Simplifying Einstein's Thought Experiments

Edward G. Lake

Independent Researcher

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detect@outlook.com

***Abstract**: Einstein's "Gedanken" experiments (thought experiments) - particularly his train-embankment thought experiments - were apparently intended to explain Special Relativity logically and in layman's terms, but they were written in an incredibly convoluted way, which seems to have resulted in them being misinterpreted by many physicists. This is the simplified logic of Einstein's key thought experiments.*

Key words: Light; train; embankment; speed of light; relativity.

I. What is a "Thought Experiment"?

A thought experiment (or in German: "Gedankenexperiment") is a scientific experiment which is conducted entirely in one's mind. It is different from a "fantasy" in that the experiment *must* obey all the rules of physics, and its *key* components and procedures have to be entirely logical. However, instead of using equipment that has not yet been constructed, you are imagining doing a scientific experiment using existing objects and events, such as moving trains, railroad embankments, boxcars, laboratories, dropped stones, the flashes of light from lightning bolts, and lighting flash simulators.

Einstein's train-embankment experiments, for example, involve a train (presumably a steam-powered train since Einstein devised the thought experiments around 1916 and earlier) that travels at about thirty or forty percent of the speed of light. That is certainly not possible, but the fact that a train is being imagined to travel at that speed is doesn't affect the experiment. The experiment is not really about trains (or embankments), it is about what a human observer would *see* as happening from *any type of vehicle* traveling at those speeds, *and* what another observer would see from a stationary location as the vehicle passes close by. You also have to imagine that it takes place in a vacuum, since the experiment isn't about air resistance or traveling through air. And, in thought experiments, you can always get a good, clear, careful look at something that is passing by you at blinding speeds. The point is that thought experiments allow you to envision what would happen according to the laws of physics if you actually *had* the right equipment and the right conditions.

II. "Reference Body" versus "Frame of Reference."

One key common misunderstanding is the difference between a "reference body" and a "frame of reference." It sometimes seems that Einstein used those terms interchangeably. In reality, understanding the difference is crucial to understanding Relativity.

In this paper, a "Reference Body" is essentially an observer at a location. What that observer observes and measures from his location can, of course, be different from what another observer observes and measures from another location. Specifically, what is seen and measured by a *moving* reference body can be different from what is seen and measured by a *stationary* reference body (or a slower moving reference body).

In this paper, a "Frame of Reference" is what the name implies: a "frame" is an enclosed space or "framework," so a "frame of reference" is an enclosed space inside of which events and measurements take place. It can also be considered to be windowless, since it is only about what is observed and measured *within* that framework.

Einstein also frequently used the term "coordinate system." This paper will try to avoid that term, but on Earth a "coordinate system" is basically the location of an observer or event as located by latitude, longitude and altitude so that measurements of distance from one "coordinate system" to another can be computed.

III. Definitions of "True" and "Correct."

"True" is a word that causes endless arguments over definitions because the opposite is "false." That involves defining two different words, and the word "false" tends to suggest a lie or something deliberately created to mislead. On the other hand, when we say something is "correct" we are saying that all the facts have been considered and they lead to the only "correct" answer.

How did Einstein define "true"? In his book "*Relativity: The Special and General Theory*," Einstein provides this explanation (I added the *italics* to highlight a key sentence):

> Geometry sets out from certain conceptions such as "plane," "point," and "straight line," with which we are able to associate more or less definite ideas, and from certain simple propositions (axioms) which, in virtue of these ideas, we are inclined to accept as "true." Then, on the basis of a logical process, the justification of which we feel ourselves compelled to admit, all remaining propositions are shown to follow from those axioms, i.e. they are proven. *A proposition is then correct ("true") when it has been derived in the recognised manner from the axioms.* The question of "truth" of the individual geometrical propositions is thus reduced to one of the "truth" of the axioms. Now it has long been

> known that the last question is not only unanswerable by the methods of geometry, but that it is in itself entirely without meaning. We cannot ask whether it is true that only one straight line goes through two points. We can only say that Euclidean geometry deals with things called "straight lines," to each of which is ascribed the property of being uniquely determined by two points situated on it. The concept "true" does not tally with the assertions of pure geometry, because by the word "true" we are eventually in the habit of designating always the correspondence with a "real" object; geometry, however, is not concerned with the relation of the ideas involved in it to objects of experience, but only with the logical connection of these ideas among themselves.
>
> It is not difficult to understand why, in spite of this, we feel constrained to call the propositions of geometry "true."[1]

The above is also an example of the complex and convoluted way that Einstein tended to explain things. Why did he use the word "correct" and then indicate that it also means "true"? Why not just use the word "correct"? (And, in the last sentence, why did his translator use the word "constrained" when "compelled" would make things much more clear?")

I would reduce everything that Einstein wrote above to one sentence:

Something is "correct" if it agrees with the laws of physics and has been demonstrated to be "correct" by experiments.

For over a thousand years nearly everyone on earth believed that the sun traveled around the Earth once per day. Then it was learned that that belief was *incorrect*. It was learned that the Earth actually rotated on an axis, and it only *seemed* that the sun was moving around the Earth. It is tempting to say that the previous version was "false" or just an "illusion," but both of those terms implies it was a "trick," something deliberately done to mislead people. The same with "real" and "unreal," the latter implies a deliberate act to mislead.

So, in this paper I will try to use "correct" and "incorrect" when describing scientific findings. And "correct" findings will describe our "real" world and our "real" universe (i.e., "reality"), while "incorrect" findings will describe a world and a universe that is "not real."

IV. The Train-Embankment and the Dropped Stone Experiments.

The first three experiments to be explained here are versions of the train-embankment thought experiment described by Albert Einstein in his book "*Relativity: The Special and General Theory.*"[2] It is the dropped stone experiment. It is perhaps the simplest experiment to understand and clearly shows the difference between "reference body" and "frame of reference," while at the same time showing very clearly how the "First Postulate" to Einstein's Special Theory of Relativity means a lot more than the way it is typically misinterpreted.

V. Dropped Stone Experiment #1.

In the first experiment we have an observer (or reference body) standing atop a railroad car that is part of a *stationary* train. The observer is designated as OT (Observer on the Train). We also have another observer (or reference body) who is standing atop a single *stationary* railroad car on a siding or embankment. This observer is designated as OE (Observer on the Embankment). In Figure 1 below, both observers drop identical stones from their positions atop identical railroad cars to the embankment identical distances below them. (While the image may unfortunately suggest they are some distance apart and one is higher than the other, they are actually within a few feet of each other and at the exact same height above the earth.)

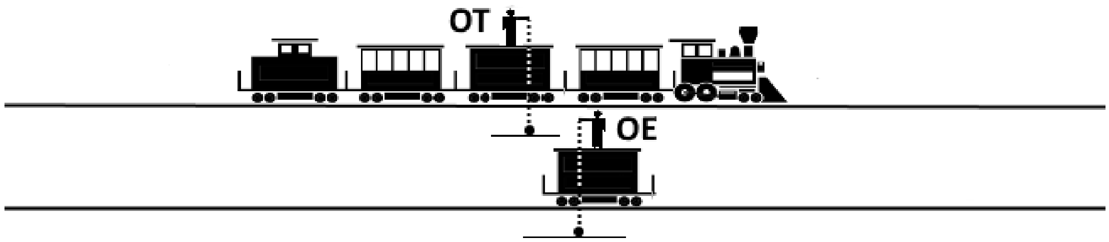

Figure 1

The stones can be dropped simultaneously or separately, since the important points of the experiment are to show that both stones fall straight down toward the center of the earth, they both hit the soft earth of the embankment, and they both remain where they landed.

VI. Dropped Stone Experiment #2.

In Experiment #2 the train is moving at hundreds of miles per hour as it approaches observer OE at his location on the siding. This is the situation in Figure 2 below. Because the experiment is taking place in a vacuum, there is no air rushing past the observer on the Train (OT) as he approaches OE. And because there is no air, there is no sound. And there are no joints between sections of rail to give the observer on the train any indication of movement. The train also moves at a constant inertial speed. So, there is absolutely nothing to show who is actually moving. OE would know he is stationary and OT and the train are moving, but OT could feel that he is stationary while OE and the embankment rush past him. So far in the experiment, there is nothing to tell who is moving past whom.

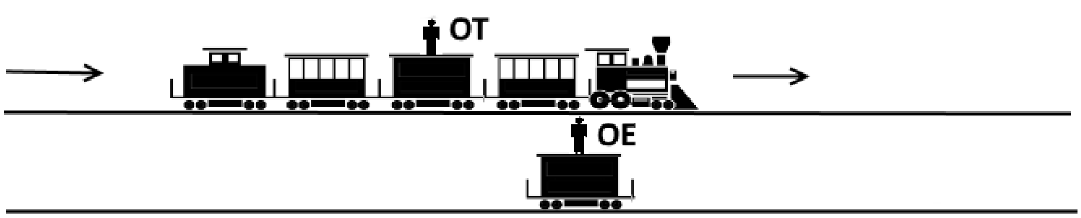

Figure 2

But, if they perform the same dropped stone experiment they did in Experiment #1, they can both quickly determine who is moving.

