Breakdown of the Special Theory of Relativity as Proven by Synchronization of Clocks

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Abstract

In this paper, a hypothetical preferred frame of reference ∑ is presumed, and a thought experiment is performed in which the time of a clock on a rod moving at constant velocity relative to ∑ is synchronized.

In relation to coordinate system of rod 1 moving at constant velocity $\boldsymbol{v}$, when an observer at ∑ and an observer on rod 1 attempt to predict the necessary synchronization of a clock of the coordinate system of rod 2 moving at constant velocity $\boldsymbol{v}'$, because the relative velocity between ∑ and rod 2 and the relative velocity between rod 1 and rod 2 are not the same, there will be a difference in the predictions of these two observers.

However, because the actual synchronization is done by the observer of rod 2, the predictions of the observer of ∑ and the observer of rod 1 cannot both be correct.

In continuing the thought experiments until now of this paper, the coordinate system of ∑, which has not been actually proven to exist, is substituted for the coordinate system of the earth. From the perspective of isotropy of light propagation, it is considered acceptable to substitute ∑ and the earth for the purposes of this thought experiment because it is not currently possible to differentiate between these two coordinate systems.

If we allow this substitution, it becomes possible to prove the existence of an inertial system in which a conflict arises between the predictions according to special theory of relativity and the actual experimental outcome.

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1. Introduction

At the end of the 19th century, most physicists were convinced of the existence of ether as a medium that propagates light. Further, they thought ether to be "absolutely at rest."

Michelson and Morley attempted to detect Earth's motion relative to the luminiferous ether, i.e. the absolute velocity. However, they failed to detect the effect they had expected [1].

In order to explain why they failed to detect the effect they had expected, Michelson concluded that the ether was at rest relative to the earth in motion (i.e. it accompanied the earth).

On the other hand, Lorentz was convinced of the earth's motion relative to the "preferred frame." He made a stopgap solution by proposing a hypothesis that a body moves through space at the velocity $\boldsymbol{v}$ relative to the ether contracted by a factor of $\sqrt{1-(v/c)^2}$ in the direction of motion [2].

Michelson believed that light emitted from a laboratory on earth propagated iotropically, while light propagated anisotropically in the interpretation of Lorentz.

However, in his special relativity (SR) published in 1905, Einstein insisted physics not require an "absolutely stationary space" provided with special property, and that there be no such things as "specially-favoured" coordinate systems to occasion the introduction of the ether-idea [3].

Einstein's aim at the time was not to explain the reason why, like Lorentz and Poincaré, the expected results were not observed in the Michelson-Morley (MM) experiment, but to derive a conversion equation between coordinate systems in order to resolve the asymmetry apparent in electromagnetism [3].

Then, as he was building his SR, he determined through definition that light traversing two paths of equal length would arrive at a reflector at the same time [4].

Therefore, Einstein did not provide an answer the question of whether two beams of light arriving at the reflectors was absolutely at the same time or not.

Incidentally, through new experimental techniques made available through the 20th century, Brillet and Hall have improved the accuracy of MM experiment by a factor of 4000 [5,6].

Also, the Kennedy-Thorndike (KT) experiment examined whether the speed of light changes according to the speed of the laboratory by creating two light paths of different lengths using an interferometer [7].

Modern descendents of the MM experiment more strictly limits the anisotropy of the speed of light. The most accurate limit today is thought to be that provided by the group from Humboldt University of Berlin, Germany [6].

Müller *et al.* performed a modern MM experiment that compared the frequencies of two crossed cryogenic optical resonators subject to Earth's rotation over more than one year [8].

The limit they obtained on the isotropy-violation parameter within the Robertson- Mansouri-Sexl framework is about three times lower than that from the experiment of Brillet and Hall [5].

Furthermore, they obtained limits on seven parameters from photonic sector of the standard model extension [9], at accuracies down to 10^{-15}, which is about two orders of magnitude lower than the only previous result [10].

They collected data for about a year and established a limit for variations in the speed of light of $\Delta c / c \leq (2.6 \pm 1.7) \times 10^{-15}$ [8,11].

This is compatible with zero within the accuracy of the experiment [12].

Incidentally, since Enrico Fermi, effective field theory has been widely used in particle physics. In the framework of this theory, the violation of Lorentz invariance is caused by background fields.

The effective theory approach to Lorentz violation was advocated by Kostelecky (Indiana University) and coworkers [13].

If a uniform background vector **b** exists, as it appears also in Figure 1 of the paper by Pospelov and Romails, **b** defines a preferred direction in space and so violates Lorentz invariance [6].

