Attempt at clarification of Einstein's postulate of constancy of light velocity

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December 5, 2005

Abstract

We have realized that under Lorentz transformations the tick number of a moving common clock remains unchanged, that is, the hand of the clock never runs slow, but the time interval between its two consecutive ticks contracts, so the relative time has to be recorded by using the τ-clocks required by the transformations, instead of unreal slowing clocks. Thus it is argued that using rest common clocks or the equivalent the measured velocity of light emitted by a moving source, which is quasi-velocity of foreign light, is dependent of the source velocity. Nevertheless, the velocity of foreign light that should be measured by using τ-clocks is independent of the source velocity. The velocity of native light emitted by a rest source obeys the postulate of relativity in accordance with both Maxwell equations and the result of Michelson-Morley experiment. On the other hand, the velocity of foreign light obeys both Ritz's emission theory except the Lorentz factor and the postulate of constancy of light velocity if measured by using τ-clocks. Thus the emission theory does not conflict with special relativity. The present argument leads to a logical consequence that the so-called positive conclusions from experiments testing constancy of the velocity of light emitted by moving sources if using common clocks or the equivalent, instead of τ-clocks, exactly contradicts Lorentz transformations.

1 Introduction

Einstein's special relativity has been seriously questioned by many people. Questions are sharply focused on the postulate of constancy of light velocity. He stated that "light is always propagated in empty space with a definite velocity *c* which is independent of the state of motion of the emitting body" [1]. This statement means that using common clocks or the equivalent in the stationary inertial reference frame, the velocity of light emitted by a moving source is identical with the velocity of light emitted by a rest source. The statement has caused a good deal of confusion and controversy that surround the following three theories:

The first is Lorentz ether theory that argues that light velocity does not depend on the velocity of its emitting source like that of a sound wave emitted by a moving bell. The Michelson-Morley interference experiment [2,3] relevant to Maxwell theory involves ether questions. As well known, according to the theory, the velocity of an electromagnetic wave is

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} \tag{1}$$

where ϵ_0 and μ_0 are electric permittivity and magnetic permeability in vacuum. *c* is a characteristic velocity. Maxwell concluded that light wave is a kind of electromagnetic wave since *c* is equal to light velocity. He thought that the wave propagated relative to the rest ether and suggested that the velocity of the earth moving relative to the rest ether could be measured. Michelson was triggered by Maxwell's idea and devised an experiment to do it. Since the idea that the ether is dragged fully by the earth is not supported by the results of Bradley's observation of the stellar aberration [4] and Fizeau's experiment [5], it was predicted that one could measure the relative velocity from a shift of interference fringes as the interferometer is rotated through 90 degrees. But, contrary to the expectation, they observed a negligible shift. However Fitzgerald [6] and Lorentz [7] still accepted the concept of rest ether and in order to explain the surprising result independently assumed that moving objects actually contract in the direction of motion through the ether with a factor $\sqrt{1 - v^2/c^2}$. Indeed the result of Michelson-Morley experiment proves that the hypothetical ether wind passing through the earth is undetectable and light velocity is constant in all directions in the source-rest frame.

The second is due to Einstein who abandoned the hypothesis of ether and made the postulate of constancy of light velocity with his insight of the relativity of simultaneity. The postulate is described by the following two equations for the stationary and a moving inertial reference:

$$x^2 + y^2 + z^2 = c^2 t^2 \tag{2}$$

$$x'^2 + y'^2 + z'^2 = c^2 t'^2 \tag{3}$$

where *c* is light velocity in vacuum. Thus the mathematical formulation of the postulate is clear but the physical meaning still needs to be clarified.

The third is emission theory or ballistic theory advocated by such as Ritz [8]. The theory argues that light velocity depends on the velocity of its emitting source like that of a bullet emitted by a moving rifle.

Now, on the basis of Lorentz transformations and Eqs.2-3, this article attempts to clarify Einstein's postulate of constancy of light velocity.