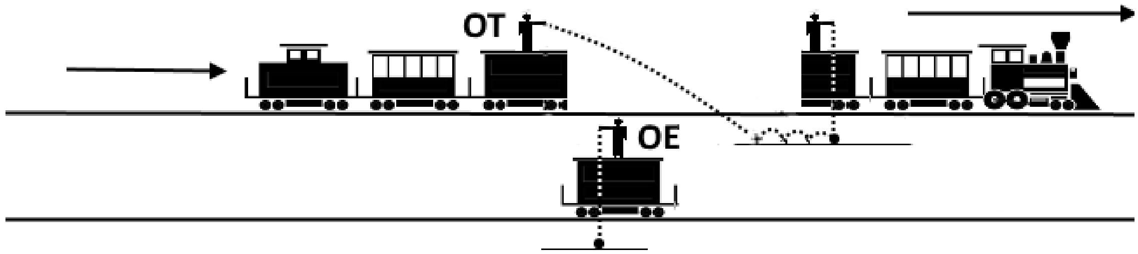

Figure 3

Figure 3 above shows what OE observes, what OT observes, and how their observations differ.

Because the train is moving, OT and his stone are also moving with the train. Therefore, when OT drops his stone at the same spot where he was located in Experiment #1 (as shown on the left in Figure 3), the stone will continue to move with the train due to inertia. Because the stone moves with the train, OT will again observe the stone as falling straight down to the earth (as shown on the right in Figure 3). There will, moreover, be a significant difference when the stone hits the earth embankment. In Experiment #1 the stone simply hit the earth and stopped. In Experiment #2, the stone bounces several times alongside the moving train before coming to a stop. That is the view from Reference Body OT.

Meanwhile, Reference Body OE observed the experiment as happening very differently. While the stone OE dropped fell straight down to the earth embankment just as in Experiment #1, the stone dropped by OT clearly did not. OE watched the stone fall in *a parabolic curve* as the stone moved with the train due to inertia. Although the stone fell in a curve instead of straight down, it seemed to take the same amount of time to hit the earth. The stone then hit the earth embankment and due to friction bounced a few times before coming to a full resting stop.

The only explanation for what both OE and OT observed would be that the train was moving and the embankment was stationary. There could be no reciprocal movement. If the train was stationary and the embankment was moving, the stone dropped by OT would have bounced in the opposite direction than shown in Figure 3 and OT would have observed OE's stone falling in a parabolic curve.

The laws of physics allowed the two observers (or reference bodies) to determine which view is "correct." What OE observed was "correct" because his view represented what is known about the laws of physics (particularly the laws of inertia and gravity), and because the dropped stone experiment confirmed those laws. OT's view of his stone dropping straight down was "incorrect" because his view violated the laws of physics (particularly the laws of inertia).

VII. Dropped Stone Experiment #3: A Framework of Reference Thought Experiment.

In Experiment #3, the train moves exactly as it did in Experiment #2, but both reference bodies are now inside the laboratories contained within their respective boxcars. The laboratories have no windows. The laboratories are their "frames of reference" (or "frameworks of reference") in Experiment #3.

The primary difference in this new experiment is that because the experiment is done inside a closed laboratory, neither observer can see what the other is doing. Neither can see anything outside of his own laboratory.

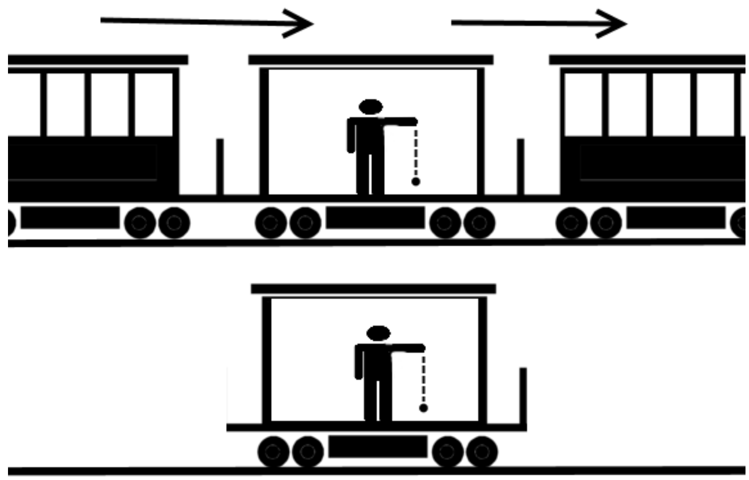

Figure 4

Figure 4 shows that OT on the moving train will drop a stone and watch it fall straight down just as before. The only difference is there is now a floor beneath him that is stationary relative to OT and the falling stone, and thus the stone hits the floor instead of a moving embankment and doesn't go bouncing off in one direction or another. OE performs the same experiment on the stationary embankment and gets the same result as in his previous dropped stone experiment. Since they cannot see each other, no one sees any effect from inertia. If we have new observers performing the experiment who have not done the previous experiments, they will both conclude that the stones fell straight down to the floor.

This experiment is often also imagined as being performed by a child on an airplane. The child tosses a ball into the air and watches it fall straight down again with no effect from the fact that the airplane is moving at 500 mph. Meanwhile, a scientist sitting next to the child can look out the window and see the earth moving past far below. The scientist knows that if an observer on the ground could somehow watch the child toss the ball, the ground-based observer would see the ball move in a curve when tossed upward, and the ball would fall back down again into the child's hands hundreds of yards away from where it was when it was tossed upwards. This explains what Einstein meant by his First Postulate:

> the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good.

In OT's laboratory OT will observe the law of gravity, the law of inertia and other laws of physics work the same way as OE will observe them in his laboratory, even though OT is *in reality* moving at very high speeds relative to OE. *There is no way to tell who is moving if neither observer looks outside their "framework of reference."*

But, what if there is a *third* Reference body located on the sun?

VIII. Thought Experiment #4: A Third Reference Body.

In the previous experiment we had only two observers, and using the laws of physics they determined that one was stationary and the other was moving. The experiment clearly showed there was no reciprocal movement. Those who argue that all motion is reciprocal will then argue that a *third* reference body will observe that *neither OT nor OE was ever stationary*. Or, if the third reference body is stationary relative to OT, he will conclude that OT is stationary and OE is moving.

In Thought Experiment #4 we simply visualize a Reference Body Observer as being on the sun. The Sun Reference Body Observer will observe himself as being stationary, and from the point of view of that observer on the sun (OS), both the train and the embankment are moving in an orbit around the sun. Therefore, there can be *nothing* truly stationary *anywhere* on the planet Earth. That part of the experiment is quite true. It confirms that all movement is relative, but it also confirms that the movement is not reciprocal. It is virtually impossible to perform a thought experiment where the sun is moving and the Earth and its sister planets are stationary, since the planets are not only moving *around* the sun, the planets are also rotating.

So, we previously viewed the observer on the embankment as being "confirmed" by three experiments to be stationary, but now OE is not only seen by OS to be moving around the earth as the earth spins on its axis, but OE is also moving in an orbit around the sun. And if we use the center of the Milky Way Galaxy as a Reference Body, the sun is also in an orbit around that center.

What Thought Experiment #4 shows us is that, while all motion is relative to another Reference Body, there is no location in our observable universe where the movement of OT and OE could be considered to be reciprocal. (See Note #1)

IX. How Light Travels.

Chapter VII of Einstein's book "*Relativity: The Special and General Theory*"[3] begins with these words:

> There is hardly a simpler law in physics than that according to which light is propagated in empty space. Every child at school knows, or believes he knows, that this propagation takes place in straight lines with a velocity c = 300,000 km./sec. At all events we know with great exactness that this velocity is the same for all colours, because if this

> were not the case, the minimum of emission would not be observed simultaneously for different colours during the eclipse of a fixed star by its dark neighbour. By means of similar considerations based on observations of double stars, the Dutch astronomer De Sitter was also able to show that the velocity of propagation of light cannot depend on the velocity of motion of the body emitting the light. The assumption that this velocity of propagation is dependent on the direction "in space" is in itself improbable.

The comment about De Sitter is particularly relevant, since De Sitter observed that the light emitted from double stars orbiting around each other, as shown on the right in Figure 5 below, must travel at *c* (300,000 kps) regardless of whether the star is moving away from the earth or toward the earth.

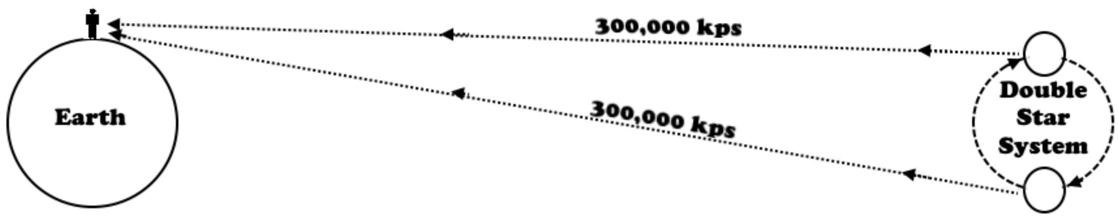

Figure 5

If light from a star moving *toward* the earth traveled at $c+v$, where v is the velocity of the star, and if the light traveled at $c-v$ when the star was moving *away* from the earth, the fast moving light would overtake the slow moving light and would result in inexplicable observations where the same star would be seen in multiple locations at the same time.

In De Sitter's observations we also have another demonstration that, while motion *is* relative, motion is *not* reciprocal. If the earth is viewed as being stationary, the double stars are moving in circles relative to the earth. But how can the double stars be viewed as being stationary? Even if you view one star at a time as being stationary, the other star will be moving around the "stationary" star while the earth appears to move toward the "stationary" star for a while and then away from the "stationary" star for a while. The laws of inertia (and common sense) say that the earth cannot move back and forth, when in motion an object must continue in motion in one direction until acted upon by an outside force. And the laws of gravity say that if you have two bodies of equal size orbiting one another, neither can be stationary. So, the double star system shows the absurdity of any claim that all movement is reciprocal.

