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EINSTEIN MISUNDERSTOOD THE SPECIAL THEORY OF RELATIVITY

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Abstract

Einstein's Special Theory of Relativity (STR) is a physical theory representing the 20th century. This paper considers two inertial frames A and B moving at constant velocity relative to each other, just as in Einstein. The x-axes of the two inertial frames are assumed to be parallel, and rods A and B, which are perfectly the same and have the same length and mass, are placed on the x-axes of each inertial frame. According to the STR, the rod B in inertial frame B, observed from the stationary frame (inertial frame A) contracts in the direction of motion, and its mass also increases. On the other hand, rod A observed from the moving frame (inertial frame B) also contracts by the same ratio in the direction of motion, but its mass does not change (the mass of rod A does not depend on velocity). In the STR, two coordinate systems moving at constant velocity relative to each other are equivalent (i.e., both are inertial frames) when considering space contraction and time

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dilation, but they are asymmetrical when considering increase or decrease of mass. The two coordinate systems may be equivalent or asymmetrical depending on which physical quantity is measured. Whether the two coordinate systems are equivalent or not is determined at Einstein's convenience. The STR makes this hard-to-accept prediction, but many physicists still accept the theory. This paper shows the error which Einstein made when measuring the length of a rod moving at constant velocity by using a Minkowski diagram.

1. Introduction

Einstein's Special Theory of Relativity (STR) is a physical theory representing the 20th century. The STR is regarded as mathematically perfect and experimentally 100% verified. At present, no one doubts this theory among orthodox physicists.

When developing the STR, Einstein assumed that two inertial frames moving at constant velocity relative to each other are equivalent (the principle of relativity). However, Suto has already shown that these coordinate systems are not equivalent. According to Suto, among the coordinate systems regarded as inertial frames by Einstein, there are coordinate systems to which a velocity vector is attached (in coordinate systems with an attached velocity vector, light propagates anisotropically). Suto presented two thought experiments for determining the magnitude of the velocity vector attached to such a coordinate system [1, 2]. The STR has already been disproved. Nevertheless, the STR is still regarded as a physical theory representing the 20th century.

Here, let us point out the problems of the STR and Einstein. Suppose that inertial frame B is moving at constant velocity v with respect to a stationary frame (inertial frame A). In this thought experiment, we are in inertial frame A together with observer A in inertial frame A. According to Einstein, these two inertial frames are equivalent assuming the principle of relativity, and thus inertial frame B moving at constant velocity can be regarded as a stationary frame. Einstein predicted that if the length of rod A in inertial frame A is measured from inertial frame B, the rod will contract in the direction of movement. Also, the time which elapses is slowed down according to the clock in inertial frame A.

Now, even if, conversely, a physical quantity in inertial frame B is measured from inertial frame A, Einstein claims that rod B will contract at the same rate, and the passage of time will be delayed. In this paper, these predictions of the STR are called "*symmetry of space contraction and time dilation*." This "symmetry of space contraction and time dilation" is an important conclusion of the STR. (The core of the STR lies not in "space contraction and time dilation" but in that symmetry.)

An accurate experiment on this "time dilation" was recently carried out at the Max Planck Institute for Nuclear Physics in Germany [3].

This time dilation has also been demonstrated in experiments using rockets and aircraft. Due to these experiments verifying "time dilation," it is thought that the correctness of the STR has been demonstrated.

However, all of these experiments have only verified time dilation of inertial frame B (the moving frame) from inertial frame A (the stationary frame). These verification experiments also verify the theory of the author opposed to the STR. The author also recognizes "space contraction and time dilation" in the moving frame. (This "space contraction and time dilation" is explained in Section 3.) However, the author does not recognize "symmetry of space contraction and time dilation."

These verification experiments have verified "time dilation," but they have not verified "symmetry of time dilation." At present, we have only carried out half of the experiment to verify the STR. Furthermore, an even more important experiment has not been performed.

Now, according to the STR, the mass (energy) of objects or particles at rest in inertial frame B increases as the velocity of inertial frame B increases.

The energy-momentum relationship in the special theory of relativity

(STR) holds in an isolated system in free space. Here, if m_0c^2 is the rest mass energy and mc^2 is the relativistic energy, the relationship can be written as follows.

$$(m_0c^2)^2 + p^2c^2 = (mc^2)^2. \tag{1}$$

The following equation holds due to Formula (1).

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \gamma m_0. \tag{2}$$

If symmetry is taken into account here, then, conversely, even when mass (energy) of an object in the stationary frame (inertial frame A) is measured from the moving frame (inertial frame B), the mass (energy) of the object must increase. However, the STR definitely does not make that prediction. In this paper, this is called the "*asymmetry of the increase in mass* (*energy*)."

According to the STR, the rod B in inertial frame B, observed from the stationary frame (inertial frame A) contracts in the direction of motion, and its mass also increases. On the other hand, rod A observed from the moving frame (inertial frame B) also contracts by the same ratio in the direction of motion, but its mass does not change (the mass of rod A does not depend on velocity).

