the general science journal

On the One-Way Speed of Light:

A Review of the CGPM Redefinition of the SI Unit of Speed

A. A. Faraj
a_a_faraj@hotmail.com

Abstract:

Throughout the present investigation, the CGMP redefinition of the SI unit of time (second), as well as the CGMP redefinition of the SI unit of length (meter) have been examined and discussed in detail. In addition, the supposition that the two redefined SI units, in question, would render the intrinsic muzzle speed of light, in a vacuum, permanently, into a physical constant, by convention, has been fully analyzed, and found to be untrue, in principle, and entirely unsubstantiated, under realistic operational conditions, and in almost every conceivable situations.

Keywords:

SI units; intrinsic speed of light; dispersive media; CGPM optical meter; relative speed of light; solar second; UHF microwave; ballistic speed of light; acceleration; gravitational fields.

Introduction:

According to the 1983 definition by the General Conference on Weights and Measures (*CGPM*), the meter is the length of the path traveled by light in a vacuum during an interval of time equals to *1/299792458* of a second [*Ref. #7*].

However, the second of time (*s*), itself, has been defined, since 1967, by the 13th General Conference on Weights and Measures, in terms of the frequency (*f*) of *9192631770* Hz of radiation, due to the unperturbed transition between the two hyperfine levels of the ground state of the cesium-33 atom, to be equal to the number (*N*) of {*9,192,631,770*} times the wave period (*T*) [*Ref. #9*]; i.e.,

$$s = \left[9192631770\right] \times \mathrm{T}$$

where:

$$\mathrm{T} = \frac{1}{\mathrm{f}}$$

and which implies, necessarily, that:

$$\lambda = \left[\left(299792458\right) \div \left(9192631770\right)\right] \ \mathrm{m}$$

where (λ) is the standard wavelength of the electromagnetic radiation whose standard frequency (*f*) is equal to *9192631770* Hz, and its speed (*c*), in a vacuum, is equal to *299792458* meter per second.

And as a result, it's inevitable that the definition of the length of the meter (*m*), as well as the definition of the duration of the second of time (*s*), in terms of the speed of light (*c*) in a vacuum, as indicated by the following simple mathematical equation:

$$c = f\lambda$$

must form a vicious circle, within which neither the length of the meter, nor the duration of the second can be independently, accurately, and properly defined, in any conceivable way, at all.

But nevertheless, within the context of the present discussion, let the 1967 General Conference on Weights and Measures (*CGPM*) as well as the 1983 General Conference on Weights and Measures

(*CGPM*), just be given the benefit of the doubt, in this way:

- The 1967 General Conference on Weights and Measures (*CGPM*), perhaps, didn't intend to define, from scratch, the duration of the second of time (*s*), solely, in terms of the frequency (*f*) of *9192631770* Hz of radiation, emitted by the unperturbed transition between the two hyperfine levels of the ground state of the cesium-33 atom, as if no previous definition of the duration of the second of time (*s*) ever existed, in any shape or form, to speak of, at all.

- The 1983 General Conference on Weights and Measures (*CGPM*), probably, didn't intend to define, from scratch, the length of the meter (*m*), solely, in terms of the path traveled by light in a vacuum during an interval of time equals to *1/299792458* of a second , as if no previous definition of the length of the meter (*m*) ever existed, in any shape or form, to speak of, at all.

- The 1967 General Conference on Weights and Measures (*CGPM*), very likely, took for granted the primary conventional definition, in accordance with which the duration of the second of time (*s*) has been defined as *1/86400* of a solar day [*Ref. #10-a*], and employed it in establishing the secondary conventional definition of the duration of the second of time (*s*), in terms of the frequency (*f*) of *9192631770* Hz of microwave radiation, given off by the unperturbed transition between the two hyperfine levels of the ground state of the cesium-33 atom, in order to make sure that the duration of the new *microwave* second of time is exactly equal to the duration of the solar second of time.

- The 1983 General Conference on Weights and Measures (*CGPM*), presumably, took for granted the primary conventional definition, on the basis of which the length meter (*m*) has been defined as the distance, at *0° Celsius*, between the axes of the two central lines marked on the bar of platinum-iridium kept at the International Bureau of Weights and Measures (*BIPM*), in Paris [*Ref. #11*], and employed it in establishing the secondary conventional definition of the length of the meter, in terms of the path traveled by light, in a vacuum, during an interval of time equals to *1/299792458* of a second, in order to make sure that the length of the new *optical* meter is precisely equal to the length of the BIPM meter.

- The 1967 General Conference on Weights and Measures (*CGPM*) and the 1983 General Conference on Weights and Measures (*CGPM*), in all likelihood, made sure that the new speed of light, in a vacuum, [*c = 299792458 optical meter/microwave second*] is absolutely equal to the traditional speed of light, in a vacuum, [*c = 299792458 BIPM meter/solar second*].

And so, now, the crucial question, here, is this:

Is it possible, in principle, at least, that the length of the new CGPM optical meter (*m*) and the duration of the new CGPM microwave second of time (*s*) would, in practice, render the speed of light (*c*), in a vacuum, constant, by definition, at all times, regardless of whether it's actually constant, or not?

Apparently, nowadays, a fair number of theoretical physicists, including, of course, many proponents of Einstein's special relativity, would like to wishfully think that the numerical value of light speed (*c*), in the vacuum of space, has indeed been fixed, in a purely conventional manner, once and for all, by the officially defined length of the new CGPM optical meter (*m*), and the officially defined duration of the new CGPM microwave second of time (*s*), for good.

And moreover, such a constantly repeated and widely publicized claim, by those theoretical physicists, seems to have discouraged experimental physicists from performing further experiments, in this regard, and to have a chilling effect on the actual measurements of the speed of light (*c*), in physics laboratories, all over the world, which appear to have never been carried out anywhere, since the last known attempt in 1976 [*Ref. #12*].

