An Analysis of Einstein's Second Postulate to his Theory of Special Relativity

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Abstract

An analysis of books, presentations and scientific papers about Albert Einstein's Second Postulate to his Special Theory of Relativity shows that there is a fundamental disagreement between what Einstein wrote and how what he wrote is being interpreted by mathematician-physicists and taught in colleges and universities around the world. An analysis of the evidence shows that Einstein was correct and the vast majority of interpretations and teachings are incorrect.

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I. INTRODUCTION

In early 1912, seven years after his Special Theory of Relativity was published, Einstein famously lamented, "Since the mathematicians have invaded the theory of relativity I do not understand it myself anymore."[1] Nine years later, in a talk he gave to the Prussian Academy of Sciences, he stated, "As far as the laws of mathematics refer to reality, they are not certain, and as far as they are certain, they do not refer to reality."[2] In one of his letters, he referred to the interpretations by mathematicians as a ***disease*** when he wrote to his friend Paul Ehrenfest, "You are one of the few theoreticians who has not been robbed of his common sense by the mathematical contagion."[3] Einstein went to his grave arguing with mathematicians and advocates of Quantum Mechanics over how to interpret his theories of Relativity.

Today, over a hundred years later, it seems the mathematicians won. It is difficult to find any book or paper that correctly cites and correctly interprets Einstein's First and Second Postulates to his Special Theory of Relativity – particularly the Second Postulate. Colleges and Universities appear to teach only the mathematicians' interpretation.

II. "EINSTEIN'S EMITTER ONLY THEORY"

Einstein's 1905 paper *On the Electrodynamics of Moving Bodies* [4] begins with a description of certain "asymmetries" regarding how magnets and conductors appear to work when one is moving while the other is "at rest." Then, while still on page 1, Einstein introduced his First and Second postulates:

> "Examples of this sort, together with the unsuccessful attempts to discover any motion of the earth relatively to the "light medium," suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest. They suggest rather that, as has already been shown to the first order of small quantities, **the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good**. We will raise this conjecture (the purport of which will hereafter be called the "Principle of Relativity") to the status of a postulate, and also introduce another postulate, which is only apparently irreconcilable with the former, namely, 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**. These two postulates suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies based on Maxwell's theory for stationary bodies."

The first postulate is, therefore, "the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good." And the 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." Note that Einstein said nothing about what any other observer might see or measure.

In this paper, I will refer to Einstein's version of his Second Postulate as "Einstein's Emitter Only Theory," and I will compare it to the "Mathematicians' All Observers Theory" that is being taught in colleges and universities around the world. Then I will examine the experiments and the evidence, which fully support Einstein's theory and fully disprove the mathematicians' theory.

III. THE "MATHEMATICIANS' ALL OBSERVERS THEORY"

The earliest interpretation of the Second Postulate I could find is by American mathematical physicist Richard C. Tolman in a scientific paper he published in 1910:

> The second postulate of relativity is obtained by a combination of the first postulate with a principle which has long been familiar in the theory of light. This principle states that the velocity of light is unaffected by a motion of the emitting source, in other words, that the velocity with which light travels past any observer is not increased by a motion of the source of light towards the observer. The first postulate of relativity adds the idea that a motion of the source of light towards the observer is identical with a motion of the observer towards the source. **The second postulate of relativity is seen to be merely the combination of these two principles, since it states 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.**[5]

And here is an interpretation of the Second Postulate as printed in 2012 in the ninth edition of a widely used college text book:

> In 1905 Albert Einstein proposed a theory that explained the result of the Michelson–Morley experiment and completely altered our notions of space and time. He based his special theory of relativity on two postulates:
>
> 1. The principle of relativity: All the laws of physics are the same in all inertial frames.

