Radar Guns and Einstein's Theories

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Abstract: *Basic radar guns provide an excellent means of explaining and demonstrating some of Einstein's theories in a very simple and undeniable way. Specifically, basic radar guns demonstrate how the speed of the emitter cannot add to the speed of the light being emitted, but the speed of light can be combined with the speed of the receiver. In practice, this appears to conflict with basic tenets of mathematicians who believe that all motion is relative, and the speed of light will be the same for the emitter as for the receiver. A step by step analysis of how basic radar guns work shatters those tenets.*

Key words: Radar; Relativity; motion; light; photon; wave; Einstein.

I. The Problem.

Einstein's Theories of Relativity have been the subject of misinterpretations and arguments for over a hundred years. No misinterpretation is more absurd than the common belief that Einstein's theories say that there is no "preferred" frame of reference and all motion is relative. Einstein's 1905 paper *On The Electrodynamics of Moving Bodies*[1], which introduced his Theory of Special Relativity to the world actually begins by describing how magnets and conductors work differently, depending upon whether they are stationary or moving.

The problem at the time was that light was believed to consist of waves which moved through some purely imaginary, invisible, *stationary* medium called the ether (or aether). But no experiment of any kind could detect any sign of the existence of such an ether. That posed two problems: (1) how can you have a wave without a medium in which the waves move, and (2) if there was no ether, to *what* is the speed of light relative?

Einstein won the Nobel Prize for his paper describing how light consist of particles (now called "photons"), not waves, solving problem #1. And Einstein's Theory of Special Relativity solved problem #2 by showing that there is a *maximum speed* for the speed of light, light always travels at its maximum speed, and the speed of *everything else* in the universe can be measured relative to that maximum speed.   Einstein stated that it makes an ether "superfluous."

But, Einstein then complicated things by explaining that the maximum speed of light is variable depending upon the rate TIME passes at the location of emission. If we have two clocks and two lamps, and one lamp and clock are in a stationary location while the other lamp and clock are moving together at very high inertial speeds (i.e., they are not accelerating), the faster moving clock will measure seconds to be longer than the seconds measured by the stationary clock. Yet the speed of light emitted by the lamps will be measured to be the same *per second* according to its accompanying clock.

This doesn't mean that there is no maximum speed of light, it just means that the true maximum speed of light can only be measured at a "stationary location in space." And there is no infallible way to find "a stationary location in space" since you cannot know that the location you believe to be stationary isn't actually moving faster than at some yet-undiscovered location.

But, you do not *need* to find any absolute motionless point in space in order to determine who is moving faster than whom. Just compare the lengths of local seconds. The object moving fastest is the object for which time moves slower and for which a second of time is longer.

That created a new and persisting problem: Many mathematician-physicists do not look at the experimental evidence but, instead, they develop mathematical equations which show that "motion is relative," and therefore Observer-1 can consider himself to be "stationary" and he can consider Observer-2 to be moving, while Observer-2 can consider himself to be "stationary" while Observer-1 is moving. And, if time slows down for the moving observer, then each can consider the other to have slower moving time.

But that only works if you cannot compare results. A person on an airplane can consider himself to be "stationary" because he feels no sense of motion, but if he looks out the window he will see that he is moving relative to the ground. If he still considers himself to be stationary, he is only doing so because he cannot tell the difference *mathematically*. Logically and scientifically, there is no basis for actually believing he is stationary.

