Relativity Theory Based on the Uniform Scaling of Physical Properties

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I. INTRODUCTION

The Laws of Physics are not derived from so-called "First Principles," but rather they are the result of efforts to consolidate experimental findings that have been compiled over an extended period of time on a certain subject. One of the prime examples is the conservation of energy. In this case, it was first necessary to clearly define what exactly constitutes "energy." What one must understand is that the word "law" does not mean that it must be obeyed, unlike an ordinance of a municipality or state, for example. Rather, a physical law can be viewed as a *challenge* to scientists to find a clear exception to it. The goal is therefore to cover an ever larger field of observations to which it applies under possibly widened conditions.

In the case of the property of energy, a key development was Joule's discovery of the quantitative equivalence of the heat of an object and the kinetic energy associated with its motion through space; the resulting combination ultimately became the First Law of Thermodynamics. History is filled with attempts to find exceptions to the law of energy conservation. They were not always made in good faith, especially since such a discovery would clearly have opened the way toward unlimited monetary advantages. The important point is that no confirmed evidence of this kind has ever been found.

Energy is a complicated quantity, however. One can imagine that ancients first arrived at the general idea of quantitative measurement based on their desire to compare the lengths of objects or the distances between different locations. This possibility became important in commercial trade. Especially in this regard, it was essential that such measurements could be carried out on a purely objective basis so as to avoid as far as possible disputes between buyer and seller. Because there were disparate groups involved in comparing their measurements of the same quantity, it was unavoidable to introduce different *units* of distance to aid in such comparisons.

Knowledge of the basic principles of arithmetic therefore became essential. It seems inevitable that a common principle would evolve according to which a *conversion factor* would be agreed upon that connected the values of a given length obtained by any two salesmen. It is clear that the value of this factor had to be independent of the object of measurement to be mutually acceptable.

One can look upon this experience as the development of a *law of physics* which can be referred to as the Principle of Rational Measurement (PRM). Accordingly, the only way that two people could legitimately disagree on the length of any object is if they employed different units in which to express their numerical values. It was found that the same argument could be applied to measurements of area and volume, in which case the implicit assumption is that we live in a fundamentally three-dimensional environment. The concept of *vector addition* of distances is also essential for this purpose since measurements of large quantities had to be made piecewise by laying some standard length end-to-end over the entire object and adding the results to obtain a total value. The triangulation procedure was invented to deal with the extremely large distances separating positions in different localities and ultimately also for astronomical objects that couldn't be reached directly.

It is not difficult to imagine how a unit of time comparable to that of distance came into play. The regular occurrence of events such as high noon and the four seasons provided clear timing units which could easily be agreed upon in different localities. Dates of birth and death could be conveniently recorded in terms of such frequency units. Unlike lengths, it is clear that time is a scalar quantity; no need for vector addition in this case. It also needs to be emphasized that time was considered to be a completely distinct quantity from distance. The apparatus used to measure each of them is qualitatively different (clocks and measuring sticks), so there was no reason to think of them as somehow interrelated. This situation is worth mentioning in the present context in which theoretical physicists look at *space-time* as a single entity.

The ratio of a given distance traversed by an object in a given amount of time gave a measure of its speed. Ratios of changes in speed over an elapsed time also became of interest. The concept of continuous motion presented some philosophical problems that were not readily understood. The bias of church dogma also reared its ugly head in such discussions. This was particularly true when attention was turned to the motion of extra-terrestrial objects such as the sun, moon and planets. It is at this point that the science of relativity got its start. Copernicus and others had concluded that the earth is not stationary but rather follows an elliptical path around the sun. In the early 17th century, Galileo[1] developed a telescope which was capable of following the trajectories of astronomical objects. He concluded that the earth was in continuous motion around the sun.

His faith in the theory probably received a jolt when he did some calculations, however. The average distance of the earth from the sun was already quite well known at this time and, of course, the elapsed time for a complete revolution was assumed to be one year, which is equal to 365.25 days = $3{,}156 \times 10^7$ s. On this basis, one finds that the speed of the earth as it travels in its orbit around the sun is 30 kms^{-1}, which is a tremendously large value even by today's standards. Given the skepticism of Galileo's contemporaries, it is not difficult to understand that he felt a compelling need to find a plausible explanation for the fact that such a large speed goes unnoticed in our everyday life, both then and now.

What he did was to imagine a boat with all its passengers captured below deck so that they could not see anything of its surrpundings.[2] He conjured up experiments with various animals which could be carried out inside the deck He then argued that there would be no way for the passengers to detect any difference from the results of their experiments which would distinguish between whether the boat was still at the original dock or instead was sailing along at high speed on a perfectly calm sea. This was pure conjecture on Galileo's part but he managed to make the scene plausible enough to convince many of his most devoted contemporaries. In more modern terms, his theory was that the laws of physics are the same in all *inertial systems*, that is, environments which are not disturbed in any way by unbalanced external forces.

The Relativity Principle (RP) is itself a *law of physics*. It is not derived on the basis of some "First Principles," but rather is a summary of past experimental results which is not in any way in conflict with observation. Just as the Conservation of Energy Principle, it presents a challenge to scientists to find a legitimate exception to it. More than this, it presents an opportunity to find new laws which are consistent with this theory of natural processes.

Keywords: *Clocks, Conservation of Energy, Conversion factors, Copernicus, First Law of Thermodynamics , First Principles, Galileo, Galileo's Ship, Inertial Systems, Laws of Physics, Length measurements, Objectivity of measurement, Principle of Rational Measurement (PRM), Relativity Principle (RP), Space-time, Units of properties, Vector addition*

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II. VELOCITY TRANSFORMATIONS

One of the earliest laws of physics deals with the combination of velocities. As a simple example, consider the case of a car leaving the origin of the coordinate system with speed v in the x direction. The driver reports that there is a train moving at speed w relative to him in the same direction. The speed of the train relative to the origin can then be assumed to have a value of v+w, that is, the sum of the other two speeds. The above law is generally referred to as the Galilean velocity transformation (GVT), but it is quite doubtful that it is due to Galileo. In more traditional mathematical terms, it is simply an application of *vector addition*, in this case of speeds.

There was confusion among physicists in the latter half of the 19th century, however, because of their inability to explain the results of a number of experiments that had been recently carried out with light waves.[1] It had started with the Fresnel light-drag experiment, which not only showed that light is slowed as it moves through a transparent medium but, by extrapolation of the value of the medium's refractive index n to a unit value, that the observed light speed in the laboratory should be completely independent of the speed v of the medium in the limit of free space [$c(v) = c$]. Maxwell's theory of electricity and magnetism published in 1864 also indicated that the speed of light had the same constant value c in each rest frame in which it is observed. This result was clearly at odds with the traditional application of the GVT which indicates that speeds should be additive and therefore that $c + v \neq c$. This led to a frantic search for an "ether" which serves as a rest frame for the light waves analogous to that known for sound waves. Michelson and Morley[2] used their newly developed interferometer to test this theory, but it merely verified the conclusion that the speed of light is independent of the rest frame through which it moves, in particular that it is directionally independent at all times of the year.

Voigt[3,4] then stepped into the fray with what in retrospect must be seen as both a daring and ingenious proposition. He speculated in 1887 that the problem lay with the Galilean transformation itself. He attempted to resolve the issue by using nothing more than a free parameter and a little algebra. The resulting transformation was ultimately rejected on other physical grounds, namely it violates Galileo's RP, but it is nonetheless deserving of more than just a footnote in history. This is because it introduced for the first time the concept of *space-time mixing,* which remains to the present day to be a dogmatic principle of theoretical physics. It contradicts one of Newton's[5] most cherished beliefs, which held sway with the physics community for several centuries, namely that space and time are completely separate entities, one measured with a yardstick and the other with a clock. The consequences of this aspect of Voigt's conjecture will be discussed in the following.

A. Derivation of the Voigt transformation

The starting point of Voigt's derivation is the classical or Galilean transformation (GT). It relates the measured values of space (x,y,z) and time (t) for a given object obtained by two observers in relative motion to one another. It is assumed that the two observers are separating with constant speed v along the common x,x' axis of the their respective coordinate systems. The relationship between their measured values is given below in terms of their respective coordinates, x,y,z,t and x',y',z',t', whereby it is assumed that the two systems are coincident at t=t'=0.

$$t' = t \tag{II-1a}$$

$$x' = x - vt \tag{II-1b}$$

$$y' = y \tag{II-1c}$$

$$z' = z . \tag{II-1d}$$

By construction, the velocity of the object in each coordinate system is obtained by division of the respective space and time coordinates at any instant. Using eqs. (II-1a-b), one therefore obtains the key relationship between the measured speeds of the object when it moves along the x,x' axis:

$$\frac{x'}{t'} = u'_x = \frac{x}{t} - v = u_x - v\,. \tag{II-2}$$

There is thus a linear relation connecting the two values of the speed of the object. More generally, the GT predicts that the corresponding velocities u and u' are related by vector addition when the object travels in a direction which is not parallel to the separation velocity of the two observers. Voigt[3] introduced a free parameter a into eq. (II-1a:

$$t' = t + ax\,. \tag{II-3}$$

Combining this relation with eq. (II-1b) of the GT[4], one concludes that $a = -vc^{-2}$ in eq. (II-3).

The above derivation can be extended to apply to motion of the light waves in an arbitrary direction by assuming instead of eqs. (II-1c-d) that $y' = \gamma^{-1}y$ and $z' = \gamma^{-1}z$ [$\gamma=(1-v^2c^{-2})^{-0.5}$]. The corresponding transformation is thus:

$$t' = t - vc^{-2}x \tag{II-4a}$$

$$x' = x - vt \tag{II-4b,II-1b}$$

$$y' = \gamma^{-1}y \tag{II-4c}$$

$$z' = \gamma^{-1}z\,. \tag{II-4d}$$

It can be seen that this set of equations reduces to the GT of eqs. (II-1a-d) in the limit of null relative velocity of the two observers, i.e. if we ignore the fact that the equations are useless in this case (with $v = 0$)[4]. More significant is the fact that the same equations reduce to the GT when c is assumed to have an infinite value. One can say then without qualification that the classical transformation (GT) contains the implicit assumption that the speed of light is infinite. This is a moot point, however, since the value of c has been determined to be 299792458 ms^{-1}.

B. Taking the Relativity Principle into Account

The space-time transformation that Voigt[3] presented is successful in satisfying the light-speed constancy condition, but it fails on other grounds. This can be seen by evaluating the inverse transformation, obtained by Gauss elimination from eqs. (II-4a-d). According to Galileo's RP, the inverse transformation should be obtained by simply exchanging the primed and un-primed subscripts in the forward set of equations and substituting −v for v. This is a mathematical procedure that mimics the situation when the observers change positions; it will be referred to as *Galilean inversion* in the following. It is easily shown that the inverse of eqs. (II-4a-d) does not satisfy this requirement, however. For example, if the inverse equation for y' is applied to eq. (II-4c), the result is $y' = \gamma^{-2} y'$, an obviously unacceptable relationship. This proves that the Voigt transformation is not consistent with the RP and thus must be rejected as a physically valid set of equations.

It is nonetheless a simple matter to modify the transformation in a way which satisfies both the RP and the light-speed constancy condition. Before doing this, it is helpful to make a change in variables to *intervals* for two different events: $\Delta x = x_2 - x_1$, $\Delta x' = x_2' - x_1'$ etc. This change allows each observer to choose his own coordinate system without the necessity of having it coincide at some point with the other coordinate system. Intervals are of course required in order to compute speeds, which remains the center of attention in this discussion. The Voigt transformation thus becomes:

$$\Delta t' = \Delta t - vc^{-2} \Delta x \qquad \text{(II-5a)}$$

$$\Delta x' = \Delta x - v\Delta t \tag{II-5b}$$

$$\Delta y' = \gamma^{-1}\Delta y \tag{II-5c}$$

$$\Delta z' = \gamma^{-1}\Delta z\,. \tag{II-5d}$$

When the above equations are used to form the following linear combination of squared quantities, the result is:

$$\Delta x'^2 + \Delta y'^2 + \Delta z'^2 - c^2\Delta t'^2 = \gamma^{-2}\left(\Delta x^2 + \Delta y^2 + \Delta z^2 - c^2\Delta t^2\right). \tag{II-6}$$

In order for eq. (II-6) to hold, it is necessary that both observers measure the speed of light to be equal to c so that both sides of the equation vanish in this case. This shows that Voigt's goal is achieved by the transformation in eqs. (II-5a-d). It is also clear that if each of the right-hand sides of the four equations is multiplied by the factor ε, the same objective is satisfied. The factor in eq. (II-6) simply becomes $(\varepsilon\gamma^{-1})^2$ and therefore this change does not alter the conclusion regarding light-speed constancy.

This circumstance thus opens up the possibility of eliminating the problem with the RP without changing the condition for the two measured values of the light speed. Lorentz[6] made this observation for a different reason, namely to define a space-time transformation that allows the electromagnetism equations to be invariant while also insuring that the RP be satisfied. Both Larmor[7] and Lorentz[8] realized at about the same time that this goal can be achieved by using the factor $\varepsilon=\gamma$ (v) to modify the Voigt transformation in this manner. The resulting set of equations is known as the Lorentz transformation (LT) and is given below $[\eta = (1-vc^{-2}\Delta x/\Delta t)^{-1}]$:

$$\Delta t' = \gamma\left(\Delta t - vc^{-2}\Delta x\right) = \gamma\eta^{-1}\Delta t \tag{II-7a}$$

$$\Delta x' = \gamma\left(\Delta x - v\Delta t\right) \tag{II-7b}$$

$$\Delta y' = \Delta y \tag{II-7c}$$

$$\Delta z' = \Delta z \,. \tag{II-7d}$$

It is obvious that the inverse of eqs. (II-7c,d) is achieved by application of Galilean inversion.

In order to achieve the corresponding results for the inverse of eqs. (II-7a,b), it is helpful to derive the following identity:[9] $\eta\eta' = \gamma^2$ [note that $\eta' = (1 + vc^{-2}\Delta x'/\Delta t')^{-1}$ is obtained by applying Galilean inversion to η]:

$$(\eta\eta')^{-1} = \left(1 - \frac{v\Delta x}{c^2\Delta t}\right)\left(1 + \frac{v\Delta x'}{c^2\Delta t'}\right) = \left(1 - \frac{v\Delta x}{c^2\Delta t}\right)\left[1 + \eta\frac{v}{c^2}\left(\frac{\Delta x}{\Delta t} - v\right)\right] \tag{II-8}$$

$$= 1 - \frac{v\Delta x}{c^2\Delta t} - \frac{v^2}{c^2} + \frac{v\Delta x}{c^2\Delta t} = 1 - \frac{v^2}{c^2} = \gamma^{-2}$$

Proof that the inverses of eqs. (II-7a,b) are consistent with the RP proceeds by applying Galilean inversion as follows:

$$\Delta t = \gamma\eta'^{-1}\Delta t' = \gamma\eta'^{-1}\gamma\eta^{-1}\Delta t = \gamma^2(\eta'\eta)^{-1}\Delta t = \Delta t \tag{II-9}$$

$$\Delta x = \gamma(\Delta x' + v\Delta t') = \gamma\left[\gamma(\Delta x - v\Delta t)\right] + \gamma v\gamma\eta^{-1}\Delta t =$$

$$\gamma^2\left[(\Delta x - v\Delta t) + v\eta^{-1}\Delta t\right] = \gamma^2\Delta x - \gamma^2 v\Delta t + \gamma^2 v\Delta t\left(1 - \left(\frac{v}{c^2}\right)\frac{\Delta x}{\Delta t}\right) = \tag{II-10}$$

$$\gamma^2\left[\Delta x - v\Delta t + v\Delta t - \Delta x v^2 c^{-2})\right] = \gamma^2\Delta x\left(1 - v^2c^{-2}\right) = \Delta x \,.$$

Keywords: *Definition of speed/velocity, Fresnel light-drag experiment, Galilean inversion, Galilean transformation (GT), Galilean velocity transformation (GVT), Galileo's RP, Gauss elimination, Larmor, Light speed constancy, Lorentz factor ε, Lorentz transformation LT, Maxwell electromagnetism theory, Michelson-Morley experiment, Newton, Refractive index n, Space-time mixing, Vector addition, Velocity transformations, Voigt conjecture, Voigt transformation, ηη' identity*

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III. THE LAW OF CAUSALITY AND THE LORENTZ TRANSFORMATION

The above discussion has shown that the Lorentz space-time transformation satisfies both the RP and the light-speed equality condition experimental data seemed to require. The question that emerges is what role does the classical velocity transformation (GVT) play in the overall description of the motion of objects. The mixing of space and time coordinates in eq.(II-7a) of the LT raised questions of its own, however. Poincaré[1] noted that there was no indisputable evidence to prove that events occur *simultaneously* for all observers. If both v and Δx are not equal to zero in eq. (II-7a), it follows that it is not possible for both Δt and $\Delta t'$ to have the value of zero required for the simultaneous occurrence of the event for the two observers. The possible validity of the LT therefore rests on the belief that remote non-simultaneity (RNS) can occur for natural processes.

