Radar Guns and Einstein’s Second Postulate

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January 10, 2022
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Abstract: Inexpensive radar guns can be used to demonstrate and clarify the Second Postulate to Albert Einstein’s Theory of Special Relativity. Along with other well-known experiments, radar guns clearly demonstrate that most college physics textbooks have an incorrect version of Einstein’s Second Postulate to his Theory of Special Relativity.

Key words: speed of light; photons; radar guns; Special Relativity; Second Postulate.

I. A Special Relativity Experiment.

The “thought experiment” shown in Figure 1 below resulted from a series of discussions I had with experts on radar guns.

Figure 1
Figure 1 depicts “The Einstein Radar Gun Experiment,” which is designed to demonstrate and clarify Einstein’s Second Postulate in his Theory of Special Relativity: “light is always propagated in empty space with a definite velocity $c$ which is independent of the state of motion of the emitting body.”[1]

While this is just a “thought experiment,” it can easily be performed in real life. In real life, of course, you don’t have Einstein as a target, you have a parked car or a highway sign, and you do not usually have two cars and two guns, you just have one gun and do each part of the experiment independently. I’ve done them dozens of times.

The thought experiment involves two police cars with radar guns. To avoid mixing radar signals, Car #1 uses a radar gun that emits photons at 35 Gigahertz (GHz) and Car #2 uses a radar gun that emits photons at 24.125 GHz.

Car #1 is moving down the road at 60 miles per hour and Car #2 is parked at the side of the road. Standing at the side of the road ahead of them is Albert Einstein wearing a shiny badge and buckle. When Car #1 is side-by-side with Car #2, officers in both cars fire their radar guns at Einstein. Even though one car is moving and the other car is stationary, the photons from both guns travel at $c$ and they hit Einstein at $c$.

Einstein’s shiny badge and buckle send new photons back to the radar guns. The new photons also travel at $c$ back to the two cars and the radar guns.

What speeds will the radar guns display?

We know what the results will be. Anyone who owns a radar gun has probably used it in these two situations many times. The radar gun in Car #2 will show no speed. The radar gun in Car #1 will show a speed of 60 mph.

The question then is: What does the 60 mph speed represent? Clearly it is NOT Einstein’s speed. So, it can only be the speed of Car #1 and the radar gun in it. The returning photons hit the gun in Car #2 at $c$, and they hit the gun in Car #1 at $c+v$, where $v$ is the speed of Car #1. That causes the gun in Car #1 to show a speed of 60 mph when the photons it emitted are compared to the returned photons. If it is a “moving mode” radar gun, it will typically show 60 mph as the “Patrol Speed.” If it is a “stationary only” radar gun, it will just show 60 mph.

What this confirms is that the versions of Einstein’s Second Postulate that are used on many (but not all) college physics textbooks are wrong. Here are ten 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.”[2]

The second postulate of relativity is that the speed of light is a universal constant, the same for all observers. [3]
Second postulate (constancy of the speed of light): Light propagates through empty space with a definite speed $c$ independent of the speed of the source or observer.\[4\]

Postulate 2: The speed of light in free space has the same value for all observers, regardless of their state of motion.\[5\]

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.\[6\]

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

Postulate II. The velocity of light is independent of the state of motion of the source and the observer.\[8\]

The second postulate states that the velocity of light in vacuum (i.e. in “empty space” – not in some medium where there may be all kinds of complicated interactions going on), is the same for every observer, irrespective of with what (constant) velocity he or she moves.\[9\]

The speed of light in free space has the same measured value for all observers, regardless of the motion of the source or the motion of the observer; that is, the speed of light is a constant.\[10\]

Postulate 2: All observers will always view the speed of light at the same rate.\[11\]

Note that all of those textbook versions of Einstein’s Second Postulate claim that the speed of light is the same for all observers. In other words, it doesn’t make any difference who is moving, light will always be emitted and received at $c$. A moving emitter will observe the light traveling away at $c$, and a moving receiver will observe the light arriving at $c$ regardless of whether he is moving toward or away from the emitter. I call this the “All Observers Theory” when comparing it to Einstein’s “Emitter Only Theory.” Of course, if the textbook versions of the “All Observers Theory” are correct, that means radar guns cannot possibly work the way the thought experiment (and real life experiments) demonstrate how they do work.