II. Einstein's Two Postulates

The stationary-vs-moving problem is routinely compounded by twisting, distorting and misinterpreting Einstein's two "Postulates." Here is how Einstein's two postulates are defined in an English language version of his 1905 paper after providing the examples of magnets and conductors working differently depending upon which is moving and which is stationary:

> 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 **postulate**s suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies based on Maxwell's theory for stationary bodies.**[2]**

The word "postulate" appears nowhere else in the paper. While most people will accept the first postulate as being "the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good," many will *insist* that the Second Postulate is **<u>not</u>**:

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

Text books sometimes inexplicably argue Einstein's Second Postulate is actually ***principle*** #2 at the top of page 4 in part §2 of his 1905 paper:

> 2. Any ray of light moves in the "stationary" system of co-ordinates with the determined velocity c, whether the ray be emitted by a stationary or by a moving body.**[3]**

The word "stationary" in that sentence allows various interpretations. But more typically, they will argue that what Einstein stated as his Second Postulate cannot be what Einstein actually *<u>meant</u>*, since they believe it conflicts with his First Postulate. Of course, Einstein clearly stated in his paper that there only *appeared* to be a conflict. Once you understand his theory, you will see *there is no conflict*.

Instead of trying to understand Einstein's Theory of Special Relativity, however, many mathematician-physicists simply provide *their own personal interpretations* of Einstein's Second Postulate. Here are just two examples from college physics textbooks (check my paper about Einstein's Second Postulate**[4]** for more 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."**[5]**

> The constancy of the speed of light**:** The speed of light in a vacuum has the same value, c = 2.997 924 58 x 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. **[6]**

Einstein's Second Postulate says ***nothing*** about what an outside observer will see. When a space traveler emits light into the darkness ahead of and behind him, the light he emits travels at *c* regardless of his speed or direction of movement – in full accordance with Einstein's Second Postulate. What an outside observer will see depends upon the movement of that observer.

Light travels at *c*, but a moving observer will encounter the light as if the light was moving at *c+v* or *c-v* where *v* is the velocity of the observer toward or away from the source of the light.

Einstein explained this many times in many different ways.

III. Einstein's Thought Experiments

Einstein didn't just state his Second Postulate one time and leave it to others to be argued about. His subsequent books and papers attempted to explain his theory and his two postulates in greater detail.

Dutch physicist Willem de Sitter observed confirmation of Einstein's Second Postulate in 1913[7] and wrote about it in 1916 in "*Einstein's Theory of Gravitation, and its Astronomical Consequences*."[8] Albert Einstein used de Sitter's observations in his 1920 book "*Relativity: The Special and General Theory*."[9]

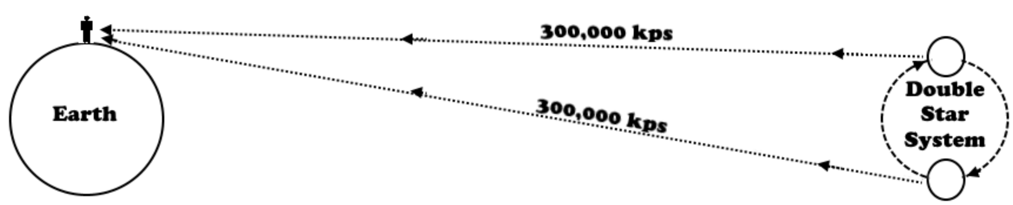

Figure 1

Figure 1 illustrates de Sitter's observation. The two stars in the double star system orbit each other, which means that when one star is moving toward the earth, the other is moving away from the earth. According to Isaac Newton and Swiss theoretical physicist Walther Ritz, the light from the star moving toward the earth should travel at *c+v*, where *v* is the speed of the star toward earth, and the light from the star moving away from the earth should travel at *c-v*. That became known as "Emission Theory." De Sitter's observations showed that "Emission Theory" was *<u>not true</u>*. The light travels at 300,000 kilometers per second (kps) from *both* stars. If "Emission Theory" were true, that would also mean that, while the slow-moving light from the receding star is traveling to the earth, the faster-moving light from the oncoming star would pass by the slower-moving light, and an observer on earth would see the same star in different locations. That doesn't happen.

Einstein agreed. He decided there must be a *maximum speed limit* in our universe that prevents light from traveling faster than 300,000 kps. And all light *must* be emitted at 300,000 kps *in all directions*. That means that, no matter how fast the emitter is traveling, *or in what direction*, the light that the source emits will travel at 300,000 kilometers **per a local second**.