Einstein[2] made the LT the cornerstone of his theory of relativity which he introduced in 1905. He approached the RNS question by developing a thought experiment[3] according to which two light lightning strikes simultaneously hit two ends of a train as it moves by a stationary platform. He concluded that it was impossible for two light flashes from the strikes moving in opposite directions toward each other would arrive at the midpoint of the train at the same time as they are found to meet from the vantage point of the platform,

One of the main predictions of his theory is the phenomenon of *time dilation*. It is based directly on eq. (II-7b) of the LT. He applied it to a case in which the object of the measurement is a clock in one of the rest frames (S') which is moving with constant speed v along the x axis away from the other rest frame (S). From the vantage point of S, it follows that this clock moves a distance $\Delta x = v\Delta t$ in a given elapsed time Δt. Substitution of this value in eq. (II-7a) leads to the relation: $\Delta t' = \gamma(1-v^2c^{-2})\Delta t = \gamma^{-1}\Delta t$. The interpretation is that the moving clock in S' has a rate which is γ times slower that its counterpart in S. On this basis it must be assumed that a moving clock always runs slower by this factor. As a consequence, there is a *symmetric relationship* for any two observers with identical clocks whereby each will find that it is the *other's* clock which is moving slower by this factor. This conclusion therefore causes one to believe that measurement is a *subjective* process, depending on the perspective of the observer. It therefore stands in contradiction to the long-held principle of complete objectivity in measurements made on a given object by different observers. In short, Einstein's view of time dilation violates the PRM discussed in the Introduction.

Einstein[2] used time dilation to make his famous energy-mass equivalence prediction ($E=mc^2$). This was at first received with considerable skepticism[4], including from Einstein himself, but over time it has proven to be of considerable consequence in the history of scientific investigation. It explained the fact that the sum of masses is not conserved in nuclear reactions. It is the underlying theoretical basis for both nuclear reactors and weapons such as the atomic bomb and is therefore beyond dispute.

The fact that there have been so many confirmations of Einstein's Special Relativity (SR) does not of course prove that it is a truly reliable theory. The rule for any theory is to maintain faith in it so long as no contradictory evidence is found, but never to stop trying to improve it by removing any clear inconsistency in its predictions. With this mind, it is important to consider possibly relevant information that can produce a new variant which continues to deal successfully with past accomplishments of the old theory, but while at the same time broadening the range of applicability of the new one.

For example, the Law of Causality has played a key role in the development of science through the ages. It basically says that nothing happens without something causing it to occur.

Newton's First Law of Kinetics[5] (Law of Inertia) is a prime example. It says that a body will continue in a straight line at constant speed until it is subjected to an unbalanced external force. By extension, each of the physical properties of the same object such as a clock will remain constant indefinitely *unless some outside force is applied*. Accordingly, it seems unavoidable to conclude that the rate of such a (inertial) clock will not change unless it is acted upon by some outside force (clock-rate corollary[6]). That being the case, one must conclude that the *ratio* of the rates of any two such clocks will be a *constant.* In other words, when these clocks are used to measure an elapsed time, their different values Δt and $\Delta t'$ will always be found to be in the same ratio, i.e. $\Delta t'=\Delta t/Q$, where Q is the rate ratio.

The Lorentz transformation (LT) is based on the use of inertial clocks in two different rest frames. One of its main characteristics [eq. (II-7a)] is that the elapsed time $\Delta t'$ measured on one such clock will depend on the relative speed v of the two rest frames and the location Δx of the object in one of the other rest frames as well as the time Δt measured on that clock, i.e. $\Delta t'=\gamma(v)(\Delta t-v\Delta x/c^2)$, where $\gamma(v)=(1-v^2/c^2)^{-0.5}$ and c=299792458 m/s. It can be seen that if both v and Δx have non-zero values, then $\Delta t'$ will not be proportional to Δt. This characteristic of the LT is known as *space-time mixing*. It stands in direct contradiction to the $\Delta t'=\Delta t/Q$ relation required by the Law of Causality. *This shows that the LT is not consistent with the Law of Causality.*

As stated earlier in this chapter, one of the consequences of the space-time mixing of the LT is that it allows the two observers mentioned above to disagree on whether two events occurred simultaneously or not.[2] This is clear from the same LT equation mentioned above. Again, if both v and Δx are not equal to zero, it follows that when $\Delta t=0$ (note that $\Delta t=0$ means that the two events did occur simultaneously for the one observer), it cannot be that $\Delta t'= 0$ as well, i.e. that the two events were also simultaneous for the other observer. This situation is referred to as remote non-simultaneity (RNS). The distinction between the LT and the $\Delta t' = \Delta t/Q$ condition required by the Law of Causality is quite clear because in the latter case when $\Delta t' = 0$, so must also Δt. For this reason the latter proportionality relation is referred to as *Newtonian Simultaneity.* This is in recognition of the historical fact that Newton was a firm believer in absolute simultaneity, that is, that if two events occur simultaneously, they will also be found to be simultaneous in any other pair of rest frames throughout the universe.

The choice for physicists is clear. Either you give up on the ancient Law of Causality in order to preserve your faith in Einstein and the LT and RNS, or you accept the conclusion of the former that Newtonian Simultaneity explains why the ratio of the rates of any two inertial clocks must have a constant value. The latter conclusion is essential for the operation of the Global Positioning System (GPS) navigation methodology.[7] In summary, the fabulous success of GPS in our everyday lives serves as an undeniable verification of Newtonian Simultaneity and its prediction that clock rates in different rest frames are always strictly proportional to one another.

There are other problems with the LT. For example, the derivation of the time dilation phenomenon leads one to conclude that elapsed times Δt measured on the stationary clock will always be γ (v) times larger than the corresponding ($\Delta t'$) values for the moving clock. If the value for the difference in times for two events is $\Delta t = 0$, i.e. indicating the simultaneity of the events for the stationary observer, it therefore follows that the corresponding value for the moving observer's clock will also be zero. In other words, on this basis simultaneity of the events for one observer demands that the events also occur simultaneously for the other, in direct contradiction to the LT claim of RNS. It is therefore inconsistent to believe in both time dilation and RNS.[8]

There is a similar problem with the FitzGerald-Lorentz length contraction (FLC) prediction based on eq. (II-7b) of the LT.[9] Einstein[2] showed that the length of a moving object is contracted by a factor of γ (v) for the stationary observer, i.e. $\Delta x' = \gamma(v)\Delta x$. Consider an example in which the speed of light is measured in the moving laboratory; it is found that $\Delta x'/\Delta t' = c$. Combining the above relation with the corresponding one for time dilation, namely $\Delta t' = \Delta t/\gamma(v)$, gives the result: $\Delta x'/\Delta t' = \gamma^2(v)\Delta x/\Delta t = c$. Yet, $\Delta x/\Delta t = c/\gamma^2(v)$ is the value of the speed of the light pulse measured in the stationary laboratory. In short, on the basis of the LT, the speed of light is not equal to c for all observers. Clearly, the effects of time dilation and the FLC do not cancel each other to give a value of c, contrary to what is claimed by SR should be the case. A similar inconsistency occurs for light moving in the y,z direction in the moving laboratory. In this case, $\Delta y'/\Delta t' = c = \gamma(v)\Delta y/\Delta t$. Thus, the speed of light in the stationary laboratory is also not found to be c in this example, rather $c/\gamma(v)$.

Keywords: *Clock-rate corollary, Constant ratio Q of clocks, $E=mc^2$, Einstein, Einstein subjectivity of measurement, FitzGerald-Lorentz length contraction (FLC), Galilean velocity transformation (GVT),Global Positioning System (GPS), Inertial rest frames, Law of Causality, Light speed equality, Lightning flashes on a train, Lorentz transformation (LT), Newton's First Law, Newtonian absolute simultaneity, Newtonian Simultaneity relation, Poincaré, Principle of Rational Measurement (PRM),. Relativity Principle (RP), Remote non-simultaneity (RNS), Space-time mixing of the LT, Special Relativity theory (SR), Time dilation,*

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IV. FAILURE OF EINSTEIN'S LIGHT SPEED POSTULATE

In formulating his version of relativity theory,[1] Einstein agonized[2] over the definition of a postulate which correctly described the observation of light-speed constancy. He concluded that the speed of light in free space has the same value c for all observers independent of their state of motion as well as that of the source of the light. It will be shown in the following how his postulate leads directly to the conclusion that the lightning strikes on the train could not possibly be simultaneous for both an observer there and one who is stationary on the platform.

A basic part of the theory has to do with how different people perceive how fast an object is moving. Just take the following simple example. You are standing on a street corner as a car passes you with a speed of v=50 km/h. The car driver reports that he sees a train moving in the same direction with speed w=30 km/h relative to him. You can safely assume on this basis that the train is moving with speed v+w=80 km/h relative to you as you stand on the corner. It is all very easy to understand.

Now change the example so that there is a light pulse instead of a train. The light pulse moves with speed w=c relative to the car. So the relative speed of the light to you on the corner will be v+c according the above example using a train.

Einstein did not agree with this conclusion, however. He assumed[3] instead (light speed postulate LSP) that the speed of light is *independent* of the speed of the observer or light source. He claimed that the procedure used above in the car-train example (the Galilean velocity transformation GVT) is only valid at low speeds much less than c.

There is a simple way to test Einstein's assumption, however. Just consider how far the light travels in a given time T relative to the car/light source on the one hand and relative to the street corner/origin on the other.[4] According to Einstein's LSP, in both cases the value of the distance of separation from the light pulse is found to be cT. *This result is clearly unacceptable,* since it is impossible that the light pulse could be the same distance from both *since their two positions are not coincident at time T.* For example, T could be as great as one year, so the distance separating the light source from the origin/street corner would be 1.0 light year (ly) in that case. This proves beyond any shadow of a doubt that Einstein's LSP in untenable.

The same procedure (*distance reframing*[4]) can be put to good use in another way in this example. The distance moved by the light source relative to the origin is vT, while that moved by the light pulse relative to the light source is cT. The total distance separating the light pulse from the origin is obtained by simply adding these two values, with the result vT+cT=(v+c)T. (Note that the addition of distances is commonplace in everyday activities such as measuring the width of a room, whereas there is no such intuitive principle for the addition of velocities.) By definition, the speed of the light pulse relative to the origin is obtained by dividing the above value by the elapsed time T, which upon cancellation gives v+c. This is exactly the value that is obtained when the GVT is applied directly. In summary, the *distance reframing procedure* contradicts the long-held position of the physics community that the motion of the light pulse relative to two different rest frames is governed by Einstein's LSP, while at the same time verifying that the GVT is totally accurate in this example as well as in any conceivable variation involving other moving objects than light.

Relegation of the GVT to the realm of low-energy physics has its price, however. Belief in the LT and Einstein's LSP forces one to accept the doctrine of remote non-simultaneity (RNS). Accordingly, two events which occur simultaneously for an observer in one rest frame may not necessarily be simultaneous for someone who is in motion relative to him. As discussed in Chapter III, Einstein was aware that there is no experimental verification for RNS[5], even though what Poincaré[6] had to say on the subject is just as true, namely that there is also no proof from experiment that all events must occur at the same time for all observers in the universe.

In order to deal with his own uncertainty on this subject, Einstein came up with an example[3] which should demonstrate without doubt that RNS is a fact of nature. He asked his readers to consider the case in which two lightning strikes occur on a passing train. They are measured to occur simultaneously for an observer O_p who is at rest on the station's platform. He argued that if the two strikes occurred on opposite sides of the position M on the platform which both were separated by a distance of L from O_p, then light emanating from them would necessarily arrive at M simultaneously. The time T_p required for this to occur is L/c, where c is the speed of light in free space.

He further assumed that the passing train was moving at a constant speed v relative to the platform as the lightning strikes occurred. On the basis of his LSP, an observer O_t who is at rest on the train at the same position M when the two lightning strikes occur, cannot find that they would also occur simultaneously for him. This is because O_t must find that the light pulse moving in the opposite direction as the train would move a distance of cT toward him at any time T while he has moved a distance of vT during the same period. The light would therefore arrive at O_t's momentary position at time $T_1=L/(v+c) < T_p$. Meanwhile the light pulse travelling in the opposite direction would also move a distance of cT by virtue of the LSP, whereas O_t would have moved a distance of vT away from this pulse. The time required for this light pulse to "catch up" with O_t is thus $T_2= L/c\text{-}v>T_p$. Clearly, $T_2>T_1$, so the light pulses do not arrive simultaneously for O_t when the LSP is used, as Einstein wished to show.[3]

Let us now consider how the substitution of the GVT for the LSP in Einstein's example of two lightning strikes changes the result. Assume as before that the light from the two strikes reaches the observer O_p located at the midpoint M of the platform simultaneously at time $T_p=L/c$. After time T has elapsed, *the sources of the strikes* have moved to positions 2L+vT and vT, respectively, that is, by taking account of the speed of the train relative to the platform. The speed of the first light pulse relative to O_t is c+v in the negative direction according to the GVT, so at time T this pulse is located at 2L+vT–(v+c)T=2L-cT. Note that this is exactly the same trajectory for this light pulse as from the vantage point of O_p.

Meanwhile, the speed of the second pulse toward O_t is c-v according to the GVT. As a result it is located at vT+(c-v)T=cT at time T. The trajectory of this one is also identical to that measured by the stationary observer O_p on the platform. Therefore, the two light pulses will also meet for O_t when 2L-cT = cT. The corresponding time is $L/c=T_p$, the same as for O_p on the platform. In summary, the arrival time is simultaneous for O_t as well as for O_p when the GVT is applied. It is thus clear that there is no RNS in this procedure using the GVT, contrary to what one must assume when the LSP is assumed instead.

It is worth noting that the relativistic velocity transformation RVT to be discussed in Chapter V, which can be derived from both the Voigt transformation and the LT, can be used to show that the light pulses do at least arrive simultaneously for the train observer O_t.[7] It can be seen, however, that when the RVT is assumed, they do not reach O_t when he is located at M, as is known to be correct based on O_p's experience, but rather at $L + vT = L(1+ vc^{-1})$. Hence, it is clear that the RVT does not give a completely accurate prediction of the motion of the two light pulses either, whereas the GVT has been shown to produce the correct result.

It is therefore clear from the above discussion that there are some experiments involving light which can be understood within the context of the GVT but not when the RVT is used in its place. The opposite is also true, however. Some experiments can be understood using the RVT, but not when the GVT is used instead. For example, the RVT performs well for the Fresnel-Fizeau light-drag experiment (see Chapter V),[8] but not in the train example discussed above. In short, the range of application of the two velocity transformations is *mutually exclusive.*

Keywords: *Distance reframing, Einstein, Fresnel-Fizeau light drag experiment, Galilean velocity transformation (GVT), GVT applicability for light speed, Light speed postulate (LSP), Lightning strikes on a train, Poincaré*, *Relativistic velocity transformation (RVT), RNS, Voigt transformation*

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V. DICHOTOMY OF THE APPLICATIONS OF THE GVT AND RVT

The goal is therefore to be able to decide on a definitive basis which of the two transformations is applicable in a given case. The solution is quite simple.[1] When *two observers in different rest frames* are to compare their measurements for the same light pulse, they must use the GVT to obtain the correct answer. By contrast, the RVT is valid when *only a single observer makes separate observations under two different conditions,* for example, namely v=0 and v≠0 for the relative speed of the medium in the Fresnel-Fizeau experiment.

The RVT is derived by taking the ratio of the distance travelled by an object to the necessary elapsed time for this to occur. When this procedure is followed using the Voigt transformation[2] of eqs. (II-5a-d), the result is:

$$u_x = \left(1 + vc^{-2}u_x'\right)^{-1}\left(u_x' + v\right) = \eta'\left(u_x' + v\right) \tag{V-1a}$$

$$u_y = \gamma^{-1}\left(1 + vc^{-2}u_x'\right)^{-1} u_y' = \gamma^{-1}\eta' u_y' \tag{V-1b}$$

$$u_z = \gamma^{-1}\left(1 + vc^{-2}u_x'\right)^{-1} u_z' = \gamma^{-1}\eta' u_z' . \tag{V-1c}$$

In these equations, $u_x = \Delta x/\Delta t$, $u_x' = \Delta x'/\Delta t'$, etc., and the definitions of γ, η and η' are the same as used in deriving the identity in eq. (II-8). The same procedure can also be used based on the LT relations.

The RVT assumes that space and time are mixed, a concept first introduced by Voigt in 1887.[2] This position stands in stark contrast to the view of classical physicists such as Newton which holds that the two observers always agree on the amount of elapsed time in which measurements are made ($\Delta t = \Delta t'$). The RVT eliminates the "c=c+v" problem through the use of the η' function. If $u_x' = c$, then $\eta' = (1+c^{-1}v)^{-1} = c(c+v)^{-1}$. As a result, in eq. (V-1a), $u_x =$

$c(c+v)^{-1}(c+v)=c$, in agreement with the light-speed constancy assumption. This is certainly not surprising, since the underlying condition in deriving the RVT is that for any choice of u_x', u_y', u_z' with a vector magnitude of c, the corresponding result for u_x, u_y, u_z must also have the same magnitude, but with a generally different direction than the original vector. It should be noted that the RVT results cannot be obtained by vector addition, contrary to the situation with the GVT.

One can divide velocity measurements involving the speed of light into two distinct categories. In the first, Type A, there are *two observers in relative motion to one anoth*er, each of which carries out measurements of the speed of a light pulse. They obtain different values which can be combined using the GVT and vector addition. It is possible for the speed of light to exceed a value of c in this case. The same procedure can be used for any object.

The second category of measurements, Type B, involves *only a single observer* who obtains measurements of the object *under two different circumstances*. The RVT must be used in order to relate these two values. It is therefore not possible for the speed of light to exceed a value of c in this case.

