected under any circumstances. This article is a kind of public appeal to scientists representing theoretical physics from representatives of technical sciences with an urgent request to help understand the resolution of the contradictions described in the article.

**Task**

Let two rows of clocks move relative to each other at speed (Fig. 1). The clocks in each row are synchronized with each other. At the moment of time "00:00:00" (the beginning of the next day), according to the clocks of one row of synchronized clocks, the clocks of the other row are also set to "00:00:00" according to the readings of the clocks of the opposite row closest to them.

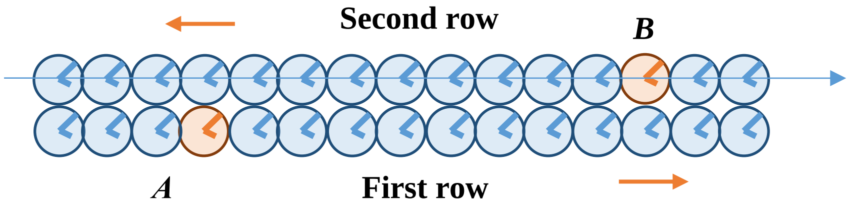



***Fig. 1. Clock problem***

The speed $c$ of relative motion of the rows is 0.9 the speed of light.

Clock A in the first row and Clock B in the second row are equipped with proximity sensors (for example, hypothetical limit switches) that are triggered when the clocks approach (pass each other). When the proximity sensors are triggered, clocks A and B stop (like stopping a stopwatch), after which these clocks can be moved to compare their readings to a researcher.

From the point of view of clock A, clock B is moving towards them with speed (Fig. 2).

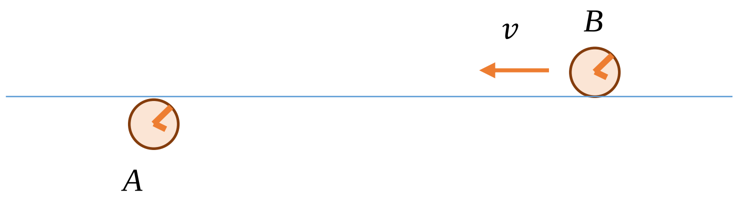



***Fig. 2. Movement of clock B relative to clock A***

**Question 1.** Calculate how much time will watch B show at the moment of stopping when meeting with watch A, if when meeting, watch A will show 100 seconds ("00:01:40,000")? The answer to this question must be found using SRT formulas indicating the source (preferably the works of Einstein).

**The solution of the problem.**

According to SRT [1, p.19], the answer can be found using the formula

$t_B = t_A \times \sqrt{1-(v/c)^2}$ seconds.

where and $v$ – the time of clocks A and B, respectively, at the meeting.

Thus, seconds.

The answer you are looking for is: Clock B, when meeting with Clock A, will show 43.6 seconds.

**Question 2.** Let us now consider this same situation from the other side. From the point of view of clock B, clock A is moving towards them with speed (Fig. 3).

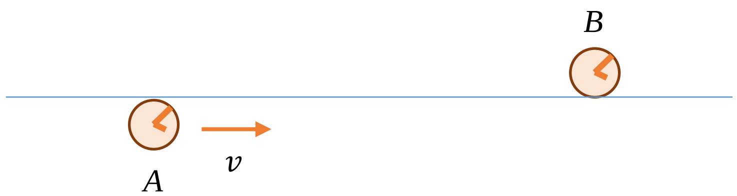



***Fig. 3. Movement of clock A relative to clock B***

How much time will watch A show when it stops when it meets watch B, if when it meets watch B shows 43.6 seconds (the number of seconds of watch B when stopped)? Solution. In this case, you need to use a similar formula

$$t_A = t_B \times \sqrt{1-(v/c)^2} = 43{,}6 \times \sqrt{1-0{,}9^2} = 19\ seconds.$$

**Answer:** Clock A, when meeting with Clock B, will show 19 seconds.

**Question 3**. After stopping clocks A and B at the moment of their meeting (Fig. 1), these clocks were moved to some researcher to compare their readings. What readings of this watch will the researcher record? **Answer**. According to the calculations made, the readings of the watch after it stops during the meeting will be as follows (question 1) clock A: 100 seconds;

clock B: 43.6 seconds.

Thus, due to motion, clock B will lag behind clock A. When answering question 2, we found that with the same readings from watch B, the readings from watch A will be different, namely 19 seconds. In other words, by the time it stops, clock A will be behind clock B.

**Discussion of solutions**

Now you need to pay attention to the following. According to calculations made using SRT, when the clock stops at the moment of the meeting, clock A will show 100 seconds, and clock B will show 43.6 seconds (answer to question 1). But all movement is relative. Clock B moves relative to clock A, but at the same time (that is, at the same time) clock A moves relative to clock B. From the point of view of an observer moving with clock A, this clock is stationary, and clock B is moving. But from the point of view of an observer moving with clock B, this clock is motionless, and clock A is moving.