This also means that a stationary observer will see that light arrive at 300,000 kps regardless of how fast or in what direction the emitter is moving. But, if the observer is moving toward or away from the light source, the light photons will arrive at $c+v$ or $c-v$, where v is the velocity of the observer.

In the book Albert Einstein wrote with Leopold Infeld in 1938[10], Einstein and Infeld described what happens when a light bulb is turned on in the center of a moving laboratory.

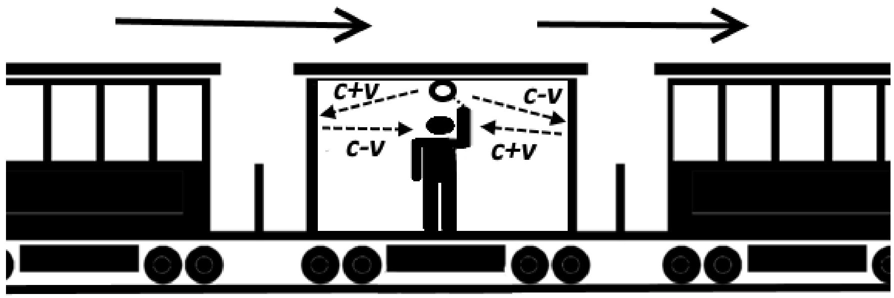

Figure 2

In Figure 2 above, the moving laboratory is on a train that is traveling at high speed (v) from left to right. When the light above the observer is turned on, the light bulb emits photons in all directions. The rear wall of the laboratory is moving toward the oncoming photons at v, so that rear wall encounters the photons at $c+v$ and that wall is illuminated first. However, the newly created photons emitted at c from the illuminated rear wall have to catch up with the observer as he moves away (at velocity v) from the point in space where those new photons were created. Meanwhile, the opposite happens with the front wall. Light photons take longer to reach the front wall because it is moving away from the oncoming photons ($c-v$), but the new photons that are created by the front wall's atoms take less time to reach the observer who observes those photons as arriving at $c+v$. The result is that the observer sees both walls illuminated at the same time even though they did not actually illuminate at the same time.

That has become known as the "relativity of simultaneity." An observer outside of the moving train who is standing stationary on the embankment, *would* see the rear wall light up first, even though the person on the train does not.

What is actually happening on that railroad car could not have been demonstrated when Einstein was developing his Theory of Special Relativity in 1905. There was no way to compare the oscillation frequency of a photon emitted from the light bulb to the oscillation frequency of a second photon that is created and emitted from the wall back toward the observer standing in the center of the railroad car. Today we have a tool that can do exactly that, and that tool is used routinely every day. It just isn't being used to help explain Einstein's theories, even though that tool, a *radar gun,* can nicely demonstrate the correct meaning of Einstein's Second Postulate. Here is how a reference book on radar technology describes Einstein's Second Postulate:

> Albert Einstein's special theory of relativity, introduced in 1905, showed that all the experimental results could be explained within the context of his theory; there was no need of the aether. Light, Einstein held, and all electromagnetic radiation, travels in

space at a constant speed of approximately 3 x 10^8 m/s, **independent of the speed of the source**.[11]

While all radars send and receive electromagnetic photons, radar speed guns used by police departments are especially useful when discussing Einstein's theories.

IV. Radar Speed Guns

A NASA web site[12] describes how a police radar gun can, in theory, use a single photon and the Doppler Effect to measure the speed of an oncoming car. The radar gun is pointed at the oncoming car and the gun emits a photon. "The force exerted by the car on the photon, … acts to add energy to the photon. Therefore, we expect the photon frequency to increase." And, "The police radar detector easily detects this frequency shift."