The phenomenon of stellar aberration refers to astronomical observations of the apparent movement of the positions of celestial objects at different times of the year. It is an example of Type A because there are two rest frames (earth and sun) relative to which the light speed is measured. The first coherent explanation for this effect is credited to James Bradley. Writing in 1727, he ascribed it to the finite velocity of light and the motion of the earth relative to the sun, and he used the classical theory of motion (GVT) to quantify his position. There was longstanding wide acceptance for his arguments, but they eventually met with considerable scepticism because they were thought to be incompatible with new experimental data obtained at the beginning of the next century. The latter results led to the development of numerous theories that posited the existence of an aether that was assumed to be essential to the true theory of the motion of light.

The matter came to a head in 1905 when Einstein published what has come to be known as the Special Theory of Relativity (SR).[3] He rejected the need for an aether to explain the outstanding questions, but assumed instead that "light in a vacuum always moves with a definite velocity, independent of the velocity of the emitting body." This conclusion was in conflict with Bradley's explanation of stellar aberration which assumed, in concert with the classical (Galilean) theory, that the speed of light emitted from the sun depends on the state of motion of an observer located on the earth's surface.

One can use the distance reframing procedure discussed in Chapter IV to prove that Bradley's interpretation is correct. Accordingly, in a given time period T, the sun moves a distance of vT relative to the earth whereas the light emitted from the sun moves a perpendicular distance of cT in the same period. The total distance travelled by the light pulse is therefore obtained using the Pythagorean theorem to have a value of $(v^2+c^2)^{0.5}$ T. Division by T gives the value of the light speed relative to the earth to be $(v^2+c^2)^{0.5}$, which is greater than c. The aberration angle is thus found to be $\tan^{-1}$ (v/c). Use of the RVT instead[4,5] gives an incorrect value for this angle, namely $\tan^{-1}$ (γ v/c). It does so by assuming that the light pulse emanating from the sun has a speed of c/γ rather than the correct value of c. For typical speeds of the earth relative to the sun, however, $\gamma(v)$ differs from unity by on the order of only 10^{-8}, and this difference is therefore too small to be confirmed in actual observations.

The Fresnel light-drag experiment, on the other hand, is a concrete example of Type B. The experiment itself involves observations of the speed of light in transparent media. In the early 19th century, it was already clear that the value of the light speed varied when the speed of the medium v relative to the laboratory was increased. The measured value (c') was found to satisfy the formula given below (n is the refractive index of the medium):

$$c' = \frac{c}{n} + v\left(1 - \frac{1}{n^2}\right). \tag{V-2}$$

If n is changed to its free-space value (n=1), it is found that the v-dependence in eq. (V-2) disappears entirely, and one is led to conclude that c'=c(v) under this condition. This result is seen to be a verification of Einstein's[3] LSP. The RVT of eqs. (V-1a-c) leads to the same result for light moving in free space. Moreover, it also leads directly to eq. (V-2) when the light moves through a medium with refractive index n. This result was first obtained by von Laue[6] in 1907 and has been hailed as one of the first successes of Einstein's theory[7].

The derivation proceeds by assuming that u_x'=c/n in eq. (V-1a). One then obtains in agreement with eq. (V-2):

$$u_x = \eta'\left(\frac{c}{n} + v\right) = \left(1 + \frac{v}{cn}\right)^{-1}\left(\frac{c}{n} + v\right) = \tag{V-3}$$

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

after making various approximations based on the condition that v<<c.

The crucial distinction in the Fresnel experiment is that there is *only one observer* in this case, as opposed to two in the example of stellar aberration. The quantities u_x and u_x' *refer to the same observer making separate observations under two different conditions,* namely v=0 and v≠0. The assumption of light-speed constancy is then suggested by the special case for the free-space value of n=1, in which case u_x=u_x'=c, as already discussed in connection with eq. (V-2). It is also clear that the GVT cannot be reasonably applied under this condition since it requires that two different observers are involved in making the speed determinations *at the same time.* In short, the range of application of the two velocity transformations is mutually exclusive. The RVT performs well for the Fresnel light-drag experiment (Type B), but not in the description of stellar aberration (Type A), whereas the opposite is the case for the GVT.

Another Type B example for which the RVT is essential involves the acceleration of electrons in electromagnetic fields. The objective in this case is to cause an electron to attain faster-than-c speed. As in the Fresnel light-drag experiment, there is but one observer who performs measurements under two different conditions, i.e. in this case before and after the field is applied. The assignments of velocities in the RVT in the two cases are made on this basis.

The value of v in the equations is taken to be the product of an acceleration a due to the field and a time difference Δt during which the field is applied. Einstein[3] predicted successfully that a massive particle such as the electron can never exceed or be equal to c, as will be discussed subsequently. The assumption of light-speed constancy is justified because of the limiting case where the magnitudes of the two velocities each approach a value of c, i.e. one starts with the electron moving with a speed very close to c and ends up with a new velocity after application of the field with a magnitude which is only infinitesimally greater but is still less than c. This experiment cannot be explained on the basis of the GVT.

Another important example where the RVT is essential but for which the GVT cannot be used successfully is in deriving the theoretical explanation of the phenomenon of Thomas spin precession.[8,9] This case has some similarities to that discussed above regarding attempts to accelerate an electron to faster-than-c speed.

The focus in both cases is on the state of motion of the electron in two different situations, before and after application of a field, so the application of the GVT is ruled out in this case as well. The derivation of Thomas spin precession is different, however, in that it uses the Lorentz transformation (LT) rather than the RVT. The result is the following expression for the angular velocity ω_T of the electron:

$$\omega_T = c^{-2}\gamma^2\left(\gamma+1\right)^{-1}\mathbf{axv}, \qquad \text{(V-4)}$$

where v and a, respectively, are the instantaneous velocity and acceleration of the electron at a given time. It will be shown subsequently that the LT is not essential in this derivation; a different version of the space-time transformation than the LT achieves the same result.[10]

The Sagnac effect[11] is another example of a Type B experiment. It can be explained[12] entirely on the basis of Einstein's light-speed postulate and the RVT. Two light beams travelling in opposite directions on a circular platform of radius r rotating with frequency ω must travel different distances before interfering. Beam A must travel completely around to reach this point on the platform during one full revolution. The distance travelled is therefore assumed on the basis of the light-speed postulate to be $d_A = ct_A = 2\pi r + r\omega t_A$, where t_A is the corresponding time of travel. The other beam (B) does not make it all the way around, so its distance travelled during one full revolution of the wheel before reaching the point of interference is $d_B = ct_B = 2\pi r - r\omega t_B$. Solving for the respective elapsed times gives $t_A = 2\pi r\,(c - r\omega)^{-1}$ and $t_B = 2\pi r\,(c + r\omega)^{-1}$. The difference is thus $\Delta t = t_A - t_B = 2\pi r(2r\omega)(c^2-r^2\omega^2)^{-1} \approx 4\pi r^2\omega c^{-2} = 4A\omega c^{-2}$, which is the observed value in the laboratory (A is the area of the platform). An observer in another inertial system simply measures a different value for Δt because his proper clock runs at a different rate than that at rest in the laboratory, but the same value for the light speed is measured in both cases according to the light-speed postulate.

The RVT is used extensively in the analysis of particles emitted by rapidly moving sources. Experiments of this kind are of Type B since they only involve a single observer (the laboratory) in which the particles are accelerated. For example, consider the case[13] in which a Σ^0 hyperon decays to a photon plus Λ particle. The variables which are to be inserted in eq. (V-1a) in one example are defined as follows: v is the speed of the Σ^0 particle in the laboratory rest frame, u_x' is the speed of Λ in this rest frame and u_x is the final speed of Λ after the decay has occurred. There is a collimating effect such that the higher the value of v, the more the particles get beamed forward in the laboratory rest frame. The GVT is unable to produce the correct values of u_x in this Type B example.

Keywords: *Bradley, Dichotomy of applications of GVT and RVT, Distance reframing, Einstein, Einstein's LSP, Electron acceleration in electromagnetic fields, Fresnel-Fizeau light drag experiment, GVT, Limiting speed for non-zero masses, Lorentz transformation LT, Particle collisions, RVT, RVT equations, SR, Sagnac effect, Stellar aberration of light, Thomas spin precession, Type A and Type B experiments, Vector addition of velocities, Voigt transformation, Von Laue*

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VI. PROPERTIES OF THE RVT AND NEWTON-VOIGT TRANFORMATION

The utility of the Relativistic Velocity Transformation (RVT) has been demonstrated In Chapter V. It remains to show that it satisfies a number of essential requirements, particularly with regard to the light velocity equality in different rest frames and Galileo's RP. The former characteristic is considered below by forming the following linear combination /of squared quantities contained in eqs. (II-1a-c):

$$u_x^2 + u_y^2 + u_z^2 - c^2 = \eta'^2 \left[u_x'^2 + 2u_x' v + v^2 + \gamma^{-2} \left(u_y'^2 + u_z'^2 \right) \right]$$

$$-\eta'^2 c^2 \left(1 + \frac{2vu_x'}{c^2} + \frac{u_x'^2 v^2}{c^4} \right) =$$

$$\eta'^2 \left[\left(\left(1 - \frac{v^2}{c^2} \right) \left(u_x'^2 + u_y'^2 + u_z'^2 \right) + \frac{v^2 u_x'^2}{c^2} \right) + 2vu_x' - c^2 - 2vu_x' - \frac{v^2 u_x'^2}{c^2} \right] = \quad \text{(VI-1}$$

$$\eta'^2 \gamma^{-2} \left(u_x'^2 + u_y'^2 + u_z'^2 - c^2 \right).$$

It is clear that when the speed of the object is equal to c in one rest frame, it will also be equal to c in the other, as required. A key aspect of eq. (VI-1) is the fact that the $\eta'^2\ \gamma^{-2}$ factor on the left-hand side is positive definite. As a consequence, if the object's speed is less than c in one rest frame, it will also be less than c in the other. Moreover if it is greater than c in one frame, it will also be greater than c in the other. The latter situation can only occur if the inertial mass of the object is equal to zero, which therefore is consistent with greater-than-c speeds of photons. This topic has been dealt with in earlier work[1,2], but there has been great resistance in the physics community to this possibility.

Soon after Einstein's original paper on the special theory of relativity (STR)[3], questions began to arise as to the maximum speed that particles can attain. It was pointed out that the group refractive index of light (n_g) is less than unity for condensed media in wavelength regions of *anomalous dispersion* (near absorption lines)[4]. Since the speed of light in condensed media was found experimentally[5] to be equal to cn_g^{-1} for normally dispersive liquids (with $n_g>1$), it was argued that light speeds exceeding the value in free space ($c=299792458$ ms^{-1}) might be possible in media with $n_g<1$.

Sommerfeld[4] vigorously denied the latter possibility on the grounds that it would contradict a basic tenet of SR: there can be *no disagreement as to the time order of eve*nts. He claimed instead that the speed of energy transport of the waves[6] was the only quantity of experimental significance, and that its value must necessarily be less than c in all conceivable situations.

This theoretical position has received wide-spread acceptance to the present day, but in 1993 new experimental evidence[7,8] emerged that appeared to demonstrate unequivocally that $u>c$ light speeds were indeed attainable in media with $n_g<1$. However, even these results were not sufficient to dispel the general reluctance on the part of the physics community to accept as fact that single photons can indeed travel with faster-than-c speeds under the above conditions[7,9]. It has been shown in Chapter III, IV, however that the LT itself violates the Law of Causality. Therefore, there is no reason to dispute the conclusion that faster-than-c speeds for photons and other particles with zero rest mass can occur.

The RVT is also consistent with the RP. This is shown below by applying the Galilean inversion operation to the RVT eqs. (V-3a-c) and making use of the $\eta\eta' = \gamma^2$ identity derived in eq. (II-7).

$$u_y' = \gamma^{-1}\eta u_y = \gamma^{-1}\eta\gamma^{-1}\eta' u_y' = u_y' \tag{VI-2}$$

$$u_x' = \eta\left(u_x - v\right) = \eta\left[\eta'\left(u_x' + v\right) - v\right] =$$

$$\gamma^2\left(u_x' + v\right) - \eta v = \gamma^2\left(u_x' + v\right) - \frac{v\gamma^2}{\eta'} = \tag{VI-3}$$

$$\gamma^2 u_x' + \gamma^2 v - \gamma^2 v\left(1 + \frac{v u_x'}{c^2}\right) = \gamma^2 u_x'\left(1 - \frac{v^2}{c^2}\right) = u_x'$$

As discussed above, the space-time mixing equation of the LT in eq. (II-7b) needs to be replaced in order to be consistent with the Δt' = Δt/Q relation deduced from the Law of Causality. In this respect it is important to see that this equation is related to eq. (II-7a) of the LT by the following proportionality relation:

$$\Delta t' = \Delta t / Q = \left(\frac{\eta}{\gamma Q}\right)\gamma\eta^{-1}\Delta t \tag{VI-4}$$

One can therefore take advantage of Lorentz's observation[10] that the equal light-speed relation of both the LT and the original Voigt transformation can be preserved by multiplying each of the right-hand sides of these transformations by a constant factor (see the discussion in Chapter II). As a result, a different transformation that also satisfies the equal light-speed condition can be obtained by multiplying each of eqs. (II-7a-d) with (η/γQ):

$$\Delta t' = \left(\frac{\eta}{\gamma Q}\right)\left(\gamma\left(\Delta t - vc^{-2}\Delta x\right)\right) = \left(\frac{\eta}{\gamma Q}\right)\gamma\eta^{-1}\Delta t = \frac{\Delta t}{Q} \tag{VI-5a}$$

$$\Delta x' = \left(\frac{\eta}{\gamma Q}\right)\gamma\left(\Delta x - v\Delta t\right) = \frac{\eta\left(\Delta x - v\Delta t\right)}{Q} \tag{VI-5b}$$

$$\Delta y' = \left(\frac{\eta}{\gamma Q}\right)\Delta y \tag{VI-5c}$$

$$\Delta z' = \left(\frac{\eta}{\gamma Q}\right)\Delta z \qquad \text{(VI-5d)}$$

The same result is obtained if one multiplies by a factor of η/Q each of the Voigt transformation eqs. (II-5a-d). The resulting set of equations will be referred to as the Newton-Voigt transformation (NVT). Note that it contains the *Newtonian Simultaneity* relation explicitly in eq. (VI-5a). The latter designation for the Δt'= Δt/Q relation is in recognition of the fact that it implies that each event in the universe occurs simultaneously for all observers in the universe, which conclusion stands in full agreement with the long-held view of Newton and classical physicists in general that space and time are completely separate entities.

The consistency of the NVT with the equal light-velocity requirement is demonstrated by forming the following linear combination of squared quantities from the NVT:

$$\Delta x'^2 + \Delta y'^2 + \Delta z'^2 - c^2\Delta t'^2 = \left(\frac{\eta}{\gamma Q}\right)^2 \left(\Delta x^2 + \Delta y^2 + \Delta z^2 - c^2\Delta t^2\right). \qquad \text{(VI-6)}$$

The fact that $(\eta/\gamma Q)^2$ is positive definite allows for the same conclusions regarding speeds of the object that are either greater or less than c than are found for the RVT as a consequence of eq. (VI-1).

It remains to be shown that the NVT is consistent with the RP. This can be done by applying Galilean inversion to each of its equations. This procedure leads to a key requirement for the quantity Q and its counterpart Q' when applied to eq. (VI-5a):

$$\Delta t = \frac{\Delta t'}{Q'} = \left(\frac{1}{Q'}\right)\frac{\Delta t}{Q} = \frac{\Delta t}{QQ'} \qquad \text{(VI-7)}$$

It is clear that the only way to satisfy the RP is for Q' to be the reciprocal of Q. From a physical point of view, this condition simply reflects the fact that the two proportionality factors have the reciprocal relationshionship expected for comparison of elapsed times from the different vantage points of the two rest frames represented in the space-time transformation. The two quantites are most simply looked upon as *conversion* factors between different units of time. The reciprocality condition is exactly the same as for all other physical properties, and also for other quantities such as currency values. For example, the conversion factor for changing from kilometers (km) to meters (m) is 1000, whereas the factor for the opposite change from m to km is 1/1000. In what follows it will therefore be assumed that QQ' = 1 in all applications of Galilean inversion. The proofs for the spatial components proceed as follows:

$$\Delta y = \left(\frac{\eta'}{\gamma Q'}\right)\Delta y' = \left(\frac{\eta'}{\gamma Q'}\right)\left(\frac{\eta}{\gamma Q}\right)\Delta y = \frac{\eta'\eta}{\gamma^2 \Delta y} = \Delta y \qquad \text{(VI-8)}$$

$$\Delta x = \left(\frac{\eta'}{Q'}\right)\left(\Delta x' + v\Delta t'\right) = \left(\frac{\eta'}{Q'}\right)\left[\left(\frac{\eta}{Q}\right)\left(\Delta x - v\Delta t\right) + \frac{v\Delta t}{Q}\right] =$$

$$\gamma^2\left(\Delta x - v\Delta t\right) + \eta' v\Delta t = \gamma^2\left(\Delta x - v\Delta t\right) + \gamma^2\eta^{-1}v\Delta t) = \qquad \text{(VI-9)}$$

$$\gamma^2\left(\Delta x - v\Delta t\right) + \gamma^2 v\Delta t\left(1 - \frac{v\Delta x}{c^2\Delta t}\right) =$$

$$\gamma^2\left(\Delta x - v\Delta t\right) + \gamma^2 v\Delta t - \frac{\gamma^2 v^2\Delta x}{c^2} =$$

$$\Delta x\left(\gamma^2 - \frac{\gamma^2 v^2}{c^2}\right) = \Delta x\,.$$

The chronology of the relativistic space-time transformations will be reviewed below in terms of Lorentz's ε factor[10] discussed in Chapter II. The Voigt transformation is characterized by a value of $\varepsilon=\gamma^{-1}$. The fact that it satisfies the Lorentz criterion shows that it does satisfy the equal light-velocity requirement, but it is deficient because of its lack of consistency with the RP. The LT is characterized by ε=1, so it also satisfies the light-speed condition. It is also consistent with Galileo's RP, however, and this fact has led physicists to look upon it as a perfectly reliable means of describing the relationships between the measured values of any physical property by observers in two different rest frames. It has been pointed out, however, that the LT is not consistent with the Law of Causality and is therefore unacceptable as a law of physics. Finally, the NVT is characterized by a value of $\varepsilon=\eta/\gamma Q$. It has furthermore been shown that it is consistent with both the RP and the Newtonian Simultaneity relation for measured times in the two rest frames, and is therefore also consistent with the Law of Causality.