In the STR, two coordinate systems moving at constant velocity relative to each other are equivalent (i.e., both are inertial frames) when considering space contraction and time dilation, but they are asymmetrical when considering increase or decrease of mass. The two coordinate systems may be equivalent or asymmetrical depending on which physical quantity is measured. Whether the two coordinate systems are equivalent or not is determined at Einstein's convenience. The STR makes this hard-to-accept prediction, but many physicists still accept the theory.

Section 5 of this paper discusses Einstein's method of measuring rod length using Minkowski diagrams. Also, based on that discussion it is shown that Einstein misunderstood the measurement method of the STR. Before that, the principle of constancy of light speed assumed by Einstein is checked in Section 2.

2. Principle of Constancy of Light Speed Assumed by Einstein

Einstein assumed the following two principles when developing the special theory of relativity (STR).

(1) Principle of relativity.

(2) Principle of constancy of light speed.

First, Einstein explained the principle of relativity as follows [4].

"The laws by which the states of physical systems undergo change are not affected, whether these changes of state be referred to the one or the other of two systems of co-ordinates in uniform translatory motion."

In addition, he explained the principle of constancy of light speed as follows [5].

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

Light is always propagated at a constant velocity c, regardless of the velocity of the source emitting the light. In this paper, this principle is called the "*principle of constancy of light speed* I" (*principle* I). (However, note that Einstein himself did not classify the principle of constancy of light speed.)

Einstein also said the following [5].

"These two postulates suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies based on Maxwell's theory for stationary bodies."

However, the STR cannot be developed with these two assumptions alone (principle of relativity and principle I). Einstein also explained the principle of constancy of light speed as follows [6].

"Let a ray of light start at the "A time" t_{A} from A towards B, let it at the "B time" t_{B} be reflected at B in the direction of A, and arrive again at A at the "A time" t'_{A}. In accordance with definition the two clocks synchronize

$$t_{\mathrm{B}} - t_{\mathrm{A}} = t'_{\mathrm{A}} - t_{\mathrm{B}}. \tag{3}$$

....

In agreement with experience, we further assume the quantity

$$\frac{2\mathrm{AB}}{t'_{\mathrm{A}} - t_{\mathrm{A}}} = c, \tag{4}$$

to be a universal constant - the velocity of light in empty space."

In Formula (4), when the distance covered by light making a round trip over the interval AB is divided by the time needed for the round trip, light speed becomes c. This principle will be called the "*principle of constancy of light speed* II" (*principle* II).

Here, the author has assigned numbers to the formulas in Einstein's paper. If an observer carrying out this experiment is in a classically stationary frame, then the light speed for the outward and return path are both c. This principle, whereby light emitted from a light source propagates isotropically, will be called the "*principle of constancy of light speed* O" (*principle* O).

In this paper, the coordinate system where principle O holds is defined to be the classically stationary frame S_{cl}. Also, the coordinate system where principle O does not hold, but principle II does, is defined to be the classically moving frame S'_{cl}.

To establish Formula (3), Einstein's thinking was as follows [7].

"We imagine further that at the two ends A and B of the rod, clocks are placed which synchronize with the clocks of the stationary system, that is to say that their indications correspond at any instant to the "time of the stationary system" at the places where they happen to be. These clocks are therefore "synchronous in the stationary system." We imagine further that with each clock there is a moving observer, and that these observers apply to both clocks the criterion established in Section 1 for the synchronization of two clocks. Let a ray of light depart from A at the time *t_{A}, let it be reflected at B at the time t_{B}, and reach A again at the time t'_{A}. Taking into consideration the principle of the constancy of the velocity of light we find that

$$t_{\mathrm{B}} - t_{\mathrm{A}} = \frac{r_{\mathrm{AB}}}{c - v} \tag{5}$$

and

$$t'_{\mathrm{A}} - t_{\mathrm{B}} = \frac{r_{\mathrm{AB}}}{c + v}, \tag{6}$$

where r_{AB} denotes the length of the moving rod measured in the stationary system."

*"Time" here denotes "time of the stationary system" and also "position of hands of the moving clock situated at the place under discussion."

The following sentence continues after this.

"Observers moving with the moving rod would thus find that the two clocks were not synchronous, while observers in stationary system would declare the clocks to be synchronous."

Based on Einstein's requirements, an observer in a moving frame must synchronize the times of two clocks placed at the ends of a rod in his own coordinate system. When adjusting the clock at the front side of the rod, the time of the clock must be set back.

If the times of two clocks in a moving frame are set so they can be regarded as synchronized in the moving frame, then the light speed becomes c when calculated using the following Formula (7). (Light speed for the round trip also becomes c) [4].

"Any ray of light moves in the "stationary" system of co-ordinates with the determined velocity c, whether the ray be emitted by a stationary or by a moving body. Hence

$$\text{velocity} = \frac{\text{light path}}{\text{time interval}}, \tag{7}$$

where time interval is to be taken in the sense of the definition in Section 1." ("definition in Section 1" refers to Formula (3) of this paper.)