But the important question here is: WHY doesn't the light travel faster when the emitter is moving toward the observer and slower when the emitter is moving away from the observer? Everything else works that way. A bullet fired from a stationary rifle will travel at v. A bullet fired from the same rifle aboard a moving train will travel at the velocity of the train plus the velocity of the bullet or $v+v'$.

But light doesn't work that way. Why? The only answer seems to be that there is a natural limit on how fast light can travel. Light can travel no faster than c, it cannot travel at $c+v$.

Of course, that natural speed limit would *not* apply to what is measured by an outside observer. An observer moving toward a source of light at *0.1c* would measure the light as arriving at *c+0.1c*. Neither the observer nor the light exceeded the natural maximum velocity.

X. Thought Experiment #5. Comparing light speeds.

Einstein realized that it is a law of nature that the maximum speed of light (and of everything) is 300,000 kilometers per second (simplified from 299,792,458 meters per second). Nothing moving in our universe can exceed that speed limit. In Einstein's paper "*The Principle Ideas of the Theory of Relativity*,"[4] Einstein has a thought experiment which he stated this way:

> Based upon many experiments, physicists became convinced that light propagates through empty space at a speed of c = 300,000 kilometers per second, entirely independent of the velocity of the body that emits this light. Imagine a ray of light sent by the sun in a distinct direction. According to the law just stated, this ray travels a distance of c per second. Now imagine the sun later hurls a body into space such that it flies with a velocity of 1,000 kilometers per second in the same direction as the ray of light. This is easy to imagine. We now can similarly imagine this projected body as an alternative body of reference and ask ourselves: what is the propagation velocity of light in the judgment of an observer who does not sit on the sun but rather on the projected body? The answer seems simple. When the hurled body runs after the light at 1,000 kilometers per second, the ray of light advances against it by only 299,000 kilometers per second. The same situation would prevail if the ray of light were not sent by the sun but rather by the projected body, because we know that the velocity of light does not depend upon the state of motion of the light source.

What Einstein is saying in his convoluted way is that light emitted from the stationary reference body known as "the sun" is measured by an observer reference body on the sun to be traveling at *c*, which is 300,000 kps, as shown in Figure 6 below. However, an observer on the ejected object (or moving reference body) that is traveling at 1,000 kps is seeing the light travel past him at 299,000 kps or *c-v*, where *v* is the velocity of the moving body. That is fully understandable (although it might be totally incomprehensible to countless physicists who believe the speed of light is the same for all observers (See Note #2)).

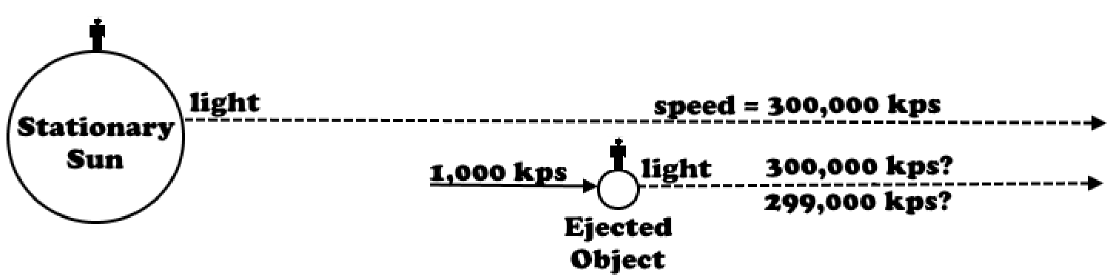

Figure 6

But, what happens when the observer on the object reference body emits light in the same direction? There is only one correct answer in the three possibilities:

1. If his light is also emitted at 300,000 kps relative to *his* location, then the light he emitted actually travels at 301,000 kps, which is faster than the natural speed limit *and* in violation of the observation that the speed of light does not depend upon the state of motion of the light source.

2. If the light is emitted at 299,000 kps, which is how he measures the light from the sun, that means that when combined with his speed his emitted light *would* travel at 300,000 kps, but that would also mean this his speed was added to the speed of light he emitted, and that has been shown to be invalid by De Sitter's observations.

3. If the light is emitted at 299,000 kps and does *not* combine with the speed of the source, then it travels at *a different velocity* than the light emitted by the sun. It does not travel at c as defined by the observer on the sun.

The correct answer is 3. But how can that be? Einstein provides the answer in his paper "*The Principle Ideas of the Theory of Relativity*":

> The same ray of light travels at 300,000 kilometers per second relative to the sun and also relative to the body projected at 1,000 kilometers per second. If this appears impossible, the reason is that *the hypothesis of the absolute character of time is false. One second of time as judged from the sun is not equal to one second of time as seen from the projected body.*

In other words, the light from the sun travels at 300,000 kilometers <u>per second</u> *as seconds are measured on the sun*, and light from the projected body travels at 300,000 kilometers <u>per second</u> *as seconds are measured on the projected body*.

This also means that the faster the emitting body travels, the slower light emitted from that body will travel. So, the speed of the emitter *actually does* affect the speed of the light emitted, but in a very different way than anything else is affected by a moving body. The light from the double star system will still arrive on earth at *c* speed whether the star was moving away from the earth or toward the earth, it just won't arrive at what is measured as *c* on earth.

XI. Measuring the Speed of Light.

The first attempts to measure the speed of light were accomplished by measuring the orbits of moons around Jupiter. Danish Astronomer Ole Römer noticed that the time between eclipses of a moon would vary throughout the year, depending upon whether the Earth was moving towards Jupiter or away from it.[5] The observed time interval between successive eclipses of a given moon was about seven minutes greater when the observations were carried out while the Earth in its orbit was moving away from Jupiter than while it was moving toward Jupiter. Römer reasoned that, when the Earth was moving away from Jupiter, the observed time between eclipses was increased above the true value (by about 3.5 minutes) due to the extra distance that the light from each successive eclipse had to travel to reach the earth. Conversely, when the Earth was moving toward Jupiter, the observed interval between eclipses was decreased (by about 3.5 minutes) because of the decreased distance that the light had to travel on each successive eclipse. In other words, when the Earth was moving *away* from Jupiter it took longer for the light to reach Earth, since the light would arrive at what we would now describe as c-v where v is the speed of the Earth away from Jupiter's moon. And, when the Earth was moving *towards* Jupiter, the light would arrive at $c+v$. Based upon the triangulated distance to Jupiter, Römer estimated the speed of light to be about 220,000 kilometers per second. He was off by 80,000 kps, or about 27%, but that was because the numbers used at that time for the diameter of the Earth's orbit and Jupiter's orbit were vastly underestimated.

Measuring the one way speed of light emitted from a celestial object is problematic because you cannot really know with precision exactly *when* a specific photon was emitted by the celestial object. Even if you know how far away the emitter is from the observer, you cannot calculate how long it took a *specific* photon to travel the distance. After Römer made his estimate, others began using more precise Earth-based methods to measure the speed of light.

Virtually all the methods used then and today to measure the speed of light involve measuring the *two-way* speed of light. Light is sent to a mirror, it bounces off the mirror and returns to the sender. The time between emission and receipt divided by 2 is the speed of light *per second* between the emitter and the mirror. But what is the length of a second?

Today a "second" is officially defined as "The duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom."**[6]** So, it is a *count of events*. If motion causes the "transition between two hyperfine levels of the ground state of the cesium 133 atom" to slow down, then a second becomes longer. A second is considered to have been measured when 9,192,631,770 periods of radiation have been counted – regardless of how long it takes to count that number.

In his 1905 paper introducing his Theory of Special Relativity, "*On the Electrodynamics of Moving Bodies*," Einstein made a key observation: The faster an object travels the slower time will pass for that object, therefore

> a balance-clock at the equator must go more slowly, by a very small amount, than a precisely similar clock situated at one of the poles under otherwise identical conditions**[7]**

That means that a laboratory located at the equator is moving at 1,656 kilometers per hour, or 46 meters per second around the Earth's axis. If you have a laboratory at the North Pole, it is rotating in place and not really moving laterally at all. If you have a laboratory somewhere in between, say Milwaukee, Wisconsin, that laboratory is moving at 1,200 kilometers per hour or 333.33 meters per second. And if you measure the speed of light at any one of those locations, you will still get a speed of 299,792,458 meters per second *because* the length of a second is the time it takes to count 9,192,631,770 periods of radiation, and the count takes longer when the clock or experimental equipment is moving faster.

That means that (considering only the effects of motion, not of gravity) light emitted inside a Frame of Reference laboratory at the North Pole will actually travel faster than light emitted inside a Frame of Reference laboratory in Milwaukee, and light emitted inside a Frame of Reference laboratory in Milwaukee will actually travel faster than light emitted inside a Frame of Reference laboratory located on the equator. But no observer inside any of these Frames of Reference will detect the difference even though their clocks all measure the length of a second to be slightly different.

This brings us to the issue of "The Relativity of Simultaneity."

XII. Defining the word "simultaneous."

In that same 1905 paper about Special Relativity Einstein wrote:

> We have to take into account that all our judgments in which time plays a part are always judgments of simultaneous events. If, for instance, I say, "That train arrives here at 7 o'clock," I mean something like this: "The pointing of the small hand of my watch to 7 and the arrival of the train are simultaneous events."