The laboratory velocity $\boldsymbol{v}(t)$ relative to the hypothetical preferred frame of reference $\sum$ has contributions from the motion of the Sun through $\sum$ with a constant velocity v_s=369km/s [14], Earth's orbital motion around the Sun (orbital velocity v_e=30km/s), and Earth's daily rotation (velocity $v_d \approx$ 330m/s at the latitude of Konstanz) [12].

Although no specific grounds are provided, this is $v_d/c \approx 10^{-6}$, even when assuming that only the earth's rotation, the smallest velocity here, contributes to breakdown in the isotropy of light propagation.

Therefore, if the motion of the earth were causing a change in the speed of light, it should be possible to easily detect such a change with current technology, but no such change has been actually observed.

This paper cannot explain why anisotropic properties of light propagation were not detected in the experiment of Müller *et al*. Even though the earth is in motion, light propagates isotropically relative to a fixed laboratory on the earth [1,7,8,12].

Thus, this paper introduces a new coordinate system in which is moving in constant velocity relative to a rest system and a thought experiment is performed in this coordinate system. However, even when repeating experiments in this coordinate system as performed on earth, there is no assurance that anisotropy of light propagation will be detected.

Thus, using the sufficient speed of the moving system, we devise another experiment using an unambiguous method to prove a breakdown in SR.

Incidentally, according to the kinematical analysis of Robertson [15] as well as Mansouri and Sexl [16], SR follows unambiguously from experiments establishing the isotropy of space (MM experiment [1]), the independence of the speed of light from the velocity $\boldsymbol{v}$ of the laboratory relative to ∑ (KT experiment [7]), and special relativistic time dilation (Ives-Stilwell (IS) experiment [17]) [12].

In this paper, based on this IS experiment and Einstein's "principle of constancy of light speed [3]," a thought experiment is performed, and finally, considering the MM experiment and KT experiment, the coordinate systems of ∑ and the earth are substituted to prove a breakdown in SR.

2. Time adjustment of clocks in a moving coordinate system

In this chapter, we first verify the importance of the role of the "definition of simultaneity" as Einstein built his SR.

Let us imagine a case in which two clocks A and B are accurately ticking at the same tempo at two locations in space, A and B. Einstein stated that if we define that the time required for light to reach B from A is equal to the time required for light to reach A from B, it is possible to compare the time of the two clocks [4].

In other words, if light is emitted in the direction of B from A at the time t_{A} of clock A, reaches and is reflected at B at t_{B} of clock B, and the light returns to A at time $t_{\mathrm{A'}}$ of clock A, then this time relationship can be represented by the following two formulas.

$$t_{\mathrm{B}} - t_{\mathrm{A}} = t_{\mathrm{A'}} - t_{\mathrm{B}}. \quad (1)$$

$$\frac{1}{2}(t_{\mathrm{A}} + t_{\mathrm{A'}}) = t_{\mathrm{B}}. \quad (2)$$

Einstein determined that if these formulas are true, the two clocks on this coordinate system represent the same time by definition. After verifying the above, we actually synchronize clocks following Einstein's directions.

In this chapter, we postulate that there exists a hypothetical preferred frame of reference ∑ - Einstein's "rest system" - in which light is propagated rectilinearly and isotropically in free space with constant speed c [15]. The natural candidate for ∑ is the cosmic microwave background.

According to Einstein's "principle of constancy of light speed," because the speed of light does not depend upon the velocity of the source of the light and is always constant, light will always propagate anisotropically for a coordinate system moving at constant velocity relative to this rest system.

Let there be a given stationary rigid rod of length L as measured by a ruler which is at rest, and its axis moving in parallel in the positive direction of the rest system x axis at constant velocity $\boldsymbol{v}$.

However, let the velocity of the rod considered in this paper to be moving at such a high velocity to require the application of SR.

Let us imagine that clocks A and B are set up at A and B each end of this rod 1, and the times of each of these clocks are synchronized while the system is at rest. (See Fig.1)

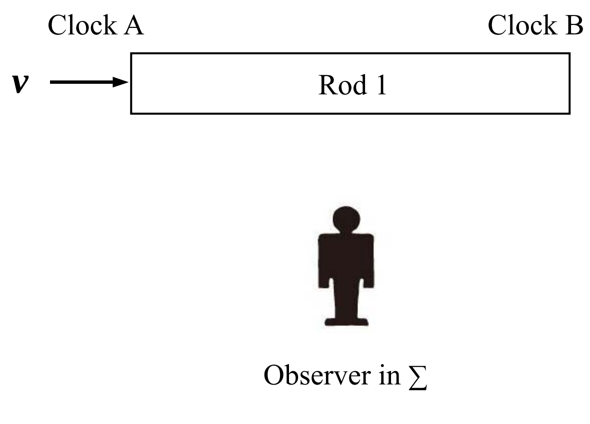

Fig.1 Rod 1 is moving at a constant velocity $\boldsymbol{v}$ relative to ∑. Clocks A and B are set up at A and B each end of this rod, and the times of each of these clocks are synchronized while the system is at rest.