The experimental results which have been claimed as verifications of the LT invariably involve the RVT and are thus do not require the LT at all. The NVT is also consistent with the RVT and so the Type B experiments mentioned in Section V can just as well be claimed as successes of the NVT.

The Thomas spin precession[11] experiment requires more careful consideration, however. The LT is indeed used to derive eq. (V-4) but the two rest frames in question are separated by an infinitesimal speed and the final result is obtained by taking the limit of v=0 in the LT. In this limit each of the values of η, γ and Q are equal to unity, so the NVT is indistinguishable from the LT in this situation. In other words, the Newtonian Simultaneity relation is not relevant in deriving eq. (V-4) and therefore Thomas was able to use the LT to obtain the spin precession result.

Keywords: *Distinct space and time, Conversion factors, Type B experiments, Thomas spin precession, RP, RVT, Newton-Voigt transformation (NVT), Proof of equal light speed, Galilean inversion, Law of Causality, Lorentz constant factor ε, LT. Newtonian Simultaneity equation,, Voigt transformation 2, 4*

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VII. TIME DILATION EXPERIMENTS

An essential requirement for application of the NVT is to identify the value of the factor Q that appears in each of its four eqs. (VI-5a-d). It is something than can only be determined on the basis of experimental data. Its value is specific for any given pair of rest frames to be considered in the transformation. The need for such a quantity arises from the Law of Causality and the Clock-rate Corollary to Newton's Laws of Motion.[1,2] Therefore, studies of time dilation are the obvious place to look for the necessary experimental data to fix the value of Q.

The transverse Doppler effect (TDE) has long been accepted as an experimental proof of time dilation. Ives and Stilwell[3] were the first to demonstrate this purely relativistic effect by employing excited hydrogen atoms with kinetic energies of up to 10 keV. They measured the displacement of the H_β line from its un-shifted position to the center of gravity of the two lines recorded on the same photographic plate when the light source was in motion with speed v toward and away from it, respectively. Similar experiments were subsequently reported independently by Otting[4] and Mandelberg and Witten.[5] It was found that the wavelength recorded on the photographic plate was larger than the rest value λ_0 of the H_β line light source by a factor of $(1+0.5\ v^2/c^2)>1$. It was argued that this result is proof of time dilation, that is, the slowing down of clocks, since it is expected that the speed of light at the source is equal to the product of λ_0 and ν_0. It was therefore assumed that the value of the frequency ν that *would be obtained* in the laboratory is *smaller* than the rest frequency ν_0 for the H_β line by the above factor.

Kündig[6] later employed the Mössbauer technique to demonstrate the TDE to even higher accuracy (1%). In this case the frequency of an ^{57}Fe x ray source was measured with a detector near the rim of an ultra-centrifuge[7,8]. The common conclusion from all these experiments is that the frequency ν of light emitted from an accelerated source is smaller than the value ν_0 measured in the laboratory when the same source is at rest there.

Two separate derivations of the relativistic Doppler effect are found in the literature. One makes use of the invariance of the phase of a harmonic plane wave with respect to a Lorentz transformation (LT)[9]. The other makes direct use of the time-dilation effect[10], and is thus better suited for the present discussion. First, one shows that the period of pulses reaching the observer must be proportional to the factor $(1+v_r/c)=(1+v\cos\chi/c)$, where $\chi=0$ corresponds to motion of the source directly away from the observer. There is also a second-order contribution, however, due to the fact that clocks run slower by a factor of $\gamma(v)=(1-v^2c^{-2})^{-0.5}$ in the rest frame of the source [note that to first order in v, $\gamma(v)=(1+0.5\,v^2/c^2)$]. If the *in situ* period for the light source is T_0, the value measured in the laboratory is therefore

$$T = \gamma T_0\left(1 + v\cos\frac{\chi}{c}\right). \tag{VII-1}$$

The wavelength λ is equal to cT, so the corresponding expression for the Doppler-shifted wavelength is

$$\lambda = \gamma\lambda_0\left(1 + v\cos\frac{\chi}{c}\right). \tag{VII-2}$$

For transverse radiation, $v_r=0$ and $\chi=\pi/2$, so it is clear that there is no first-order effect in this case (TDE). For radiation observed in any other direction, however, the same value can be obtained by eliminating the first-order effect, as already mentioned above in connection with the Ives-Stilwell experiment[3-5].

The second-order Doppler effect is therefore independent of the direction of the light source's motion relative to the laboratory observer. It is a direct measure of the amount of time dilation in the rest frame of the light source. The values of T and λ in the above equations are given with respect to the units of time and distance in the rest frame of the laboratory. In other words, they can be looked upon as the values one *would* obtain if one could directly employ the clock and meter stick located in the laboratory rest frame to carry out measurements in the rest frame of the accelerated source. This is not actually possible for the simple reason that the clock rate and the length of the meter stick change as soon as they are accelerated with respect to the laboratory rest frame. On the basis of this analysis one can identify the value of Q in the NVT to be equal to $\gamma(v)$, i.e. the conversion factor between the units of time in the relevant reference frames is $Q=\gamma(v)$.

It is possible to test this interpretation with the aid of other investigations not involving the TDE itself. In one such set of experiments[11-15], the spontaneous disintegration of accelerated pions and muons has been measured in both the upper atmosphere and in the laboratory. It was shown to quite high accuracy that the lifetimes of these particles increase in direct proportion to their γ value relative to the rest frame of the laboratory. One can also look upon the muons and pions as natural clocks. Their lifetimes are measured relative to a standard clock in the laboratory, and they are indeed found to be larger than for identical particles that have not been accelerated.

A different type of experiment that leads to the same conclusion is that carried out by Hafele and Keating[16,17] with circumnavigating airplanes. Identical atomic clocks were located on the earth's surface and on two airplanes traveling in opposite directions around the globe. After correcting for gravitational effects, it was found that the clock on the plane traveling in an easterly direction was slower than the one left behind at the airport. The westbound clock actually gained time relative to the latter, but this could be explained as the consequence of the earth's rotation about its polar axis. The observed differences in elapsed times for these clocks were found to agree with Einstein's predictions to within reasonable error limits.

Taken together, these two sets of experiments exclude any possibility that the periods of the radiation in the TDE experiments simply change in going between the light source and the observer in the laboratory. They show instead in an unequivocal manner that light frequencies and wavelengths do change when the light source is accelerated.

Nonetheless, there is no evidence to suggest that an observer traveling with an accelerated source will detect these changes. This is the result that one expects from the RP, since otherwise it would be a rather simple matter for the local observer to detect that he has changed his state of motion, even after the acceleration phase has been completed and the rest frame of the light source is again an inertial system (the ultracentrifuge experiments show that the time-dilation formula also holds when the light source is subject to a very high degree of acceleration[6-8]).

An obvious question arises from this state of affairs: why doesn't the local observer detect a change in the period and wavelength of radiation emitted from the accelerated source? The simple answer is that *all local clocks* have slowed by exactly the same proportion, and so the observer in the rest frame of the light source must continue to measure the same value for the frequency no matter how great his speed relative to the laboratory from which he departed. Another way of expressing this point is to say that the unit of time has increased from its initial value of 1 s in the laboratory rest frame to γ s in that of the light source[18]. In absolute terms *both observers obtain the same result for the period of the radiation*, but the one moving with the light source obtains the smaller value of T_0 because his result is given with respect to the larger unit of time. This conclusion is perfectly consistent with a value of $Q= \gamma$ mentioned above.

The latter argument can be readily accepted because it is perfectly consistent with Einsteinean time dilation[19]. The same line of reasoning is used to explain why observers at different gravitational potentials disagree on the magnitude of a given light frequency[20]. In that case, the unit of time is *shorter* on top of the mountain than it is in the valley below, but the *in situ* value for a given light source is the same at each location.

There is still another issue to resolve for the TDE, however. The observer co-moving with the light source also does not detect any change in the wavelength of the radiation, even though his counterpart in the laboratory finds that it has increased by the same factor of γ that the period has. Again, the object is the same for both observers, namely light waves of exactly the same frequency in absolute terms. The explanation must be completely consistent with what has already been discussed for periods of the radiation. Not only must the unit of time increase in the accelerated rest frame of the light source, *but also the unit of length.* Moreover, the latter must change in exactly the same proportion in all directions. Otherwise, it is impossible to explain why the second-order Doppler effect for wavelengths is the same for each angle of approach χ in eq. (VII-2), that is, $\lambda = \gamma \lambda_0$. The observer co-moving with the light source has no means of detecting this change in wavelength because any and all devices that he might use to make this determination *have increased in length by the same factor of γ.* It is exactly the same argument that has been accepted for many decades for radiation periods.[21]

If the unit of length did not change in direct proportion to the unit of time, regardless of orientation of the measuring device, it would also be impossible to explain why both observers measure exactly the same value for the speed of light in every direction. Speed (or velocity) is a ratio of the length travelled by an object to the corresponding elapsed time. If the unit of length is changed from 1 m to 1 cm, the *numerical* value of the distance travelled must increase by a factor of 100. The value of the speed can nonetheless remain the same as long as a corresponding decrease in the unit of time is made, that is, from 1 s to 0.01 s. Clearly, the same situation holds for the numerical values of wavelengths and periods of radiation, with the result in this case that their ratio, the phase velocity of light, *is also left unchanged when such a proportional change in the units of length and time is introduced.*

Keywords: *Atomic clocks, Derivation of TDE effec, East-west effect on clock rates, Gravitational effects on clock rates, Hafele-Keating airplane experimen, Ives-Stilwell experiment, Kündig, Law of Causality, Mössbauer effect, Muon pion lifetimes, Newton' Laws of Motion, NVT, RP, Scale Factor Q, Time dilation, Transverse Doppler effect (TDE), Ultra-centrifuge x-ray experiment, Unit of length, Unit of time*

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VIII. ASYMMETRIC TIME DILATION: THE TURNING POINT

The time dilation experiments discussed in Chapter VII verify that clocks slow down upon acceleration. The Ives-Stilwell experiment and the various studies of decay lifetimes do not verify that the effect is *symmetric*, however, i.e. that it is always the clock in motion relative to the observer that runs slower. This is because it is clearly impossible to have a detector moving in the rest frame of the accelerated radiation source.

The ultracentrifuge experiments of Hay et al.[1], Kündig[2] and Champeney et. al.[3] introduced two new elements into the investigation of the transverse Doppler effect, however. First, they eliminated the angular dependence in eq. (VII-1) by mounting the light source and absorber on a high-speed rotor so that the relative motion was almost perfectly transverse. However, more importantly in the present context, in each case the light source was located near the rotor's axis whereas the absorber was fastened near its rim. As a result, the "observer" in this version of the transverse Doppler experiment was moving faster in the laboratory than the source. The only critical quantity is the relative speed v and thus this distinction between the two types of experiments should be immaterial. Einstein's theory of time dilation and the transverse Doppler effect is *subjective*. Which clock runs slower is purely a matter of the perspective of the observer. A red shift is expected in the ultracentrifuge experiments, just as is found in the Ives-Stillwell experiment [4-6]. If measurement is objective on the other hand, a blue shift must be observed. The contrast could not be clearer.

Angular velocities ω of up to 500 revolutions per second were employed in the ultra-centrifuge study[1-3]. The results for the fractional shift in the light frequency/energy of the photons are found to be in quantitative agreement with the formula:

$\left(R_1^2 - R_2^2\right)\frac{\omega^2}{2c^2} = 2.44 \mathrm{x} 10^{20}\omega^2$. Hay et al.[1] refer to this as the "expected shift" and claim that it can be derived in either of two ways from theory: a) from Einstein's Equivalence Principle [7] by treating the acceleration of the rotor as an "effective gravitational field" or b) from the time dilation effect of SR. They do not comment directly as to whether the observed direction of the shift is to higher or lower frequency, but since the proportionality factor in the above equation is positive (see the designations of R_1 and R_2 below), a shift to the blue is clearly indicated. As a consequence, *this result stands in contradiction to the prediction of SR* that the sign of the Doppler shift should be the same as found in the Ives-Stillwell experiment[4-6], namely in the direction of longer wavelengths and lower frequencies.

The symmetry characteristics of the above formula are even more telling in this respect. The parameters R_1 and R_2 clearly refer to the distances of the absorber and source from the axis of the rotor, although no explicit designation is given in the text[1]. Since the former distance (R_a) is greater than the latter (R_s), it is clear from the sign on the right-hand side of the formula that $R_1 = R_a$ and $R_2 = R_s$. The dependence of the fractional Doppler shift $\frac{\Delta\nu}{\nu}$ on ω is thus:

$$\frac{\Delta\nu}{\nu} = \left(R_a^2 - R_s^2\right)\frac{\omega^2}{2c^2} > 0 \qquad \text{(VIII-1)}$$

The formula therefore implies that *interchanging the positions of the absorber and light source on the rotor's axis causes a reversal in the sign of the Doppler shift*.

This is clearly not the result that one expects from SR, since it claims that only the relative speed $\left|R_a - R_s\right|\omega$ of the source and absorber is material in making this determination. According to the *interpretation* of eq. (VIII-1) of Hay. et al.[1], the empirical results for transverse motion should obey the formula:

$$\frac{\Delta\nu}{\nu} = \gamma^{-1}\left(\left|R_a - R_s\right|\omega\right) - 1 \approx -\left(R_a - R_s\right)^2 \frac{\omega^2}{2c^2} < 0 \qquad \text{(VIII-2)}$$

i.e., predict a red Doppler shift regardless of the relative position of the light source and absorber on the rotor.

Kündig[2] also used the equivalence between acceleration and gravitation to discuss his experimental results and came to the same conclusion as Hay et al.[1] with regard to the potential energy difference Φ between the absorber and light source mounted on his rotating system (Φ is lower at the absorber). He went on to argue that *since a clock in the rest frame of the absorber is slowed down* as a result of the acceleration, the frequency (ν_A in his notation) observed with it would be *lower* than that of the signal emitted from the source at a higher gravitational potential. *However, this conclusion runs contrary to the standard interpretation of the gravitational red shift* [7-9] When light falls in a gravitational field, a blue shift is observed because the observer's clock runs slower than that at the location of the light source and thus *more waves per unit time are counted* than would otherwise be the case[9]. The term "gravitational red shift" was coined specifically to describe the case when light *rises* through a gravitational field, as for example when light emitted from a star is observed on earth[7]. Einstein's prediction of a red shift in the latter case is based on the assumption, long since verified experimentally, that terrestrial clocks run faster than those near the sun and therefore must record a lower frequency than is observed for an identical light source when it is located on the earth's surface. Kündig[2] assumes that the fractional changes in gravitational potential and observed light frequency are of the same sign, whereas in fact $\frac{\Delta\Phi}{\Phi} = -\frac{\Delta\nu}{\nu}$ is correct [7-9]. The conclusion from the theoretical analysis of all three ultracentrifuge Doppler experiments[1-3] is therefore that an increase in light frequency was observed, that is, a shift in the opposite direction to that found with the Ives-Stilwell experiment[4-6].

One can only speculate why this important distinction was not pointed out explicitly by Hay et al.[1] and Kündig[2] in their discussion, but the suspicion is that they were dissuaded from doing so by the fact that the SR treatment of the transverse Doppler effect predicts unequivocally that a red shift will be observed in both cases. The very fact that Einstein's Equivalence Principle[7] was invoked to explain the results of the ultracentrifuge experiments implies that it cannot be simply a matter of perspective whether the absorber clock or that at the location of the light source is running slower. There is no doubt that the rates of clocks increase when they are raised to a higher gravitational potential. It is not a question of the perspective of the observer. Kündig[2] recognizes this when he states: "We thus see that the transverse Doppler effect and the time dilatation produced by gravitation appears [sic] as two different modes of expressing the same fact, namely that the clock which experiences acceleration is retarded compared to the clock at rest." This is a concise summary of the experimental results that leaves no doubt that the measurement process is perfectly objective.

Shortly after the paper by Hay et al.[1] appeared, Sherwin[8] clarified the interpretation of their experimental results by pointing out explicitly that there was no "ambiguity" as to which clock rate is slower. He went on to make the point that the fact that a blue shift is observed when the absorber is located at the rim of the rotor does not necessarily stand in contradiction to SR. This is because the absorber/detector is subject to high acceleration in the experiment and therefore does not satisfy the conditions for successful application of SR, namely that the "observer" be in uniform motion.

