Einstein's Concept of Non-Simultaneity Could Enable us to Measure the Speed of the Earth Through Space

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Abstract

According to Einstein's thought experiment with two bolts of lightning striking at the same time the ends of a moving railroad car (as seen by an observer outside the car), an observer located in the exact middle of the car will see the signal coming from one bolt of lightning before he sees the signal coming from the other bolt of lightning. The unequal effect of the car's motion, which affects motion of the observer and the car but has no effect on the speed of light, will enable the observer to determine from within the railroad car whether or not the car is at rest or in motion, and also determine its exact speed, contradicting Einstein's principle of relativity (Postulate 1). The paper elaborates upon the possibility of performing an experiment based on Einstein's concept of *non-simultaneity* to determine the speed of the earth through space.

The essence of Einstein's concept of simultaneity

Einstein explained his concepts of simultaneity and non-simultaneity with the following words and a drawing of a thought experiment where two bolts of lightning strike the ends of a railroad car at the same time:

> "We suppose a very long train traveling along the rails with the constant velocity *v* and in the direction indicated in Fig. 1."
>
> "Just when the flashes of lightning occur, the point M' (the observer's place in the middle of the car) naturally coincides with the point M (on the embankment), but it will move towards the right in the diagram with the velocity *v* of the train."
>
> "If an observer sitting in the position M' in the train did not possess this velocity, then he would remain permanently at M, and light rays emitted by the flashes A and B would reach him simultaneously, i.e., they would meet him just where he is situated. Now in reality ... he is hastening towards the beam of light coming from B, whilst he is riding ahead of the beam of light coming from A."
>
> "Hence the observer will see the beam of light emitted from B earlier than he will see that emitted from A. Observers who take the railway train as their reference-body must therefore come to the conclusion that the lightning flash B took place earlier than the lightning flash A. We thus arrive at the important result:
>
> "Events which are simultaneous with reference to the embankment are not simultaneous with respect to the train ..." [1]

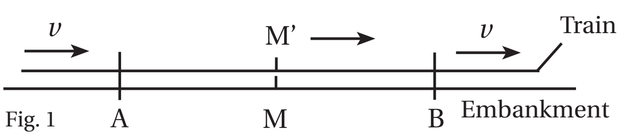

Figure 1

Let us present Einstein's thought experiment in a more visual and comprehensive way—by presenting two figures: One, when two bolts of lightning strike the railroad car at rest, the other, when the car is moving with a uniform speed to the right.

In the first figure *(Fig. 2)*, two bolts of lightning strike the ends of the railroad car at the same time when the car is at rest. The signals from the lightning bolts travel identical distances to reach an observer at M'. The observer will conclude that the two bolts of lightning struck the ends of the car simultaneously.

However, if the car is hit in the same manner while in uniform motion *(Fig. 3)*, the signal from the bolt of lightning on the left-hand side will travel a longer distance to reach the observer than the signal from the bolt on the right, because the speed of light would remain unchanged, *c*.

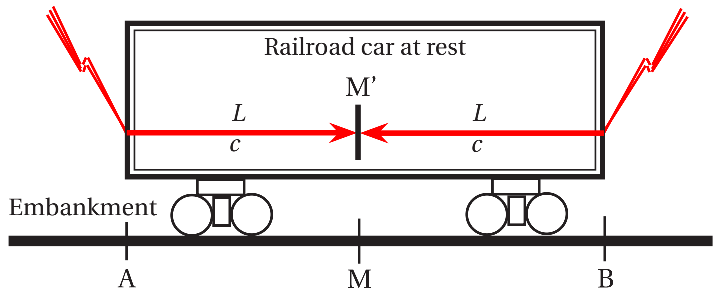

Figure 2

The outcome of Einstein's thought experiment tells us that the events that occur simultaneously in a railroad car that is at rest for an observer inside of the car *(Fig. 2)* are not simultaneous when the railroad car is in motion *(Fig. 3)*.