In this study, we first attempt to adjust time of each of these clocks, such that we achieve simultaneity in a moving coordinate system.

Let us imagine that light departs the trailing end of A in the direction of the leading end of B at time t_{A} of clock A of the coordinate system of rod 1, arrives at B at time t_{B} of clock B, and returns to A at time $t_{\mathrm{A'}}$ of clock A. Let us imagine that times t_{A} , t_{B} , $t_{\mathrm{A'}}$ of this moving system corresponds to times t'_{A} , t'_{B} , $t'_{\mathrm{A'}}$ of the rest system.

According to the SR, because rod 1 contracts by a factor of $\sqrt{1-(v/c)^2}$ in the direction of motion, the time required for light to reach B from A as measured from rest system clocks $(t'_{\mathrm{B}} - t'_{\mathrm{A}})$, in seconds, is

$$t'_{\mathrm{B}} - t'_{\mathrm{A}} = \frac{L\sqrt{1-(v/c)^2}}{c-v} \quad \text{(sec.).} \tag{3}$$

Also, because time passes more slowly in the moving system [17], during the passage of $(t'_{\mathrm{B}} - t'_{\mathrm{A}})$ seconds in the rest system, the passage of time in the moving system $(t_{\mathrm{B}} - t_{\mathrm{A}})$ as observed by an observer in the rest system can be written as follows (See Appendix).

$$t_{\mathrm{B}} - t_{\mathrm{A}} = (t'_{\mathrm{B}} - t'_{\mathrm{A}})\sqrt{1-(v/c)^2} \quad \text{(sec.).} \tag{4}$$

From these two formulas, the following formula can be derived.

$$t_{\mathrm{B}} - t_{\mathrm{A}} = \frac{L(c+v)}{c^2} \quad \text{(sec.).} \tag{5}$$

Similarly, the passage of time $(t_{\mathrm{A'}} - t_{\mathrm{B}})$ in the moving system for light to return to A from B as observed by an observer in ∑ is

$$t_{\mathrm{A'}} - t_{\mathrm{B}} = \frac{L(c-v)}{c^2} \quad \text{(sec.).} \tag{6}$$

For the sake of simplicity, these two formulas can be written as follows when t_{A} is zero.

$$\frac{1}{2}t_{\mathrm{A'}} = t_{\mathrm{B}} = \frac{1}{2}\left[\frac{L(c+v)}{c^2} + \frac{L(c-v)}{c^2}\right] \tag{7a}$$

$$= \frac{L}{c} \quad \text{(sec.)}. \qquad (7b)$$

While the observer in ∑ would judge that the passage of time of the clocks on both ends of the rod for the time for light to reach B from A is $L(c+v)/c^2$ seconds, when this light reaches B, by definition, the time shown on clock B must be L/c seconds.

However, since $L(c+v)/c^2 > L/c$,the time at clock B must be later than the time at clock A to resolve this discrepancy. Thus, if the time adjustment to make the actual time at clock B later is Δt_1 , it should be possible to take the difference between the two as this time. Namely,

$$\Delta t_1 = \frac{L(c+v)}{c^2} - \frac{L}{c} \qquad (8a)$$

$$= \frac{Lv}{c^2} \quad \text{(sec.)}. \qquad (8b)$$

Through this procedure, the two clocks achieve simultaneity in the moving system, and we verify that the thought experiment until now is simply a training exercise that applicable to existing theory.

3. Breakdown of SR as derived from synchronization of clocks

Let us consider a case in which rod 2, identical to rod 1 from chapter 2, is moving at constant velocity ***w*** (where $\boldsymbol{w} \gg \boldsymbol{v}$). (Like the clocks of rod 1, the clocks of rod 2 are synchronized while they are at rest)

Next, we repeatedly perform the thought experiment for rod 2 in the same manner as performed for rod 1 in chapter 2. Where Δt_2 is the time adjustment to be performed for clock B of rod 2,

$$\Delta t_2 = \frac{Lw}{c^2} \quad \text{(sec.)}. \qquad (1)$$

Then, rather than moving rod 2 first at constant velocity ***w***, we perform the first experiment when moving at constant velocity ***v***. In other words, in the initial stage rod 2 is moving in parallel to rod 1 at constant velocity ***v***, and at this time the clock B of rod 2 is adjusted the first time by Δt_1 in the same manner as the clock B of rod 1. (See Fig.2)