However, this argument was much more plausible to make in 1960 than it was a decade later after the timing results for atomic clocks located on circumnavigating airplanes became available[10,11]. Cesium atomic clocks were placed on aircraft that travelled in opposite directions around the world. According to the LT, both clocks should have run slower than their identical counterpart left behind at the airport of origin for the two flights. For example, let's assume that both flights took place at the Equator, and thus covered a distance of 40000 km before arriving back at the airport. If the average speed v in both directions was 800 km/h, the LT predicts on the basis of time dilation that *each* airplane clock ran slower than the stationary airport clock by a factor of 2.75×10^{-13}. This value is obtained by first computing the v/c ratio of 7.41×10^{-7} and then evaluating the Einstein time-dilation factor $\gamma-1=(1-v^2c^{-2})^{-0.5}-1 \approx 0.5v^2c^{-2}=2.75 \times 10^{-13}$. The elapsed time of each round-the world flight is calculated to be 40000 km/800 km/h= 1.8×10^5 s. Therefore, according to the LT, both airplane clocks should have arrived back at the airport with 5×10^{-8} s = 50 ns less time than the airport clock.

What HK found[11] instead is that the westward-flying airplane had 96 ns more time on its clock than that left behind at the airport, whereas the eastward-flying clock had lost 184 ns relative to the airport clock. They were only able to reconcile these results with the LT predictions by assuming that the speeds used to determine the values of the time-dilation γ factors have to be determined relative to a unique rest frame, namely that of the earth's "non-rotating polar axis." The justification for this restriction was that this rest frame, unlike those of the airplane and airport clocks, is inertial since it alone is not affected by the earth's rotation. The speeds (all in the easterly direction) of the various clocks relative to this reference are 1600 km/h for the airport clock (since the earth's rotational speed at the Equator has this value), and 800 (1600-800) and 2400 (1600 + 800) km/h for the westward- and eastward flying clocks, respectively. On this basis, it is found that the three clocks should all have lost time with respect to a hypothetical clock located at the earth's center of mass (ECM) because it is stationary with respect to the above reference frame: 50 ns for the westward-flying, 200 ns for the airport, and 450 ns for the eastward-flying clock. Computing time differences, one therefore expects that the clock flying west should return with 150 ns more, the one flying east with 250 ns less than the airport clock. Taking into account the details of the actual flight paths, HK found the results stated above of +96 ns and -184 ns, respectively. A correction for the gravitational speeding up of clocks (ghc^{-2}) for the two on the airplane also needed to be made. On this basis HK found that the expected time differences for the airplane clocks relative the airport clock agreed to within satisfactory error limits with the measured values.

In light of the conflict between remote non-simultaneity and proportional time dilation, it should be emphasized that HK's success in reconciling their experimental results with theory was only possible because they eschewed the traditional application of the LT that is found in textbooks dealing with relativity. In essence, they concluded that the LT prediction that a moving clock always runs slower than a stationary one is only applicable for perfectly inertial systems. This amounts to a two-tiered procedure for applying the LT to predict the amount of time dilation: the effect is *asymmetric* when the objects of the timing measurements are under the influence of unbalanced forces, but *symmetric* when this is not the case.

The above arrangement raises some interesting hypothetical situations when the boundary between asymmetric and symmetric time dilation is suddenly crossed. For example, consider the case of a slowly rotating planet in the context of the HK experiment. As long as the speed v of the (easterly-directed) orbital rotation is close to but still greater than zero, one must expect that the westward-flying clock will arrive back at the airport with (slightly) more elapsed time than either the airport clock or its counterpart that flew in the opposite direction (asymmetric time dilation). Yet, if the rotation stops completely, the LT prediction would revert back to the standard symmetric interpretation. Thus, from the standpoint of the eastward-flying airplane, the clock flying westward is moving at a relative speed of 1600 km/h in the original example. Accordingly, the westward-flying clock should arrive back at the airport with 200 ns *less* elapsed time than that carried onboard the eastward-flying plane. At the same time, one would have to conclude from the viewpoint of the observer on the westward-flying airplane that his on-board clock would return with 200 ns *more* elapsed time since the eastward-flying plane flies at a speed of 1600 km/h relative to him as well. That raises the obvious question as to how the two clocks could arrive back at the airport with each showing less (more) time than the other. In short, the LT prediction of symmetric time dilation is impossible to realize in practice.

On the other hand, a much more feasible outcome results in this case if we continue to use the procedure that assumes asymmetric time dilation. Lowering the earth's orbital speed to exactly zero would simply mean that each airplane clock moves with the same (800 km/h) speed relative to the ECM, in which case the prediction is that both clocks return to the airport with 50 ns less elapsed time than the clock left behind there. That would be the limiting value for both airplane clocks as the orbital speed approaches zero from both directions, exactly as one would expect based on the elapsed-time results obtained as a function of v. One therefore expects perfectly continuous behavior for both airplane clocks based on the asymmetric time-dilation interpretation, up to and including the null orbital-velocity limit.

In summary, the results of the Hafele-Keating (HK) experiments with circumnavigating atomic clocks do not mesh with the predictions of the Lorentz transformation (LT). This is the case despite the HK's attempt to reformulate Einstein's relativity theory to allow for a departure from his original interpretation of exclusively symmetric time dilation. This realization is consistent with the fact that the LT can be used to both *support* and *contradict* the occurrence of the remote non-simultaneity of events.

One can escape from this seemingly hopeless conundrum by demanding that the results of a revised theory be directly consistent with all experimental findings obtained to date. At the same time, it only makes sense to also require that Einstein's two postulates of relativity still be satisfied in the new theory. To this end it is important to see that asymmetric dilation has also been observed in all other time-dilation experiments, particular the tests made with x-ray radiation employing the Mössbauer effect[1-3]. As in the HK experiment, it was found that the periods of the associated clocks (absorber and source) mounted on a high-speed rotor are inversely proportional to γ (v_i), where v_i is the clock's speed relative to the rotor axis. It is seen that this inverse proportionality is identical with that found in the HK study, whereby the rotor axis now takes the place of the ECM as the rest frame from which clock speeds are to be measured. One can generalize these results and also bring them into a form suitable for use in a space-time transformation by simply requiring that the elapsed times measured in the two rest frames satisfy the Newtonian Simultaneity equation: $\Delta t'=\Delta t/Q$, where $Q = \gamma(v_i')/\gamma(v_i)$. The same formula is used to adjust atomic clocks carried on board satellites of the Global Positioning System.[12-14]

The fact is that clocks in motion do not always run γ times slower than the observer's clock, contrary to what the LT and SR predict. The experiments carried out with circumnavigating airplanes indicate instead that this result is only obtained when one uses a reference clock located on the earth's polar axis. One can obtain the ratio of clock rates for observers on different airplanes by first calculating their respective γ values relative to this reference clock and then computing the ratio of these two quantities. Hafele and Keating[10-11] rationalized this result by singling out the polar reference clock as the only one at rest in a truly inertial system. If true, this conclusion would greatly diminish the range of application for relativity theory since it would mean it could only be directly applied for an observer who is at rest in an inertial system.

No such restriction is in fact necessary in applying either the VT or the NVT. One simply has to know the clock-rate ratio for any two observers. This defines the conversion factor Q between their respective sets of measured elapsed times. Moreover, the reverse conversion factor is obtained as the reciprocal Q' = 1/Q. The VT and NVT can both be *applied on an instantaneous basis* independent of whether either the observer or the object of the measurement is accelerating at that moment in time. *There is no experiment which stands in contradiction to this conclusion.* In summary, there is a large amount of experimental data which indicates that *time dilation is asymmetric*, in clear opposition to Einstein's Symmetry Principle and the predictions of the LT. It is therefore reasonable to construct a theory of relativity[15] which is based squarely on Newtonian Simultaneity and eqs; (VI-5a-d) of the NVT.

Keywords: *Asymmetric time dilation, East-west clock effect, Einstein Equivalence Principle, Einstein Symmetry Principle, Hafele-Keating atomic clock experiment, Hay et. al. ultra-centrifuge experiment,, Ives-Stilwell experiment, Newtonian Simultaneity, NVT and RVT, Time dilation, Transverse Doppler effect (TDE)*

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IX. THE UNIVERSAL TIME DILATION LAW (UTDL)

The discussion in Chapter VIII shows that there was a concerted effort to explain all the measurements of elapsed times and frequencies in a manner which was somehow consistent with SR and the LT, particularly Einstein's Symmetry Principle. For example, Einstein's Equivalence Principle was invoked to rationalize the ultra-centrifuge data.[1-3] A decade later, Hafele and Keating[4,5] claimed that SR could only be used to compare elapsed times relative to the polar axis because it alone could be considered to be an inertial system in their study of atomic clocks on board circumnavigating airplanes.. It has been shown, however, in Chapter III that the LT is invalid because its space-time mixing characteristic is not consistent with the Law of Causality.[6,7] Moreover in Chapter IV it was noted that Einstein's LSP leads to a contradiction when attention is directed to the distances travelled by a light pulse in a given elapsed time relative to both its moving source and the rest frame where the emission took place (distance reframing).[8]

Once one accepts the possibility of asymmetric time dilation, however, another possibility emerges in a perfectly natural manner. In each case considered, it is possible to identify a specific rest frame which plays a key role in estimating the amount of time dilation. It is the laboratory in the ultra-centrifuge experiment, the earth's center of mass (ECM) in the Hafele-Keating study, and more generally the position from which the timing device has been accelerated to a given speed v. Einstein made a similar observation in his 1905 paper[9] when he discussed the example of an electron traveling in a circular orbit at constant speed which returns to its point of acceleration. In the following, we will refer to this as the *objective rest system*. (ORS).[10] If the speed of the clock or other timing device relative to the ORS is v, the amount of time dilation is proportional to $0.5v^2/c^2$, which in turn is equal to γ (v) - 1 to a good approximation in all cases. For the purpose of comparing the elapsed times Δt and Δt' measured for the same event by clocks moving respectively relative to the ORS with speeds v and v', one can describe this relationship in terms of the following inverse proportionality:

$$\gamma\left(v'\right)\Delta t' = \gamma\left(v\right)\Delta t\,. \tag{IX-1}$$

Because of its assumed general applicability, it is appropriate to refer to eq. (IX-1) as the Universal Time Dilation Law or UTDL.[11] It deserves the designation of "law" because it is *consistent with all the experimental tests of time dilation as yet reporte*d, many of which have been discussed in detail in Chapters VII and VIII.

One condition is that the effects of gravity have been properly accounted for in determining the values of Δt and Δt to be inserted in eq. (IX-1). This adjustment has been made explicitly in the Hafele-Keating study,[4,5] as well as in the measurements of muon and pion lifetimes.[12-16]. The ultra-centrifuge experiments[1-3] were carried out in the laboratory, so no adjustment for the effects of gravity were needed in this case, despite the fact that the authors invoked the Equivalence Principle in the interpretation of their results. The Ives-Stilwell measurements[17-19] were also carried out entirely within the laboratory, so no adjustment for the effects of gravity are required in this case either. The UTDL assumes that measured values of the γ (v) factors in eq. (IX-1) are simply approximated by $(1 + 0.5\ v^2/c^2)$ for small speeds in many cases; for much higher speeds the relativistic factor γ must be used instead.

As with all other laws of physics, as discussed in the Introduction, the UTDL extends a challenge to scientists everywhere to find an experimentally verifiable contradiction to its predictions. To date, no such contradictory evidence has been reported. Put more positively, this challenge can be looked upon as an opportunity to design new research projects that can test the validity of eq. (IX-1). One can also ask the question as to how the UTDL can be extended to cases if more than a single ORS is required. For example, how can it be applied to predict the ratio of elapsed time values where one clock is located on a satellite orbiting the moon while the other is on the earth's surface. Presumably, this goal can be accomplished by applying the UTDL twice for different ORSs. First, determine how much slower the clock on the satellite runs than its counterpart on the moon, and then combine this information with the corresponding ratio of elapsed times measured on the earth and moon.

It is easy to see that eq. (IX-1) can be used to determine the value of Q in the Newtonian Simultaneity relation, as shown below:

$$\Delta t' = \frac{\Delta t}{Q} = \gamma(v)\frac{\Delta t}{\gamma(v')} \quad . \tag{IX-2}$$

Rearrangement of these equations then leads to the desired value of Q, namely:

$$Q = \frac{\gamma(v')}{\gamma(v)}. \tag{IX-3}$$

By using the above value for the conversion factor Q in all four of the NVT eqs. (VI-5a-d), it then becomes possible to fully define this space-time transformation for a given pair of rest frames.

Keywords: *Distance reframing, Einstein's LSP, Equivalence Principle, Hafele-Keating atomic clock experiment, Ives-Stilwell experiment, Law of Causality, Muon-pion experiments, Newtonian Simultaneity, Objective rest system (ORS), Scale factor Q, Symmetry Principle of SR, Ultra-centrifuge experiment, Universal Time Dilation Law (UTDL)*

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X. ISOTROPIC LENGTH EXPANSION

The train example considered in Chapter IV also leads to some interesting results regarding length variations that occur when objects change their state of motion. The rider R on the train measures the speed of the light pulse to be c ms^{-1} as it moves from A to M. The distance between these two points is L m and thus the elapsed time is $\Delta t' = Lc^{-1}$ s. Note that each of these values is independent of the speed v of the train. It has already been shown based on the RVT that the value of the light speed on the train is also equal to c for observer S at rest on the platform. The corresponding elapsed time on his clock is larger by a factor of γ(v), i.e. $\Delta t = \gamma \Delta t'$. By the definition of speed, it therefore follows that the distance AM between A and M for observer S is equal to $c\Delta t = \gamma c \Delta t' = \gamma$ L m. Thus, application of the RVT finds that the distance measured by the observer on the station platform between these two points increases in direct proportion to γ(v). The observer R does not notice this change because the lengths of all stationary objects in his rest frame increase by the same factor. Since the speed of light is the same in all directions, it therefore follows that the above distance increases by the same factor as the elapsed time *independent of its orientation to S*. The conclusion is that there is *isotropic length expansion* in the rest frame where time dilation has occurred.

This is again a quite different result than one obtains from the LT. In that case, the distance AM on the train should decrease by the same factor of γ(v), i.e. because of Fitzgerald-Lorentz length contraction (FLC)[1], which has been discussed in Chapter III, a different answer is predicted by the FLC if AM is oriented perpendicularly to the direction of motion of the train relative to the platform, namely the stationary observer in S should find a value of L m in this case.

There are two conclusions to be drawn from this application. First, Einstein's original theory is not self-consistent. However, the RVT is just as much a part of this theory as the LT, so there is no reason for discounting predictions that are solely based on it. As a result, it is clear that Einstein's theory needs to be modified to remove this lack of consistency.

The second conclusion is based on experiment, namely measurements of wavelength in transverse Doppler studies [2-4]. The second-order Doppler effect discussed in Chapter VII is observed to increase in direct proportion to $\gamma(v)$. The measured wavelength in the laboratory is assumed to be the value that would be determined if the diffraction grating there could be transported without change to the rest frame of the accelerated light source. Thus the result of the transverse Doppler studies corresponds to *isotropic length expansion*, exactly as predicted by application of the RVT to the train example.

It should be noted that this experimental finding has been discounted by many authors by claiming that the LT and the FLC are not applicable to light waves. Yet the same argument is not used when the corresponding decrease in light frequencies required by the constancy of the light speed in free space is considered. In that case the result is hailed as an unequivocal demonstration of time dilation.

The above argument about wavelengths also overlooks a basic fact derived from the RP, however, namely local observers do not measure any change in wavelength at the light source itself. The only way to explain this result is by assuming that the dimensions of the diffraction grating in the same rest frame *have increased by exactly the same fraction* as the wavelength. Indeed, the same increase must have occurred for the observer himself in the rest frame of the source. Hence, the prediction of isotropic length expansion based on the RVT has been verified experimentally but has simply been ignored over the past 90 years because of the firm belief of physicists in the validity of the FLC and the LT.

An effective way of describing the effects of time dilation is through the use of physical units. When the rates of clocks are slowed because of a change in their state of motion, it means that the standard unit of time has increased. An observer co-moving with the clocks is generally unaware that such a change in units has taken place because it occurs uniformly for all stationary objects in his rest frame. The constant Q in the NVT of eqs. (VI-5a-d) serves as a *conversion factor* in going from one set of units to another. In the typical case where clocks are accelerated from S to S′, the unit of time increases to γ(v) s from its initial value of 1 s (Q=γ and $Q' = \gamma^{-1}$). As a result, a stationary observer in S′ will consistently measure smaller elapsed times for a given event than his counterpart in S with the faster clock.

It follows that there are also changes in the units of other physical quantities when clock rates slow. The speed of light is the same in both S and S', however, from which one concludes that the unit of velocity stays constant, i.e. the corresponding conversion factor is unity (Q^0). This fact forces a conclusion about the conversion factor for lengths and other distances, namely it must be exactly the same as for time (Q), which is clearly consistent with the concept of isotropic length expansion discussed above. The same result comes from multiplying both sides of the UTDL in eq. (IX-1) with c to obtain the corresponding relation between measured distances $D = c\Delta t$ and $D' = c\Delta t'$:

$$\gamma(v')D' = \gamma(v)D. \tag{X-1}$$

The observer in the accelerated rest frame measures smaller distance values because his unit of distance is greater. A simple means of visualizing this general situation is to consider the case of a rocket ship moving at $v = 0.866$ c relative to the surface of the earth. In that case the conversion factor between the two sets of units is $\gamma = 2$, i.e the clocks on the rocket run only half as fast as those on the earth. The observer R on the rocket doesn't notice any change in his clock rate until he looks out the window and notices that the time it takes the earth to make one rotation about its axis is only half of the normal value of 86400 s. He nonetheless finds that an object at rest on the Equator moves at the same speed w around the earth's axis as it did prior to the rocket's flight. How is this possible? Because the equatorial distance is now only half its normal size from R's vantage point on the rocket; the earth's volume is only one-eighth its normal value. In reality, the dimensions of the earth have not changed at all, but R still obtains the smaller values for its rotation time and equatorial distance because his units are twice as large as normal in both instances.