It's therefore imperative, from theoretical and experimental perspectives, to thoroughly examine the 1967 CGPM definition of the microwave second of time (*s*) and the 1983 CGPM definition of the optical meter (*m*), as well as to analyze, in more details, the relationship of both to the time-honored definition of the solar second of time (*s*) and to the longstanding definition of the BIPM meter, respectively.

In particular, it's of vital importance, within the current context, to determine whether or not, in reality, it's logically and practically feasible to turn the speed of light (*c*) into a physical constant, as well as to conceal, somehow, its potentially observable variations, in the lab, all the time, through mere convention, and by nothing more than choosing freely the 1983 CGPM definition of the optical meter (*m*) as the basic length unit, along with the 1967 CGPM definition of the microwave second of time (*s*) as the basic time unit, over the traditional BIPM meter, and the historical solar second of time (*s*).

In addition, due to the fact that, in physics, the actual meaning of the term ***'constancy'*** is necessarily theory-dependent, the following definitions of the phrase '*constant speed of light*' have to be made explicit and crystal clear, from the outset, as well as the notable differences, between those definitions, must be taken into consideration, throughout the present investigation:

1. According to Newton's ballistic theory, the speed of light (*c*) is constant only, relative to the light source, at the time of emission. And hence, as defined within the framework of this theory, the constancy of the speed of light, relative to the light source, is short-term and prone to vanish, as soon as the speed of the light source changes, either in magnitude, or in direction, or in both, even by the slightest of margins.

2. According to Maxwell's electromagnetic theory, the speed of light (*c*) is always constant only, relative to the luminiferous aether. And therefore, as defined within the framework of this specific theory, the constancy of the speed of light, relative to the luminiferous aether, is permanent and unchanging, under all conceivable circumstances; and irrespective of the fact that the speed of light (*c*) is presumed to be inconstant and continuously changing, relative to everything else, in motion, even by the tiniest amount, relative to the luminiferous aether.

3. According to Einstein's theory of special relativity, the speed of light (*c*), in a vacuum, is always constant, for all light receivers, regardless of their motion, relative to the light source. Thus. as defined within the framework of this particular theory, the constancy of the speed of light, relative to all light receivers, is perpetual and unvarying, under all possible circumstances.

It should be noted, in this regard, however, that the notion of constant speed of light (*c*), as defined on the basis of Einstein's vacuum-based theory of special relativity, has been artificially imposed by its second postulate. While, by comparison, the notion of constant speed of light (*c*), as defined within the framework of Maxwell's aether-based theory of electromagnetism, has been a deduced theoretical result, which seems to naturally flow out, in a straightforward manner, from the wave model of light.

It's pretty clear, at first glance, nonetheless, that the aforementioned claim about turning the speed of light (*c*), instantly, into a physical constant, by merely replacing the traditional solar second of time with the 1967 CGPM microwave second of time (*s*), and the traditional *BIPM* meter with the 1983 CGPM optical meter (*m*), has only been intended, from the start, to be related, exclusively, to the constant speed of light (*c*), as defined within the framework of Einstein's theory of special relativity.

But, does the vacuum-based special theory of Herr Einstein, really, need, in any way, to have the speed of light (*c*) turned, at once, into a physical constant, anyhow, with the help of the 1967 CGPM microwave second of time (*s*), and the 1983 CGPM optical meter (*m*)?

Isn't supposed that the speed of light (*c*) has, in free space, from the very beginning, been made constant, by Einstein's second postulate, according to which the speed of light, in a vacuum, has to be always the same, for all observers, regardless of their motions, relative to the light source?

Well, seemingly, from the standpoint of sociology of science, Einstein's special theory of relativity does appear, at first glance, to need a little bit of extra help, from the 1967 CGPM microwave second of time (*s*), as well as the 1983 CGPM optical meter (*m*), in turning the speed of light, in a vacuum, into a physical constant. And that is, probably, because, although Einstein's second postulate might, somehow, satisfy theoretical physicists, it is not going to be enough, by itself, to deter the vast majority of experimental physicists from trying, over and over again, to outperform their predecessors, and to hone their technical skills, along with improving the efficiency of their lab instruments, at measuring the speed of light (c), in all possible scenarios, to such a degree that may well, end up toppling the second postulate of Herr Einstein, if there is, indeed, somewhere, something wrong with it.

And more importantly, the second postulate of Einstein's theory of special relativity — in accordance with which the speed of light (*c*), in a vacuum, has been presupposed to be always constant, for all light detectors, regardless of their motion, relative to the emitting body — is all but impossible to justify logically, mathematically, kinematically, dynamically, experimentally, or in any other scientific way. And so, obviously, it would be a great help, no doubt, if the 1967 CGPM microwave second of time (*s*), and the 1983 CGPM optical meter (*m*), were, anyhow, able, all by themselves, to turn, in a purely conventional manner, the speed of light (*c*), in a vacuum, into a physical constant.

But, no matter how many times one would like to wish both of them good luck, in such a tough assignment, the 1983 CGPM optical meter (*m*) and the 1967 CGPM microwave second of time (*s*) could never turn the speed of light (*c*), in a vacuum, into a physical constant, for the following reasons:

> A.) The distance covered by light rays, in the vacuum, during the duration of one 1967 CGPM microwave second of time (*s*) remains the same and exactly equal to the distance that had been covered by light rays, in the vacuum, during the duration of one solar second of time (*s*), in the days of young Albert Einstein at the Patent Office, in Bern, Switzerland.
>
> B.) The distance covered by light rays, in the vacuum, during the duration of 1/*299792458* of a microwave second of time (*s*) stays the same and precisely equal to the distance that was being measured, between the axes of the two central lines marked on a bar of platinum-iridium at *0*° Celsius, and kept at the International Bureau of Weights and Measures (*BIPM*), in Paris, during the initial formulation of Einstein's second postulate, in the city of Bern, Switzerland.
>
> C.) The speed of light rays *299792458* optical meter (m) per microwave second of time (*s*), in a vacuum, remains exactly the same and stays precisely equal to the speed of light rays *299792458 BIPM* meter (m) per solar second of time (*s*), just as it was during the time that

Albert Einstein spent, in Bern, Prague, and Berlin, along with the town of Princeton, as well.