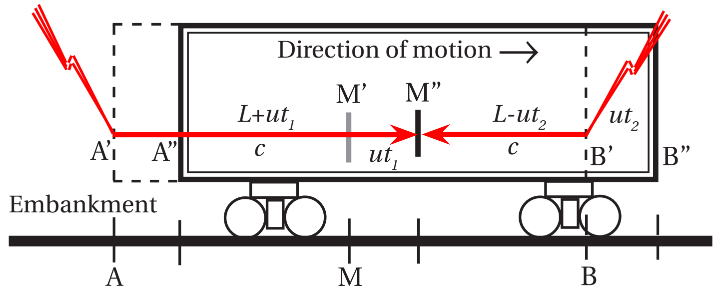

Figure 3

The outcome of Einstein's thought experiment tells us that the events that occur simultaneously for an observer in a railroad car that is at rest *(Fig. 2)* do not appear simultaneous when the railroad car is in motion *(Fig. 3)*. This leads to an *outcome that was not foreseen by Einstein.*

Einstein's concept of non-simultaneity offers an opportunity to detect motion from within a moving railroad car

Einstein stated in the last quote: *"If an observer sitting in the position M' in the train did not possess this velocity, then he would remain permanently at M, and light rays emitted by the flashes A and B would reach him simultaneously ... ,"* that is, at the same time. Einstein also tells us that if the car with the observer were moving when the two bolts of lightning struck the car simultaneously, the observer would be *"... hastening towards the beam of light coming from B, whilst he is riding ahead of the beam of light coming from*

A." Therefore, "... the observer will see the beam of light emitted from B earlier than he will see that emitted from A" (Fig. 3).

If this is the case, the observer will be able to determine whether the railroad car is at rest or in motion. If the observer possessed instruments that could determine the difference in the arrival of the two signals, he or she would have been able to determine the changes in the speed of the car. The time difference in the arrival of the signals is directly related to this speed.

While the concept of contraction helped explain the null results of the MM experiment, where the inequalities caused by the constancy of the speed of light were perfectly compensated for with contractions, in Einstein's thought experiment of two bolts striking the railroad car, the differences in the optical paths are so great that they cannot be compensated for by contractions. In fact, no relativistic principle can be employed here to negate the fact that the observer in the railroad car will be able to distinguish when the railroad car is at rest or in motion. Einstein tells us that the signals from the two bolts of lightning in a moving car (and the clocks in *Fig. 5*) will arrive at the observer at different times, that is, non-simultaneously.

Einstein's concept of simultaneity explained with the use of four synchronized atomic clocks

Einstein's principle of relativity and his concept of simultaneity are often demonstrated in physics textbooks with a group of synchronized clocks. Suppose we place four such synchronized atomic clocks in a railroad car, as shown below. They are positioned at an equal distance from an observer M located in the middle of the car.

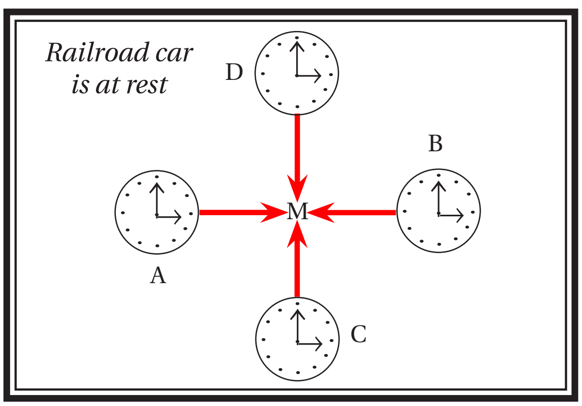

Figure 4

The example of four clocks is identical to Einstein's example of two bolts of lightning striking a railroad car at the same time. When the car is at rest, the signals from the clocks will travel equal distances to the observer, so that the observer will register the same time for all four clocks *(Fig. 4)*.