So, the word "simultaneous" means two or more events occurred at the same time. Unfortunately, simultaneous events as seen by one observer may not be simultaneous as seen by another observer. In that case we may need to determine if the events were "correctly" described as "simultaneous" by either observer, and if so, by *which* observer. The "correct" definition of "simultaneous" would then be that the events occurred at the same moment in time, regardless of how they were *observed* to occur. If two lightning bolts appear to strike simultaneously as you look out a window, but one struck a tree across the street and another struck a hilltop miles away, it is obviously "incorrect" to say those strikes were "simultaneous," since it would take longer for the light to reach you from the distant strike.

If someone else happened to be midway between where the two lightning bolts struck and they observed the light from the two strikes to arrive simultaneously, then it would be "correct" for them to say the lightning strikes were simultaneous even if you and no one else saw them as such.

But if you observe two flashes of light from *moving* emitters, or one flash from a moving emitter and the other from a stationary emitter, then whose observation is "correct" becomes more difficult to determine. We need 3 additional experiments to demonstrate that issue.

XIII. Experiment #6: Train-Embankment Lightning Bolts (Version #1).

This train-embankment thought experiment from *Relativity: The Special and General Theory*[8] involves simulated two lightning bolts from Emitter-A and Emitter-B and begins with the moving train and the observer on the train (OT) approaching the stationary observer on the embankment (OE). The lightning bolt emitters are located on the embankment between the two observers as shown in Figure 7 below.

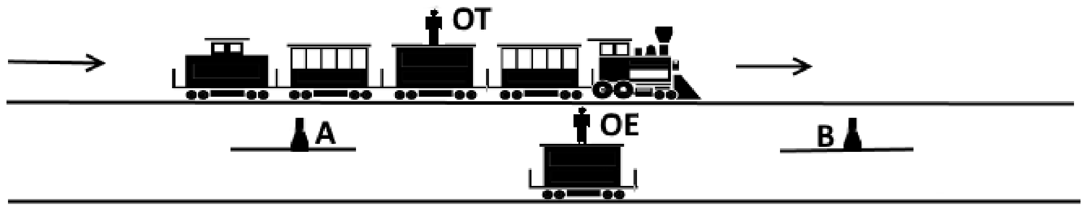

Figure 7

When the train reaches the point where it is exactly midway between the lightning bolt emitters and where the observer on the train is directly adjacent to and at his closest proximity to the observer on the embankment, a point where the two observers are in effect facing one another, the lightning bolt emitters are triggered. This is shown in Figure 8.

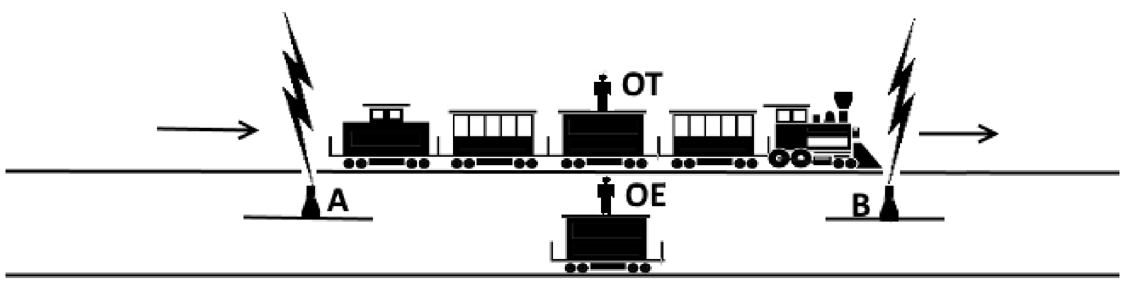

Figure 8

In Einstein's thought experiment, of course, he uses real lightning bolts. I am using simulated lightning to avoid arguments with people who cannot imagine two lightning bolts coincidentally hitting simultaneously in exactly the right spot for a scientific experiment. How the lightning bolts are triggered has absolutely nothing to do with the thought experiment. Neither does the fact that in reality the lightning strikes would have to be much farther apart for anyone to notice differences in the photon arrival times.

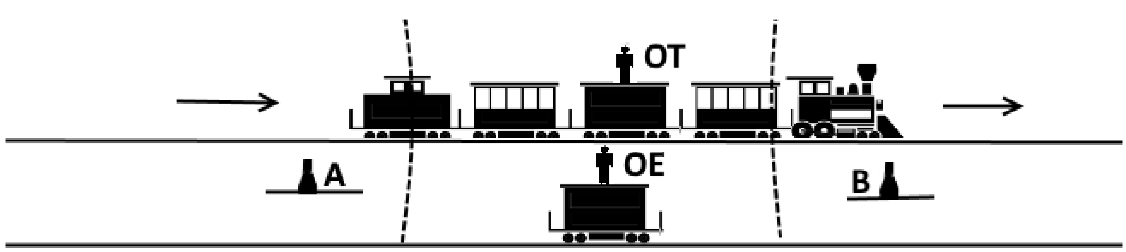

Figure 9

Figure 9 shows how light travels from the lightning bolt emitters while neither observer is yet aware of the emissions, because light from neither emitter has yet reached either one of the observers. The light photons are still en route. The light photons are traveling at *c* as measured on the embankment, not as measured on the train but that will have no effect on the experiment.

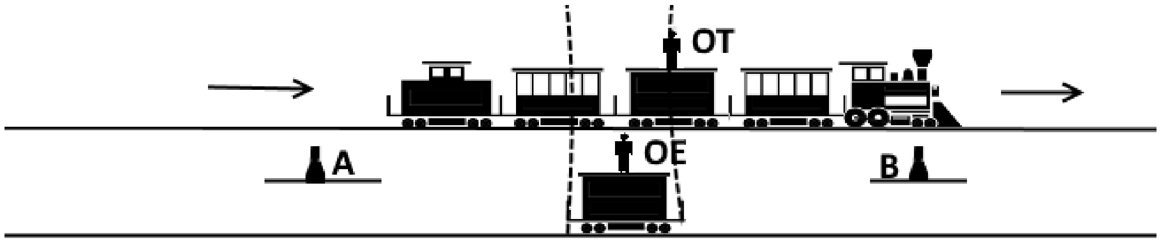

Figure 10

In Figure 10 above, the light from lightning Emitter-B reaches the observer on the train. OT encounters the light arriving at $c+v$ where c is the speed of light *as measured on the embankment*, and relative to the point where the lightning bolt was emitted, and v is OT's velocity relative to the embankment and also to the point where lightning bolt B was emitted.

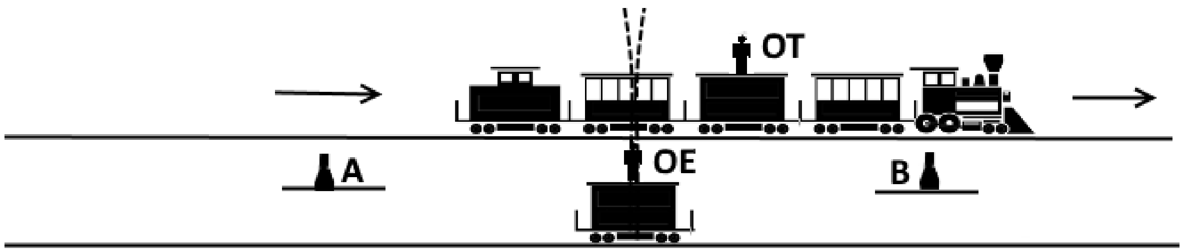

Figure 11

In Figure 11 above, the photons from both lightning emitters simultaneously reach the observer on the embankment. Since OE is stationary, he encounters the light from A and B arriving at c as c is measured on the embankment.

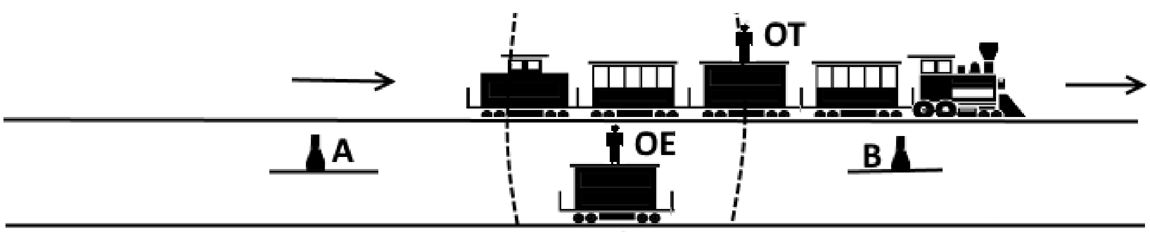

Figure 12

In Figure 12 above, the light from Emitter-A finally reaches the observer on the train. He encounters the photons traveling at c-v, where again c is the speed of light as measured on the embankment and v is OT's velocity *away* from Emitter-A.

OT has now seen both lightning flashes and observed them as arriving at different times, not simultaneously. The fact that the light was not traveling at c as c is measured aboard the train made no difference. Meanwhile, the observer on the embankment (OE) saw the two flashes as occurring simultaneously.

It's also important to understand that very shortly OT will be passing the point where flash B was emitted. OT will be able to see the simulator apparatus (or the smoldering point where an actual lightning bolt struck). Since OE is stationary, he will *never* be passing that point during the course of the thought experiment. If all motion was reciprocal, OE would somehow have to pass that point, too. But in reality, it cannot happen.