Does this mean that there is something wrong with The Einstein Radar Gun Experiment? Not necessarily. What it means is that we need to have other experiments which clarify which version is correct. There are many such experiments. They all show the same results as shown in the radar gun experiment. And there are NO experiments which confirm the incorrect version used in so many college textbooks.
1. **The Sagnac Effect.**

In 1911, French scientist Georges Sagnac performed an experiment involving a moving emitter and moving mirrors on a rotating platform, as depicted in Figure 2 below. The results have become known as the "Sagnac Effect." The experiment involved a light source emitting photons toward a half-silvered mirror which split the beam, sending photons clockwise and counterclockwise away from the emitter and toward a series of three mirrors which redirected the photons around a square and then to the detector (the "moving observer") as the entire measuring apparatus rotated on the platform.

![Figure 2](image_url)

Figure 2

The experiment can be envisioned as being similar to a person on a rotating carousel tossing balls (in a vacuum, of course) to a person ahead and to a person behind as the carousel rotates. It is different in that, while a tossed ball will travel at the speed of the carousel plus the throwing speed, light cannot exceed the "throwing speed" (or emitted speed) and thus will not combine with the speed of the carousel. However, the catcher’s (observer’s or detector’s) speed will mathematically combine.

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 "All Observers Theory."
2. **The Michelson-Gale Experiment.**

In 1925, "The Michelson-Gale Experiment"\[^{[13]}\] 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 from the Sagnac experiment 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," a vastly greater travel distance than used in lab equipment. It was also different from the Sagnac experiment in that the equipment didn’t rotate in a circle but only moved sideways as the Earth turned on its axis.

However, it was similar to the Sagnac experiment in that the light beam was split and sent around the rectangle in both directions, being re-emitted by mirrors along the way.

The results of the experiment 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 Earth’s rotation had no effect. So, again “Einstein’s Emitter Only Theory” is confirmed, and the “All Observers Theory” is disproved.

3. **The Annual Doppler Effect.**

![Figure 3](image)

In 1887, an astronomical experiment performed by Hermann Vogel and Julius 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 as it orbits the sun.\[^{[14]}\] In the experiment, the star is a stationary emitter and the earth is a moving observer. As shown in Figure 3 above, in June, when the Earth is moving at speed \(v\) (67,000 mph) toward a star located near the ecliptic, light photons from that star arrive at \(c + v\) and appear shifted toward the blue end of the visible light spectrum because more of the photon’s oscillations reach the observer in a unit of time. In December, when the Earth is moving away from the star, the light from the star arrives at \(c - v\) and is “red-shifted” because fewer photon oscillations are seen by the observer in a unit of time. So, again “Einstein’s Emitter Only Theory” is confirmed, and the “All Observers Theory” is disproved.
4. **Mirrors on the Moon.**

Calculations performed by a NASA scientist in 2009 were consistent with the velocity of the observer adding to the oncoming speed of light when the observer is traveling toward the source of the light. I.e., the calculations were fully consistent with Einstein’s “Emitter Only Theory” and in direct conflict with the “All Observers Theory.”

But, interestingly, the scientist did not accept what he had calculated.

The paper is titled “Lunar Laser Ranging Test of the Invariance of c.”[15] 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.

The experimental data was collected at the Apache Point Observatory (APO) which is located in Sunspot, New Mexico. APO is operated by the University of New Mexico, but is owned by a consortium of universities. According to Gezari’s paper, experimental data collected by the University of California, San Diego (UCSD) during a UCSD project called APOLLO (Apache Point Lunar Laser-ranging Operation) was supplied to NASA scientist Gezari by the head of the APOLLO project, and Gezari used that data to make his calculations. After examining the data and his calculations, Gezari observed that the results showed that light could either travel 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 “All Observers Theory” interpretation of Einstein’s Second Postulate.

5. **Alväger et al.**

When those who accept the incorrect version of Einstein’s Second Postulate as it is stated in most college physics textbooks are asked if there are any experiments which support their beliefs, they most frequently cite Alväger et al.[16] But the experiment performed at the CERN Proton Synchrotron by T.Alväger, F.J.M. Farley, J.Kjellman and
L. Wallin merely confirms what Einstein wrote. It was an experiment to prove that the speed of the emitter does not affect the speed of light. And it did exactly that. The experiment didn’t involve a moving receiver, only a moving emitter. In the experiment, gamma rays were produced in the decay of 6-GeV pions traveling at 0.99975c. The gamma rays arrived at c, and any re-radiation from the target also traveled at c.