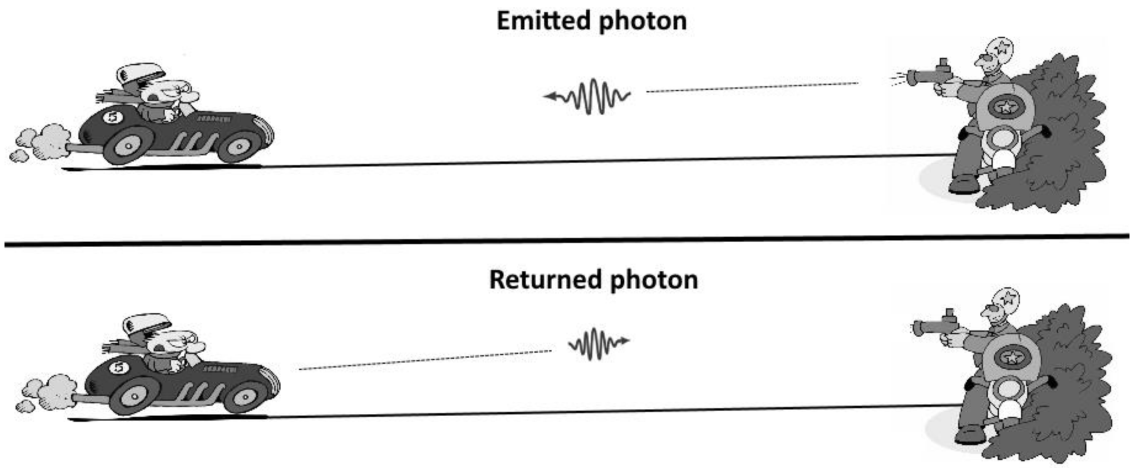

Figure 3

This means that, as illustrated in Figure 3 above, a radar gun can emit one perfectly aimed photon at the headlight of the target vehicle. Because the target is approaching, the photon hits the target at $c+v$, where v is the speed of the target. The Doppler Effect occurs when kinetic energy from the moving target is added to the original energy of the photon. An electron within an atom within the target absorbs the incoming photon as if the photon had higher energy and a higher frequency than originally emitted. The atom within the target cannot retain the energy of the new photon, so the electron emits a *new* photon back toward the radar gun. That new photon also travels at c, the speed of light, but it has a shorter wavelength (and a higher frequency and higher energy) than the original photon.

When that photon is returned to the gun, the gun can compute the speed of the moving headlight by comparing the frequency of the photon the gun emitted to the frequency of the photon that came back. In reality, of course, the radar gun emits a quick burst of billions of photons. The gun has a narrow funnel-shaped transmitter that is about 2 inches in diameter at the end facing the target. As soon as the photons are emitted, the gun turns off its transmitter and turns on its receiver. The 2-inch cluster of photons will spread to about 75 feet in diameter by the time it hits a moving target if it is about 500 feet away. Only a tiny fraction of those photons will actually hit a smooth surface on the target vehicle, like its headlights. As a result of the Compton Effect,[13][14] the electrons in a headlight will emit and scatter new photons in many directions, and only a very tiny fraction of those photons will get back to the 2-inch receiver on the radar gun. The additional returned photons serve no real purpose except to ***verify*** what was measured by the single photon. The radar gun, however, must be the right type of radar gun.

V. Different Types of Radar Guns

For purposes of this paper, radar guns can be organized into two general categories: "**basic"** radar guns and "**complex"** radar guns. Unfortunately, you cannot always tell by just looking at the gun whether it is a basic or complex radar gun.