However, solving the problem from the point of view of clock B (question 2), we came to the conclusion that when the clocks meet, clock B will show 43.6 seconds, and clock A will show 19 seconds.

In other words, stopped clock B will show 43.6 seconds, and stopped clock A will show 100 seconds (answer to question 1), and at the same time (at the same time) 19 seconds (answer to question 2).

This results in a contradiction: clock A stopped during the meeting will show 100 seconds and 19 seconds at the same time. When meeting with clock B, clock A will simultaneously move ahead and lag behind it. Obviously this cannot be.

**On the concept of “relativity of simultaneity”**

The question arises: can the concept of “relativity of simultaneity” help explain the contradiction that has arisen? According to the principle of “relativity of simultaneity”, if two events separated in space are observed simultaneously in a reference frame “moving” with a speed > 0, then they will be observed non-simultaneous relative to the “stationary” frame.

However, in SRT this concept is applicable only if there are two events separated in space. In our case, there is only one event: two clocks A and B meet nearby when moving relative to each other, and at the moment of approach they stop. The clock stops only once. Therefore, the same stopped clock cannot have two readings at the same time.

That is why the relativity of simultaneity in this case does not help explain the contradiction that has arisen.

**Controversies that have arisen**

The contradictions that relativistic “time dilation” leads to are that

1. One event occurs simultaneously at two completely different points in time according to the same clock;

2. The same clock at the same point in time (the moment the event occurs) shows two completely different times. In accordance with the law of non-contradiction of formal logic, both the first and second are impossible. In a more general sense, the contradiction that has arisen is that.

3. Calculations of the same physical quantity (the time of occurrence of one event using the same clock) in different ways with the same initial data lead to completely different values that are absolutely incompatible with each other.

The listed contradictions need to be resolved by scientists - theoretical physicists.

**Controversy in satellite navigation systems**

In relation to satellite navigation systems GPS, GLONASS and others, the following contradiction occurs.

On the one hand, satellites move in orbits relative to the earth's surface. Therefore, according to SRT, there should be a slowdown in the clocks of navigation satellites and, accordingly, their lag behind the clocks on Earth.

As noted in the introduction, the daily lag of the GPS or GLONASS satellite clock compared to the stationary clock on Earth must be at least 7000 ns.

But, on the other hand, from the point of view of observers on satellites, the satellites are motionless, and the clocks on the earth's surface move relative to them. Therefore, from the point of view of the clocks on the satellites, the opposite effect should occur, that is, the clocks on Earth should run slower than the clocks on the satellites. In other words, the clocks on the satellites should advance by at least 7000 ns per day compared to the earth's clocks.

The contradiction is that satellite clocks, on the one hand, must lag behind earthly clocks. On the other hand, satellite clocks should be faster than Earth clocks. . But how do satellite clocks actually tick without taking into account "gravitational time dilation" (the actual difference in elapsed time between two events, measured by observers at different distances from the gravitating mass)?

If we assume that one row of synchronized clocks is located at the equator of some planet that has no atmosphere, and the other row of synchronized clocks moves in a circular orbit at a very low altitude (in this case, gravitational time dilation can be neglected due to its smallness), then what kind of clock Will they go slower: a stationary clock on the surface of the planet, or a moving clock in orbit? From the point of view of an observer moving in orbit along with the clock, the clock in orbit is stationary, and the clock on the surface of the planet, on the contrary, is moving.

**Ways to resolve contradictions**

The above contradictions need to be resolved by scientists - representatives of theoretical physics.

In this case, their resolution is possible in the following ways. One of the ways is to search for the causes of contradictions and resolve them without going beyond the scope of SRT. Another way is to develop theories alternative to SRT. Einstein also noted that the same complex of physical phenomena and experimental facts can be explained by several different theories [10]. Therefore, the phenomena described by SRT can be described by other, alternative theories. An alternative SRT theory is, for example, the theory of aberration [3-9].

**Conclusion**

The solution to the problem of clocks moving towards each other showed the following. Relativistic “time dilation”, the essence of which is that moving clocks go slower than stationary ones, leads to the following contradictions:

1. One event occurs simultaneously at two completely different points in time according to the same clock;

2. The same clock at the same moment in time (the moment of occurrence of one event) shows two completely different times.

3. Calculations of the same physical quantity in different ways with the same initial data lead to completely different values that are absolutely incompatible with each other.

These contradictions require resolution. This article is a kind of appeal to physicists with a request to publish articles in scientific publications in which a detailed analysis of the given problem will be made, outlining a methodology for its solution that is consistent within the framework of technical sciences.

According to Einstein, “for the same set of experimental facts there may exist several theories that differ significantly from each other” [10]. Therefore, instead of STR, when calculating the progress of a moving clock, to eliminate errors, you can use the theory of aberration - the first alternative theory to SRT, which has been confirmed experimentally [3-9].

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