6. Filippas and Fox.

The experiments performed by T. A. Fillipas and J. G. Fox in 1964 were very much like the experiments by Alväger et al., except that Fillipas and Fox did their experiment at the Carnegie Tech synchrocyclotron. The title of their paper was “Velocity of Gamma Rays from a Moving Source.”[17] The experiment involved propelling a meson particle at high speeds and measuring the speed of the gamma ray particles that are released as the meson particle decays. The experiment was done to prove that the speed of the meson particle does not add to the speed of the gamma ray particles that are released, i.e., the speed of the emitter does not add to the speed of light that is emitted. The last two sentences in the abstract are: “We have compared our results with what would have been expected on the assumption that the initial photon velocities were c + v and c - v. The results were in complete disagreement with this assumption.”

Once again, the experiment did not involve a moving receiver, so it does nothing to confirm the incorrect version of Einstein’s Second Postulate found in so many physics textbooks. It only verifies Einstein’s correct version.

II. A Second Special Relativity Experiment.

There’s another interesting experiment that can be easily performed with radar guns that challenges very different incorrect versions of Einstein’s Second Postulate that may be in as many college textbooks as the incorrect versions cited on page 3 of this paper. Here are ten examples of those “Second Postulates”:

2. The constancy of the speed of light: The speed of light in a vacuum has the same value, $c = 2.997 \times 10^8$ m/s, in all inertial reference frames, regardless of the velocity of the observer or the velocity of the source emitting the light.[18]

The principle of the constancy of the speed of light: The speed of light in free space has the same value $c$ in all inertial reference frames.[19]

The speed of light in free space has the same value in all inertial frames of reference.[20]
Postulate II. Constancy of velocity of light: The velocity of light is the same in all inertial systems.[21]

2. The speed of light, is constant, the same in all inertial reference frames, independent of any relative motion of the source and of the observer.[22]

Light travels in a vacuum with the same speed \( c \) in any direction in all inertial frames.[23]

2. Constancy of the speed of light: The speed of light in vacuo has the same value \( c \approx 3 \times 10^8 \text{ m/s} \) in all inertial frames, regardless of the velocity of the observer or the source.[24]

2. In any given inertial frame, the velocity of light \( c \) is the same whether the light be emitted by a body at rest or by a body in uniform motion.[25]

There exists an inertial frame in which light signals in vacuum always travel rectilinearly at constant speed \( c \), in all directions, independently of the motion of the source.[26]

There is an inertial frame in which the speed of light is a constant, independent of the velocity of its source.[27]

Here again is the correct version of Einstein’s Second Postulate: “light is always propagated in empty space with a definite velocity \( c \) which is independent of the state of motion of the emitting body.”[1] Note that it says nothing about inertial frames. In fact, Einstein’s 1905 paper describing Special Relativity does not contain the word “inertial.”

A radar gun experiment demonstrating that inertial frames are not needed for Einstein’s Second Postulate is extremely simple: You merely point the radar gun at the ground ahead as you accelerate from a stationary position to any speed greater than 10 mph (radar guns typically do not show speeds of 10 mph or less). The radar gun will show your changing speed as you accelerate, which is again in accordance with photons returning from the ground ahead being received by the radar gun at \( c+v \) where \( v \) is your constantly changing speed.

III. What is the problem?

Why do all those textbooks use inertial frames when, in reality, Einstein’s Second Postulate does not mention or need inertial frames? And why to so many other textbooks claim that light travels at \( c \) for all observers? Some college textbooks explain why:
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The Postulates of Relativity
Relativity stands on two basic physical postulates, both rooted in experiment. The first is the fact that physical laws remain the same in all inertial reference frames-reference frames such as two spaceships moving at constant velocity with respect to each other. The second is more astonishing: the speed of light always remains the same, independent of the reference frame from which it originates or from which it is observed. Let’s discuss these postulates in some detail.

The first postulate comes from the relativity of natural motion-the fact that experiments can only tell you about relative motion, relative velocities, never about any absolute motion. When you sit in a moving spaceship and look out at another spaceship, which ship seems to be moving? It’s always the other spaceship.