When the railroad car is in motion, however, the signals from the clocks will travel at speed *c* different optical distances to reach the observer at M' *(Fig. 5)*. In the same manner in which Einstein described the travel paths of the signals from the two bolts of lightning, we can repeat Einstein's argument and state that the observer will be *"hastening toward the signal coming from clock B, while the observer is riding ahead of the signal coming from clock A."*

Einstein's conclusion, *"Hence the observer will see the beam of light emitted from B earlier than he will see that emitted from A,"* must apply in this situation. The observer would, therefore, observe different times on the clocks. By measuring the time difference, he will be able to determine not only that the railroad car is moving but also *the speed of the car*.

There is no reason for the observer in the railroad car to doubt that the clocks could change their timekeeping characteristics in an unequal manner when the car starts moving at a uniform speed. The only thing that is added to the system at rest is the motion of the railroad car, which equally affects the timekeeping abilities of all four clocks.

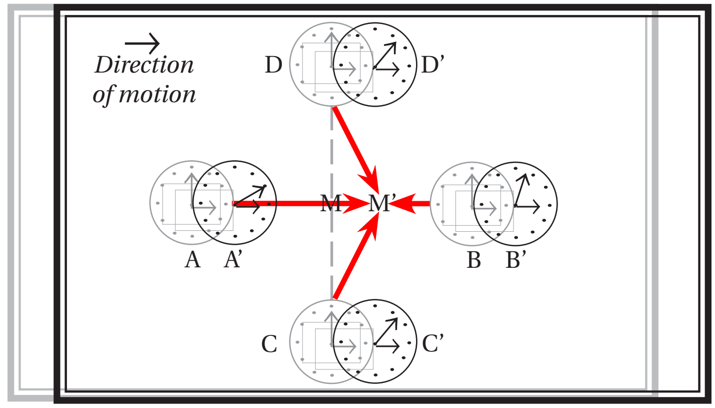

Figure 5

Suppose the observer in the train notices a greater difference in times as shown by the four clocks. If nothing had changed in the railroad car—that is, if the clocks and the observer remained in the same place—the observer would have to conclude that the train must be traveling at a greater speed.

However, if the difference in times begins to decrease, the observer will have to conclude that the train is decelerating. If, a moment later, all four clocks show the same time, the observer will have to conclude that the train has come to a stop. That is, in Einstein's language, *the events that appear to an observer to be simultaneous when the car is at rest do not appear simultaneous when the car is in motion.* The concept of this non-simultaneity is expressed in the time difference, from which an observer can deduce the speed of the car. That is to say, according to Einstein's concept of simultaneity, the state of rest is not the same as the state of uniform motion, and the laws of physics are *not* the same in all inertial frames of reference.

Therefore, Einstein's concept of non-simultaneity is in direct contradiction with his own theory, which states that it is impossible to detect motion from inside a uniformly moving vehicle. Because this theory is intimately connected to Einstein's principle of relativity, the concept of non-simultaneity is in direct contradiction with this principle.

The essence of Einstein's principle of relativity

Peter J. Nolan presented in his textbook, *Fundamentals of College Physics,* a representative interpretation of Einstein's principle of relativity, which also is known as Postulate 1 of the special theory of relativity.

> "In 1905, Albert Einstein formulated his Special or Restricted Theory of Relativity in terms of two postulates:
>
> **"Postulate 1**: The laws of physics have the same form in all frames of reference moving at a constant speed with respect to one another. This first postulate is sometimes also stated in the more succinct form: The laws of physics are invariant to a transformation between all inertial frames.
>
> **"Postulate 2**: The speed of light in free space has the same value for all observers, regardless of their state of motion.
>
> "Postulate 1 is, in a sense, a consequence of the fact that all inertial frames are equivalent. If the laws of physics were different in different frames of reference, then we could tell from the form of the equation used which frame we were in. In particular, we could tell whether we are at rest or moving. But the *difference*

between rest and motion at a constant velocity cannot be detected. Therefore, the laws of physics must be the same in all inertial frames." [2] (Emphasis added.)