Since it was a planned and carefully devised experiment, not a happenstance event where two lightning bolts just happen to hit at the right time and in the right place, all observers would be fully aware of what occurred. OT will understand that, although he saw the lightning bolts hit at different times, that observation was "incorrect" and was the result of how the experiment was arranged. He would also know that it was a demonstration of the "Relativity of Simultaneity" and what OE saw was "correct." Relative to OE the lightning events were simultaneous, relative to OT the events were not simultaneous. The difference in light speed aboard the train versus on the embankment was irrelevant.

It should also be clear that if lightning bolt Emitter-B is moved further down the track, it can be arranged so that the observer on the train will see simultaneous flashes while the observer on the embankment does not. So, there is no point in performing that experiment.

XIV. Experiment #7: Train-Embankment Lightning bolts (Version #2).

In the next simulated lightning bolts experiment, everything is the same as in previous experiment except that the two lightning bolt emitters are no longer on the embankment, they have been placed aboard the train at the same distance apart they were when they were on the embankment. One is on a platform at the end of the caboose and the other is on a platform at the front of the engine.

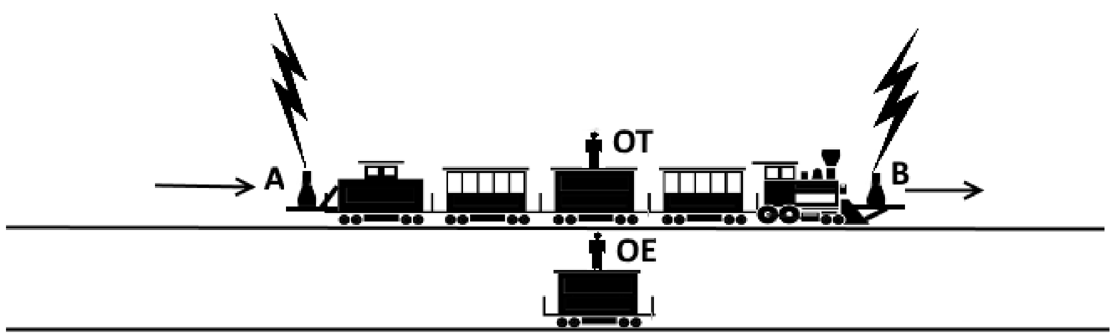

Figure 13

As shown in Figure 13 above, the lightning bolts are once again emitted simultaneously, this time by the emitters on the train, and they are once again triggered when OT and OE are facing each other and are exactly midway between the lightning emissions.

The emitters are moving at *v*, which means when they emit light at "a definite velocity *c* which is independent of the state of motion of the emitting body," the light is NOT emitted at *c* plus the velocity of the train. However, as we learned in Experiment #5, the light does not travel at *c* as measured by OE on the embankment. As we observed in Experiment #6, light emitted by a moving emitter on the train will travel at *c* as *c* is measured aboard the train by the reference body (OT).

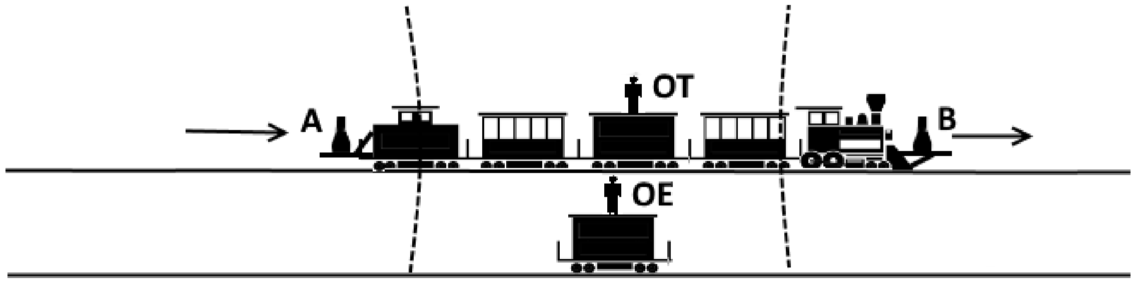

Figure 14

As in Experiment #6, the light photons from the lightning emitters travel at c toward the two observers as shown in Figure 14. The only difference is that in this experiment *c* is slower than it was in Experiment #7 because seconds are longer aboard the moving train.

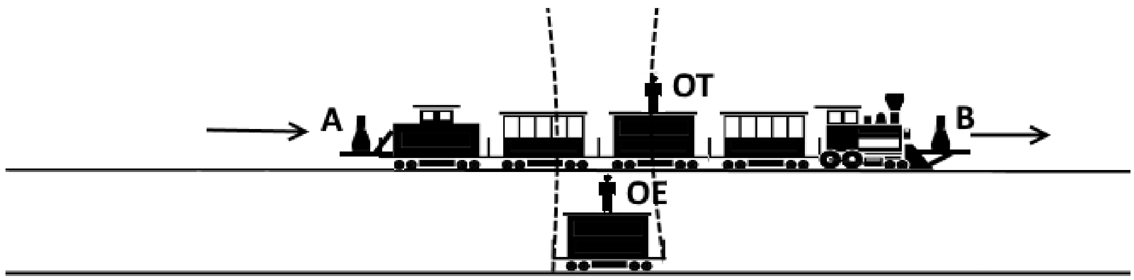

Figure 15

Figure 15 shows light reaching OT first, just as in Experiment 7.

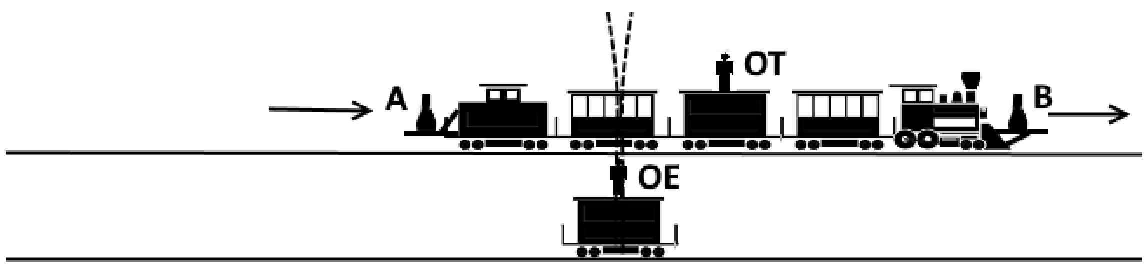

Figure 16

Figure 16 shows both flashes of light reaching OE simultaneously, as in Experiment #7.

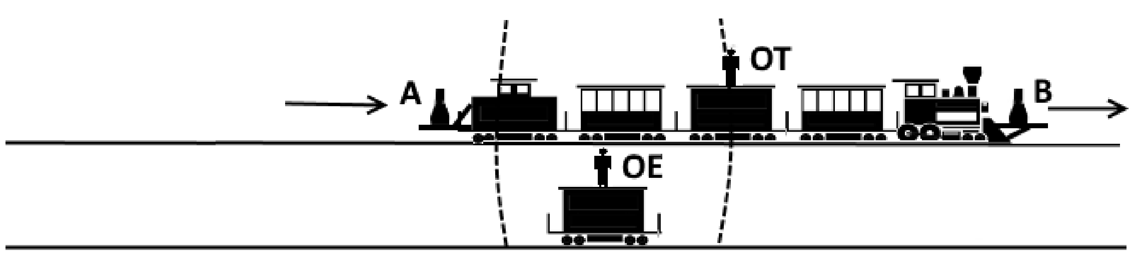

Figure 17

Figure 17 shows light from Emitter-A reaching OT, making him aware that there were two lightning flashes and they again were *not* synchronous to his Reference Body.

XV. Experiment #8: Train-Embankment Lightning bolts (Version #3).

In the next version of the train-embankment experiments, we leave emitter A aboard the caboose of the train and we place Emitter-B back on the embankment where it was before.

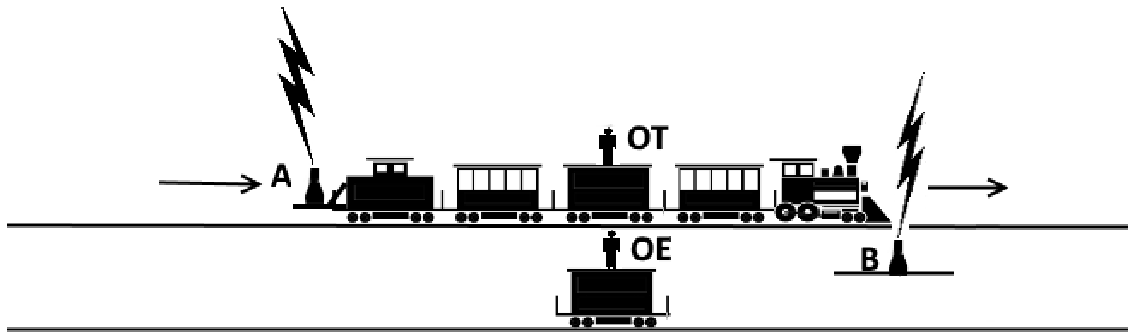

Figure 18

Figure 18 above shows the lightning bolt simulators emitting identical lightning flashes *simultaneously* at the exact moment the two observers are adjacent to each other and exactly midway between the two flashes.