Light originally propagated anisotropically in a certain inertial frame can also be regarded as propagating isotropically from a relativistic perspective, if the times of two clocks on the x-axis of the inertial frame are synchronized (relativistically isotropic propagation).

In this paper, a theory different from the STR is developed by assuming principle I and principle II, which Einstein initially recognized as principles. This theory will be tentatively referred to as STH because it is a theory devised by the author Suto.

3. Rod Contraction and Slowing of Time Derived from the Principles of Constancy of Light Speed I and II

When Einstein developed the STR, he assumed the principle of relativity, i.e., that all inertial frames are equivalent. Einstein thought it was impossible to differentiate inertial frames into classically stationary frames where light propagates isotropically, and classically moving frames where light propagates anisotropically. However, Suto has previously pointed out that classically moving frames have a velocity vector attached. The thought experiment discussed here strictly distinguishes between classically stationary frames and classically moving frames.

In the textbook of French [10], the slowing of clock time and contraction of length are explained through separate thought experiments using light pulses. In this paper, those issues are considered together in a single thought experiment. The principles used in this thought experiment are principle I and principle II (including principle O). The following predicts measured values using assumptions acceptable to Einstein.

Consider a laboratory whose interior floor is a square. The Michelson interferometer is placed in this laboratory (Figure 1) [8].

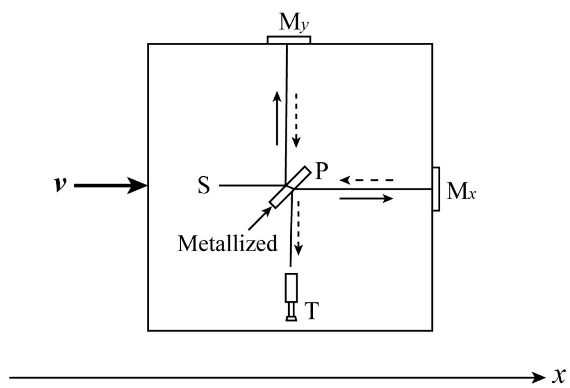

Figure 1. This figure shows the view from above of a laboratory moving at constant velocity v with respect to S_{cl}.

At the center of the room, there is a glass plate (beam splitter) P with a semi-transparent metal coating on its front face. The angle between this glass plate and the x-axis is $45°$. Light emitted from the light source S strikes this glass at an angle, and the light is split in two. One beam passes through the plate, strikes a mirror M_x is reflected, and retraces its path to the splitting point P. On the second light path, the beam is reflected by the glass plate P, arrives at mirror M_y, is reflected there, and returns to the splitting point P. (Only the essential parts of the experimental instrument are shown here. Equipment not needed for the discussion in this paper has been omitted.)

This laboratory is moving at constant velocity v along the x-axis of frame S_{cl}. The light path length PM_x measured indoors is taken to be $L_x/2$ and the path length PM_y, is taken to be $L_y/2$. (However, in measurements in the laboratory, L_x and L_y are equal.) In addition, the light path length when $L_x/2$ is measured from frame S_{cl} is taken to be $L'_x/2$, and the light path length when $L_y/2$ is measured from frame S_{cl} is taken to be $L'_y/2$. (However, L_y and L'_y are equal.)

Here, the time required for light to make a round trip over PM_x is measured from frame S_{cl}. If this round trip time is taken to be t'_x, then the observer in frame S_{cl} applies the principle I to this light propagation, and thus:

$$t'_x = \frac{L'_x}{2(c-v)} + \frac{L'_x}{2(c+v)} = \frac{L'_x c}{c^2 - v^2} = \frac{L'_x}{c(1 - v^2/c^2)}. \tag{8}$$

Next, the time for light to make a round trip over PM_y is measured. If this round trip time is measured in frame S_{cl} and taken to be t'_y, then

$$t'_y = \frac{L'_y}{c(1 - v^2/c^2)}. \tag{9}$$

Here, t'_x and t'_y are the times which elapse on the clock in frame S_{cl}.

The method of deriving Formula (9) is explained in many textbooks so here it is omitted [9, 10].

Incidentally, the predicted effect could not be detected from the Michelson-Morley experiment. This means that t'_x and t'_y are equal. In the end, the following relationship can be derived from Formulas (8) and (9).

$$L'_x = \frac{L'_y}{\gamma}. \quad (10)$$

Here, L'_y and L_x are equal, so Formula (10) can be written as follows.

$$L'_x = \frac{L_x}{\gamma}. \quad (11)$$

When measured from frame S_{cl}, the laboratory contracts by $1/\gamma$ times in the direction of motion. This contraction is physical contraction due to the fact that some force has acted on the laboratory, and this can be regarded as true (contraction I).