Keywords: *Conversion factor, Distance and speed factors, FLC and LT, Isotropic length expansion, NVT, RP, RVT, Scale factor Q, Transverse Doppler experiments, Units of time and distance*

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XI. UNIFORM SCALING AND AN ADDENDUM TO THE RP

The experiments mentioned in Chapters IX and X are complemented by a study of the variation of inertial mass m_I carried out in 1909. Bucherer[1] observed the variation of inertial mass of electrons with speed v relative to the laboratory in an electromagnetic field. It was found that m_I is also directly proportional to γ (v), the same as for time and distance. As a consequence, there is also an inverse proportional relationship completely analogous to the UTDL of eq. (IX-1) which relates values of the inertial mass m_i and m_i' measured in two different rest frames:

$$\gamma(v')m_i' = \gamma(v)m_i \, . \tag{XI-1}$$

On this basis, one can also conclude that the conversion factor for inertial mass must also be equal to Q, the same as for time and distance.

The conversion factors for all other physical properties can be deduced on the basis of their composition in terms of the three fundamental quantities: inertial mass, distance and time.[2] They will be referred to as *kinetic scale factors* in anticipation of future developments regarding the scaling pertaining to the effects of gravity. As a first example, consider the scaling of speed as a ratio of distance travelled to elapsed time. It has already been pointed out that the constancy of the speed of light in free space implies that the scale factor in this case is unity, i.e. Q^0. Consistency with the RP requires that the same scaling applies to the *relative speeds*, i.e. the speed of any two objects in relative motion to one another. Contrary to what is claimed in SR, however, the GVT is valid for all cases in which the speed/velocity of an object is measured *relative to two observers who are themselves in relative motion to one another.* As discussed in Chapter V, *vector addition* must be applied in such cases in order to obtain the correct value of the speed relative to each observer.

In the case of light in free space, the invariance required by kinetic scaling implies that the speed c is always referenced to the relevant light source. This form of the light speed postulate is consistent with the Michelson-Morley null interference effect;[3] both light beams travel the same distance from source to wall and back again, always with the same speed c. This is a form of the light-speed postulate which is consistent with the NVT, and replaces Einstein's LSP, which has been shown in Chapter IV to be invalid. It would be in violation of the RP if it were possible that observers in different rest frames to disagree on the value of the relative speed of any two objects. This would allow the passengers located below deck on Galileo's ship to distinguish whether they were sailing on a perfectly calm sea or were in fact still located at the dock prior to setting sail.

The kinetic scale factors for other physical properties must be integral multiples of Q in order to be consistent with the overall scaling procedure[2]. For example, the unit of energy E is proportional to the product of inertial mass m_i and the square of the speed v. As a consequence, because v is invariant to the scaling, the value of the energy scale factor is the same as for inertial mass, i.e. its value is also Q.

Acceleration is the ratio of speed to elapsed time; therefore it scales as the reciprocal of time, namely as Q^{-1}. Force has the unit of inertial mass times acceleration; it therefore scales as $Q \times Q^{-1}=Q^0$. Note that the same result is obtained by using the definition of force as the ratio of energy to distance, i.e. the scale factor is again deduced to be Q/Q= 1. Linear momentum has units of inertial mass times speed, so its scale factor is also Q. Another way to obtain the scale factor for force is to make use of Newton's Second Law of Motion F=dp/dT; this leads to the same scale factor of Q^0, so everything is consistent. Angular momentum scales as Q^2 by virtue of the fact that it is the product of inertial mass and linear momentum (1+1=2). Planck's constant h has the same unit as angular momentum. This is consistent with the energy/frequency ratio since frequency scales as Q^{-1} (the reciprocal of the time period), so multiplying with h leads to a factor of Q for energy (1=2–1), consistent with what has been deduced above.

The laws of physics are generally equations with the same units of physical properties on both sides. The above examples therefore demonstrate that the laws are always invariant to kinetic scaling. As a consequence, it is possible to extend the RP as follows[4]: *The laws of physics are the same in all inertial systems, but the units in which they are expressed will vary from one system to another.* Kinetic scaling is not restricted to inertial systems, however. It can be applied equally well *on an instantaneous basis* when either or both of the two rest frames are subject to an unbalanced external force. In the latter case, the value of Q will normally vary over the course of the measuring process.

The Uniform Scaling procedure described herein is consistent with the Principle of Rational Measurement (PRM) discussed in Chapter I. As a consequence, it is possible to deduce the value of the scale factor for a given pair of rest frames based on available information from a third rest frame. To illustrate this point, it is helpful to employ a more detailed notation with additional information given in parentheses. The value Q (S,S') refers to the scale factor between the observer's rest frame S and that of the object S'. Because of the PRM, the scale factor for two rest frames Q (2,3) can be obtained by taking the ratio Q(1,3)/Q(1,2) in terms of known scale factors involving a third rest frame. Because the reverse scale factor Q' is equal to 1/Q, it is possible to change the above ratio into the product Q(2,1) Q(1,3), i.e. where Q(2,1)= 1/Q(1,2). The example mentioned in Chapter X has three rest frames: the moon M, which is the common reference frame, is denoted with index 1, the earth E, which is the observer's rest frame, is denoted with index 2, and the satellite X, which is the rest frame of the object, is denoted with index 3. In the present notation, this means that Q (E,X) = Q (E,M) Q (M,X). In other words, the known value of Q (E,M) for the earth-moon relationship is combined with the other known value Q (M,X) for the moon-satellite relationship to obtain the unknown value Q (E.X) for the earth-satellite relationship. It helps to understand this result by noting that the amount of time dilation on the moon clock relative to its counterpart on earth is amplified by the corresponding amount of time dilation on the satellite clock relative to that of the moon clock. The advantage of the notation is that it makes clear which rest frame is that of the observer (left-hand index) and which one is that of the object (right-hand index).

The Uniform Scaling procedure assumes that at any given time there is a unique kinetic scale factor Q that allows a stationary observer in one rest frame to convert the values of measurements *in any other rest frame in the universe* to his own system of units. It is a completely rational system which makes it possible for an observer to ascertain the value of Q for any other pair of rest frames using the method outlined above. By contrast, Einstein's Symmetry Principle derived from the LT in SR leads to the conclusion that such straightforward relationships cannot exist. It is clearly impossible to define conversion factors in such a fundamentally subjective theory where it is not even clear which of two clocks runs slower/faster than the other.

Keywords: *Addendum to the RP, Determination of scale factors, Einstein's LSP, Einstein's Symmetry Principle, Galileo's ship, Kinetic scale factors, Light speed postulate of NVT, Objectivity of Q scaling factors, PRM, Scale factor for inertial mass (Paper 3), Uniform Scaling method, UTDL, Vector addition*

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XII. GRAVITATIONAL SCALE FACTORS

The elements of an analogous scaling procedure for gravitational effects on physical properties were laid down by Schiff in his 1960 paper[1]. His main interest was to design a relatively simple method for describing the proposed bending of light by gravitational forces. He based his method to a large extent on Einstein's[2] Equivalence Principle in which it was argued that the magnitude of a given light frequency increases by a factor of $S=1+\frac{gdh}{c^2}$ as the source is raised by a distance dh in a gravitational field of local magnitude g (c is the speed of light in free space). The derivation of this result assumes[2,3] that the gravitational mass m_G of an object is equal to its inertial mass m_I (weak equivalence principle). It otherwise makes use of Newton's Inverse Square Law (ISL) and the well-known result of SR[4] for the energy E of an object, $E=m_I c^2=\gamma(u)\mu c^2$, where μ is its proper mass, u is its speed and $\gamma(u)=\left(1-\frac{u^2}{c^2}\right)^{-0.5}$. In this respect, it must be noted that the argument given in Chapter III based on Newtonian Simultaneity to prove that the LT is invalid only is relevant for measurements of space and time and therefore does not apply to measurements of energy and momentum.

When an object falls between the above two potentials, respective local observers measure different energies, an effect which in classical physics is regarded as the conversion of gravitational potential energy $m_G gdh$ into an equal amount of kinetic energy. Einstein instead explained it as resulting from the change in the unit of energy as the distance from a gravitational source is varied[4]. He went on to argue[2] based on the Doppler effect[3] that the unit of light frequency ω changes in exactly the same proportion as the energy, which in turn is consistent with Planck's radiation law of quantum mechanics[5]. Terrestrial experiments by Pound and

Rebka[6] have verified Einstein's result to an accuracy of 5%, and subsequent work has lowered the possible discrepancy to at most 1% [7].

Einstein extended this result to other temporal processes such as reaction rates (*jeder physikalische Prozess*[2]), concluding that the unit of time decreases with gravitational potential by the same factor as the energy increases. He also gave an argument[2,3] indicating that the unit of distance measured parallel to the gravitational field increases by the same factor, while that for distances measured perpendicular to the field is unchanged. The above results are only valid for infinitesimal variations in gravitational potential, but it is a simple matter to eliminate this restriction by carrying out an appropriate integration between any two distances from the gravitational source. A convenient means of incorporating this extension into the theory is to define a factor A_p, such that

$$A_p = 1 + \int_{R_p}^{\infty} \frac{g dR}{c^2} = 1 + \frac{GM_s}{c^2 R_p}, \qquad \text{(XII-1)}$$

(G is the universal gravitation constant, M_s is the gravitational mass of the source, and R_p is the distance of the object from the source). Accordingly, the ratio of the radiative frequency/energy observed at R_o to that generated at R_p is $\frac{A_o}{A_p}$. Note that the logic underlying this conclusion is very similar to that used in Chapter XI to determine values of the kinetic scale factor as ratios of the values of Q/γ in different rest frames. The notation Q(S,S') can also be used for gravitational scale factors. The same method for relating scale factors in different rest frames also holds for the gravitational quantities, namely S(2,3) = S (2,1) S(1,3). These relationships are again reflective of the *objectivity* of the Uniform Scaling method as a whole. It is also important to point out that the form of the scale factor S= A_o/A_p is consistent with the general rule that the corresponding factor for "role reversal" must be the reciprocal of the original, i.e. in this case $S'=A_p/A_o=1/S$.

Given the above history, it is useful to take a critical look at what has occurred. To begin with, it is interesting that one of the main innovations that Einstein contributed was his decision to look upon the energy variation as the distance from a gravitational source is varied as resulting from the change in the unit of energy.[4] As emphasized at the end of Chapter X, it is not possible in SR to take the analogous position for the effects of motion on clock rates when one assumes that everything must be consistent with the predictions of the LT, specifically Einstein's Symmetry Principle. The conclusion that energy scales as S is based on solid theoretical arguments, namely Newton's ISL and the $E=mc^2$ relation of SR. The corresponding conclusion about the scaling of frequencies is less obvious, however. It requires that Planck's constant h is invariant to gravitational scaling. This turns out to be true but one would certainly like a better justification for this conclusion. That is provided by the Pound-Snider study[6,7] and also by the results of experiments with atomic clocks left on a mountain top for a lengthy period of time.[8] As a result, there is sufficient grounds to assume that the scale factor for frequency is the same as for energy; accordingly, the unit of time must vary as S^{-1}.

The scale factor for velocity/speed was also deduced by Einstein based on his Equivalence Principle[2,3] . In this case, experimental verification has come from Shapiro[9,10] in what he referred to as the "Fourth Test of Relativity." The situation is more complicated than usual, however. Schiff[1] used the following scaling in his computation of the displacement of star images by the effects of gravity:

$$v_{tr}(O) = Sv_{tr}(P) \tag{XII-2a}$$

$$v_{rad}(O) = S^2 v_{rad}(P) \tag{XII-2b}$$

Since the goal is to define a scaling procedure which allows an observer to convert measured values obtained at one gravitational potential to the units of another observer at a different gravitational potential, it is clear that eq. (XII-2b) should be eschewed for this purpose. This is because motion of an object radial to the field necessarily changes the gravitational potential at which it is located. Hence, it is concluded for the purposes of attaining this goal that speed/velocity must vary as S, the same as for energy.

The corresponding scale factor for inertial mass can be deduced from Einstein's $E=mc^2$ relation[4]. It therefore follows that inertial mass scales as the ratio E/c^2, i.e. as S^{-1}, (-1=1/1+1), the same as for time. Note that consideration of the scaling of the radial component of the velocity would lead to a dual scaling for inertial mass, which is not acceptable. A similar situation existed in SR, whereby there were supposed to be two different kinds of mass. This uncertainty was eventually removed by Planck,[11] thereby leading to the unique kinetic scale factor of Q based on eq. (XI-1). The scale factor exponent for distance (D =vT) is seen to be null (S^0), i.e. as 0=1-1.

The situation is now perfectly analogous to that encountered with kinetic scaling in Chapter XI. The gravitational scale factors for all other physical properties can be deduced to be integral multiples of S based on knowledge of their composition in terms of the three fundamental quantities, inertial mass, distance and time. For example, the energy scale factor is the product of the inertial mass factor with the square of the factor for speed, as already discussed with regard to the original derivation of $S=1+\frac{gdh}{c^2}$. The scale factor for linear momentum p is the same as for distance (S^0); it is obtained as the product of the speed and inertial mass factors, i.e. SxS^{-1}. Force scales as S since it is the ratio of momentum to time (1=0/-1). Alternatively, it is obtained as the product of inertial mass and acceleration, which scales as S^2 by virtue of its definition as the derivative speed with respect to time (2=1/-1). Angular momentum, which is the product of distance and linear momentum, is invariant to gravitational scaling. Note that Einstein[2] obtained his results for the scaling of energy and frequency by assuming that Planck's constant h, which has the same units as angular momentum, is invariant to the scaling, even though he gave no justification for this assumption.

The acceleration due to gravity $g=GM/r^2$ must scale in exactly the same manner as linear acceleration a= dv/dt. It would be in clear violation of the RP if this were not so. This means that GM must scale the same way as ar^2; the gravitational scale factor for this product is S^2, The gravitational mass M must be the same for all observers, so its scale factor for it is S^0. This means that the universal gravitation constant must vary as S^2. Its value is G=6.6743 10^{-11} $m^3kg^{-1}s^{-2}$, but this numerical value varies with the units of an observer at another gravitational potential. The unit of time (s) varies as S^{-1} while the units of distance and gravitational mass are completely independent of gravitation potential, so it is clear that scaling G with S^2 is indeed necessary. The corresponding value of the kinetic scale factor of G is Q, as the computation based on the kinetic scale factors for space and time show (1=3+0-2). Note also that this choice of scale factor means that GM/c^2r, the general formula for the A_p and A_o factors used to define S, are invariant to scaling; this conclusion is also consistent with the fact that the unit of GM is the same as for c^2r, namely m^3s^{-2}. Since the unit of gravitational mass is different than that for inertial mass, there is merit in using a different notation such as kg_M to distinguish it from the kg used for the m_i unit. Note that in the product GM the unit of gravitational mass is simply cancelled out. Note also that G and M appear together in a product in all relevant formulas, so one could just as well use a separate designation for the unit of GM, namely as m^3s^{-2}.

An important aspect of the Uniform Scaling method is the complete independence of kinetic and gravitational scaling from one another. This belies the oft quoted opinion that gravity cannot simply "be painted onto SR." Experimental evidence for this decoupling of gravity and motion comes from the Hafele-Keating study of atomic clocks on circumnavigating airplanes.[12,13] The amount of time dilation during the course of the flights is always obtained by *simply adding the two individual values for the effects of motion and gravity on the clock rates;* there is no such thing as a *cross term* that must be brought into the computations.

It is in fact possible to define the scaling factor for each property as a product of the individual values of the appropriate integral multiples of Q and S. In the following, we will refer to this quantity as Z. The mks unit is given in each case; note that the scaling can be applied equally well to the units. For example, Z = QS for energy and QS^{-1} for both time and inertial mass. Further examples are given below in Table 1.

Table 1. Kinetic and gravitational scaling factors for a number of physical properties. The results are given in terms of the numerical quantities Q and S defined in the text.

Quantity	Unit in the mks system	Combined Scale Factor Z
Energy (E)	Joule (J)	QS
Time (T)	Second (s)	QS^{-1}
Frequency ($\nu = T^{-1}$)	Hertz (hz)	$Q^{-1}S$
Distance (L)	Meter (m)	QS^0
Speed (v)	Meter per Second (ms^{-1})	Q^0S
Inertial Mass (m_I)	Kilogram (kg)	QS^{-1}
Gravitational Mass (m_G)	Kilogram (kg_M)	Q^0S^0
Universal Gravitation Constant (G)	($m^3s^{-2}kg_M$)	QS^2
Acceleration (a)	Meter per Second^2 (ms^{-2})	$Q^{-1}S^2$
Acceleration Due to Gravity (g)	Meter per Second^2 (ms^{-2})	$Q^{-1}S^2$

There is a connection between the kinetic and gravitational scaling factors when an object is in free fall. If one assumes that $E=mc^2$ holds locally at both R_o and R_p, it follows from the energy conservation principle that for macroscopic bodies the exact ratio is $\frac{\gamma(u_o)}{\gamma(u_p)}$, where u_o and u_p are the respective speeds of the object measured locally as it falls (rises) between R_p and R_o. In other words, the exact definition of A_p must ensure that

$$\frac{\gamma(u_p)}{A_p} = \frac{\gamma(u_o)}{A_o} \tag{XII-3}$$

as the object's distance from the gravitational source is varied (assuming that no other forces are present).