All and all, if it was a non-starter and all but impossible, for Albert Einstein and his colleagues, to turn the speed of light (*c*), in a vacuum, into a physical constant, in a purely conventional way, through the employment of the BIPM meter (m) and the solar second of time (*s*), then it would, most certainly, be an entirely non-starter and all but impossible, for present-day physicists, to turn the very same speed of light (*c*), in a vacuum, into a physical constant, in a totally conventional manner, through the utilization of he 1983 CGPM optical meter (*m*) as well as the 1967 CGPM microwave second of time (*s*).

1. The Actual Value of Speed of Light:

Historically speaking, the last actual measurement of the speed of light (*c*) and, reportedly, the most accurate, so far, has been the one that was carried out, through the use of lasers, by Woods et al, in 1976 [*Ref. #12*]. According to their experimental report, the following actual value of the speed of light, in a vacuum, (*c*), was successfully measured:

$$c = 299792459 \pm 0.2 \text{ BIPM meter (m) per solar second (s)}$$

And therefore, the upper limit of the measured speed of light, in a vacuum, is (c_U):

$$c_U = 299792459.2 \text{ BIPM meter (m) per solar second (s)}$$

While the lower limit of the measured speed of light, in a vacuum, is (c_L):

$$c_L = 299792458.8 \text{ BIPM meter (m) per solar second (s)}$$

And since the CGPM adopted value for the speed of light (*c*), in the vacuum of space:

$$c = 299792458 \text{ optical meter (m) per microwave second (s)}$$

the CGPM value is less than the upper limit of the BIPM value by Δc_U:

$$\Delta c_U = (299792459.2) - (299792458) = 1.2 \text{ m/s}$$

On top of that, the same CGPM value is notably less than the lower limit of the BIPM value by Δc_L:

$$\Delta c_L = (299792458.8) - (299792458) = 0.8 \text{ m/s}$$

where, in both cases, it has been taken for granted that:

$$\frac{m}{s} = \frac{BIPM \text{ meter (m)}}{\text{solar second (s)}} = \frac{optical \text{ meter (m)}}{\text{microwave second (s)}}$$

Thus, the BIPM value of the speed of light, in a vacuum, as measured by Woods et al, has to be always greater than the official CGPM value of the speed of light, in a vacuum, by an amount of ≥ 0.8 m/s.

However, if the above assumption is discarded and explicitly dropped, then the official CGPM value of the speed of light, in a vacuum, can, from a purely algebraic standpoint, be either rendered equal to the upper limit of the BIPM value of the speed of light, in a vacuum, by explicitly making the following new assumption:

$$\frac{CGPM \text{ speed units}}{\text{BIMP speed units}} = \left[\frac{optical \text{ meter}}{\text{microwave second}}\right]\left[\frac{\text{solar second}}{\text{BIMP meter}}\right] = \left[\frac{299792458}{299792459.2}\right]$$

or it can be made equal to the lower limit of the BIPM value of the speed of light, in a vacuum, by explicitly making this other new assumption:

$$\frac{CGPM \text{ speed units}}{\text{BIMP speed units}} = \left[\frac{optical \text{ meter}}{\text{microwave second}}\right]\left[\frac{\text{solar second}}{\text{BIMP meter}}\right] = \left[\frac{299792458}{299792458.8}\right]$$

but not equal to both, at the same time.

In any event, what is the most unwelcome outcome — so to speak — for officially adopting, and arbitrarily imposing worldwide the CGPM numerical value as the final and exact numerical value of the intrinsic muzzle speed of light, in a vacuum, by the physics community?

Without a shadow of a doubt, one of the most negative consequences of embracing the official CGPM numerical value, as the final and precise value of the speed of light, in a vacuum, is the indefinite moratorium that has been willy-nilly imposed upon narrowing, through performing actual experiments, the published 1976 margin of error, in the reported measurements, by Woods et al [*Ref. #12*].

Also, the imposition of the official CGPM value, as the only permissible numerical value, for the speed of light, in the vacuum, can have potentially adverse effects, in certain fields, such as the field of interplanetary navigation, in which even the tiniest deviations of the officially adopted numerical value, from the true numerical value of the speed of light, in the vacuum, would lead, due to the vast distances involved, to numerous significant errors, in calculations as well as in measurements.

But probably, the immediate and most negative consequence of all, at physics laboratories, here, on Earth, for taking, at face value, the official CGPM numerical value of the speed of light, in the vacuum, is the inevitable corruption of ultraprecise computations and theoretical predictions, and having all ultraprecise experiments fundamentally undermined and badly undercut, long before they even start.

2. With Regard to Uniform Motion:

The CGPM definition of the optical meter requires necessarily that, during the entire process of measurements, the source of light, the light measuring device, and the measuring observer must remain at rest with respect to each other in the reference frame of the laboratory. And moreover, the distance covered by the light beam, during the duration of 1/*299792458* of a second, must be, from start to finish, in the vacuum. Otherwise, the specified procedures, for measuring the standard length of the CGPM meter, by optical means, would utterly fail to satisfy the following basic condition:

$$\frac{\text{standard length of CGPM meter}}{\text{standard length of BIMP meter}} = 1$$

upon which the CGPM definition of the optical meter has been implicitly based.

And most certainly, the CGPM procedures, for measuring the standard length of the optical meter, must break down, in the following situations:

1. If the distance traversed by the light beam, during the duration of 1/*299792458* of a second, is, from beginning to end,, in an optical medium whose refractive index is equal to *n*, then the measured actual length of the optical meter, in this special case, must be equal to (m_n):

   $$m_n = \frac{m_v}{n}$$

   where (m_v) is the length of optical meter in the vacuum.

2. If the source of the light beam is in uniform motion, relative to the reference frame of the laboratory, then the measured actual length of the optical meter, in this special case, must vary

with varying distance between the moving light source and the stationary laboratory.