2. The constancy of the speed of light: The speed of light in a vacuum has the same value, c = 2.997 924 58 x 108 m/s, in all inertial reference frames, **regardless of the velocity of the observer or the velocity of the source emitting the light**.[6]

A little research will find other college text books with minor variations on that same "all observer" wording. Examples:

"Second postulate: The speed of light is a constant and will be the same for **all observers independent of their motion relative to the light source**."[7]

"The unusual properties of the velocity of light are: **It is a constant for all observers, irrespective of how they are moving**. It is a universal speed limit, which no material object can exceed. **It is independent of the velocity of its source and that of the observer.**"[8]

"Einstein concluded by 1905 that Maxwell's theory must be reinterpreted: the speed of light will be exactly the same – a universal constant – for all observers, no matter whether they move (with constant velocity) relative to the source of the light. This highly original insight became Einstein's second postulate of relativity, the Principle of the Consistency of the Speed of Light:

"Light and all other forms of electromagnetic radiation are propagated in empty space with **a constant velocity c which is independent of the motion of the observer or the emitting body**.

"Einstein is saying that, whether moving at uniform speed toward or away from the source of light or alongside the emitted light beam, **any observer** always

measures the exact same value for the speed of light in a vacuum, which is about 3.0 x 108 m/s or 300,000 km/s (186,000 mi/s)."[9]

There are a great many scientific papers and many other books which describe the second postulate in a similar way.

I will call this interpretation the "Mathematicians' All Observers Theory."

IV. COMPARING THE THEORIES

Einstein's theory is simple and straightforward. There is a physical limit to how fast light can travel, and therefore light cannot exceed that limit in any frame of reference. Light is emitted at its maximum speed of 299,792,458 meters **per local second**, (mathematically referred to as *c*) regardless of whether the emitting source is moving or not. The emitting body's velocity (referred to as *v*) cannot be added to the speed of light being emitted, since $c + v$ would produce a speed greater than the maximum that light can travel. Einstein says nothing about what others may observe or measure for the speed of light, since their movements do not actually affect the speed of the light they observe. However, an observer approaching the source of light will measure the light to arrive at $c + v$, where *v* is his velocity, and if the observer is moving away from the source of the light, he will measure the light to arrive at $c - v$. That is totally in tune with common sense. How could an observer affect the speed of light he didn't create? That would make no sense.

When Einstein wrote that the Second Postulate "is only apparently irreconcilable with" the First Postulate, he seems to have been referring to the fact that while the observer standing next to the emitter measures light **he emits** as moving at a speed that is independent of his own

speed, that fact does **not** necessarily apply to light he may measure coming from another source outside of his frame of reference. Light coming from another source **can** arrive at c + or – v, where v is his own velocity. Some may interpret that to mean that different laws of electrodynamics and optics apply to the light from the other source. According to Einstein, such an interpretation would be incorrect. Light that is emitted by a moving emitter will travel at the speed of light as it exists **at the source of the light**, and light coming from another source (in the same "frame of reference" or in another "frame of reference") will travel at the speed of light as it exists **at its source**. The same "equations of mechanics hold good" for both emitters of light.

It appears that most mathematicians, however, could not accept that. Some books and papers explain why. One such book, "Fundamentals of Modern Physics" by Dr. Peter J. Nolan,[10] explains the problem this way (with my comments in **bold** and in brackets):

> Postulate 2 says that the velocity of light is always the same independent of the velocity of the source or of the observer. **[As we have seen, it says <u>nothing</u> about any observer.]** This can be taken as an experimental fact deduced from the Michelson-Morley experiment. **[The Michelson-Morley experiment[11] also says <u>nothing</u> about outside observers.]** However, Einstein, when asked years later if he had been aware of the results of the Michelson-Morley experiment, replied that he was not sure if he had been. Einstein came on the second postulate from a different viewpoint. According to his first postulate, the laws of physics must be the same for all inertial observers. If the velocity of light is different for different observers, then the observer could tell whether he was at rest or in motion at some constant velocity, simply by determining the velocity of light in his frame of reference. **[Einstein's Theory of Relativity says that each observer will measure the speed of light to be *c* in his local frame of reference.]** If the

observed velocity of light c' were equal to c then the observer would be in the frame of reference that is at rest. If the observed velocity of light were c' = c - v, then the observer was in a frame of reference that was receding from the rest frame. Finally, if the observed velocity c' = c - v, then the observer would be in a frame of reference that was approaching the rest frame. Obviously these various values of c' would be a violation of the first postulate, since we could now define an absolute rest frame (c' = c), which would be different than all the other inertial frames. **[Einstein specifically stated that "the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest," and since he was only concerned with the speed of the emitter, other frames of reference are of no concern.]**