Incidentally, an observer in the coordinate system S'_{cl} of the laboratory applies the principle II to this light propagation, and thus the round trip times of light t_x and t_y are predicted as follows:

$$t_x = \frac{L_x}{c}. \quad (12)$$

$$t_y = \frac{L_y}{c}. \quad (13)$$

In the end, t_y elapses in frame S'_{cl} while t'_y elapses in frame S_{cl}. In addition, $L_y = L'_y$ and thus Formula (9) can be written as follows:

$$t'_y = \frac{\gamma L_y}{c}. \quad (14)$$

Next, if this is compared with Formulas (13) and (14):

$$t'_y = \gamma t_y. \quad (15)$$

When observed from frame S_{cl}, the time t_y which elapses in frame S'_{cl}

is delayed compared to the time t'_y which elapses in frame S_{cl}. Actually, this prediction has been verified by experiments where the life of elementary particles is extended. In the end, space contraction and time delay in frame S'_{cl} can be predicted if the principle I and principle II are assumed.

When the length of a body in a moving frame is measured from a stationary frame in this thought experiment, the body contracts in the direction of motion. Also, time elapsing on the clock in the moving frame proceeds more slowly than time on a stationary clock. This contraction of the body is physical contraction, and the time slowing is an *a priori* slowing of tempo. The author believes that Einstein also accepted this view.

Now if, conversely, an observer in a moving laboratory measures the length of a rod in the stationary frame, what will happen?

If the principle of relativity is applied to two inertial frames, then even when measurement is done from a moving frame, a rod in a stationary frame will physically contract, and the time slowing must also be a real slowing. This differs from Einstein's explanation, but the STR must be a theory capable of explaining the predictions of this thought experiment. The next section discusses the case where an observer in a moving frame measures the length of a rod in a stationary frame.

4. Contraction of Rod Interpreted by Borrowing Einstein's Measurement Method

In this section, the lengths of rod A and B are moving at constant velocity relative to each other.

The author has previously presented a thought experiment that can discriminate the difference between S_{cl} and S'_{cl} [1, 2, 8, 11, 12, 13]. Therefore, of the coordinate systems for rods A and B moving relative to each other, it is permissible to assume, in this paper, that the coordinate system for rod A is S_{cl}, and the coordinate system for rod B is S'_{cl}. There are observers B_2 and B_1 at the front and back ends of moving rod B. Also, the clocks used by observers B_1 and B_2 are taken to be clock B_1 and clock B_2.

Einstein presented two methods for an observer in a stationary frame to measure the length of moving rod B. If that is used as a reference point, then there are the following two methods for measuring the length of rod A in a stationary frame from a moving frame.

Measurement Method 1. The time needed for both ends of rod A in a stationary frame to pass in front of an observer in a moving frame is measured by an observer in a moving frame, using a clock B which advances slowly in the moving frame. If that time is taken to be Δt_{B}, the length L'_{A} ($v\Delta t_{\text{B}}$) of rod A becomes as follows. That is,

$$L'_{\text{A}} = v\Delta t_{\text{B}} = \frac{L}{\gamma}. \tag{16}$$

In this measurement, it appears that rod A has contracted. However, the cause of this contraction is not because the rod A actually contracted. This is only an apparent contraction which occurs because the time of the clock B used for measurement advances slowly. (contraction IIa)

In the case of Formula (11), in contrast, if Δt_{A} is taken to be the time needed for both ends of the rod B in the moving frame to pass in front of the observer in the stationary frame, then the length L'_{B} ($v\Delta t_{\text{A}}$) of rod B is as follows.

$$L'_{\text{B}} = v\Delta t_{\text{A}} = \frac{L}{\gamma}. \tag{17}$$

As has already been discussed, this contraction is physical. (contraction I) The cause of the contraction is unknown.

Measurement Method 2. Observers at both ends of rod B read off the positions of both ends of the rod B from the x_A - coordinate of the stationary frame at the same time in the moving frame. Then that measured value (distance between the two points in terms of their x_A - coordinates) is compared with the length of rod A.

The moving observers B_1 and B_2 read off the position of both ends of rod B from the x_A - coordinate in S_{cl}. Observer B_1 is at the rear end and observer B_2 is at the front end of the moving rod B.

At an arbitrary time, a light signal is emitted from S_B in the center of rod B. An observer in S_{cl} applies the "principle of constancy of light speed I" to this light propagation. When the light signal emitted from S_B has arrived at both ends of the rod, observers B_1 and B_2 read off the x_A - coordinates in S_{cl}.

Then the two observers of rod B compare the length of the x_A - coordinate they themselves read off, and the length of the stationary rod A.

Now, the observer in S_{cl} measures time until the light signals emitted from S_B arrives at the observers B_2 and B_1 at both ends of the rod. If these times are taken to be t_2' and t_1', then since the distance from S_B to the rod end is $L/2$,

$$t_1' = \frac{L}{2\gamma(c+v)}, \tag{18}$$

$$t_2' = \frac{L}{2\gamma(c-v)}. \tag{19}$$

Incidentally, the observer in S_{cl} determines the following values for the distance traveled by the light signal until it reaches both ends of the rod B.