3. Likewise, if the laboratory is in uniform motion, relative to the reference frame of the light source, then the measured actual length of the optical meter, in this case too, must vary with varying distance between the uniformly moving laboratory and the stationary light source.

4. If the measuring clock is in uniform motion, relative to the reference frame of the laboratory, then, in this particular case. the duration of 1/*299792458* of a second cannot be measured, due to the Doppler effect on the standard microwave frequency (f) of *9192631770* Hz, given off by the unperturbed transition between the two hyperfine levels of the ground state of cesium-33 atoms, in uniform motion, relative to the stationary laboratory.

5. Similarly, if the laboratory is in uniform motion, relative to the reference frame of the clock, then, in this case as well, the duration of 1/*299792458* of a second cannot be measured, due to the Doppler effect on the standard microwave frequency (f) of *9192631770* Hz, emitted by the unperturbed transition between the two hyperfine levels of the ground state of cesium-33 atoms at rest, relative to the uniformly moving laboratory.

However, in the special case, in which the light source, the measuring observer, the measuring instruments, and the laboratory are all moving uniformly, together, with the same speed in the same direction, any potentially adverse effects (if any) on the CGPM procedures, for measuring the standard length of the optical meter, are less obvious. And that is, clearly, because, in this particular case, the presence of any possible negative effects, on the measurements of the *CGPM* optical meter, depends, decidedly, upon the choice of the physical theory, within the theoretical framework of which the unknown adverse effects, at issue, have to be discovered and evaluated.

For instance, in accordance with the kinematics of Newton's ballistic theory, the Larmor-Lorentz theory, Einstein's special theory, and Ritz's new-source emission theory, and Stewart's elastic-impact emission theory, if the light source, the measuring observer, the measuring instruments, and the laboratory are all moving with the same speed in the same direction, then their collective motion would have no effect, negative or otherwise, upon the CGPM procedures, for measuring the standard length of the optical meter, as if the physics laboratory, in question, along with everything in the inside of it, is at absolute rest, relative to the free space of the universe.

By contrast, according to the kinematics of Huygens' stationary aether theory, Fresnel's partially dragged aether theory, and Maxwell's electromagnetic theory, the uniform linear motion of the light source, the measuring observer, the measuring instruments, and the laboratory, collectively, would, certainly, lead to negative second-order effects, on the CGPM procedures, for measuring the standard length of the optical meter, which can, in principle, be noted and measured, from inside the reference frame of the uniformly and linearly moving laboratory itself.

In short, unlike in the measurements of the length of the BIPM meter, the degree of accuracy, in the measurements of the length of the CGPM optical meter, in the special case in which the light source, the measuring observer, the measuring instruments, and the laboratory have all been assumed to be moving, together, with the same speed in the same direction, depends, to a large extent, on the selection of the physical theory, within the conceptual framework of which the explicitly specified steps of the CGPM procedures, for measuring the standard length of the optical meter, ought to be carried out.

3. Concerning the Effects of Acceleration:

As the Michelson-Gale experiment [*Ref. #13*] and similar experiments have clearly demonstrated, linear and angular accelerations, along with Coriolis force [*Ref. #14*], can produce significant effects on measurements, performed through the use of interferometers and other measuring instruments, on the surface of Earth. And subsequently, it's to be expected that the Coriolis effect as well as angular and linear accelerations would, most likely, have a noticeable and negative impact, on the CGPM procedures, for measuring the standard length of the optical meter, and possibly on the CGPM procedures, for measuring the standard duration of the microwave second of time, as well.

One specific type of acceleration, which may, well, adversely impact, simultaneously, both the standard length of the CGPM optical meter and the standard duration of the CGPM microwave second of time, in a potentially significant way, here, on the surface of the earth, is gravitational acceleration.

Among the pressing problems, posed by gravitational acceleration, in this regard, is the fact that the evaluation of its potentially negative effects, on the measurements of the standard length of the CGPM optical meter and the standard duration of the CGPM microwave second of time, requires, first of all, to pick out one single gravitational theory, from a list of several gravitational theories, and then to make an epistemologically somewhat less justifiable bet, on its topmost validity and reliability.

And so, the dependency of the CGPM operational procedures, upon the selection of the physical theory, is, undoubtedly, one of their major weakness. That is because the definitions and measurements of basic units, in physics, must be independent of any physical theory. Otherwise, the physical theories may, well, corrupt the whole verification process, and end up playing the role of verifying the physical measurements, instead of the physical measurements playing the role of verifying the computed predictions of those physical theories, as mandated, by the scientific method.

Notwithstanding the observation that physical theories, in general, treat the effects of gravitational acceleration, on ponderable bodies, to a high degree, in the same way, the calculated predictions, based on each physical theory, differ significantly, with regard to the effects of gravitation, on the speed, momentum, kinetic energy, wavelength, and frequency of light.

Take, for example, the effects of gravitational acceleration, on the frequencies of light, as computed in accordance with Newton's theory of gravity, as well as in accordance with Einstein's general theory of relativity, respectively.

According to Newton's universal law of gravitation, all computed changes, in the frequencies of light beams, propagating in gravitational fields, must be due to the motion of the emitting atoms themselves under the influence of gravity. And that is because, within the framework of this physical theory, the force of gravity can never change the emitted frequencies of the light beams, in question, per se, in any shape or form, at all.

In brief, on the basis of Newton's theory of gravity, the effects of gravitational acceleration, on the frequency of light are exactly the same as the effects of optical media, on the frequency of incident light, at whatever angle of incidence upon them. In other words, the effects of gravitational acceleration, on the frequency of light, must be always equal to nil. And consequently, gravitational acceleration, according to Newton's theory of gravity, would not produce any effect, to speak of, on the CGPM chosen frequency (*f*) of *9192631770* Hz of microwave radiation, for measuring the standard duration of the microwave second of time, as long as the source of the cesium-33 atoms ─ in their unperturbed transition between the two hyperfine levels of the ground state ─ continues to stay at rest, relative to the gravitational field, or to essentially take place, in regions outside the influence of any gravitational field, altogether.