Summing up: According to the "Mathematicians' All Observers Theory," the speed of light is the same for all observers. If you have ten different space ships all approaching a light source at different speeds, they will all measure the light from that source as arriving at the same speed the light **source** measures it, i.e., 299,792,458 meters second. According to "Einstein's Emitter Only Theory," only the source (the emitter) will measure the speed of light traveling at *c*, and the ten space ships will all measure light arriving at a different $c + v$, where v is each individual ship's velocity.

The two interpretations couldn't be more different.

V. PUBLISHED EXPERIMENTS TESTING THE SECOND POSTULATE

Physicist Richard Feynman once said that it does not make any difference how beautiful your theory is, it does not make any difference how smart you are, who developed the theory, or

what his name is, "**If it disagrees with experiment, it is wrong.** In that simple statement is the key to science."[12]

Before we can examine the experiments to measure the speed of light, we must first understand how mirrors work.

> "What actually happens on a microscopic level is that the incoming photon is absorbed by the electrons of the mirror, which are set into oscillation by the photon's oscillating electric field. The result is, for some materials (shiny ones), that the electrons' oscillation creates a **new photon** that moves away from the mirror in the opposite direction. The incoming and outgoing photons are free and move at speed c, but **they are not the same photon**…"[13]

In other words, when a mirror "reflects" light from some source, it doesn't just "bounce back" light as common terminology would suggest, the atoms in the mirror actually **absorb** the light photons and instantly **emit <u>new</u> photons**. The mirror becomes a **<u>new</u> emitter**.

In the standard equipment for measuring the speed of light, at one end of a vacuum chamber of a specific length – say 2 meters - we have an atomic clock, a light source and a detector. At the opposite end of the vacuum chamber is a mirror. The light source **emits** a pulse of photons toward the mirror. The mirror is a stationary "observer" awaiting the arrival of the photons. The atoms in the mirror absorb the photons and **emit** new photons back to the detector, which has become a stationary "observer" awaiting the arrival of the new photons. The atomic clock measures the time it took for the photon pulse to travel 2 meters from the source to the mirror and the time it took for another photon pulse to travel the 2 meters from the mirror back to the detector next to the light source. The time it took for the light to travel the 4 meter distance is measured to be the speed of the light. As long as the equipment is stationary and small enough

to fit within a laboratory, the speed of light should be measured to be 299,792,458 meters second.

So, what do experiments show?

As we saw in the quote from Dr. Nolan's book, mathematicians sometimes cite the Michelson-Morley experiment[11] as confirming the "Mathematicians' All Observers Theory." That experiment measured the speed of light moving in two different directions inside their laboratory, the second direction being 90 degrees different from the first. The experiment showed the speed of light in both directions to be the same, which agrees with "Einstein's Emitter Only Theory" but has no meaning to the "Mathematicians' All Observers Theory." As with the standard method for measuring the speed of light, there were no moving emitters or moving observers involved.

Searching further for experiments which mathematicians cite as confirming the "Mathematicians' All Observers Theory," I found that mathematicians frequently cite the pion experiment by Alväger et al. in 1964[14] as confirming their theory. Alväger et al. measured the speed of gamma rays emitted by a beam of pions moving at almost the speed of light with respect to their laboratory. They found that the speed of the light emitted by the moving sources was the same as light emitted by sources "at rest" in the laboratory. In other words, there was no moving observer involved. They confirmed "Einstein's Emitter Only Theory" but proved nothing about the "Mathematicians' All Observers Theory."

Mathematicians also cite an experiment performed in 2011 by E. B. Aleksandrov et al.[15] They did basically the same thing as Alväger; they measured "the velocity of the light pulse emitted by an ultrarelativistic electron bunch." They determined that the speed of light was not

affected by the speed of the "ultrarelativistic electron bunch," further confirming "Einstein's Emitter Only Theory." Again, there was no moving observer involved.