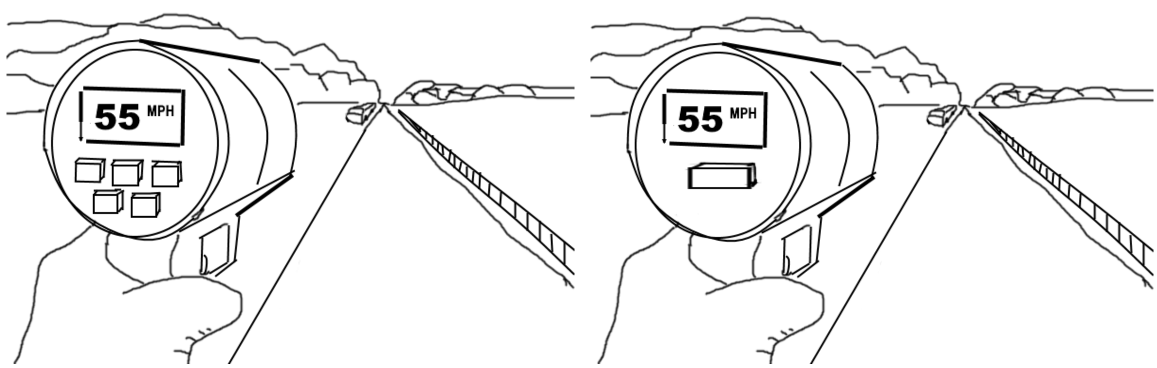

Figure 4

Figure 4 above shows two different radar guns being pointed at an oncoming car that is traveling toward the gun at 55 miles per hour. There is no simple way to tell, however, which of the guns in Figure 4 is a "basic" gun and which is a "complex" gun. The fact that one has more buttons on the back is misleading, since that is a "basic" radar gun.

With both types of guns the operator starts it working by pressing a power on/off button on the back beneath the display screen. The operator then simply points the gun at a target and squeezes the trigger. That is where the similarities end.

A "basic" radar gun emits photons toward the target and uses a device called a "Local Oscillator" (LO) within the gun to generate a small number of identical photons for comparison to the returned photons. Another device, called a "duplexer," makes certain that none of the photons emitted by the transmitter accidentally leak into the receiver. Police Department and manufacturer rules require that a "basic" radar gun be stationary when it is used. This is because, as described above, movement of the gun will <u>not</u> affect the results. It will always emit photons that travel at the same speed, *c*, the speed of light. That means that, regardless of how fast the gun is moving toward or away from the target, the gun will still just show the actual speed of the target. And if the gun is pointed at a highway sign next to the road, no matter how fast the gun is moving, it will show the highway sign to be stationary. This is evidently confusing to people unfamiliar with Einstein's Second Postulate (or who have been taught the various ***incorrect*** versions of Einstein's Second Postulate), so it is simply easier to make it a violation of the rules to use the gun while moving.

The primary difference between a "basic" radar gun and a "complex" radar gun is in how the "radome" that covers the emitter/receiver end of the radar gun is constructed.

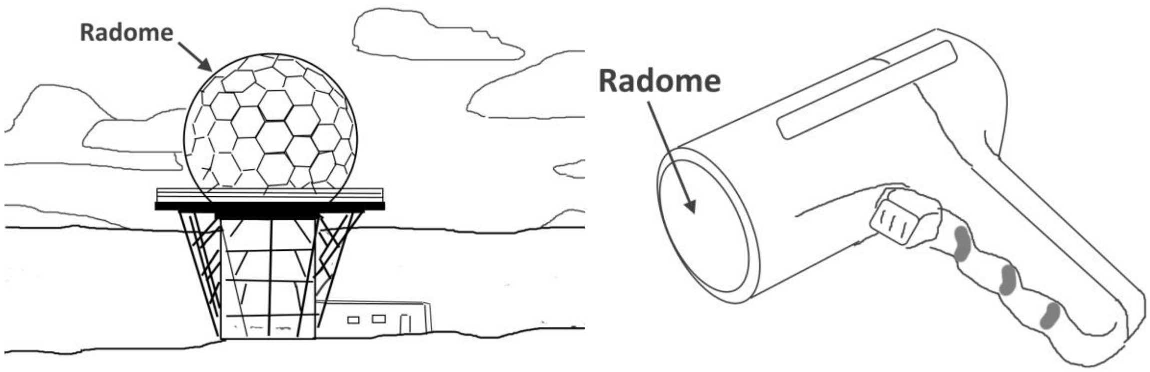

Figure 5

On the left in Figure 5 above is a spherical "radome" that covers the actual working components of a large weather-radar transmitter/receiver, protecting the delicate equipment from rain and snow and wind. On the right in Figure 5 is a rounded, circular "radome" that covers the front end of a radar gun, protecting the gun's internal components from rain, snow and wind – and mishandling.