Travel distance x_- in the negative direction of the x_A - axis

$$x_- = ct_1' = \frac{Lc}{2\gamma(c+v)}. \tag{20}$$

Travel distance x_+ in the positive direction of the x_A - axis

$$x_+ = ct_2' = \frac{Lc}{2\gamma(c-v)}. \tag{21}$$

The observers at both ends of rod B obtain the following values as the length of the rod B read off from the x_A - axis of the stationary system, based on Formulas (20) and (21).

$$L' = x_+ + x_- = \gamma L, \quad L < L'. \tag{22}$$

The length of rod B in this case is longer than rod A. That is,

$$\text{Length of rod B : Length of rod A, } \gamma L : L \to \gamma : 1 \tag{23}$$

Incidentally, if the principle of relativity is applied to the coordinate system of rod B, the length of rod A must match Formula (11).

Thus, the observers on rod B make the following judgment based on Formula (21).

$$\gamma : 1 \to 1 : \frac{1}{\gamma}. \tag{24}$$

When the length of rod A is measured from the coordinate system of rod B, rod A is contracted by $\frac{1}{\gamma}$ times in the direction of motion (contraction IIb).

The left side of Formula (22) signifies that the rod B in S'_{cl} has lengthened. However, if that is the case, then different results are obtained using the two measurement methods. That is not acceptable, so here it is conjectured that the right side of Formula (24) was derived by applying the principle of relativity.

Thus there is a match between the contraction rate observed by the observer in the stationary frame, and the contraction rate observed by the observer in the moving frame. However, the causes of contraction differ between the two coordinate systems. Therefore, an asymmetry exists between these two inertial frames, and as a result it is not appropriate to apply the principle of relativity to these two inertial frames.

Einstein describes the contraction of rod length as follows [14].

"The X dimension appears shortened in the ratio $1 : \sqrt{1-v^2/c^2}$, i.e., the greater the value of v, the greater the shortening.

……

It is clear that the same results hold good for bodies at rest in the "stationary" system, viewed from a system in uniform motion."

Regarding contraction when a rod in a stationary frame is measured from a moving frame, Einstein finds a way out very easily. This can be understood from the following two sentences.

"It therefore follows that the length of a rigid metre-rod moving in the direction of its length with a velocity v is $\sqrt{1-v^2/c^2}$ of a metre. … If, on the contrary, we had considered a metre-rod at rest in the x-axis with respect to K, then we should have found that the length of the rod as judged from K' would have been $\sqrt{1-v^2/c^2}$; this is quite in accordance with the principle of relativity which forms the basis of our considerations." [15].

"Here the contraction of moving bodies follows from the two fundamental principles of the theory, without the introduction of particular hypotheses; and as the prime factor involved in this contraction we find, not the motion in itself, to which we cannot attach any meaning, but the motion with respect to the body of reference chosen in the particular case in point.” [16].

Furthermore, in Einstein’s speech in Japan, he said the following.

“If a rigid body moves, its length must contract in the direction of movement. This is called Lorentz-Fitzgerald contraction, but this contraction appears to be completely relative. If there are assumed to be two identical trains which pass by each other, then length contraction is observed when an observer looks from one to the other, but if the situation is now reversed, and the latter looks at the former, the same sort of contraction must be occurring. It is clear that the cause of this is the relativity of simultaneity.” (This is an English translation of a Japanese book.)

The following table compares STR and STH with regard to rod contraction and time slowing.

Table 1. Comparison of STR and STH with regard to rod contraction and time slowing

		STR	STH
Assumed principles		Principle of relativity Principle O	Principle I Principle II Principle O
Principles not used		Principle I, II	Principle of relativity
Observation of frame S' from frame S	Rod B length	Contraction by $1/\gamma$ times *1	Real contraction by $1/\gamma$ times
	Passage of time	Slowing at ratio $1 : 1/\gamma$	Real slowing at ratio $1 : 1/\gamma$
Observation of frame S from frame S'	Rod A length	Contraction by $1/\gamma$ times *2	The length of a rod A does not change. However, this can be explained (interpreted) as apparent contraction *3
	Passage of time	Slowing at ratio $1 : 1/\gamma$	No change in the passing of time. However, this can be interpreted as time passing more slowly
Difference between frame S and frame S'		The two are equivalent (Principle of relativity)	The two are not equivalent. A velocity vector is attached to the moving frame

With STR, the cause of rod contraction cannot be regarded as having been clearly explained. However, there must be a theory that can explain the physical contraction (Formula (11)) discussed in Section 3.

In the author's opinion, rod contraction *1 and *2 in the STR is physical contraction. However, Einstein looked to the relativity of simultaneity for the cause of rod contraction. This corresponds to contraction *3. However, with this measurement, rod length in a stationary frame is measured from a moving frame. According to the STR, if an observer in a moving frame attempts measurement, this observer becomes an observer in a stationary frame. In measurement based on the STR, there is no such thing as observation of a stationary frame from a moving frame. Einstein has not correctly explained rod contraction in the STR which he developed.

In the following Section 5, it is shown how the length of a rod moving at constant velocity was measured by Einstein using a Minkowski diagram.