In order to apply the Uniform Scaling method, it is first necessary to determine the values of the Q and S scaling parameters. Let us take the Hafele-Keating study[12-13] of the rates of circumnavigating clocks as an example. In order to compute the value of Q it is necessary to recognize that the pertinent ORS is the ECM. The observer rest frame (S) is that of the airport in which the flights originated, whereas the object rest frame (S') is that in which a given airplane is momentarily located. The corresponding speeds relative to the ORS are denoted by v and v', respectively. That is all the information needed to compute the value of Q (S,S'). It is equal to the ratio γ (v')/γ (v).

The value of the gravitational scaling parameter S requires knowledge of the distances R_o (for the observer at the airport) and R_p (for the airplane) by which they were separated from the ECM at the time in question. The constants A_o and A_p are then determined as $1 + GM/c^2r$ by substituting the above values of R_o and R_p for r in each case (M is the gravitational mass of the earth). The value of S is then computed to be the ratio A_o/A_p. This calculation does not make use of an estimate of the average value of g, which was used as an approximation in the H-K study.

The elapsed time τ s for a given portion of the flight determined on the airplane clock is then multiplied with the factor Q/S to determine the corresponding amount of time which *would* be measured on the airport clock *in the units employed there.* Since Q/S>1 for the airplane clock flying in an easterly direction, the latter *loses* $(Q/S-1)\tau$ s relative to the airport clock for the current period The total amount of time lost is then obtained by integrating the respective $(Q/S-1)\tau$ s values for each portion of the flight over the entire duration from take-off to landing. This is a *theoretical* value which can then be compared with the actual difference of the total time registered on the airplane clock relative to that measured on the airport clock when the airplane has returned to the airport. In the actual study,[13] it was found that the eastward-flying clock lost 59 +/- 10 ns relative to the airport clock, while the westward-flying clock gained 273 +/- 7 ns.

The gravitational red shift was predicted by Einstein on the basis of his Equivalence Principle.[2] As been discussed earlier in this chapter, his assumption of a direct connection between gravitation and kinetic effects is incorrect because the two can be treated totally independent of one another. Nonetheless, he was able to anticipate the relationship between measurements of frequency made by observers at different gravitational potentials. The Uniform Scaling procedure takes note of this independence of the two effects, as shown in Table 1. Accordingly, one expects that an observer located on the earth's surface will measure a smaller value for a given frequency than his counterpart located during the surface of the sun, just as Einstein predicted in 1907.

The first step in the derivation is to identify the sun as the gravitational source. The distance separating the earth observer (O) from the sun's center of mass is designated R_o. It is greater than the corresponding value R_p for the observer (P) located near the surface of the sun. These values are then used to determine the values of A_i factors defined in eq. (XII-1). As a consequence, $A_p > A_o$; this means that the gravitational scale factor $S = A_o/A_p < 1$. The conversion factor for frequencies is S (see Table 1), so O needs to multiply the measured value of the frequency ν of a light source located on the sun's surface by S<1 to convert this value to his system of units. The result is that O records a smaller value for the frequency, namely S ν, than P, i.e. a gravitational red shift has been found.

There is confusion[2,3] about what happens to the associated wavelength of light λ, however. Normally, one expects that $c = \lambda\nu$, and so a decrease in frequency automatically means an increase in wavelength. According to Table 1, however, the wavelength should be the same at all gravitational potentials since it is a distance quantity. The reason for the discrepancy is that the speed of light scales as S, i.e. Sc, which is only consistent with λ being constant with respect to changes in gravitational potential. This is a key point since it also plays a role in the theory of the (apparent) bending of light by gravity, as will be discussed in Chapter XV..

The Pound-Snider experiment[6.7] is another interesting example that can be explained in a quite straight forward manner by the Uniform Scaling method. An x-ray source was mounted on the top of building and radiation was emitted toward the ground at a distance of h=22.5 m below. The gravitational source in this case is the ECM. The approximate definition of the gravitational scaling parameter can be employed with sufficient accuracy: $S= 1 + gh/c^2$. The x-ray radiation frequency ν of the x-rays is received below with a value of Sν. The difference is not due to a change in the absolute value of the frequency, but rather because of a difference in the unit of frequency at the two gravitational potentials. An interesting expect of the experiment is that the x-ray absorber performs with optimum efficiency when the value of the frequency is the same as for the emitter, i.e. ν. The experiment accounted for the increase in frequency to Sν received below by causing the detector to move with variable speed v downward relative to the rest frame in which the radiation was received. The increase in frequency due to the Doppler effect is (v/c)ν . Maximum efficiency of the absorber was therefore achieved by eliminating the effect of gravitation by means of this increase in frequency, i.e. by choosing the value of v so that

$$\frac{v}{c} = \frac{gh}{c^2} . \qquad \text{(XII-4)}$$

The value of g is 9.89 m/s^2, so the optimum value of v is estimated to be gh/c = 7.42x10^{-7} m/s on this basis. In the experiment, to an estimated precision of 0.8%, minimum transmission was obtained at this absorber velocity.

Keywords: *Compilation of Q and S scale factors, Definition of A_p factors, Definition of the gravitational scale factor S, Doppler effect, E=mc^2, Einstein Equivalence Principle, Einstein's Symmetry Principle, Free fall relation for A_p and γ factors, Gravitational scaling of light speed, Hafele-Keating atomic clock study, Hafele-Keating study, Newton's Inverse Square Law, Objectivity of S scaling factors, Planck's radiation law, Pound and Rebka experiments, Pound-Snider experiment, Radial velocity scaling, Schiff scaling method, Separation of Q and S scale factors, Shapiro's Fourth Test of Relativity, Uniform Scaling method, Values of gravitational scale factors for other properties, Weak equivalence principle*

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XIII. UNIFORM SCALING AND GPS

As discussed in previous chapters, the rates of clocks are known experimentally to change with both their state of motion (time dilation) and their position in a gravitational field (red shift). The Hafele-Keating study[1,2] found that the earth's center of mass (ECM) plays a central role in each case. The fractional change in rate depends on the speed of a given clock relative to that position as well as the corresponding difference in gravitational potential. As a result, in comparing different clocks on the earth's surface, it is necessary to know both the latitude χ of each clock as well as its altitude h relative to sea level[3]. The slowing down of clock rates due to their motion is inversely proportional to γ ($R_E\Omega\cos\chi$) , where Ω is the earth's rotational frequency (2π radians per 24 h = 86 400 s) and R_E is the earth's radius (or more accurately, the distance between the location of the clock and the ECM).

In order to have a network of clocks located on the earth's surface, it is first necessary to designate one (Z) as a standard (note that in the following discussion it is assumed that all clocks run at constant rates). Theoretically, there is no restriction on its location. Its latitude χ_Z and altitude r_Z relative to the ECM are then important parameters in computing the ratio of the rates of each clock in the network with that of the standard clock. For this purpose it is helpful to define the ratio Q as follows:

$$Q = \gamma\left(\frac{R_E\Omega\cos\chi}{R_E\Omega\cos\chi_Z}\right). \qquad \text{(XIII-1)}$$

This ratio tells us how much slower (if Q>1) or faster (if Q<1) the given (secondary) clock runs than the standard if both are located at the same gravitational potential. The gravitational red shift needs to be taken into account to obtain the actual clock-rate ratio, however. For this purpose, it is helpful to define a second ratio S for each secondary clock:

$$S = 1 + g\left(r - r_Z\right)c^{-2}, \tag{XIII-2}$$

where r is the distance of the clock to the ECM. This ratio tells us how much faster (S>1) the secondary clock runs relative to the standard by virtue of their difference in gravitational potential. The elapsed time Δt on the secondary clock for a given event can then be converted to the corresponding elapsed time Δt_Z on the standard clock by combining the two ratios as follows

$$\Delta t_Z = QS^{-1}\Delta t\ . \tag{XIII-3}$$

It is possible to obtain the above ratios without having any communication between the laboratories that house the respective clocks. The necessary synchronization can begin by sending a light signal directly from the position of a secondary clock A that lies closest to Z. The corresponding distance can be determined to as high an accuracy as possible using GPS. Division by c then gives the elapsed time read from clock Z for the one-way travel of the signal. The time of arrival on the standard clock is then adjusted backward by this amount to give the time of emission $T^{S0}(Z)$ for the signal, again as read from clock Z. The corresponding time of the initial emission read from clock A is also stored with the value $T^0(A)$. In principle, all subsequent timings can be determined by subtracting $T^0(A)$ from the current reading on clock A to obtain Δt= Δt (A) to be inserted in eq. (XIII-3). The time T^Z of the event on the standard clock is then computed to be:

$$T^Z = QS^{-1}\Delta t\left(A\right) + T^{S0}\left(Z\right), \tag{III-4}$$

where Q and S are the specific values of the ratios computed above for clock A.

Once the above procedure has been applied to clock A, it attains equivalent status as a standard. The next step therefore can be applied to the clock which is nearest either to clock A or clock Z. In this way the network of standard clocks can be extended indefinitely across the globe. Making use of the “secondary” standard (A) naturally implies that all timings there are based on its adjusted readings. It is important to understand that no physical adjustments need to be made to the secondary clock, rather its direct readings are simply combined with the Q and S factors in eq. (III-4) to obtain the timing results for a hypothetical standard. A discussion of this general point has been given earlier by van Flandern[4]. The situation is entirely analogous to having a clock in one's household that runs systematically slower than the standard rate. One can nonetheless obtain accurate timings by multiplying the readings from the faulty clock by an appropriate factor and keeping track of the time that has elapsed since it was last set to the correct time. The key word in this discussion is "systematic." If the error is always of quantitatively reliable magnitude, the faulty clock can replace the standard without making any repairs.

The same principles used to standardize clock rates on the earth's surface can also be applied for adjusting GPS satellite clocks. More details about such procedures may be found elsewhere,[5,6], so only a brief summary will be given in the present work. Assume that the clock is running at the standard rate prior to launch and is perfectly synchronized with the standard clock (i.e. as adjusted at the local position). In order to illustrate the principles involved, the gravitational effects of other objects in the neighborhood of the satellite are neglected in the following discussion, as well as inhomogeneous characteristics of the earth's gravitational field. The main difference relative to the previous example is that the Q and S factors needed to make the adjustment from local to standard clock rate using eqs. (III-3,4) are no longer constant. Their computation requires a precise knowledge of the trajectory of the satellite, specifically the current value of its speed v and altitude r relative to the ECM. The acceleration due to gravity changes in flight and so the ratio S also has to be computed in a more fundamental way. For this purpose, it is helpful to define the following quantity connected with the gravitational potential:

$$A(r) = 1 + \frac{GM_E}{c^2 r}, \qquad \text{(III-5)}$$

where M_E is the gravitational mass of the earth (5.975×10^{24} kg) and G is Newton's Universal Gravitation Constant (6.67×10^{-11} Nm^2/kg^2). The value of S is therefore given as the ratio of the A (r) values for the satellite and the standard clock:

$$S = \frac{A(r_Z)}{A(r)}, \qquad \text{(III-6)}$$

which simplifies to eq. (III-2) near the earth's surface (with $g = GM_E r_Z^{-2}$). The corresponding value of the Q ratio is at least simple in form:

$$Q = \frac{\gamma(v)}{\gamma(v_Z)} = \frac{\gamma(v)}{\gamma(R_E \Omega \cos \chi_Z)}. \qquad \text{(III-7)}$$

Note that the latitude χ_Z is not that of the launch position relative to the ECM, but rather that of the original standard clock. The accuracy of the adjustment procedure depends primarily on the determination of the satellite speed v relative to the ECM at each instant.

In this application the underlying principle is to adjust the satellite clock rate to the corresponding standard value over the entire flight, including the period after orbit has been achieved[5]. The correction is made continuously in small intervals by using eq. (III-3) and the current values of Q and S in each step. The result is tantamount to having the standard clock running at its normal rate on the satellite. This above procedure super-cedes the "pre-correction" technique commonly discussed in the literature[3] according to which the satellite clock is *physically* adjusted prior to launch. The latter's goal is to approximately correct for the estimated change in clock rate expected if the satellite ultimately travels in a constant circular trajectory once it achieves orbital speed. The present theoretical procedure has the advantage of being able to account for departures from a perfectly circular orbit and also for rate changes occurring during the launch phase.

Keywords: *Computation of the S gravity factor, Definition of A(r) factor, GPS, Hafele-Keating study, Newton's Universal Gravitation Constant G, Pre-correction of atomic clocks, Synchronization of atomic clocks, Von Vlandern suggestion*

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XIV. SCALING OF ELECTROMAGNETIC PROPERTIES

The applications of the Uniform Scaling method in the previous chapters have dealt exclusively with mechanical variables that are multiples of the three fundamental quantities: distance, mass and time. This raises an interesting question, however. What about other quantities such as electric charge and voltage which appear in the laws of electricity and magnetism? In this regard it is noteworthy that the Giorgi system of units[1] which was introduced in 1901 ensures that whenever *the results of electromagnetic calculations* involve exclusively kinematic quantities, they automatically come out in terms of the mks system of units. The purpose of the discussion in the present chapter is to show that it is possible to define an alternative system of units that allows one to express all electromagnetic quantities *directly* in the mks system.

A. Choices of mks units

A simple way to begin this analysis is to consider how Coulomb's Law is formulated in the Giorgi system. The force F_e in Newton (1 N = 1 kg m/s^2) between two electric charges q_i and q_j (expressed in Coul) separated by a distance of r_{ij} m is given by the vector relation:

$$\mathbf{F_e} = \frac{q_i q_j \mathbf{r_{ij}}}{4\pi\varepsilon_0} r_{ij}^{\ 3}, \tag{XIV-1}$$

where ε_0 is referred to as *the permittivity of free space*. The Giorgi unit for ε_0 is defined in such a way (Coul^2/Nm^2) so as to insure that the result for F_e in eq. (XIV-1) is expressed in the mks unit of force (N). The point that needs to be emphasized with regard to this equation is that it serves as a *definition of both electric charge and ε_0.* In order to satisfy the above requirement in the mks system, it is actually only necessary that the unit for the product of two electric charges q_i q_j

divided by ε_0 is Nm^2. This shows that there is an *inherent redundancy* in any system of electromagnetic units *that cannot be removed by experiment.* One is free to choose any unit for electric charge q as long as the corresponding definition of ε_0 satisfies the above condition.

For example, one attractive possibility is to give electric charge the same unit as energy, namely J = Nm, and to give ε_0 the unit of N. Another, perhaps less attractive, possibility would be to make ε_0 dimensionless. This is in fact what is done with the older Gaussian set of units in which charge is expressed in esu. In that system the quantity $4\pi\varepsilon_0$ in Coulomb's Law is missing entirely. One can do this and still remain in the mks system by defining the unit of electric charge to be $N^{0.5}m$. The key point is that there is no *a priori* reason for avoiding such a choice because charge is only defined experimentally through eq. (XIV-1).

There is only one other relationship that must be satisfied in order to extend such an mks-type system to the description of magnetic interactions. The constant μ_0 in the law of Biot and Savart[2] must satisfy the equation below from Maxwell's electromagnetic theory:

$$\varepsilon_0 \mu_0 c^2 = 1, \qquad \text{(XIV-2)}$$

where c is the speed of light in free space (299792458 m/s). The unit in the Giorgi system is N/Amp^2 or $Ns^2/Coul^2$. If the unit of ε_0 is N, it follows from eq. (XIV-2) that the corresponding unit for μ_0 is s^2/Nm^2. Alternatively, if ε_0 is to be dimensionless, then the unit for μ_0 becomes s^2/m^2.

Once the unit of electric charge has been fixed in the mks system, the corresponding units for all other quantities that occur in the theory of electricity and magnetism are determined by the standard equations in which they occur. An extensive list of such quantities illustrating this point is given in Table 2. The corresponding units are always given in terms of those of force, length and time in the mks system. Two sets are given in each case, one in which the unit of electric charge is Nm and the other in which it is $N^{0.5}m$. The former is referred to as the Nms system so as to distinguish it from the standard mks system for purely kinematic quantities, the other as the $N^{0.5}ms$ system, in which ε_0 is dimensionless. Just a few examples will be given below which emphasize the practicality of the concepts introduced above.

The unit of potential (or emf) U is dimensionless in the Nms system since it is proportional to electric charge and inversely proportional to ε_0 and a distance given in m. It has the unit of $N^{0.5}$ in the other system based on the same definition. Since the electric field E is the gradient of a potential, it follows that it has a unit of m^{-1} in the Nms system and $N^{0.5}/m$ in the other. The unit of current I is Nm/s in the former case, while that of resistance R (I=V/R) is accordingly s/Nm. In the $N^{0.5}ms$ system, R has the unit of s/m, i.e. the reciprocal of that of velocity, whereas the unit for I is $N^{0.5}m/s$.