Searching for published papers which **disprove** the "Mathematician's All Observers Theory," I found several.

In 1911, French scientist Georges Sagnac performed an experiment involving a moving emitter and moving mirrors. The results have become known as the "Sagnac Effect."[16] The experiment involved splitting a light beam and sending photons clockwise and counterclockwise away from the emitter and toward a series of mirrors and then to the detector (the "moving observer") as the entire measuring apparatus rotated on a large disk. It can be envisioned as being similar to a person on a rotating carrousel tossing balls (in a vacuum, of course) to a person ahead and to a person behind as the carrousel rotates. It is different in that, while a tossed ball **will** travel at the speed of the carrousel plus the throwing speed, light cannot exceed the "throwing speed" (or emitted speed) and thus will **not** combine with the speed of the carrousel. However, the catcher's (observer's or detector's) speed **will** combine.

Continuing the carrousel analogy: when the ball is tossed in the same direction that the carrousel is moving, a **stationary** outside observer would see the ball travel at the tossed speed **plus** the carrousel's speed or $b + v$. The pitcher and catcher, however, would both see the ball travel at b, since they are both moving at the same speed as the carrousel. Light, however, would work differently. Because light is emitted at c in all directions, the **stationary** outside observer **and** the emitter would see the light travel at c. The catcher (i.e., detector), however, will measure the light to arrive a $c - v$ because the detector is moving **away** from the light as the light catches up with it.

When the ball is tossed in the opposite direction than the carrousel is moving, a stationary outside observer would see the ball travel at the tossed speed **minus** the carrousel's speed or $b - v$. The pitcher and catcher would again both see the ball travel at b, since they are both moving at the same speed as the carrousel. Light, working differently because light travels at the emitted speed in all directions, would be seen to be traveling at c by both the emitter and the stationary outside observer. The catcher (i.e., detector), however, will measure the light to arrive a $c + v$ because the detector is moving **toward** the light as it approaches.

The results of the Sagnac experiment showed that the light that moved with the rotation was measured to be traveling at $c - v$, where v was the speed of the rotating disc and the "moving observer" detector, and $c + v$ in the reverse direction, where light traveled against the rotation. The experiment fully confirmed "Einstein's Emitter Only Theory" and disproved the "Mathematician's All Observers Theory."

In 1925, a different yet significantly similar experiment known as "The Michelson-Gale Experiment"[17] was performed by A. A. Michelson and Henry G. Gale on a tract of land near the current location of Midway Airport in Chicago, Illinois. It was different in that the equipment included a vacuum chamber that consisted of "a twelve-inch pipe laid on the surface of the ground in the form of a rectangle 2010 x 1113 feet." It was also different in that the equipment didn't rotate in a circle but only moved sideways as the Earth turned on its axis. It was similar to the Sagnac experiment in that the light beam was split and sent around the rectangle in both directions, being reemitted by mirrors along the way. The results showed that light traveled at $c + v$ when moving east to west against the rotation of the Earth, the light traveled at $c - v$ when moving west to east with the rotation of the Earth, and light traveled at c when moving north to

south where the rotation had no effect. So, again "Einstein's Emitter Only Theory" is confirmed, and the "Mathematicians' All Observers Theory" is disproven.

VI. AN UNPUBLISHED EXPERIMENT TESTING THE SECOND POSTULATE

A search to find **unpublished** scientific papers which **disprove** the "Mathematicians' all observers" version of the Second Postulate found one very interesting paper.

An experiment performed by NASA in 2009 confirmed that the velocity of the observer **will be** added to the oncoming speed of light when the observer is traveling toward the source of the light. I.e., they fully confirmed "Einstein's Emitter Only Theory" and disproved the "Mathematicians' All Observer Theory." But, amazingly, ***they did not accept what they had confirmed***.