However, if it happens that, during the time of emission, the source of the cesium-33 atoms is moving, in the direction of the gravitational field, then, the part of light, given off, at the end of the wave period (*T*), will move at a greater speed than the speed of the light part, which has been given off, by the same source of the cesium-33 atoms, at the start of the same wave period (*T*). And as a consequence, the CGPM standard frequency (*f*) of *9192631770* Hz of microwave radiation will continue to be shifted towards the blue end of the electromagnetic spectrum, in direct proportion to the length of the light path, inside as well as outside the gravitational field, indefinitely.

And conversely, if it just so happens that, during the time of emission, the source of the cesium-33 atoms is moving, in the opposite direction to that of the gravitational field, in question, then, the part of light, given off, at the start of the wave period (*T*), will move faster than the part of the light, given off, by the same source of the cesium-33 atoms, at the end of the same wave period (*T*). And as a result, the CGPM standard frequency (*f*) of *9192631770* Hz of microwave radiation will continue to be shifted towards the red end of the electromagnetic spectrum, in direct proportion to the length of the light path, inside as well as outside the gravitational field, indefinitely.

As a matter fact, the unlimited increase, in the amount of red shift, in direct proportion to the distance, between light sources and light receivers, in the frequencies of radiation, emitted by light sources moving, in the opposite direction to that of the gravitational field, is a testament to the extraordinary strength of the explanatory power of Newton's theory of gravity, and one of the main reasons why Newton's universal law of gravitation can, in principle, be used to easily explain away Hubble's law of cosmic redshift, naturally, and without having to resort to stretching the empty space of the universe — very much like the surfaces of inflating balloons — and similar physically unrealistic hypotheses.

By comparison, according to Einstein's general theory of relativity, all possible changes in the frequencies of light beams, traveling in gravitational fields, have to be always caused by the effects of gravitational potentials, upon the clock rates, at the locations of their sources receivers.

And since, as calculated within the framework of this particular physical theory, the clock rate runs slower at lower gravitational potentials, and faster at higher gravitational potentials, the frequencies of light rays, emitted by sources, located at lower gravitational potentials, in the direction of light receivers, located at higher gravitational potentials, ought to be always shifted towards the red end of the electromagnetic spectrum.

And inversely, the frequencies of light rays, emitted by sources located at higher gravitational potentials, in the direction of light receivers, located at lower gravitational potentials, must be always shifted towards the blue end of the electromagnetic spectrum.

However, outside of the gravitational field, Einstein's theory of general relativity — unlike Newton's theory of gravity — does not predict any changes, in the frequencies of light rays, directly or indirectly proportional to the distance between the light source and the light detector. And for this specific reason, its calculated predictions, concerning the gravitationally shifted frequencies of light cannot be utilized in explaining away Hubble's law of cosmic redshift.

But, for all that, the computed amounts of gravitational shifting of light frequencies, on the basis of Einstein's general theory of relativity, are, obviously, more than enough to mess up and completely ruin the CGPM standard frequency (*f*) of *9192631770* Hz of microwave radiation, for measuring the duration of the microwave second of time.

All in all, the aforementioned dependency of the CGPM operational procedures, for measuring the standard length of the CGPM optical meter as well as the standard duration of the CGPM microwave second of time, upon the selected physical theory, is, demonstrably, the most unsatisfactory feature of the whole CGPM operational toolkit, from beginning to end.

4. On the CGPM Speed of Light:

One of the crucial questions, which has to be addressed and fully dealt with, here, is this:

Is it theoretically and practically possible that defining the standard length of the CGPM optical meter ─ as the length of the path traveled by light in a vacuum during an interval of time equals to *1/299792458* of a second, as well as defining the standard duration of the CGPM microwave second of time, in terms of the frequency (*f*) of *9192631770* Hz of microwave radiation, induced by the unperturbed transition between the two hyperfine levels of the ground state of the cesium-33 atom ─ can, in principle, permanently conceal all potential variations, in the numerical value of the speed of light, in a vacuum, and turn it, for all intents and purposes, into an unchanging physical constant?

It goes without saying that the answer to the above question would depend, of course, on what type of the speed of light is being investigated theoretically and measured, somehow, in the lab:

A. The Intrinsic Muzzle Speed of Light:

As mentioned, earlier in the current discussion, although it has been deemed, generally, to be constant, the intrinsic speed of light, nevertheless, is defined differently, by various physical theories. For instance, Maxwell's electromagnetic theory considers the value of the intrinsic muzzle speed of light to be always constant, with respect to the luminiferous aether. While, at the same time, Newton's ballistic theory regards the numerical value of the intrinsic muzzle of light to be constant only, with reference to the emitting body, during the time of emission. And by contrast, Einstein's special theory of relativity postulates that the intrinsic muzzle speed of light, in the vacuum, is the one and only speed that light rays, traveling in a vacuum, can have; and hence, it must have the same numerical value, for all observers, regardless of their speeds, relative to any of the infinite number of emitting sources.

Let's assume, for a moment, that the actual numerical value of the intrinsic speed of light, as dictated by nature itself, is greater, by an amount equal to *10* m/s, than its CGPM value of *299792458* m/s.

Within the framework of each one of the three physical theories, above, is it feasible that, in practice, experimental physicists would, actually, be able to notice the discrepancy between the presupposed

CGMP numerical value and the true numerical value of the intrinsic muzzle speed of light, in the lab?

Obviously, it all hinges upon how wide the scope of the investigation, conducted by those experimental physicists in the lab, really is. If, for example, the only objective is to measure the travel time of the experimental beam, by using clocks, and then multiplying the measured duration, by the CGPM value of *299792458* m/s, then, highly likely, the experimental physicists, in this case, are not going to notice any discrepancy, at all; regardless of how large the amount of the travel time of the experimental light beam, as measured in the reference frame of the physics laboratory, actually is. And that is because, in most settings, variations, in the numerical value of the intrinsic speed of light can have no noticeable effect, on the CGPM frequency (*f*) of *9192631770* Hz, given off during the unperturbed transition between the two hyperfine levels of the ground state of the cesium-33 atom. This is on one hand.