5. Rod Contraction Predicted from a Minkowski Diagram

This section discusses rod contraction by creating a Minkowski diagram, i.e., a depiction of Minkowski events [17]. (Figure 2)

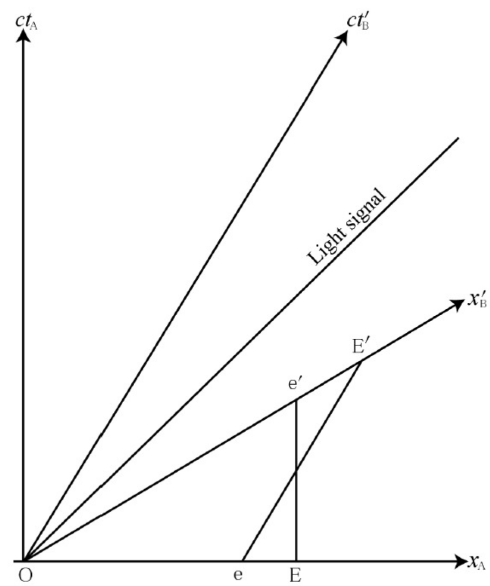

Figure 2. Figure 2 shows two inertial frames moving relative to each other using a Minkowski diagram.

First, consider two inertial frames S_A and S'_B moving at constant velocity relative to each other. Here, frame S_A is taken to be the stationary frame, and it is assumed that events occurring in frame S_A

are given as world points in terms of $x_A t_A$ - coordinates. S'_B is taken to be an inertial frame moving at constant velocity v relative to this frame S_A. Events occurring in frame S'_B are given as world points on the $x'_B t'_B$ - coordinates. The x_A - axis and x'_B - axis in the two coordinate systems are assumed to be parallel. The discussion here is limited only to motion in the x_A direction.

Rods with the same length when stationary are placed on the x_A - axis and x'_B - axis. The length of rod A stationary in frame S_A is OE, and the coordinates of the rod ends are $x_A = 0$ and $x_A = \text{E}$. Also, the length of rod B stationary in frame S'_B is OE′, and the coordinates of the ends of rod B are $x'_B = 0$ and $x'_B = \text{E}'$. Point O indicates the origin with $x_A = 0$, and $t_A = 0$, and the origin with $x'_B = 0$ and $t'_B = 0$. Also, in this figure, the slope of the world line of light is assumed to be $45°$. The t'_B - axis is the path of $x'_B = 0$, but this is the path of the origin of frame S'_B. Also, the x'_B - axis is the world line for the point $t'_B = 0$. The lines where t'_B is constant are parallel to this x'_B - axis. The world line of one end of the rod in frame S_A is the ct_A - axis, and the other end is the line parallel to the ct_A - axis passing through E. This line intersects with the x'_B - axis at e′. Also, the world lines for the two ends of the rod stationary in frame S'_B are the ct'_B - axis and the line parallel to the ct'_B - axis passing through E′. This line is the intersection of the x_A - axis and e.

Oe is the value when an observer in S_A measures the distance OE′, and Oe′ is the value when the distance OE is measured by an observer in S'_B. However, Ee′ is parallel to the ct_A - axis, and eE′ is parallel to the ct'_B - axis. Therefore, the relationship between OE, OE′, Oe and Oe′ is as follows.

$$\frac{\text{Oe}}{\text{OE}} = \frac{\text{Oe}'}{\text{OE}'} = \frac{1}{\gamma}. \tag{25}$$

The situation thus far is explained as follows in the textbook of Born [18].

"For the sake of brevity, we shall now let E, e, etc., stand for the segments $\overline{OE}$, $\overline{Oe}$, etc., as well as for the end points of these segments. The meaning of e′ is as follows: An observer at rest in S′ who wants to measure the length of the unit rod at rest in S will find as a result of a simultaneous observation O end e′ for it end points. Simultaneous observation in the S′-system is essential because the S′-unit is moving with regard to the observer in S′. Since the unit in S′ is given by E′ the result of the S-measurement is the e′/E′ part of the S′-unit."

The propagation of light seen from the two inertial frames is actually different. This means that the two inertial frames are not equivalent. It also means that the Cartesian coordinate system and oblique coordinate system in the Minkowski diagram are not equivalent. (Figure 3)

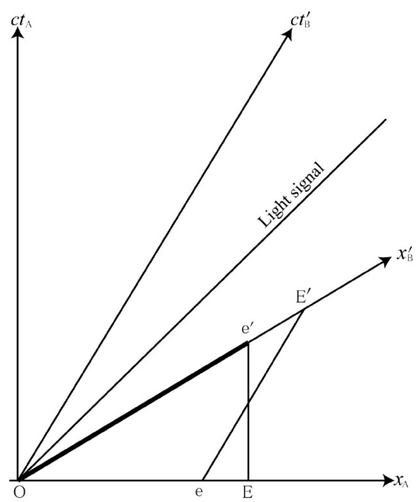

Figure 3a

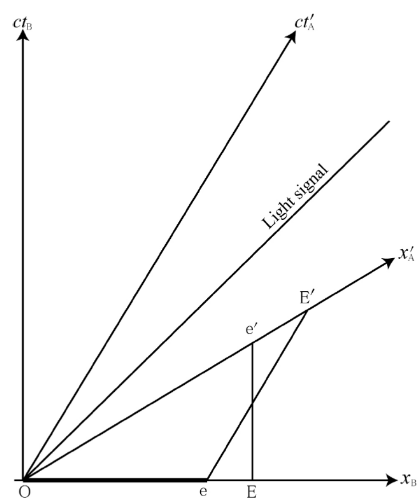

Figure 3b

Figure 3a. In this diagram, an observer in a moving frame measures the length of rod A in a stationary frame. The length of rod A obtained at this time becomes Oe′. Einstein and Born used this measurement method. However, this is not a measurement method based on the STR. It is a measurement method based on the STH.