The paper is titled "*Lunar Laser Ranging Test of the Invariance of c*."[18] It was written by a NASA scientist, Daniel Y. Gezari, who made the paper public via Cornell University and their arXiv.org library web site. The abstract reads as follows:

> The speed of laser light pulses launched from Earth and returned by a retro-reflector on the Moon was calculated from precision round-trip time-of-flight measurements and modeled distances. **The measured speed of light (c) in the moving observer's rest frame was found to exceed the canonical value c = 299,792,458 m/s by 200±10 m/s, just the speed of the observatory along the line-of-sight due to the rotation of the Earth during the measurements.** This result is a first-order violation of local Lorentz invariance; the speed of light seems to depend on the motion of the observer after all, as in classical wave theory, which implies that a preferred reference

frame exists for the propagation of light. However, the present experiment cannot identify the physical system to which such a preferred frame might be tied.

In other words, NASA scientists emitted a pulse of regularly spaced photons from a point on earth, bounced those photons off a reflector on the moon, and then recorded the spacing between the photons' arrival times at that same point on earth. The results showed that light either traveled faster than the speed of light **or** the movement of the earth during the round trip had to be added to the speed of light in direct violation of the "Mathematicians' All Observer" interpretations of Einstein's Second Postulate.

The experiment was basically very simple (although in practice it is incredibly complex) and very similar to the Michelson-Gale Experiment, merely involving much greater distances. A reflector left on the moon by the Apollo 15 mission was designed to bounce any light emitted directly toward it directly back toward the light source. The light source used by NASA in this instance was a laser at their Apache Point Observatory in New Mexico.

The expected travel time for the light would therefore be calculated using the distance from the transmitter to the reflector and back again to the detector located next to the emitter. This is very similar to the way light is typically measured in laboratories on Earth, with two major differences: (1) The distance between the emission point and the mirror is much greater, and (2) the Earth is spinning on its axis, and the emitter and detector were therefore moving toward the reflector (as in Michelson-Gale). (The moon is also moving, but its movement is negligible compared to the rotation speed of the Earth.)

The motion of the Earth did not affect the actual speed of light, in accordance with "Einstein's Emitter Only Theory," but it did affect the distance the light had to travel to complete

the experiment. As a result, the observer at the Apache Point Observatory who believed that the speed of light is the same for all observers calculated the incoming light was traveling at the speed of light plus the speed of the observatory, "a first-order violation of local Lorentz invariance," i.e., an "impossibility."

The paper by Gezari is an attempt to figure out how this apparent "impossibility" can happen. The author suggests "a preferred reference frame exists for the propagation of light." But he couldn't figure out how it works, so he wrote, "However, the present experiment cannot identify the physical system to which such a preferred frame might be tied."

If you do not misinterpret the Second Postulate, of course, you do not need a "preferred reference frame," and everything worked just as Einstein predicted it would work in "Einstein's Emitter Only Theory."

What happened in the Lunar Laser Ranging experiments is that Apache Point emitted evenly spaced multiple pulses toward the reflector on the moon. Apache Point was a moving emitter (moving at roughly 500 mph) as the Earth spun on its axis. In accordance with "Einstein's Emitter Only Theory," the photon pulses traveled at c on their way to the moon. The reflector on the moon then emitted new photons back toward the Earth, again at c. At that point, the observatory on Earth became a **moving observer**, approaching the oncoming light pulses at roughly 500 mph, and reducing the time between pulses. The receiver at Apache Point measured the photon pulses arriving at $c + v$, where v is the 500 mph speed of the observatory. The scientists at NASA saw their equipment measuring light traveling at $c + v$, and at least one NASA scientist didn't believe what his experiment showed. So, he wrote a paper about it.

VII. OTHER "EXPERIMENTS" AND EVIDENCE

During the past couple decades, police departments around the world have been gradually implementing the use of laser speed guns to catch violators of local speed laws – replacing the older radar guns. The technique is referred to as "lidar" (LIght Detection And Ranging) and directly relates to the "Sagnac Effect," to "Michelson-Gale," and to the Lunar Laser Ranging Experiments, in that a "moving observer" is involved, fully demonstrating and confirming which interpretation of the Second Postulate is correct.