Of particular interest here is the connection between Postulate 1 and the ability to detect uniform motion. This connection is summarized in Nolan's last sentences: *"But the difference between rest and motion at a constant velocity cannot be detected. Therefore, the laws of physics must be the same in all inertial frames."*

However, Einstein's concept of non-simultaneity tells us just the opposite. It tells us that the laws of physics are not the same in all inertial frames of reference. In Einstein's thought experiment, where the railroad car is moving at a uniform speed, not everything is equally affected by the motion of the train. The speed of the light signals from the two bolts of lightning are the exception—they continue to travel at the same speed. *It is because of this unequal effect that the laws of physics cannot be the same in all inertial frames of reference*. And because the laws of physics cannot be the same, an observer on the train can detect the motion of the train and also can determine the exact speed of the train. The observer also can deduce when the train stops or starts moving.

This means that because of the unequal effect of the motion of the train on the components of the experiment, where the *uniform motion does not affect the speed of the light signals but affects the distances traveled by these signals*, the laws of physics are different in different inertial frames of reference. Einstein's thought experiment is direct proof of these arguments.

Unaware of these contradictions, Einstein proceeded with the formulation of the fundamental principles of his theory of relativity expressed by the two postulates of relativity.

Einstein's two fundamental postulates cannot exist at the same time—one postulate denies the existence of the other

From the analysis of Einstein's thought experiment regarding the two bolts of lightning, it follows that Einstein's principles of simultaneity and non-simultaneity, along with his theory of the constancy of the speed of light, are in direct contradiction with his own principle of relativity and in contradiction with his notion of the inability to detect motion from within a uniformly moving vehicle. In other words, Einstein's two postulates of relativity cannot exist at the same time.

If we want to keep the constancy of the speed of light, that is, Postulate 2 of the theory of relativity, we must abandon Einstein's principle of relativity (Postulate 1), because the constancy of the speed of light will enable us to detect motion from within a uniformly moving vehicle.

If, on the other hand, we want to keep Einstein's principle of relativity, we must abandon the theory of the constancy of the speed of light, because the principle of relativity mandates that the state of rest is indistinguishable from the state of uniform motion, which the constancy of the speed of light would enable us to differentiate. That is to say, Einstein's two postulates of relativity contradict each other to such a degree that one denies the existence of the other.

Einstein's concept of non-simultaneity would enable us to measure the speed of the earth through space

Experiments performed with the Cosmic Background Explorer satellite (COBE) in 1989 found that the earth and our solar system travel at 360 to 390 km/s through space in the direction of the constellation Leo. Einstein's concept of non-simultaneity offers a theoretical possibility to verify the above-found speed. Once again, whenever there is a theoretical possibility there is also a practical one.

Einstein's two bolts of lightning striking a railroad car at the same time could be replaced with two signal generators (or two lasers) sending synchronized waves or pulses to a receiver and an oscilloscope. The receiver and the oscilloscope *(Fig. 6)* would take the role of the observer M in Einstein's thought experiment. The setup would be placed on a rotating platform in the same manner several Michelson-Morley-type experiments have already been performed. The signals from atomic clocks could be used to drive and synchronize the signal generators (or the lasers).

In this experiment, the two synchronized signals that travel from the signal generators would be oriented perpendicularly relative to the direction of the motion of the earth, as shown in *Figure 6*. In this orientation, the length of the optical paths of the two beams would remain the same as the platform moves from left to right. The beams from the signal generators will travel equal distances and arrive at the receiver M at the same time, that is simultaneously, as was the case in Einstein's thought experiment with two bolts of lightning. A hypothetical and highly simplified setup is shown in the figure below.

Motion
of the
earth

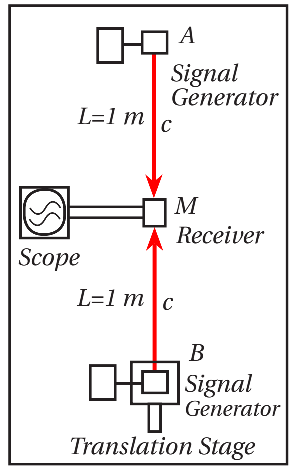

Figure 6

This same-time arrival would be displayed on an oscilloscope as two sine waves in phase.