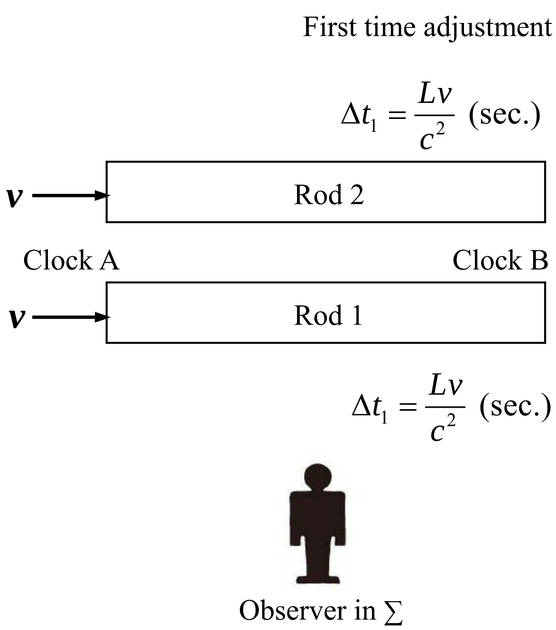

Fig.2 Time adjustment Δt_1 of clock B of rod 1 and first time adjustment Δt_1 of clock B of rod 2, as predicted by observer in a hypothetical preferred frame of reference ∑.

Then, we accelerate rod 2 until constant velocity $\boldsymbol{w}$, and we assume that this velocity $\boldsymbol{w}$ is the speed at which the relative velocity between rod 1 and rod 2 is $\boldsymbol{v}'$.

Therefore, according to the addition theorem for velocities of the SR, this velocity relationship can be represented as follows.

$$w = \frac{v + v'}{1 + \frac{vv'}{c^2}} \quad (2)$$

.

Here, if the second time adjustment of the clock B of rod 2 when rod 2 reaches velocity $\boldsymbol{w}$ is Δt_3, then an observer in ∑ can determine that the following relationship exists between these three time adjustments.

$$\Delta t_2 = \Delta t_1 + \Delta t_3. \quad (3)$$

From the above, an observer in ∑ can predict Δt_3 as follows. (See Fig.3)

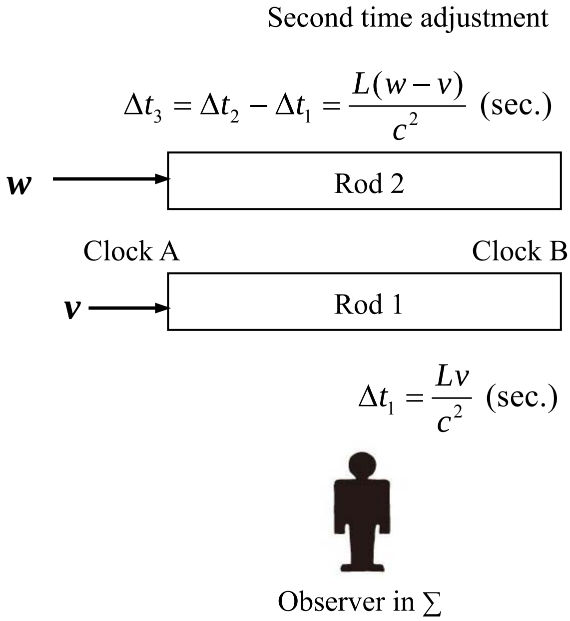

Fig.3 Second time adjustment Δt_3 of clock B of rod 2, as predicted by observer in ∑.

$$\Delta t_3 = \Delta t_2 - \Delta t_1 \tag{4a}$$

$$= \frac{L(w-v)}{c^2} \quad \text{(sec.).} \tag{4b}$$

Incidentally, according to the theory of SR, if there is an inertial system in which objects are in relative motion between each other, then the only important velocity is the relative velocity between coordinate systems. Therefore, an observer on the coordinate system of rod 1 would perceive that his coordinate system was at rest and that the coordinate system of rod 2 was moving at constant velocity $\boldsymbol{v}'$. Thus, an observer on rod 1 could assert that the time adjustment of clock B of rod 2 would be Δt_4 as follows. (See Fig.4)