The only real difference between lidar as it is used by police officers and the scientific experiments is that the police officers are generally stationary while they measure the oncoming speed of law violators. When the lidar gun emits pulses of photons toward an oncoming vehicle, the speeder is a "moving observer" who encounters the photons traveling at $c + v$, where v is the speeder's velocity. Just as happens with mirrors, the atoms in the speeder's vehicle absorb the laser light and the speeder then becomes an emitter as he emits new photons at c back to the lidar gun being operated by the stationary police officer.

The lidar gun calculates the difference between the times the lidar pulses were initially emitted and the time between the receipts of the return pulses. It counts the number of nanoseconds it took for the round trip of the pulses at the speed of light. Since the distance light travels in a single nanosecond (a billionth of a second) is a known distance, the difference in the time it takes for two pulses to reach the speeder and the time it takes those two pulses to return provides the distance the speeder traveled between the two pulses. By taking several hundred samples over the course of a third of a second or so, the lidar gun can calculate the speed of the oncoming car with very high accuracy.

Let's assume it calculates the speeder's speed to be 90 mph. We can then perform another experiment where the police car and lidar gun are moving toward the speeder at 60 mph.

The police car is now a moving emitter, but the light emitted still travels at *c* in accordance with "Einstein's Emitter Only Theory." The oncoming observer again encounters the light moving at $c + v$, where v is 90 mph just as in the first "experiment." The speeder's car then becomes a moving emitter and sends back the pulses at *c*. The oncoming police car is now a moving observer and measures the oncoming light as arriving at $c + v$, where v is the police car's 60 mph velocity. Since the lidar gun cannot determine who is moving, it calculates the speeder's velocity to be 150 mph.

If the "Mathematicians' All Observers Theory" were valid, the lidar gun would measure the speed to be zero, since all measurements of the speed of light would be the same.

Before there were any lidar guns, traffic control police cars had been using "radar guns" to catch violators of speed laws since 1949.[19] The word "radar" was originally a U.S. Navy abbreviation for "RAdio Detection And Ranging."

Again, the principles and steps are very straight forward. However, instead of emitting evenly spaced pulses of light, radar emits radio waves at *c* and at a specific frequency (i.e, a specific spacing between wave peaks). Because the oncoming vehicle is moving toward the police car, the radio waves are received by the moving observer at $c + v$, a faster rate (higher frequency) than at which they were transmitted. The waves are emitted back at *c*, but ***at the higher frequency***. The radar gun's receiver measures the frequency of the new incoming waves versus the frequency of the radio waves it emitted and calculates the speed of the oncoming vehicle.

Just as lidar guns mimic what was done in the scientific experiments, there was an astronomical experiment that mimicked how radar guns work. In 1887, Vogel and Scheiner discovered the "annual Doppler effect," the yearly change in the Doppler shift of stars located near the ecliptic due to the orbital velocity of the Earth.[20] When the Earth is moving toward a star near the ecliptic, light from that star arrives at $c + v$ and is shifted toward the blue end of the spectrum because more wave peaks reach the observer in a unit of time. When the Earth is moving away from the star the light from the star arrives at $c - v$ and is "red-shifted" because fewer wave peaks reach the observer in a unit of time.

VIII. CONCLUSION

A little research will find dozens of college professors repeating the "Mathematicians' All Observers Theory" in on-line "study guides" and "lecture notes." And, it is very often accepted as an unquestionable fact, even though it means that if you have ten observers traveling at different velocities toward a light emitting body, they will all inexplicably measure the light as arriving at 299,792,458 meters per second. Those who interpret the Second Postulate as working that way will argue that such a finding may seem "illogical," but that is the nature of Relativity, it is "non-intuitive." Mostly they seem to argue that it is what Einstein wrote (which it isn't), and therefore it must be accepted – even if you think it is wrong.

It **is** wrong, it **isn't** what Einstein wrote, it has been **disproved** by countless experiments, so it **shouldn't** have to be accepted, and it definitely **isn't** what should be taught in schools.

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