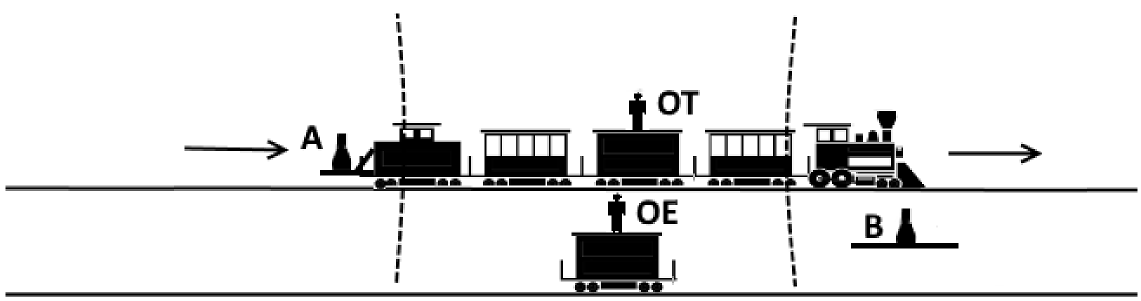

Figure 19

Figure 19 shows the photons from Emitter-A travel more slowly than photons from Emitter-B, which explains why the moving photons from Emitter-B are closer to the observer on the embankment than photons from Emitter-A. Note the photons from Emitter-A have just reached the cupola on the caboose. Meanwhile, the light from Emitter-B is moving at the same rate as in Experiment #6 and has reached the same point reached in Figure 9.

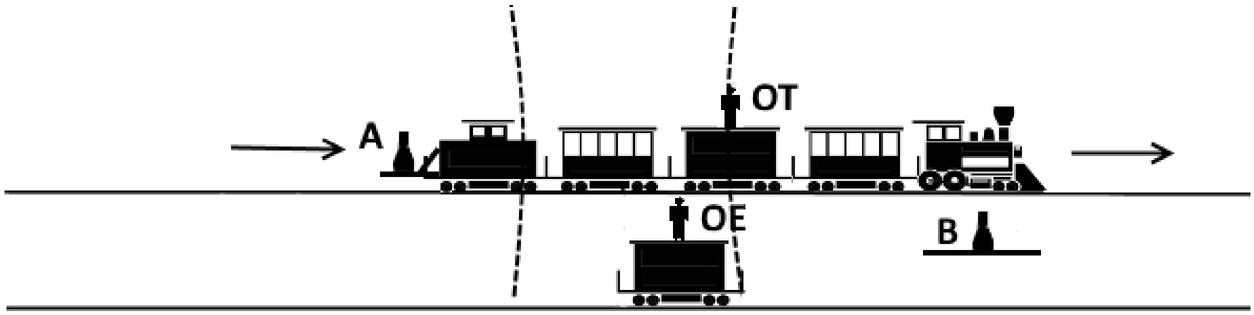

Figure 20

Figure 20 above shows that the photons from Emitter-B have reached the observer on the train, just as in Figure 10 in Experiment #6. However, the photons from Emitter-A have only just passed the cupola on the caboose and have not yet reached either observer.

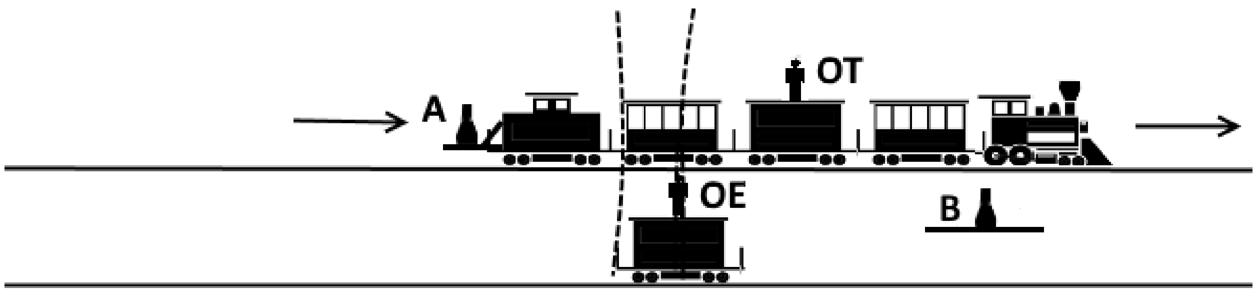

Figure 21

Figure 21 shows the faster photons from Emitter-B reaching the observer on the embankment just as in Figure 11 in Experiment #6, but the slower moving photons from Emitter-A have only reached the passenger car next to the caboose.

The rest of the experiment can be visualized without illustrations. The next event will be when light from Emitter-A reaches OE. Even though OE was equal distances from the simultaneous lightning flashes, because the photons from Emitter-A traveled slower than photons from Emitter-B, it took longer for the photons from Emitter-A to reach OE. So, in this experiment *neither* observer sees the simultaneous lightning flashes as occurring simultaneously even though they were both equal distances from the flashes when they occurred simultaneously. Einstein referred to this as “the relativity of simultaneity.”

XVI. Experiment #9: Repeating the Framework of Reference Thought Experiment.

In Experiment #9 we again have observers OT and OE perform identical experiments inside their inertial Frameworks of Reference laboratories. This time, however, the focus will be on measuring time and the speed of light, instead of inertia and gravity. The equipment they use to measure the speed of light is the standard equipment used in most laboratories, as seen in Figure 23 below.

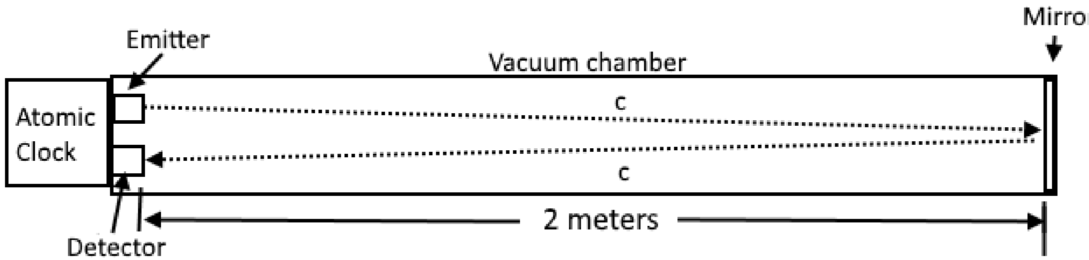

Figure 23

Inside a vacuum chamber, the emitter emits a photon toward a mirror 2 meters away. The mirror absorbs the photon and instantaneously emits a new photon back to the detector which is also 2 meters away. An atomic clock measures the time between the first emission and the receipt back at the detector and then computes the speed light must have traveled to cover those 4 meters and converts that to the speed of the light per second.

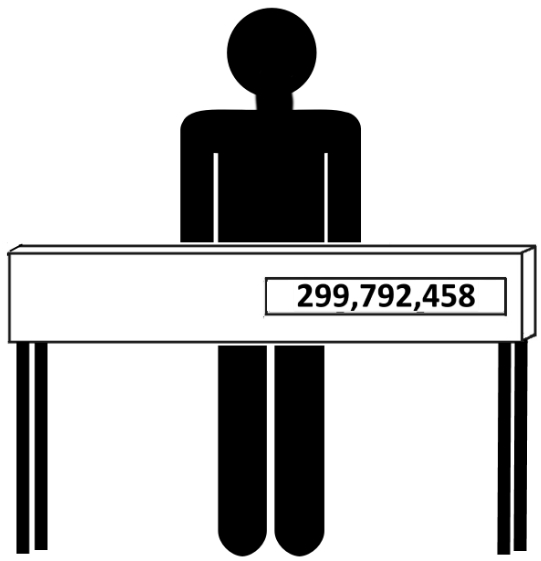

Figure 24

Figure 24 shows the setup to be used by both observer reference bodies. Since the entire experiment is performed within the closed framework of their individual laboratories, as shown in Figure 25 below, they are not able to see any of the speed of light effects they observed when they were outside and atop the boxcars containing their laboratories.

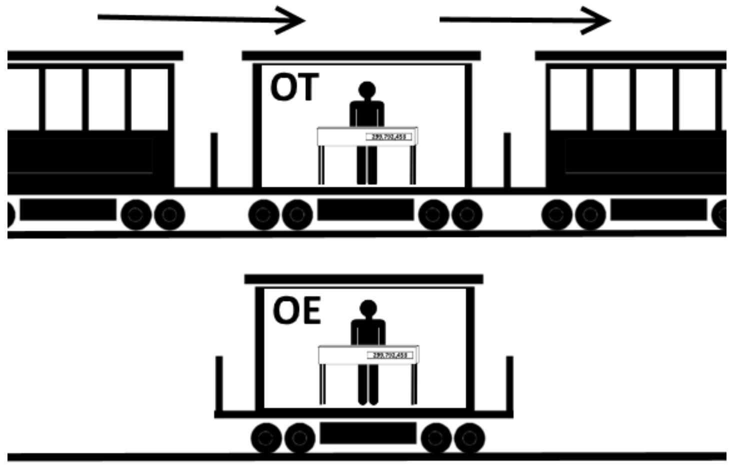

Figure 25

Within OE's stationary laboratory, light emitted from the emitter will travel at *c* to the mirror, the mirror encounters the light traveling at *c*, the mirror emits a new photon which travels at *c* to the detector which encounters the photon traveling at *c*. The computer measures the speed of light to be 299,792,458 meters per LOCAL SECOND.

Within OT's moving laboratory, light emitted from the moving emitter will travel at local *c* to the moving mirror, but since the mirror is moving away from the arriving photon, the mirror will encounter the photon arriving at c-v. The mirror then emits a new photon at local *c*, the new photon travels at local *c* to the oncoming detector which encounters it arriving at $c+v$. The atomic clock and computer compute the speed of light to be $c+v-v$=299,792,458 meters per LOCAL SECOND.