Figure 3b. In this diagram, a person who was previously an observer in a moving frame now becomes an observer in a stationary frame, and measures the length of rod A in a moving frame (the initial stationary frame). The length of rod A obtained at this time becomes Oe. This is a measurement method based on the STR that takes into account the principle of relativity.

The contraction of Formula (24) corresponds to the rod length Oe′ obtained through measurement by an observer in the oblique coordinate system in Figure 3a. If we proceed based on the STR, on the other hand, then the length of rod A measured by an observer on rod B which has newly become a stationary frame, must be Oe in Figure 3b. This contraction corresponds to Formula (16).

With the STR, a person who has newly become an observer in a stationary frame is not permitted to measure the length of a rod using a clock whose time passes slowly in a moving frame. (However, this is allowed in the STH which recognizes the difference between the two inertial frames.)

The method of measuring the length of rod A, proposed by Einstein (who completed the STR) and used by Born, is actually not a measurement method based on the STR. The measurement method proposed by Einstein is the measurement method of the STH which stands opposed to the STR.

In the STR, which assumes the principle of relativity, the Cartesian coordinate system and oblique coordinate system are interchangeable [19].

If the two coordinate systems are equivalent, then it is acceptable to measure the Cartesian coordinate system from the oblique coordinate system. However, in this case, contraction measured by the observer in the moving frame (Formula (16) and Formula (24)) is not a physical contraction. However, if the STR is a correct theory, it must be a theory that can explain the physical contraction of Formulas (11) and (17).

Incidentally, this paper does not regard the Cartesian coordinate system and oblique coordinate system as equivalent. However, it is not possible to confirm the difference between the Cartesian coordinate system and the oblique coordinate system through measurement of rod length. Formula (17) is obtained through measurement from the perspective of the observer in the stationary frame, and Formulas (16) and (24) are obtained through measurement from the perspective of the observer in the moving frame. This is because the same contraction rate is obtained in measurement by either observer, although the reasons are different.

6. Discussion

What does it mean to say that two inertial frames moving relative to each other are equivalent? It does not mean that measurement of physical quantities in an oblique coordinate system (moving frame) from the Cartesian coordinate system (stationary frame) in Figure 3a is equivalent to the reverse measurement. (Einstein, however, understood the meaning of equivalence in this way.) The principle of relativity asserts that measurement of physical quantities in an oblique coordinate system from the Cartesian coordinate system in Figure 3a is equivalent to measurement of physical quantities in an oblique coordinate system from the Cartesian coordinate system in Figure 3b.

If the principle of relativity is applied to a moving frame, then an observer in the moving frame cannot measure physical quantities in the stationary frame while still being an observer in the moving frame.

If an observer, who was in a moving frame at the beginning, measures a physical quantity in a coordinate system moving at constant velocity, the measurement is done by adopting the standpoint of an observer in a stationary frame.

That is, in the original STR developed by Einstein, measurement of physical quantities in a Cartesian coordinate system from the oblique coordinate system in Figure 3a is not allowed. Einstein had an incorrect understanding of the STR he himself developed. Therefore, the two types of measurement methods proposed in Section 4 by Einstein are not acceptable in the original STR. This measurement is allowed from the perspective of this paper (STH) which recognizes the difference between the two inertial frames.

Now, how does an observer who has newly transitioned to being an observer in a stationary frame measure the physical quantities in a moving frame? In this case, an observer in the oblique coordinate system in Figure 3a measures physical quantities in the oblique coordinate system from the Cartesian coordinate system in Figure 3b. That is, measurements carried out by observers in the two inertial frames are measurements of physical quantities in the oblique coordinate systems in Figures 3a and 3b from the Cartesian coordinate systems in Figures 3a and 3b. This means that the two coordinate systems are equivalent.

However, Einstein and Born explained the contraction of rods predicted by STR by measuring physical quantities in the Cartesian coordinate system from the oblique coordinate system in Figure 3a. Einstein completely misunderstood the STR he himself developed.

Einstein regarded the two inertial frames as equivalent, and thus the Cartesian coordinate system and the oblique coordinate system of the Minkowski diagram is equivalent. Therefore, for Einstein, observing the Cartesian coordinate system from the oblique coordinate system in Figure 3a is the same as observing the oblique coordinate system from the Cartesian coordinate system in Figure 3b.