On the other hand, if the scope of the investigation, in question, includes checking for the amounts of momentum and kinetic energy, in addition to measuring the duration of the experimental beam, then, in the given case, the experimental physicists would, certainly, notice that the amounts of kinetic energy and momentum, for the experimental light beam, as measured in the physics laboratory's frame of reference, are definitely greater than the computed amounts of momentum and kinetic energy, on the basis of each physical theory, through the use of the presupposed CGPM numerical value of *299792458* m/s, for the intrinsic muzzle speed of light, relative to the luminiferous aether, relative to the emitting body at the time emission, and relative to all observers in the vacuum, respectively.

And finally, Let's assume, as before, that the actual numerical value of the intrinsic speed of light, as laid down by nature itself, is greater, by an amount equal to *10* m/s, than its CGPM value of *299792458* m/s; but, this time around, the distance (*d*), over which the experimental beam flies from Point A to Point B, is predetermined and known to the desired number of decimals, beforehand.

Is it realistic, in such a case, to expect that the experimental physicists would spot the discrepancy between the presupposed CGMP numerical value and the real numerical value of the intrinsic speed of light, as measured in the frame of reference, in which the physics laboratory is at rest?

Notwithstanding the fact that the given distance (*d*) must been measured by employing the standard length of the CGMP optical meter, the experimental physicists would, for sure, detect the hidden discrepancy, between the presupposed CGPM numerical value and the real numerical value of the intrinsic muzzle speed of light, by simply executing the following few steps in the right order:

- Calculate the flight time (t) of the experimental beam, from Point A to Point B, on the assumption that the CGPM speed value of *299792458* m/s holds true:

$$t = \frac{d}{c} = \left[\frac{d}{299792458}\right] \text{seconds}$$

- Use the lab clock to measure the flight time (t_{lab}) of the experimental beam, from Point A to Point B, over the predetermined distance (*d*), as many times as necessary.

- If everything has been done properly, the discrepancy, in question, should be noticed:

$$t_{lab} = \left[\frac{d}{299792468} \right] \text{ seconds}$$

- And it follows, therefore, that the ensuing mathematical relationship:

$$t > t_{lab} \Leftrightarrow c < c_{lab}$$

can be, experimentally, demonstrated and fully verified to be true, even if the standard length of the CGPM optical meter and the standard duration of the CGPM microwave second of time have been taken for granted, right from the very beginning.

B. The Relative Speed of Light:

The relative speed of light is the numerical magnitude of the vector sum of the intrinsic muzzle velocity (c) of incident light, and the velocity (v_o) of the measuring observer, at the time of reception, with respect to the reference frame, in which the observer is at rest. And although it appears mathematically to be almost identical to the ballistic speed of light — the numerical magnitude of the vector sum of the intrinsic muzzle velocity (c) of emitted light, and the velocity (v_s) of the light source, at the time of emission, as measured in the reference frame, in which the observer is at rest — the relative speed of light is kinematically quite different from the ballistic speed of light in two important respects:

1. The ballistic speed of light, in accordance with ballistic and emission theories, is the actual speed, at which light rays travel, relative to the vacuum of space, and which can be observed as well as measured, in any frame of reference. While, by contrast, the relative speed of light, according to all physical theories, can be observed and measured only in the reference frame, in which the measuring observer is at rest.

2. The ballistic speed of light can be defined and calculated only, within the framework of ballistic and emission theories of light. While the relative speed of light, by comparison, can be defined and worked out, within the conceptual framework of all physical theories, including the framework of Einstein's special relativity which does not, explicitly acknowledge, in a straightforward manner, the notion of relative speed of light, despite its extensive deployment of the concept of the displacement of light, upon which the notion of the relative speed of light has been founded, right from the start.

And so, now, what kinds of potential effects, if any, can the relative speed of light, as already defined above, possibly have on the aforementioned CGPM measurements?

First and foremost, since the CGPM operational procedures have specified, explicitly, that the source of the experimental light beams, the source of the cesium-33 atoms, and the measuring observer must be at rest, together, in the reference frame of the physics laboratory, throughout the entire process of measuring the standard length of the CGPM optical meter, and the standard duration of the CGPM microwave second of the time, all potential effects of the relative speed of light, on that process, are non-existent and automatically excluded, by definition.

Nonetheless, when it comes to measuring the relative speed of light itself, the CGPM operational procedures are evidently powerless to hide, from the prying eyes of measuring observers, in any conceivable way, its potentially adverse and significant effects.

Assume, for example, that an observer at rest, in the reference frame of the physics laboratory, is approaching directly the incident light rays, at a uniform linear speed (v_o) greater than zero. And simultaneously those light rays are flying,directly, over a predetermined distance (**d**), towards the same measuring observer, during the time of reception.

Since the relative speed of light, in this case, is equal equal to ($c + v_o$), the displacement formula is as follows:

$$d = ct - v_o t$$

where (t) stands for the flight time over the distance (d), in accordance with all physical theories.

And so, it's practically possible, in the lab, for the measuring observer to easily take note of the implied discrepancy, by simply comparing the measured flight time of the light rays, over the distance (d):

$$t = \frac{d}{c + v_o}$$

to the calculated flight time (t_{cal}) of the light rays, over the distance (d)

$$t_{cal} = \frac{d}{c}$$

in order to reach the conclusion that the following mathematical relationship:

$$t < t_{cal} \Leftrightarrow \left(c + v_o\right) > c$$

has been, indeed, experimentally verified and shown to hold good.

C. The Ballistic Speed of Light:

As pointed out, above, the ballistic speed of light (c_{bal}), within the context of ballistic and emission theories of light, is, always, equal to the numerical magnitude of the vector sum of the intrinsic muzzle velocity of light (c) and the velocity (v_s) of the light source, during the time of emission.

The ballistic speed (c_{bal}) of light can be computed, in the reference frame of the light source, through the use of the following mathematical equation:

$$c_{bal} = \sqrt{c^2 + v_s^2 + 2cv_s \cos(\phi)}$$

where (ϕ} denotes the angle between the two vectors (c) and (v_s), as measured in the reference frame of the light source.