If they cannot look outside of their frames of reference, and if they are using the standard equipment for measuring the speed of light, they will both get the same result.

We know, however, that the length of a second is longer aboard the moving train, so while both measure the speed of light to be 299,792,458 meters per second, their seconds were not of equal length. So, their measured speed of light is actually different.

XVII. Experiment #10: Turning on a light in a Frame of Reference.

Einstein described an additional thought experiment in the book he wrote with Leopold Infeld[9] that nicely shows the difference between what Reference Body OE on the embankment atop the stationary railcar would observe versus what Reference Body OT inside a moving and closed Framework of Reference laboratory would observe.

In this thought experiment, the observer on the moving train enters his laboratory and does nothing more than pull the chain that turns on a light bulb that is hanging from the ceiling in the center of the laboratory. He sees the whole laboratory illuminated at the same time as shown in Figure 26 below. However, this is an *incorrect* view.

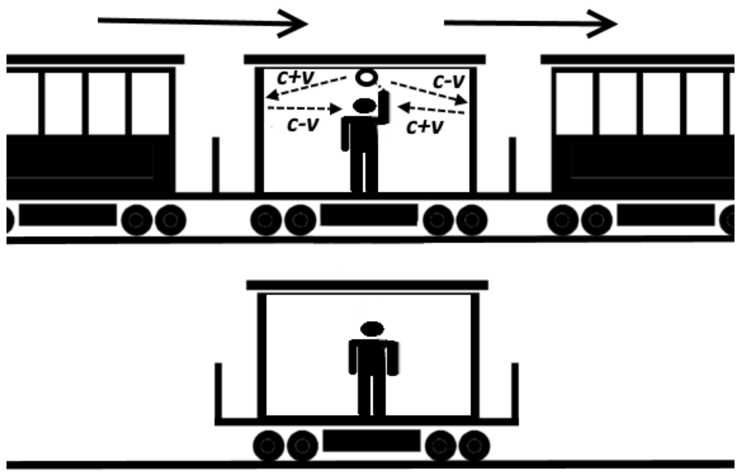

Figure 26

As we saw in previous experiments, because the train is moving, the photons from the lightbulb travel toward the rear wall at *c* while the rear wall moves toward the oncoming photons at *v*. The rear wall will therefore encounter those photons at *c+v*. The rear wall will then bounce back new photons at *c* to the observer who is moving away from the point in space where the photons were emitted at velocity *v*. So OT will encounter those photons arriving at *c-v*.

The reverse happens with the front wall. The photons from the lightbulb travel at *c* toward front wall which is moving away from the point where the light was emitted at velocity *v*. So the wall encounters the light at *c-v*. It bounces back new photons toward observer at *c*, but OT is moving toward the point where the light was emitted at *v*. He encounters those photons traveling at *c+v*.

The *c+v-v* effect is that OT observes both walls to be illuminated at the same time.

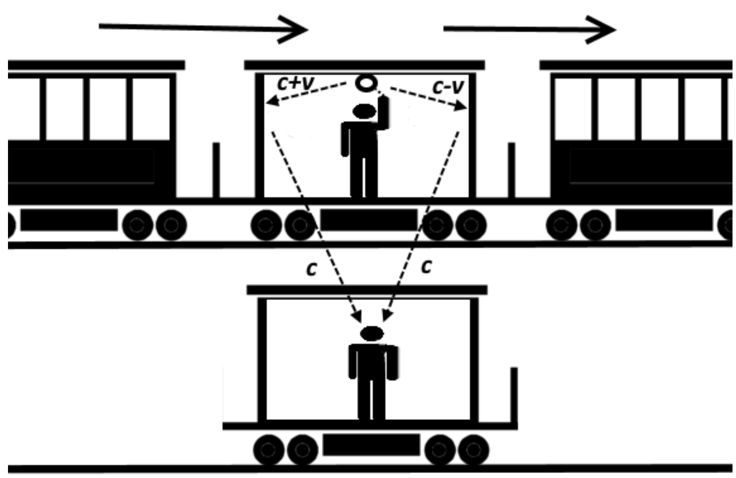

Figure 27

Meanwhile, in Figure 27 above we have removed the side of OT's laboratory so that OE can look inside. The photons that encountered the rear wall at *c+v*, illuminating it first, will bounce toward OE at *c*, and because he is stationary he will not experience the off-setting effect that OT experienced. He will see the rear wall illuminated first. Then OE will encounter the photons that hit the front wall at c-v, and he will see the front wall be illuminated.

Einstein and Infeld explained this thought experiment in great detail, and there can be no misinterpretation of what was demonstrated. Here is what they wrote:

> Once more, the example of the moving room with outside and inside observers will be used. Again a light signal is emitted from the centre of the room and again we ask the two men what they expect to observe, assuming only our two principles and forgetting what was previously said concerning the medium through which the light travels. We quote their answers:
>
> *The inside observer*: The light signal travelling from the centre of the room will reach the walls simultaneously, since all the walls are equally distant from the light source and the velocity of light is the same in all directions.
>
> *The outside observer*: In my system, the velocity of light is exactly the same as in that of the observer moving with the room. It does not matter to me whether or not the light source moves in my C.S. [Co-ordinated System] since its motion does not influence the velocity of light. What I see is a light signal travelling with a standard speed, the same in all directions. *One of the walls is trying to escape from and the opposite wall to approach the light signal. Therefore, the escaping wall will be met by the signal a little later than the approaching one. Although the difference will be very slight if the velocity of the room is small compared with that of light, the light signal will nevertheless <u>not</u> meet these two opposite walls, which are perpendicular to the direction of the motion, quite simultaneously.*
>
> Comparing the predictions of our two observers, we find a most astonishing result which flatly contradicts the apparently well-founded concepts of classical physics. *Two events, i.e., the two light beams reaching the two walls, are simultaneous for the observer on the inside, but are not simultaneous for the observer on the outside.*

XVIII. Experiment #11: Motion and the Doppler Effect.

In Experiment #10 we saw that when an observer inside a moving laboratory turns on a light in the center of his laboratory, he will see the front wall be illuminated at the same time as the rear wall, while an outside observer sees the rear wall illuminated first. The outside observer could determine that the laboratory on the train was moving, but the inside observer could not.

Is there any way for the observer inside the moving laboratory to determine if he is moving or not? Yes, there is. He can not only tell if he is moving or not, he can tell in what *direction* he is moving. All he needs to do is measure the "Doppler Effect" that results when light is returned from a moving object – such as the front and rear walls of the laboratory. In Figure 27 the stationary observer on the embankment saw the rear wall of the moving laboratory illuminated before the front wall was illuminated. If he had the right equipment to measure the *wavelengths* of the light returned from the walls, he would also have been able to determine that the wavelength of the light returned from the rear wall was *shorter* than the wavelength of the light that came directly from the lightbulb. And he would have been able to determine that the light returned from the front wall had a *longer* wavelength than the light that came directly from the lightbulb.

Because the speed of the moving lightbulb on the train cannot affect the speed of the light it emits, and because the lightbulb emits photons of light randomly in all directions, those light photon travel at c in all directions. However, when those photons hit atoms in a moving surface, the *new* photons that are emitted by that surface will be oscillating at a different frequency and wavelength than the original photons. The arriving photons arrive with the additional energy of their movement when they hit at c+v, and the photons have less energy when they hit at c-v. The atoms in the surface emit *new* photons that correspond to the different energies encountered.

This is the operating principle behind basic radar guns used by law enforcement agencies around the world.

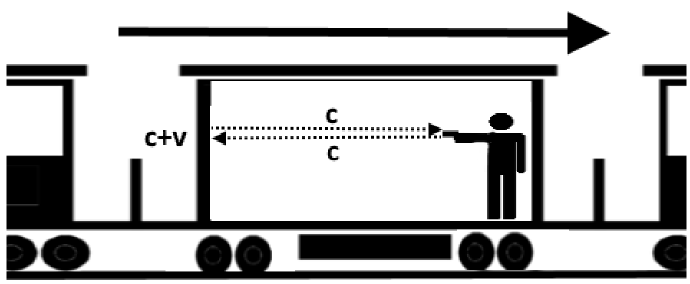

Figure 28

So, if an observer in a closed laboratory on the train moving at 60 miles per hour (mph) were stand near the front wall of the laboratory and fire a standard radar gun at the rear wall, as shown in Figure 28 above, the photons emitted by the gun would travel at *c* to the rear wall which is moving at *v*, the photons would be absorbed by atoms in the rear wall as arriving with the additional energy of *c+v*, and new photons would be emitted randomly at *c*, with some of the photons returning to the receiver on the radar gun. The processors within the radar gun would compare the wavelength (or oscillating frequency) of the returning photons to a sample of the photons the gun emitted, and the gun would show the rear wall to be moving at 60 mph.

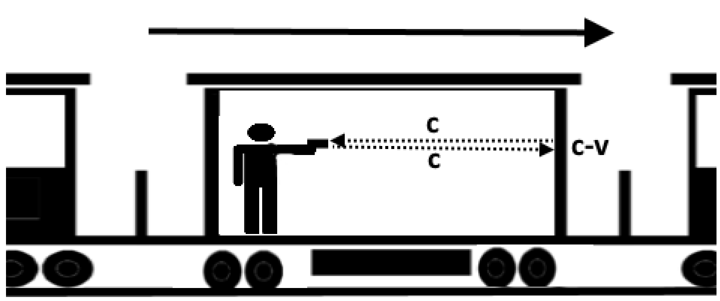

Figure 29

And, of course, if the observer were to repeat the experiment while standing at the rear wall and pointing the radar gun at the front wall, as shown in Figure 29, he would get identical results. (In theory, he should get a *negative* 60 mph, but radar guns are built to simply compare two frequencies and show the difference in miles per hour. The difference is 60 mph either way, and that is what the gun displays.)