2 Common clocks and τ-clocks

In order to clarify the relation between the light velocity and source velocity, it is most important to distinguish time from clock hand positions. The *t* in Eq.2 is recorded by using common clocks but *t*' in Eq.3 is calculated according to the Lorentz transformation formula:

$$t' = \frac{t - xv/c^2}{\gamma}, \ \ \gamma = \sqrt{1 - v^2/c^2} \tag{4}$$

if the relative motion is in the *x* direction. As mentioned in Ref.[9], according to similarity between space and time and correspondence between a ruler and a clock, like the number of the divisions on a moving ruler, the tick number of a moving common clock is independent of the relative velocity *v* and thus invariant under Lorentz transformations. So the hand of the moving common clock never runs slow but the time interval between its two consecutive ticks contracts (i.e. the ticking rate (ticks/s) increases). Thus, in the stationary inertial reference frame the time *t* can be recorded by using a common hand clock or the equivalent but the *t*' in the moving frame has to be recorded by τ-clocks as shown in Fig.1. It is the characteristic of the common hand clock that one tick represents one second. Nevertheless the readings on τ-clocks depend its relative velocity and position in the moving frame where one tick no longer represents one second. The γ values indicated on the τ-clocks' hand represent the different relative velocities. The readings in seconds on the circle to which the sliding arrow points represent the duration of an event in the moving frame. For example, for the case of relative velocity 0.866*c*, namely, γ=0.5, Fig.1(a) shows that the τ-clock at the origin of the moving frame ticks 0.5 seconds and Fig.1(b) shows that the τ-clock a light-second away from the origin ticks the same but runs 0.866 seconds earlier than the one at the origin.

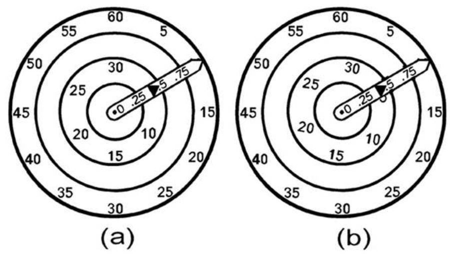

Figure 1: The τ-clocks moving in the x direction, for example, running at $\gamma = 0.5$: (a) at the origin of the moving frame, (b) at the position a light-second away from the origin on the the positive x' half-axis.

Einstein's concept of a clock that one tick of the clock always represents one second in moving inertial frames is wrong and leads to the clock paradox or twin paradox as pointed out in Ref.[9]. With the concept of the τ-clock, it will be possible to clarify the postulate of constancy of light velocity.

3 Light velocity and light quasi-velocity

It is also important to distinguish the velocity unit m/s from m/tick in the context of special relativity. In classical mechanics the velocity vector **v** of an object in a reference frame is defined as **v**=d**r**/d*t*, **r**=(*x*,*y*,*z*) and the time *t* is measured by common clocks. But, in special relativity time has relative simultaneity. The standard unit of velocity m/s is used in both theories. In special relativity a velocity with unit m/tick in moving inertial reference frames, instead of m/s, may be called as quasi-velocity. Equivalently, the velocity of light emitted by a moving source with respect to the stationary inertial reference frame may also, thus, be called as light quasi-velocity. We will see light quasi-velocity is dependent of the state of motion of the emitting body.

For the case of one dimension, from Eqs.2-4, we have

$$x = \pm ct \tag{5}$$

and

$$x' = \pm ct' = \pm c(\frac{t - xv/c^2}{\gamma}) = \pm\frac{(c \mp v)t}{\gamma} \tag{6}$$

where *t* is the time indicated by the tick readings on a common clock. By the definition of velocity mentioned above, the velocities $(c \pm v)/\gamma$ (m/tick, in the moving frame) are light quasi-velocities. From Eq.6 we have two-way average light quasi-velocity

$$[(c-v)/\gamma+(c+v)/\gamma]/2=c/\gamma \text{ (m/tick)} \tag{7}$$

so the average light velocity on the interval Lorentz-contracted in the moving frame is *c*. This result independent of the relative velocity expresses constancy of two-way average light velocity on the contracted interval.