With respect to the reference frame, in which the measuring observer is at rest, the ballistic speed of light can be readily obtained, by using this specific mathematical formula:

$$c_{bal} = \left(\sqrt{1 - \frac{v_s^2}{c^2} \sin^2(i)} \right) + v_s \cos(i)$$

where (i) stands for the angle between the observer's line of sight and the velocity vector (v_s), as measured in the frame of reference, in which the measuring observer is at rest.

As in the case of relative speed of light, the ballistic speed (c_{bal}) of light can have no noticeable effects on the specified CGPM operational procedures, for measuring the standard length of the optical meter, and the standard duration of the microwave second of time.

But, it is, clearly, going to be a foregone conclusion, however, that the CGPM operational procedures cannot, in practice, conceal, directly or indirectly, from the measuring observer, any of the possibly significant effects, due to the ballistic speed (c_{bal}) of light, per se.

Suppose, for instance, that light rays ─ given off by an emitting body approaching directly with a linear uniform speed (v_s) greater than nil, during the time of emission ─ are flying, over a predetermined distance (**d**) that has been measured to the desired precision in advance, towards the reference frame of the physics laboratory, in which the measuring observer is at rest.

Since the incident light rays have been emitted by a light source approaching directly with the speed (v_s) the stationary observer, during the emission process, their ballistic ballistic speed (c_{bal}) can be computed through the employment of the following mathematical formula:

$$c_{bal} = c + v_s$$

And subsequently, the measuring observer can easily discover the implied discrepancy, by merely comparing the measured flight time of the light rays, over the distance (*d*):

$$t = \frac{d}{c_{bal}} = \frac{d}{c + v_s}$$

to the computed flight time (t_{cal}) of the light rays, over the distance (*d*)

$$t_{cal} = \frac{d}{c}$$

in order to find out that the following mathematical relationship:

$$t < t_{cal} \Leftrightarrow c_{bal} > c$$

has been, indeed, experimentally demonstrated to be true.

D. The Speed of Light in Dispersive Media:

Since the early years of the twenty-first century, many experiments have demonstrated, time and time again, that experimental light beams can, with relative ease, travel ─ within the boundaries of artificially prepared dispersive optical media─ at numerical speed values much greater than the numerical value of the intrinsic muzzle speed (*c*) of light, in empty space.

But, regardless of how many hypotheses have been proposed, over the years, in order to explain away those experimentally verified superluminal speeds of light, and to anyhow save the deeply entrenched notion of the unchanging and constant speed of light, the fanciful supposition of turning each and every superluminal speed, in question, into a physical constant ─ through the application of the CGPM convention ─ is, definitely, not among them. Otherwise, such extremely high speeds of light would have never been observed, after the year 1983, to begin with, in the first place.

In point of fact, the aforementioned CGPM convention, regarding the optical meter and the microwave second of the time, cannot conceal, from measuring observers, speeds higher than the muzzle speed of light (*c*), in free space, even within the boundaries of regular dispersive media, such as the optical medium of air, under normal conditions, at sea level.

For instance, if an optical medium is assumed to be in uniform linear motion, relative to the frame of reference, in which the measuring observer is at rest, as in the widely published case of the Fizeau experiment [*Ref. #15*], then the speed of incident light rays, emitted by a stationary source of light, in the laboratory, as measured by the observer, can be computed by using the Fresnel equation, below:

$$c' = \frac{c}{n'} = \left(\frac{c}{n}\right) \pm v\left(1 - \frac{1}{n^2}\right)$$

where (c') is the speed of the light rays, as measured in the laboratory; (n') is the refractive index of the moving optical medium; (n) is the refractive index of the same optical medium, when it's at rest, relative to the same laboratory; and (v) is the speed of the optical medium, relative to the frame of reference of the laboratory, in which the measuring observer is at rest.

And so, if it assumed, as a given, the following set of data:

$$n = 1.0003$$
$$v = 0.9c$$
$$c = 299792458 \text{ m/s}$$

it can be readily seen that light rays traveling in the same direction, inside the optical medium of air, under normal conditions, at sea level, do, indeed, achieve a superluminal speed {c'}, with respect to the stationary observer, in the reference frame of the laboratory:

$$c' = 299864362.34271086 \text{ m/s}$$
$$\text{c}' \approx (1.00023985) \times c$$

That is despite the fact that the basic speed unit, for the two given speeds (c & v), above, is composed of the CGMP optical meter, and the CGMP microwave second of time, respectively.

5. Concluding Remarks:

It is worth mentioning, within the present context, that the standard length of the CGPM optical meter is precisely equivalent to the wavelength of the microwave ─ classified as an ultra high frequency (UHF) ─ and which the numerical value of its frequency (f) is equal to (*299792458 Hz*) [*Ref. #10-b*].

However, even though the simple mathematical relation, below:

$$\lambda = \frac{c}{f} = \frac{299792458}{299792458} = 1$$

does produce a numerical result equal to (*1*), it is not possible to determine or to somehow manage to know what the basic unit, for the wavelength (λ), could be, unless both the length of the CGMP optical meter, and the duration of the CGMP microwave second of time, have been both predefined, prior to carrying out the calculations and the measurements.

And moreover, in accordance with the above mathematical relationship, the numerical value of the computed wavelength (λ) of the ultra-high-frequency microwave, in question, varies, in direct proportion to the numerical value of the intrinsic muzzle speed of light (c), in empty space, While, at the same time, the numerical value of the given frequency (f) of (*299792458 Hz*) remains unchanged and constant, regardless of any variations, in the numerical value of the muzzle speed of light (c).

In other words, if the numerical value of the muzzle speed of light (c) lies, somewhere, within the numerical range, below:

$$0 < c < \infty$$

the numerical value of the ultra high frequency (UHF) of the microwave:

$$f = 299792458 \quad \text{Hz}$$

would stay unchanged and exactly the same. But, at the same time, the numerical value of the wavelength (λ) of the same ultra-high-frequency microwave would lie, somewhere, within the very same numerical range, between zero and infinity.