This does *not* violate Einstein's First Postulate, which is:

the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good.

No laws of electrodynamics or optics were broken by the radar gun experiments. And the equations of mathematics hold good, as long as you do not falsely assume that motion is reciprocal.

XIX. Experiment #12: An <u>Incorrect</u> Thought Experiment.

I often encounter people who perform an *<u>incorrect</u>* "thought experiment" where two spaceships encounter one another in totally empty space and the claim is that no observer on either spaceship can tell who is moving. Observers on each spaceship can claim to be stationary while the other spaceship moves past.

First of all, they are creating a fictitious situation where space is totally empty. In reality, there is no place in our universe where an observer looking out windows on a spaceship would we be unable to see stars and galaxies which can be used as points of reference.

Secondly, they *can* determine by experiment which spaceship is moving relative to the other. Of course, the laws of inertia cannot be used as in the dropped stone experiments. Two stones released outside of two spaceships will just move along with the spaceships forever and prove nothing. In hypothetical "totally empty space" there is nothing to provide the gravity to change the trajectory of the moving stone. If you view the spaceships as being sources of gravitation, they will have the same gravitational pull on their respective dropped stones and again will not show who is moving and who is stationary.

Moreover, as seen in Experiment #4, they are probably *both* moving. In "totally empty space" they just have no third reference body to use to judge their relative velocities.

However, we now know that they can determine who is moving faster than the other by comparing the lengths of their timed seconds. This can be done by having each spaceship send to the other spaceship two electromagnetic signals of any kind that are exactly one second apart. If the two spaceships are *not* traveling at exactly the same speed, the faster moving spaceship will measure the received signals to be less than one local second apart because his local second is longer, and the slower moving spaceship will measure the received light flashes to be more than one local second apart because his local second is shorter.

In addition, as we saw in Experiment #11, they would undoubtedly have some form of radar, and if they have radar guns they can point them at each other. When they do so, unless by pure happenstance they are moving at the same speed relative to the stationary point where the Big Bang occurred, their radar guns will show the speed the other spaceship is traveling relative to their own space ship. And that relative velocity will *not be reciprocal*.

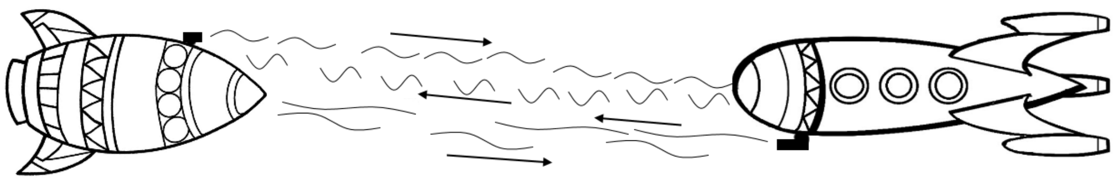

Figure 30

Each radar gun will emit photons at c toward the other spaceship, as depicted in Figure 30 above. Those longer wavelength photons will hit atoms in the hull of the other spaceship at $c+v$, where v is the speed of the oncoming spaceship. New photons oscillating at the shorter $c+v$ frequency will be returned to the radar guns. If one ship is traveling at 10,000 mph and the other is traveling at 15,000 mph, that is what the radar guns will show. They will *not* show a "closing speed" of 25,000 mph, nor will they show they are both moving at the same speed, which would make no sense whatsoever.

You do not have to go into outer space to perform this experiment. The same experiment can be performed by having two patrol cars approach each other, one moving at 30 mph while the other travels at 60 mph. The radar gun that is moving at 30 mph will measure the other car to be traveling at 60 mph, and the radar gun moving at 60 mph will measure the other car to be traveling a 30 mph. This isn't because each radar gun "assumes" it is "stationary," it is because *neither radar gun can emit photons faster than c*. Atoms in vehicle surfaces moving at velocity v will encounter those photons traveling at $c+v$ or $c-v$ and will absorb and emit new photons that represent the energy difference between c and the velocity (v) of the surface.

So, in Experiment #12 we have at least *two* ways to confirm via experiment which spaceship is moving faster than the other (or which spaceship is "stationary" and which is moving), and that is what makes the "incorrect" thought experiment "incorrect."

Furthermore, nowhere in our universe would the movement of the two spaceships or two police cars or observers OT and OE be reciprocal. And any thought experiment which results in their movements being reciprocal is an *incorrect* thought experiment. It would be an experiment that disobeys the laws of physics.

XX. **Conclusion**:

Any survey of college and university physics textbooks will find very few (if any) textbooks which fully agree with what is explained in this paper. Mostly they misinterpret Einstein's First Postulate, which is once again:

> the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good.

Many textbooks interpret that as meaning that any experiment performed in any inertial location will produce the same results as in any other inertial location. That is *not* correct. It just means if you use the same equations of mechanics in identical experiments in two frames of reference, the experimental results will be the same. If $a+b=c$ in one inertial frame, $\boldsymbol{a'}+\boldsymbol{b'}$ will equal c' in another inertial frame. But *a, b* and *c* are *variables*, and those variables can produce different results in one frame versus another. You will get *c* as the speed of light in both frames, but *c* and *c'* may not have the same value when one frame is compared to the other.

In Special and General Relativity *c* is a variable. It is 299,792,458 meters *per second* in all inertial frames of reference, but *the length of a second* can vary greatly from one frame to another due to difference in the velocity of the emitter and the gravity affecting the emitter.

Einstein's Second Postulate is:

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

A great many college physics textbooks will claim that the Second Postulate is just a restatement of the First Postulate, and they claim that it just means that the speed of light is the same everywhere. But we now see that is only true for measurements done inside *an inertial Framework of Reference*. It might have been more understandable if the Second Postulate had been written as:

> light is always propagated in empty space with a definite velocity *per second* even though the state of motion of the emitting body changes *the length of a second*.

That version might require a lot of study to understand, but it makes it clear that the speed of light can be different in different inertial Frames of Reference and between Reference Bodies moving at different speeds.

The reader may have noticed that this simplified explanation of some of Einstein's thought experiments makes no mention of "length contraction," which was how Einstein explained time dilation. Since there has never been any confirmation of "length contraction," I think it was simply the only *cause* for time dilation that Einstein could come up with by using what was known and believed in his time. In my paper *The Reality of Time Dilation*[10] I describe how "particle spin" seems to be the cause of time dilation. When a particle moves laterally, its spin slows because it cannot spin or move faster than the speed of light. In Einstein's day, sub-atomic particles (electrons, protons and neutrons) were evidently thought to be actual solid (but extremely small) particles, and atoms were like miniature solar systems with solid particles orbiting the compacted nucleus.

In this paper I also make no mention of the ether (or aether) that was (and sometimes still is) believed to fill the universe, providing a stationary reference body for all motion calculations. In Einstein's 1905 paper on Special Relativity, he concluded that the aether was "superfluous" and unnecessary. But it *was necessary* for mathematicians who *need* a stationary reference body to measure all motion against. Without it, motion becomes reciprocal to a mathematician. In my paper *The Reality of Time Dilation* I conclude that the stationary point where the Big Bang occurred can be used as the point against which all motion is measured. But, it seems that Einstein never believed in the Big Bang Theory. He may have felt the ether was "superfluous" because all motion can be considered relative to the speed of light.[11]

So, while the above simplification of some of Einstein's thought experiments is in full agreement with Einstein's thought experiments, Einstein and I do not agree on the ***cause*** of time dilation, and it seems mathematician *need* a stationary point of reference in our universe.

XXI. Notes.

#1 – In Section 142 of the book "*Duration and Simultaneity*" by Henri Bergson[12] it says:

> "let us not forget that all motion is reciprocal or relative: if we perceive them coming towards us, it is also true to say that we are going towards them."

Bergson's entire book appears to be a claim that *Einstein's theories state that all motion is reciprocal*.

A college textbook titled "*Understanding Physics*" by David Cassidy, Gerald Holton and James Rutherford contains this:

> Special relativity introduced an important break with the mechanical world view concerning the notion of absolute rest and absolute motion, which ceased to exist as a result of Einstein's work. Until that time, most physicists defined absolute rest and motion in terms of the so-called ether, the stuff that filled all of the space and transmitted light and electric and magnetic forces. As noted earlier, Einstein simply ignored the ether as "superfluous," since only relative motions were used in his theory.[13]

And that same book contains this:

> Einstein demonstrated in special relativity that measurements of space and time depend upon the relative motion of the observers.[14]

#2 – I have a paper titled "*An Analysis of Einstein's Second Postulate to his Theory of Special Relativity*"[15] which lists many textbooks which mistakenly interpret Einstein's Second Postulate as meaning that "the velocity of light in free space appears the same to all observers regardless both of the motion of the source of light and of the observer."[16]

XXII. References.

[1] Albert Einstein (Robert W. Lawson, translator), *Relativity: The Special and General Theory*, Methuen & Co. Ltd. (1920), pp 1-2

[2] ibid, pp 7-8

[3] ibid, pp 14

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