In order for the weather-radar to work, the radome must be totally transparent to the radar photons that are emitted and received, otherwise the radome could cause interference and distort what is observed on the radar screens inside the weather station. In a "basic" radar gun, the radome is also designed to be totally transparent to electromagnetic photons in the frequency range being used by the radar gun, so that no emitted photons bounce off the radome and reenter the gun via the receiver. Thus, the gun emits photons that travel to their targets, and the Doppler Shift of the returning photons can be used to measure the distance to the target(s). Typically, the "basic" radar gun shows only the speed of the fastest target.

A "complex" radar gun works very differently. A "complex" radar gun has a radome that is **not** fully transparent to electromagnetic photons in the frequency range used by the radar gun. According to one text on radar principles:

> The S-5 is a homodyne [i.e., single frequency] radar system and requires a sample of the transmitted signal to serve as the LO. **The radome is not totally transparent to the transmitted energy by design.** Some of the transmitted energy is reflected back to the receiver side of the reflector. This transmitted energy serves as the LO that mixes with the returned Doppler-shifted signal.[15]

And according to that same text, at least one manufacturer **purposely** developed such a radome to reflect some of the emitted RF (Radio Frequency) photons back into the receiver, clearly being fully aware of the complexities that adds to the gun.

> Kustom [Signals, Inc.] developed a plastic radome that fit over the end of the horn to purposely reflect a small amount of RF power back into port 2 and create an LO reference signal at the required mixing level.[16]

What this does is allow the "complex" radar gun to determine ***its own*** speed. That means the gun doesn't necessarily have to be stationary when it is measuring speeds. The photons that bounce off the radome give the gun its own speed, and the photons that bounce off a target still work the same way as a basic gun, except that speed comparisons are made to the gun's actual speed, not to zero.

In addition to having some of the emitted photons bounce off the radome and reenter the gun, instead of using an unreflected LO reference signal, some manufacturers also digitize the information the gun produces, which adds another level of complexity to a "complex" radar gun.

A "complex" radar gun, such as the Bushnell Speedster 101911 sports radar gun, which looks like the gun on the right in Figure 4, first "filters" the signal to remove "errors," then the signal is "digitized in an Analog to Digital Converter (ADC), and passed onto the Digital Signal Processing (DSP) chip. Using complex algorithms, the DSP chip filters out false and low level return signals, to identify and display the speed of the desired target." The DSP chip software also filters "out bad information, providing valid accurate information."[17]

Exactly what it considers to be "bad information" isn't made clear by material supplied for the Bushnell gun, but, since it is designed for use in sports, it does **not** show the tip of a golf club as moving faster than the golf ball the club hit, while a typical basic radar gun will show **only** the fastest speed measured, which is most likely the tip of the golf club. The Bushnell software also prevents measuring the speed of an arrow shot toward the gun, probably because the point of the arrow returns too few photons to be considered "good information." And, by design, the Bushnell also measures any movement of the radar gun itself which might affect a reading. That means that "if you would like to know the speed of the vehicle you are in, point the Speedster at a stationary object, such as the ground."[18]

Of course, the gun doesn't actually measure "the speed of the vehicle you are in," it measures the speed of *the radar gun* relative to the target. And due to the "cosine effect,"[19] the gun may not even measure the correct speed of the gun. If the target is directly ahead of the gun, the speed will be accurate, but if the target is traveling at 100 mph and it is 20 degrees away from directly ahead, the gun will show the target's speed to be about 87 mph, at 50 degrees the gun will show the target's speed to be about 65 mph, and at 90 degrees the gun will show "no reading" for the target, just as if the target was stationary instead of traveling at 100 mph.