Thus, all inertial reference frames-frames that move at constant velocity relative to each other-are equivalent; there is no preferred frame, and physical laws must be formulated to reflect this relativity. This is the meaning of the first postulate above.[28]

Einstein’s theory is based on two postulates, the first that electromagnetic waves propagate at velocity $c$ in any inertial frame of reference, and the second that there is no preferred frame of reference. The second postulate is really one of symmetry, for any observer has the right to consider themselves stationary and others as moving.[29]

Einstein’s postulate about the laws of physics being the same in different reference frames only applies to inertial frames. (We know that accelerating frames must be different, because they have pseudoforces, such as centrifugal force.) Another way of stating Einstein’s postulate is that There is no experiment we can perform to tell us which inertial frame is moving and which is at rest. There is no ‘preferred’ inertial frame. All we can talk about is the relative motion of two inertial frames.[30]

In reality, Einstein’s theories say there is a “preferred frame of reference,” it is just not a specific location that can be easily identified.

According to Einstein, nothing can travel faster than the speed of light. Einstein also showed that the faster you travel relative to the speed of light, the slower time passes for you. That includes photon emitters. The faster an emitter travels, the longer
a second is for that emitter, and the slower the speed of 299,792,458 meters per second becomes when that emitter emits light photons at c.

This means that, if you can find a place in the universe where a second is shorter than anywhere else, and emitted light can therefore travel faster than anywhere else, you have found a “preferred frame of reference.” And, of course, any other location that is stationary relative to that “preferred frame of reference” is also a “preferred frame of reference.” So, there should be countless “preferred frames of reference” out there. The problem is finding them.

The earth spins on its axis at 1,040 mph at the equator. According to Einstein, “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.”[31] And the earth also travels at 67,000 mph as it orbits the sun.[32] And the sun travels at 486,000 mph as it orbits the center of the Milky Way Galaxy.[32] And the Milky Way Galaxy is moving at 1,342,161 mph toward the constellation Hydra.[33]

The Hafele-Keating experiments in October 1971[34] showed that time moves faster if you are traveling against the spin of the earth. That indicates that time will also move faster when you travel in the opposite direction from the earth’s orbit around the sun, and opposite to the sun’s orbit around the center of the Milky Way, and away from the constellation Hydra. Or you could begin by just travelling as fast as you can away from the constellation Hydra. That may not bring you to a “preferred frame of reference” where time ticks faster than anywhere else in the universe, but it’s a step in the right direction.

IV. Conclusion.

Radar guns routinely demonstrate that when moving at velocity v toward a reflective object, photons from the gun will travel at the speed of light, c, and hit the object at c, but reflected photons traveling at c returning from the object will hit the moving radar gun at c+v where c is the speed of light and v is the speed of the gun. This established fact is supported by the many scientific experiments described on pages 4 through 7 of this paper. This does not mean that light can travel at c+v, it merely means that any college textbook, paper, or other source which claims that light is received at c by “all observers” is not only wrong, it is also ignoring key facts needed to understand Einstein’s Relativity and how the universe around us works.

Of course, listing page after page of incorrect versions of Einstein’s Second Postulate can create the suspicion that there are no “correct” versions. To counter that suspicion, and although they are a lot harder to find, I managed to locate a dozen correct versions:
Postulate 2. The speed of light in a vacuum is equal to the value c, independent of the motion of the source.\[^{35}\]

light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body.\[^{36}\]

Postulate 2: "Light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body." ("Principle of the Constancy of the Velocity of Light")\[^{37}\]

light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body.\[^{38}\]

light always propagates in empty space with a constant velocity c which is independent of the state of motion of the emitting body and the measuring instrument.\[^{39}\]

The velocity of light is independent of the motion of its source.\[^{40}\]

Postulate 2 (Constancy of the Velocity of Light): The speed of light in empty space is an absolute constant of nature and is independent of the motion of the emitting body.\[^{41}\]

The velocity of light is independent of the motion of the light source.\[^{42}\]

2. Regardless of the motion of its source, light always moves through empty space with the same constant speed.\[^{43}\]

E2. Light is always propagated in empty space with a definite velocity c which is independent of the state of motion of the emitting body.\[^{44}\]

It is a cardinal postulate of relativity theory that the velocity of light is a constant, independent of the velocity of its source.\[^{45}\]

The constancy of the speed of light, which is always propagated in empty space at \(c = 3 \times 10^8\) m/s, independently of the state of motion of its source.\[^{46}\]

V. References.

\[1\] Albert Einstein, *On the Electrodynamics of Moving Bodies*, Annalen der Physik 17 (1905)


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