Now, we see the light velocity *c* (m/s), instead of light quasi-velocity (m/tick), is independent of the relative velocity due to the relativity of simultaneity. Since Ritz's emission theory [8] involves the light quasi-velocity (m/tick) dependent of the source, the theory is consistent with the postulate of constancy of light velocity except the Lorentz factor $1/\gamma$. In fact, in Einstein's derivation of Lorentz transformations he wrote the time increments $\triangle t = \pm(x-vt)/(c\mp v)$ which equal to

$$\triangle t=\pm\frac{(x-vt)/\gamma}{(c\mp v)/\gamma}=\pm\frac{x'}{(c\mp v)/\gamma} \tag{8}$$

It is the same as Eq.6. Indeed, he had already shown that the light quasi-velocity (m/tick) depended on the relative velocity between inertial reference frames.

4 Native light and foreign light

Concerning the relation between the light velocity and observers, it is important to distinguish native light from foreign light with respect to rest observers. According to the postulate of relativity, the velocity of light emitted from rest light sources should have the definite value *c* with respect to the source-rest frame. We call such light as native light. By using rest common clocks, the velocity of native light relative to the rest observers is definite *c* beyond debate.

Now the question is that in the moving frame at velocity *v* relative to the stationary frame, observed by a rest observer in it, what is the velocity of the light emitted by the rest source in the stationary frame? This light may be called as foreign light by the rest observer in the moving frame. In fact, the *c* in Eq.3 is exactly the velocity of foreign light measured by using τ-clocks. Since the case of the moving observer relative to the source-rest frame is equivalent to that of the moving source relative to the observer-rest frame, if using common clocks for the foreign light, instead of τ-clocks, from Eq.6 we get quasi-velocities $(c-v)/\gamma$ in the direction of the positive *x'* and $(c+v)/\gamma$ in the opposite direction. They do depend on the relative velocity *v* and in comparison with the Galileo transformations are only different by the Lorentz factor. But the two-way average light quasi-velocity is c/γ, or saying, on the interval Lorentz-contracted it is *c*. Therefore, using common clocks for measuring velocity of foreign light, we have constancy of two-way average light velocity on the contracted interval.

5 Effects of extinction of light in media

As mentioned above, the vacuum velocity of light emitted by a rest source is definite *c* relative to the source and the vacuum quasi-velocities of light emitted by the moving source at velocity *v* are $(c \pm v)/\gamma$ in the stationary frame. However we are aware that there exists extinction of light in media which reflect light, transmit light, and re-emit light along with absorbing light [10-12]. The extinction that is brought about entirely on the boundary of condensed media can change foreign light into native light and thus light quasi-velocity (m/tick) into light velocity (m/s) in the medium-rest frame. Especially, interstellar gas and dust have certainly extinction effect although the details are unclear to us. Thus, although the postulate of constancy of light velocity apparently is viable in some cases under the condition of using common clocks, we should bear in mind that, according to Lorentz transformations or Eqs.2-3, the postulate of constancy of light velocity is valid only provided that we use common clocks to recorded time for measuring the velocity of native light and use τ-clocks to record time for measuring the velocity of foreign light. In a word, the Lorentz transformations and Einstein's equations (Eqs.2-3) are tenable but his statement "light is always propagated in empty space with a definite velocity *c* which is independent of the state of motion of the emitting body" is incorrect if same clocks are used regardless of whether the emitting source is in motion or at rest.

6 Conclusion

We have realized that under Lorentz transformations the tick number of a moving common clock remains unchanged, that is, the hand of the clock never runs slow, but the time interval between its two consecutive ticks contracts, so the relative time has to be recorded by using the τ-clocks required by the transformations, instead of unreal slowing clocks. Thus it is argued that using rest common clocks or the equivalent the measured velocity of light emitted by a moving source, which is quasi-velocity of foreign light, is dependent of the source velocity. Nevertheless, the velocity of foreign light that should be measured by using τ-clocks is independent of the source velocity. The velocity of native light emitted by a rest source obeys the postulate of relativity in accordance with both Maxwell equations and the result of Michelson-Morley experiment. On the other hand, the velocity of foreign light obeys both Ritz's emission theory except the Lorentz factor and the postulate of constancy of light velocity if measured by using τ-clocks. Thus the emission theory does not conflict with special relativity. The present argument leads to a logical consequence that the so-called positive conclusions from experiments testing constancy of the velocity of light emitted by moving sources if using common clocks or the equivalent, instead of τ-clocks, exactly contradicts Lorentz transformations.

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