$$\Delta t_4 = \frac{Lv'}{c^2} \neq \frac{L(w-v)}{c^2} \text{ (sec.)}$$

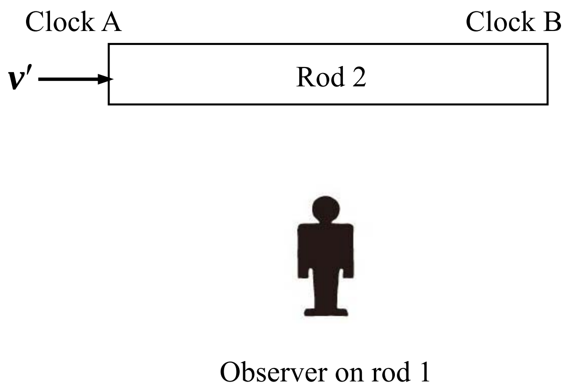

Fig.4 Time adjustment Δt_4 of clock B of rod 2, as predicted by observer on rod 1 who believes his coordinate system is at rest.

$$\Delta t_4 = \frac{Lv'}{c^2} \quad \text{(sec.).} \tag{5}$$

Ultimately, the times predicted by the observer in ∑ and the observer on rod 1 are different.

4. Discussion

When measuring the length of a moving rod, because the length of objects is a relativistic physical quantity, a difference in the length of the rod occurred depending on the relative velocity of the observer and the rod’s coordinate system. However, because the observer of rod 2 is actually performing the time adjustment in this case, this adjusted time is absolute.

In other words, it is impossible that both Δt_3 and Δt_4 are correct.

Therefore, a determination of which observer’s prediction is correct in this problem can be reached with certainty.

Incidentally, while a hypothetical preferred frame of reference ∑ was presumed in the thought experiment of the previous chapter, even with modern technology, relative velocity between ∑ and the earth has not been observed. In other words, anisotropy of light propagation has not been detected on the earth and the existence of ∑ is yet to be proven.

Therefore, some may argue that claims of a breakdown of SR based on assumption of the existence of ∑, which has not been observed, are meaningless. When claiming a breakdown in

SR through an assumption of $\sum$, SR, which should not be able to predict the existence of $\sum$ in the first place, should remain unscathed. Also, because the mere existence of $\sum$ would prove a breakdown in SR, it may be unnecessary to further prove a breakdown in SR through thought experiments.

To respond to these criticisms, as supported by the results of the MM experiments [1,5,8] and KT experiments [7,12,18], this paper proposes to substitute $\sum$ with the coordinate system of the earth as the rest system of the thought experiment of this paper. While this substitution is an essential component of this paper, if this substitution is accepted, then a breakdown of SR can be proven through experiments using rod 1 and rod 2 moving at constant velocities. However, this paper makes no assertion that the earth itself is $\sum$ nor that there is no relative velocity between $\sum$ and the earth.

Although the earth is moving, if perspective is limited to isotropy of light propagation, then it is currently not possible to differentiate between the earth and $\sum$. Therefore, when performing the "synchronization of clock of rod 2" in this paper, even if $\sum$ is substituted for the earth as the rest system, the result of the experiment does not change. In other words, even in experiments on the surface of the earth, it should be possible to detect a difference between Δt_3 and Δt_4.

5. Conclusion

In this paper, observers in two coordinate systems predicted the synchronization of clock B of rod 2 moving at constant velocity. The observer on earth predicted this time to be $L(w-v)/c^2$ (sec.), while the observer on rod 1 predicted the time to be Lv'/c^2 (sec.). The predictions of the two observers were different because the relative velocity between each observer and rod 2 was different, and this paper concludes that the latter prediction was incorrect.

This was because the observer on rod 1 did not take into consideration the movement of his own coordinate system relative to an intrinsic rest system.

While SR considers the coordinate systems of rod 1 and rod 2 to be rest systems, this paper showed that inertial systems in which light does not propagate isotropically cannot be considered to be rest systems.

Because the coordinate systems of rod 1 and rod 2 experienced an acceleration stage before reaching constant velocity motion, a state of anisotropy exists between the earth and these coordinate systems.

This is the same as the famous “twin paradox,” which explains the reason why one twin who travels through space would age more slowly than the other twin who stayed behind on earth [19].

While technically difficult, it is theoretically possible to prove a breakdown in SR by performing an experiment which introduced two inertial systems moving at constant velocity to the earth.

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The author expresses his gratitude.

Appendix

In building the theory of special relativity, Einstein proposed the following “principle of constancy of light speed [3].”

“Light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body.”

Therefore, $c- v$ of Formula (2.3) does not represent changes in light speed. Because the rod is moving from the perspective of the stationary observer, the difference in speed between light and the rod is observed as $c- v$.

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