The platform would then be rotated 90^0 so that the direction of the signals would be parallel to the motion of the earth *(Fig. 7)*.

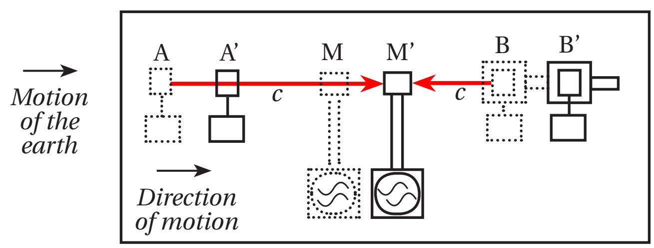

Figure 7

Once again, as Einstein explained, the receiver will be *"riding ahead of the beam of light coming from A,"* so the signal would travel a longer optical path (AM') to reach the receiver and the oscilloscope. The receiver would also be *"hastening towards the beam of light coming from B,"* so this signal would travel a shorter path (BM'). As the relativistic contractions are too small to affect the results, the unequal optical paths would cause the signals to arrive at the receiver (observer M) at different times, that is, as Einstein explained, they would arrive non-simultaneously. The difference in the arrival times would indicate the speed of the earth through space.

If the optical paths in our experiment in *Figure 7* were 1 m long and the earth traveled through space at a speed of 390,000 m/s, a change in the orientation of the platform would shorten the optical path of the signal emitted by the signal generator B by 1.3 mm, while the optical path of the beam emitted from the signal generator A would increase by 1.3 mm.

The difference in the optical paths in this experiment is huge in optical terms. This difference should be detectable by modern photonics technology either through interferometry, signal comparisons, time arrival of the signals or time delays, beat frequency changes, emission of pulses or any other method. The latest desktop atomic clocks are achieving a precision exceeding 10^{-15} parts per second. They could be used to drive and synchronize the waves or pulses emitted by two independent sources. It is not a matter of whether such an experiment can be performed; it is only a matter of time, which might be now.

One of the signal generators or a laser in *Figure 7* could be mounted on a motorized translation stage, which would allow us to perform a control test before the platform is rotated. The manual changing of the length of an optical path would create a phase shift or time delay, simulating the effect of the platform's rotation.

It should be mentioned that in the two-signal experiment, two signal sources are used to mimic Einstein's thought experiment and demonstrate the non-simultaneity in this experiment as well. The actual experiment could take a different form.

If the 90^0 rotation of the platform does not show any change, a control test by manual change of the optical path could again be performed to show the change that should have occurred, if light traveled at a constant speed *c*, as stipulated by Einstein and his concept of non-simultaneity.

If it is not possible to synchronize the two beams and compare the wave arrivals at the receiver, we should be able to observe a sort of a "spike" when the change in the length of an optical path does occur. In other words, we should to be able to discriminate inherent signal fluctuations from those due to the changes in the length of an optical path.

Any phase changes or occurrence of spikes during the rotation of the platform would confirm Einstein's concept of non-simultaneity and the concept of the constancy of the speed of light (Postulate 2), but it would invalidate Einstein's principle of relativity (Postulate 1), because we would be able to detect motion of the earth through space by an experiment performed on earth.

On the other hand, the absence of phase shifts or time delays would invalidate Einstein's concept of non-simultaneity and the concept of the constancy of the speed of light. However, this result would confirm Newton's and Galileo's principle of relativity and the concept of the addition of speeds.

Either result could make this experiment one of the most important experiments in physics.

References

[1] Albert Einstein, *Relativity*, Crown Trade Paperbacks, 1961, p. 29.
[2] Peter Nolan, *Fundamentals of College Physics*, 2nd edition, 1993, Wm. C. Brown Publishers, p. 859