However, in the author's STH, the Cartesian coordinate system and the oblique coordinate system are strictly distinguished. (A velocity vector is attached to the oblique coordinate system.) This paper has pointed out that there are different reasons for rod A contraction obtained through observation from the moving frame in Figure 3a and rod A contraction obtained through observation from the stationary frame in Figure 3b. (In the STR, which assumes the principle of relativity, it is impossible for there to be different reasons for the contraction.)

7. Conclusion

By using Minkowski diagrams, this paper has shown the significance of applying the principle of relativity to two inertial frames moving relative to each other.

According to Einstein, the Cartesian coordinate system (stationary frame) and oblique coordinate system (moving frame) in Figure 3a are equivalent. However, when an observer in the moving frame observes physical quantities in the stationary frame, that observer measures physical quantities as an observer in a stationary frame. Therefore, in the original STR, it is impossible for an observer in the oblique coordinate system in Figure 3a to measure physical qualities in the Cartesian coordinate system.

The fact that the two inertial frames are equivalent does not mean that the Cartesian coordinate system and oblique coordinate system in Figure 3a are equivalent. (However, Einstein understood the meaning of equivalence in this way.)

The following figures summarize the discussion in this paper. In Figure 4, the length of rod B is measured from the coordinate system of rod A. In Figure 5, the length of rod A is measured from the coordinate system of rod B.

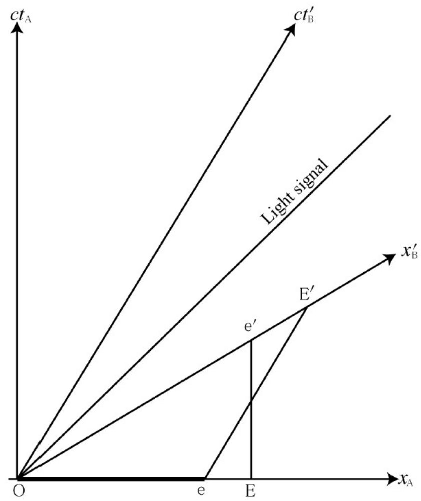

Figure 4a

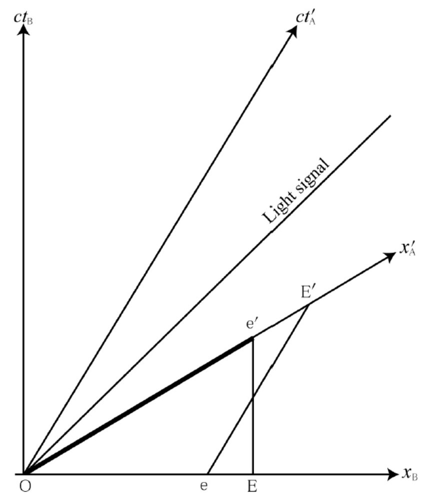

Figure 4b

Figure 4a. Length Oe of rod B measured based on this paper (STH) and the original STR.

Figure 4b. Length Oe′ of rod B claimed by Einstein.

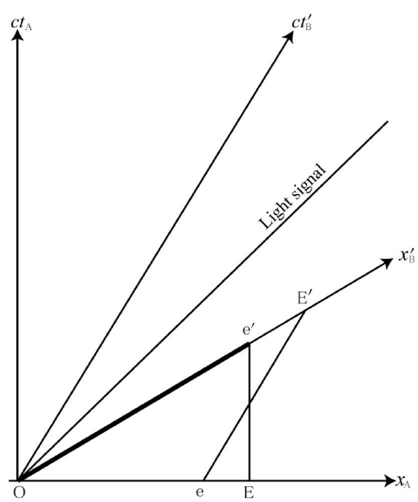

Figure 5a

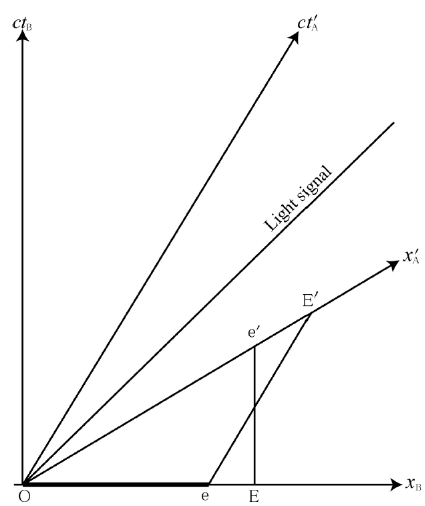

Figure 5b

Figure 5a. Length Oe′ of rod A measured according to this paper (STH) and Einstein.

Figure 5b. Length Oe of rod A measured based on the original STR.

These figures indicate measurements based on the original STR, measurements claimed by Einstein, and measurements based on this paper (STH).

Einstein developed his theory of the STR, which cannot really be regarded as physics, and then provided a mistaken explanation for that theory. That is, Einstein made a double mistake.

As a result, when many physicists in later generations pointed out contradictions in the STR, Einstein came through unscathed [20, 21].

This paper has verified that Einstein did not have a correct understanding of the STR which he himself developed.

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