Now, beside the aforementioned uncertainy, in the last measurements, performed by Woods et al, in 1976 [*Ref. #12*], is there any realistic scenario, in which the intrinsic muzzle speed of light (c), in free space, might vary and have any numerical value, between zero and infinity, without altering the numerical value of the frequency (f), as outlined above?

Assuming that the definition of the vacuum of space does not, necessarily, exclude gravitational fields, it is quite possible, within the framework of Newton's ballistic theory, for the intrinsic muzzle speed of light (c), to have any numerical value, between zero and infinity, without changing, in any way, the given numerical value of the frequency (f) of light, in these two major cases:

- If the light beam spends an interval of time (t) to traverse a uniform gravitational field whose acceleration is equal to (g), before reaching the measuring observer, then the instantaneous muzzle speed of light (c'), as measured in the reference frame of the observer, can be calculated by using the following mathematical formula:

$$c' = c \pm gt$$

depending on the direction of the velocity vector (*c*), with respect to the acceleration vector (*g*).

- If the light beam traverses a distance (*d*) in a uniform gravitational field whose acceleration is equal to (g), before reaching the measuring observer, then the instantaneous muzzle speed of light (*c′*), as measured in the reference frame of the observer, can be calculated by using the following mathematical formula:

$$c' = \sqrt{c^2 \pm 2gd}$$

depending upon the direction of the vector (*c*), with respect to the vector (*g*).

It can be concluded, therefore, that, in accordance with Newton's ballistic theory of light, gravitational fields, in general, can significantly change the numerical value of the intrinsic muzzle speed of light (*c′*), in empty space, along with the wavelength of light(λ). But, at the same time, gravitational fields can have no effect whatsoever, on the numerical value of the frequency of light (*f*), in free space.

By comparison, according to Einstein's general theory of relativity, gravitational fields, generally, can produce significant effects upon the numerical value of the frequency of light (*f*) and the wavelength of light(λ). in empty space. However, on the basis of this particular theory, gravitational fields cannot produce any effect, at all, on the numerical value of the intrinsic muzzle speed of light (*c*), in the vacuum of physical space [*Ref. #16*].

And so, in the final analysis, the CGMP procedures, for measuring the standard length of the optical meter, would not work properly, within the framework of Newton's ballistic theory, if gravitational fields are present, in empty space. Although, by virtue of the fact that, based on this physical theory, gravitational fields produce no effect, to speak of, upon the numerical value of the frequency of light (*f*), in empty space, the CGMP procedures, for measuring the standard duration of the microwave second of time, are going work just fine. That is on one hand.

On the other hand, the CGMP procedures, for measuring the standard length of the optical meter, as well as the CGMP procedures, for measuring the standard duration of the microwave second of time are not going to function properly, at all, within the framework of Einstein's general theory of relativity, whenever gravitational fields are at work, in the vacuum of empty space. That is because both the frequency (*f*) and the wavelength (λ) change, together, under the sway of gravity, at the same time. And more specifically, within the framework of Einstein's general theory of relativity, in the case, under discussion, dividing the intrinsic speed of light (*c*), in the vacuum of free space, by the frequency (*f*) of the ultra-high-frequency (UHF) microwave, fails, necessarily, to render the wavelength (λ) of the same microwave exactly equal to one CGPM optical meter; i.e.,

$$\lambda = \frac{c}{f} = \frac{299792458}{f} \neq 1$$

In conclusion, therefore, it's neither feasible in practice, nor permissible in theory, for physicists to be, somehow, able to turn, by the sheer force of will power, the intrinsic muzzle light speed of [*299792458 ms-*^{1}], in the void of free space, into a physical constant, through the mere employment of the CGMP procedures, for measuring the standard length of the optical meter, and the standard duration of the microwave second of time, in physics laboratories, around the world.

REFERENCES:

1. ***Stenger, V.,***
   "Is the Speed of Light Variable?"

2. ***Gibson, P.,***
   "*Relativity- the Special and the General*"

3. ***Proceedings of the 19th IEE***,
   "Absence of Transverse Doppler Shift at Microwave Frequencies"

4. ***Valigra, L.,***
   "*Faster than the Speed of Light*"

5. ***Thevenaz, L, et al,***
   "*Light that travels…faster than light*"

6. ***Choi, C.,***
   "*Speed of light broken with basic lab kit*"

7. ***Historical context of the SI***:
   "Unit of length (meter)"

8. ***Gibbs, P.,***
   "How is the speed of light measured?"

9. ***Britannica:***
   "Second (unit of time)"

10. ***Wikipedia:***
    a) "Second" & *b)* "Electromagnetic spectrum"

11. ***SI Brochure:***
    "The International System of Units (SI)"

12. ***The University of Oklahoma:***
    "History of the Speed of Light (c)"

13. ***Doug Marett:***
"The Michelson-Gale Experiment"

14. ***UBC Department of Physics:***
"UNDERSTANDING THE CORIOLIS FORCE"

15. ***Fizeau, H.;***
"On the Effect of the Motion of a Body upon the Velocity with which it is Traversed by Light"

16. ***Phys. Rev. Focus 16, 1:***
"The Weight of Light"

Related Papers:

A. ***Effect of Reflection from Revolving Mirrors on the Speed of Light:***
A Brief Review of Michelson's 1913 Experiment

B. ***Doppler Effect on Light Reflected from Revolving Mirrors:***
A Brief Review of Majorana's 1918 Experiment

C. ***Absolute Velocities:***
The Detailed Predictions of the Emission Theory of Light

D. ***Restricted Relativity:***
A Detailed Account of the Main Objections

E. ***The Double-Star Experiment:***
A Comprehensive Review of de Sitter's 1913 Demonstration

F. ***Doppler Effect on Durations of Events:***
A Detailed Account of Undulatory and Ballistic Predictions

G. ***The Infinite Universe::***
The Best of All Viable Cosmological Models