Other "complex" radar guns give readings for multiple targets, and/or give readings for the vehicle carrying the gun (i.e., the gun) **and** the speed of a target. Some have multiple emitters and receivers. Such radar guns are primarily used by the police when they are in a moving patrol car.

Basic radar guns are to be used by the police *only* when sitting in a patrol car that is parked at the side of the road or when the officer is standing next to the parked car while holding the gun. Such basic radar guns best demonstrate Einstein's theories.

Extensive research to hunt for what "basic" radar guns display while moving resulted in only finding two user's manuals that have these questions and answers:

> Q. Will my radar work while my vehicle is moving?
>
> A. **No**, the Genesis-VPD radar gun is a stationary only model, so your motor vehicle should be parked. You need to hold the radar steady while operating it.**[20]**

And

> Q. Will my radar work while my vehicle is moving?
>
> A. **No**, the GHD and SCOUT radar guns are a stationary only models, so your vehicle should be parked. You need to hold the radar steady while operating it.**[21]**

There is no explanation in the manuals or anywhere else for what "work" means when the answer is that the gun will NOT work. But it seems most likely that it means the gun will show "no reading" when pointed at the ground or a highway sign from a moving vehicle, and when pointed at the back of a truck traveling at the same speed as the gun, the gun will show the truck's actual speed, not a relative speed of zero.

VI. A Proposed Experiment

The above examination of the workings of radar guns suggests an interesting experiment.

A basic radar gun that is in a patrol car going 60 mph and is pointed at the back of a truck that is in front of the patrol car and is also traveling at 60 mph will give the truck's speed as 60 mph. Logically, therefore, you should get the same result if the radar gun is inside the truck and is pointed at the front wall of the truck's interior. Or, the gun can be inside Einstein's railroad train *gedanken* moving laboratory as shown in Figure 6 below.

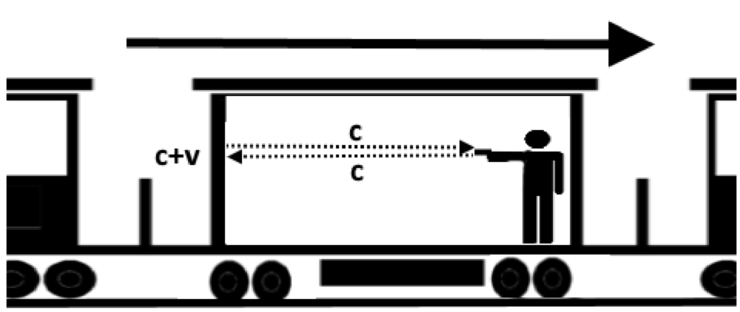

Figure 6

Figure 6 shows an observer with a basic radar gun firing the gun at the rear wall on a train that is moving from left to right at velocity *v*, which we can assume to be 60 mph. Since the movement of the emitter does not affect the speed of the photons emitted, the photons travel to the wall at *c*. However, the rear wall is moving toward the oncoming photons at velocity *v* (i.e., 60 mph), thus the photons hit the atoms in the rear wall at *c+v*. New photons with higher energy and a shorter oscillating wavelength are then emitted by electrons in atoms in the wall back to the radar gun at velocity *c*. The radar gun receives and compares the oscillating wavelength of the photons it emitted to the wavelength of the returned photons and calculates the speed of the rear wall (and the laboratory) to be 60 mph.

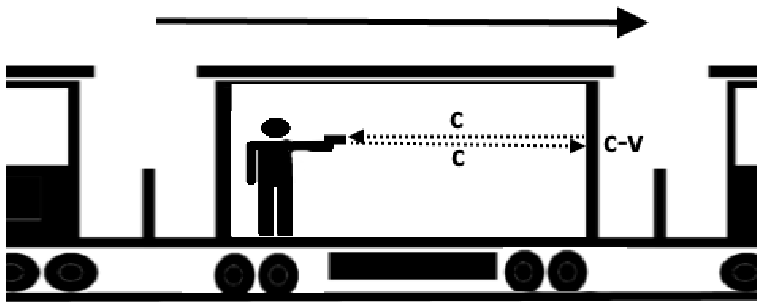

Figure 7

When the observer moves to the opposite end of the laboratory on the train as shown in Figure 7, and when he fires the basic radar gun at the front wall, the front wall encounters the photons traveling at *c-v*, and the atoms return photons with less energy and a longer wavelength. The radar gun compares the wavelength of the photons it emitted to the wavelength of the photons it received back and calculates the speed of the train to be *negative* 60 mph. (All three of the radar guns mentioned above which do not "work" when moving are "directional guns," which means they will show the direction the target is moving relative to the gun. Negative 60 generates an arrow on the screen showing the target is moving away from the gun.)

This *gedanken* experiment says that an observer within an inertial frame of reference *can* determine if he is moving or not relative to the ground outside by using a basic radar gun, and he can (if his radar gun has the capability) even tell in which *direction* his reference frame is moving. This is *not* movement relative to any imaginary ether (or aether), it is movement **relative to the speed of light** as measured at a given location. Photons are **emitted** at 300,000 kps, regardless of any movement by the emitter. But photons are received at *c+v* or *c-v* by moving objects at that general location. When new photons are sent back to the gun, the difference in oscillation frequency from the original photons and can be used to tell how fast the other object is moving toward or away from the emitter.

And it is <u>not</u> a violation of Einstein's **First** Postulate, which simply says,

> the same laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good.**[22]**

No laws of electrodynamics and optics were violated, and the equations of mathematics still hold good.

VII. Conclusion

The explanations above clearly conflict with what is written in most college physics textbooks. Such textbooks typically describe light as waves, and they describe the Doppler Effect as working the same way whether the emitter is moving toward an observer or the observer is moving toward the emitter. Very few (if any) textbooks contain anything like this quote from Richard Feynman's book "*QED*":

> "I want to emphasize that light comes in this form — particles. It is very important to know that light behaves like particles, especially for those of you who have gone to school, where you were probably told something about light behaving like waves. I'm telling you the way it does behave — like particles.[23]

In paragraphs following the one quoted above, Prof. Feynman described in detail how a photomultiplier can count individual photons emitted from a weak light source.

Einstein said somewhat the same thing about light consisting of photons, but it was in his typical, much more convoluted and less easily decipherable way:

> Indeed, it seems to me that the observations of "blackbody radiation," photoluminescence, production of cathode rays by ultraviolet light, and other related phenomena associated with the emission or transformation of light appear more readily understood if one assumes that the energy of light is discontinuously distributed in space. According to the assumption considered here, in the propagation of a light ray emitted from a point source, the energy is not distributed continuously over ever-increasing volumes of space, but consists of a finite number of energy quanta localized at points of space that move without dividing, and can be absorbed or generated only as complete units.[24]

There can be no doubt that light consists of photons, not waves, and when radar gun photons are emitted toward a target or are returned from a target they are actually a scattering of oscillating particles/photons that are totally unlike any continuous wave.

And, of course, Einstein's 1905 Theory of Special Relativity explains how all motion can be measured relative to the maximum speed of light. So any claim that every object in the universe can consider itself to be "stationary" while viewing other objects as moving relative to itself is probably the most absurd belief in all of physics. That belief is also responsible for the slightly lesser absurd belief that light will always be measured by a moving observer to arrive at c, **not** at $c+v$ or c-v, where v is the speed of the observer.

The velocity of every object in the universe can be measured relative to the maximum speed of light, and all observers who are moving relative to a source of light or the source of other electromagnetic energy will observe that light to be arriving at $c+v$ or $c–v$. Only observers who are stationary relative to the light source will measure that light to arrive at c.

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