In the Giorgi system of units, the magnetic force F_m for a given charge q moving with velocity v in magnetic field B is defined as:

$$\mathbf{F_m} = q\mathbf{v} \times \mathbf{B} . \tag{XIV-3}$$

It therefore follows that B has the unit of s/m^2 in the Nms system and $N^{0.5}s/m^2$ in the $N^{0.5}ms$ system. The Nms unit of magnetic flux (Weber in the Giorgi system or Tesla m^2) is s, consistent with the requirement that an induced emf, which is dimensionless in the Nms system of units, is given by the derivative of the magnetic flux with respect to time. In the $N^{0.5}ms$ system its unit is $N^{0.5}s$. It is easy to show that the units are consistent for Maxwell's equations in both of these systems of units. For example, the differential form of Faraday's law of electromagnetic induction,

$$\mathbf{curlE} = \frac{-\partial \mathbf{B}}{\partial t}, \tag{XIV-4}$$

has the units of m^{-2} on both sides in the Nms system and $N^{0.5}/m^2$ in the other.

There are two main advantages of the above definitions.[3] First, it amounts to a much more compact system of units, where all properties are expressed completely in terms of the fundamental units of the mks system. There is a more important advantage, however. The Uniform Scaling method can be applied directly for any combination of electromagnetic quantities.

Table 2. Correlation of the units of electromagnetic quantities in various systems. The standard Giorgi system is compared with two alternatives, the Nms and $N^{0.5}$ms systems, whose units are exclusively multiples of N, m and s in the standard mks system for strictly mechanical variables. The quantities are also subdivided into K-type scaling classes, as discussed below.

Quantity	Symbol	Giorgi	Nms	$N^{0.5}$ms	Scaling Class
Electric charge	q	Coul	Nm	$N^{0.5}$m	K
Permittivity	ε or ε_0	$Coul^2/Nm^2$	N	____	K^2
Current/mmf	I	Amp	Nm/s	$N^{0.5}$m/s	K
Permeability	μ or μ_0	N/Amp^2	s^2/Nm^2	s^2/m^2	K^{-2}
Potential/emf	V	Volt	_____	$N^{0.5}$	K^{-1}
Resistance/impedance	R/Z	Ohm	s/Nm	s/m	K^{-2}
Electric field	E	Volt/m	1/m	$N^{0.5}$/m	K^{-1}
Volume charge density	ρ	$Coul/m^3$	N/m^2	$N^{0.5}/m^2$	K
Surface charge density	σ	$Coul/m^2$	N/m	$N^{0.5}$/m	K
Electric dipole moment	μ_e	mCoul	Nm^2	$N^{0.5}m^2$	K
Electric quadrupole moment	Q_{ij}	m^2 Coul	Nm^3	$N^{0.5}m^3$	K
Electric polarization	P	$Coul/m^2$	N/m	$N^{0.5}$/m	K
Electric displacement	D	$Coul/m^2$	N/m	$N^{0.5}$/m	K

Electric susceptibility	χ	Coul/mVolt	N	____	K^2
Polarizability	α	m^2Coul/Volt	Nm^3	m^3	K^2
Coefficient of potential	p_{ij}	Volt/Coul	1/Nm	1/m	K^{-2}
Capacitance/coeff. of capacitance	C or c_{ij}	Coul/Volt	Nm	m	K^2
Current density	J	Coul/m^2s	N/ms	$N^{0.5}$/ms	K
Conductivity	g	Coul/msVolt	N/s	1/s	K^2
Resistivity	η	msVolt/Coul	s/N	s	K^{-2}
Magnetic flux	Φ	Weber	s	$N^{0.5}$s	K^{-1}
Magnetic induction	B	Weber/m^2	s/m^2	$N^{0.5}$s/m^2	K^{-1}
Magnetic vector potential	A	Weber/m	s/m	$N^{0.5}$s/m	K^{-1}
Magnetic scalar potential	U*	Amp	N/ms	$N^{0.5}$m/s	K
Magnetic dipole moment	M	m^2Amp	Nm^3s	$N^{0.5}m^3$/s	K
Magnetization	M	Amp/m	N/s	$N^{0.5}$/s	K
Inductance	L	Henry	s^2/Nm	s^2/m	K^{-2}
Magnetic current per unit area	J_m	Amp/m^2	N/ms	$N^{0.5}$/ms	K
Magnetic intensity	H	Amp/m	N/s	$N^{0.5}$/s	K
Reluctance	*R*	Amp/Weber	Nm/s^2	m/s^2	K^2
Admittance	Y	Mho	Nm/s	m/s	K^2

B. Simple scaling procedures

The interdependency of the definitions of electric charge q and permittivity ε_0 also presents other options for the choice of units for electromagnetic quantities than those of the Giorgi system. The esu system of units[4] employs a much smaller unit of electric charge than Coul, for example, which therefore makes it unnecessary to include the $4\pi\varepsilon_0$ factor in eq. (XIV-1), which is to say that in this system of units, $\varepsilon_0 = 1/4\pi$. The system of atomic units, in which the electronic charge e serves as the unit of electric charge, makes the same choice for ε_0. In the present chapter we will illustrate how the various electromagnetic units of the Giorgi system can be modified in a systematic manner so that the latter condition is also fulfilled for mks units.

To begin this discussion, it is important to note that the value of ε_0 in the Giorgi system is based directly on the speed of light in mks units: the value of $4\pi\varepsilon_0$ is equal to $10^7/c^2$. Since the speed of light in free space is no longer measured but is simply defined by international convention to have the above value[5], it follows that there is also no need to determine quantities such as the Coulomb (Coul) and ε_0 that are ultimately based on the value of c. A convenient quantity with which to scale the various standard Giorgi units is $K = (4\pi\varepsilon_0)^{-0.5} = 10^{-3.5}c \approx 94802$. In the following we will refer to the new set of units as the KNms system. First, we define the corresponding value of the permittivity as $\varepsilon_0' = K^2\varepsilon_0$, so that $4\pi\ \varepsilon_0' = 1$ N. In general, the units in the new system are those given in Table 2 under the Nms heading, that is, with the unit of electric charge equal to 1 J = 1 Nm. It should be clear, however, that the numerical value attached to ε_0' in the new system is completely independent of this choice. One could just as well choose the unit of charge to be $N^{0.5}m$, for example, or any other combination of N, m and s, as long as one adheres to the requirements already discussed in Chapter XIV.A.

The objective in changing the numerical values of electromagnetic constants such as ε_0 is clearly to simplify computations in this important area of physics. One of the problems with changing over from the Giorgi to the Gaussian system of units is that in many cases this requires using different formulas for the same interaction. One can avoid this difficulty by agreeing at the outset that all formulas in the new KNms system will be the same as for the Giorgi system, since the latter have become standard over the past century. Let us consider eq. (XIV-1) as the first example. In order to retain the same form for this equation while using the above value for ε_0', it is simply necessary to change the numerical value of each electric charge. Specifically, one has to change the unit of charge to K^{-1} Coul. This means that the value of the electronic charge (e') becomes K times larger than the standard value in Coul, i.e, e' = 94802 x 1.602 x 10^{-19} J = 1.5187 x 10^{-14} J. In effect then, the change from the Giorgi to the KNms system of units occurs by multiplying both the numerator and denominator in eq. (1) by the same factor (K^2). The result is that one has the same form for eq. (1) as in the Gaussian or atomic unit versions, i.e. where $4\pi\varepsilon_0 = 1$ and thus does not appear explicitly.

The main point that the above discussion reveals is that it is useful to divide the variables that commonly occur in the theory of electricity and magnetism into classes according to the way in which their numerical values need to be scaled. In the KNms system, this means that each such variable needs to be associated with a specific power of K. This information has also been given in Table 2 in each case. Since $\varepsilon_0' = K^2\varepsilon_0$, for example, it is necessary to multiply the Giorgi value for μ_0 by K^{-2} in order to be consistent with eq. (XIV-2), that is, without changing the value of c. As a result, $\mu_0' = 4\pi/c^2$. Again, the preferred approach is not to eliminate ε_0' and μ_0' from the formulas in the KNms system, rather only to change their numerical values relative to those in the Giorgi mks system so that the form of the standard equations in the latter system is completely retained.

Other quantities that belong to the same K-class in Table 2 as electric charge are charge densities ρ and σ, dipole moment μ, quadrupole moment Q, current I, current density J, magnetic dipole moment m, magnetization M and magnetic intensity H. The corresponding quantities of K^{-1} type are: electric potential U, electric field E, magnetic field (or induction) B, magnetic flux

Φ and magnetic vector potential A. A check of all formulas in which the latter quantities appear shows that they always occur with counterparts in the K class mentioned first, as, for example, q and B in eq. (XIV=3) or q and E in the corresponding expression for electric force.

Some quantities do no not have to be scaled at all (K^0-type). They include all dimensionless quantities such as magnetic susceptibilities and refractive indices. The same is of course true for all non-electromagnetic quantities such as force, energy and angular momentum. A less trivial example is the Poynting vector ($E \times H$), which is a product of a K^{-1}- and K-type variable, respectively. All other commonly occurring quantities are either of K^2- or K^{-2}-type. In addition to ε_0 among the former are the dielectric constant ε and electrical susceptibility χ (Table 2), as well as polarizability, capacitance, reluctance, conductivity and admittance. Some examples of K^{-2}-type are in addition to μ_0: permeability μ, resistance, coefficient of potential p_{ij}, resistivity η and inductance L. The latter quantity is defined as $d\Phi/dI$, which is a ratio of a K^{-1}–type quantity to the current, which is of K-type.

The conversion factors between the Giorgi and the present KNms systems of electromagnetic units for a number of the most commonly used quantities are given in Table 3. Unlike the case for the corresponding conversion between the Gaussian and Giorgi systems[3], the formulas in which they are to be used respectively are exactly the same, as discussed above. To be specific, we have given these factors as functions of c rather than of K itself. Clearly, any other value of K could be used while still allowing the Giorgi formulas to be retained in the new system of units. The value of the electric charge in any such system of units is K times that of the numerical value in the Giorgi system ($e=1.602 \times 10^{-19}$). As long as one adheres to the scheme of dividing the variables into K-type classes according to the prescriptions of Table 2, this information is sufficient to characterize any new system of this type. In other words, the scaling procedure is always perfectly defined by the value chosen for K in a specific instance.

Table 3. Conversion of various electromagnetic units from the Giorgi to the KNms system discussed in Chapter XIV (c is the speed of light in free space, 299792458 m/s).

Quantity	Giorgi	KNms
Electric charge	1 Coul	$10^{-3.5}$c Nm
Electric current	1 Amp	$10^{-3.5}$c Nm/s
$4\pi\varepsilon_0$	10^7c^{-2} Coul^2/Nm^2	1 N
$\mu_0/4\pi$	10^{-7} N/Amp^2	c^{-2} s^2/Nm^2
Electric field	1 Volt/m	$10^{3.5}$ c^{-1} 1/m
Potential	1 Volt	$10^{3.5}$ c^{-1}
Magnetic induction	1 Weber/m^2	$10^{3.5}$ c^{-1} s/m^2
Magnetic intensity	1 Amp/m	$10^{-3.5}$c N/s
Magnetic flux	1 Weber	$10^{3.5}$ c^{-1} s
Electric displacement/polarization	1 Coul/m^2	$10^{-3.5}$c N/m
Capacitance	1 Farad=Coul/Volt	$10^{-7}c^2$ Nm
Inductance	1 Henry	10^7c^{-2} s^2/Nm

Keywords: *Atomic units, Conversion of units (Table 3), Correlation of units (Table 2), Coulomb's Law, Esu system of units, Faraday's law of induction, Gaussian system of units, Giorgi System, K-classes of variables, Law of Biot and Savart, Magnetic Force, Maxwell's equations, mks system of units, Redundancy in Electromagnetism units, Scaled value of electric charge, Scaling of em units, Uniform Scaling*

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XV. DISPLACEMENT OF STAR IMAGES

The Uniform Scaling method discussed in the previous chapters is based on a set of laws of physics which summarize a wide variety of experimental results. It is not derived from so-called First Principles. Many of the ideas underlying the Uniform Scaling method are inspired by a 1960 paper by Schiff[1] outlining a simple computational procedure that leads to the (tentative) conclusion that light rays are deflected when they pass close to the sun. It also offers a consistent explanation for the gravitational red shift. He stated that both effects can be obtained "in a valid manner without using the full theory," i.e. Einstein's General Theory of Relativity (GR)[2]. He emphasized that when future experiments are analyzed, "it is important to understand the extent to which they support the full structure of general relativity, and do not merely verify the equivalence principle and the special theory of relativity." It also should be noted that Schiff makes use of Newton's classical gravitation theory in arriving at his conclusions.

In the following, it will be shown that neither the Equivalence Principle nor SR is required to justify Schiff's method. This is an important observation since it has been pointed out in Chapter III that SR is not a valid theory because it relies on the space-time mixing characteristic of the LT, therefore rendering it to be inconsistent with the Law of Causality.[3,4] Moreover, in Chapter IV it has been shown that Einstein's light-speed postulate, which is a key assumption in the derivation of the LT, is also not tenable.[5] The gravitational red shift is simply a fact of nature; the rates of clocks increase as they are taken to higher gravitational potentials. The Hafele-Keating experiments[6,7] show unequivocally that the effects of gravity and motion are completely separate from one another, in direct contradiction to Einstein's Equivalence Principle The Uniform Scaling method takes note of this state of affairs by using distinct conversion factors for the effects of acceleration and gravity to describe the relationships between measured values of properties in different rest frames.

The purpose of the present chapter is to demonstrate via explicit trajectory calculations that the above experiments can be successfully interpreted by merely assuming that the *speed of light for a stationary observer varies with lateral distance from the sun.* It will be shown that the observed angular displacement of star images is predicted quantitatively on this basis, and it is therefore concluded that the light rays themselves are actually *not* deflected as they pass near massive bodies, but rather are merely slowed down.

A key assumption in Schiff's approach[1] is that local observers always measure the speed of light to have a constant value of c. Moreover, the light moves in the same perfectly straight-line trajectory for a succession of such observers, that is, the *local* light velocity is always constant in both direction and magnitude. The calculations then proceed on the basis of arguments given much earlier by Einstein[8,9] that the unit of time varies in a well-defined manner [see eq. (5) of Schiff's paper] with the position of the observer in a gravitational field. The same assumption in the Uniform Scaling method is found in Table 1 of Chapter XII. Schiff also made an additional assumption that the unit of distance in the direction *radial* to the sun varies in inverse proportion to the unit of time, i.e. as S, whereas that in transverse directions is independent of gravitational potential [his eqs. (5) and (6), respectively]. This approach gives results for the angle of light deflection by the sun which are in quantitative agreement with Einstein's predictions based on GR.[2]

Schiff began by considering the periods of three clocks "in a gravity-free region, in which they are accelerated upward with acceleration g." He found that the times T_A and T_B satisfy the following approximate relationship:

$$T_B \approx T_A \left[1 + \left(\frac{GM}{c^2 r_B} \right) - \left(\frac{GM}{c^2 r_A} \right) \right], \qquad \text{(XV-1)}$$

where G is the universal constant of gravitation, c is the speed of light in free space, M is the spherically symmetric mass from which the field arises, and r_A and r_B are the distances from the center of the gravitational mass. In his derivation, clock A is located at the higher gravitational potential ($r_A > r_B$), so that $T_B > T_A$. Consequently, the clock B at the lower potential is predicted to run slower than its counterpart A, which is in quantitative agreement with the corresponding result for the scaling of time in Table 1, i.e. with index O =A and P= B, so that S=Ao/Ap <1.

Schiff next applied his analysis to distances. He distinguished between distances measured transverse L_{tr} and radial L_{rad} to the gravitational field on the basis of the Lorentz-FitzGerald length contraction relationships derived in SR:

$$L_{tr}\left(O\right) = L_{tr}\left(P\right) = S^0 L_{tr}\left(P\right) \qquad \text{(XV-2)}$$

$$L_{rad}\left(O\right) = SL_{rad}\left(P\right), \qquad \text{(XV-3)}$$

The latter two equations when combined with the scaling of time in Table 1 then give the corresponding proportionalities for the respective transverse v_{tr} and radial v_{rad} components of velocity:

$$v_{tr}\left(O\right) = Sv_{tr}\left(P\right) \qquad \text{(XV-4)}$$

$$v_{rad}\left(O\right) = S^2 v_{rad}\left(P\right), \qquad \text{(XV-5)}$$

A key assumption in Schiff's method is that the local observer (P) travelling with a light ray always measures the speed of light to be c. The calculation starts with the light ray at a large distance away from the earth moving along the x axis. The light velocity is resolved into its transverse and radial components and then scaling proceeds in accordance with eqs. (XV-4 and 5). The light trajectory over the entire distance to the earth is then computed analytically in Schiff's approach.

An alternative, and computationally equivalent, method[10] makes use of a finite differences approach. In each cycle, the light is assumed to travel over a short time Δt at the current velocity along the x axis, at which time the position of the light has changed by Δx. The new position is recorded and serves as the origin for further motion in the next cycle. At each stage of the calculation, the light velocity is directed along the x axis, so that the perpendicular distance Y_1 from the sun remains constant throughout. The calculation continues until the light has reached its final position at the surface of the earth. The sum of the distance changes in each cycle is then set equal to $X(Y_1)$.

The procedure is then repeated for a different lateral distance Y_2 from the sun. If $Y_2 > Y_1$, it is found that the corresponding distance travelled by the light $X(Y_2) > X(Y_1)$. This result is understandable since the damping of the light velocity decreases as the lateral distance from the sun increases, so the light can travel farther before the same amount of time has elapsed. The situation for a series of such passes is illustrated in Fig. 1. The line connecting the end points of the various light rays constitutes a *wave front*. The interpretation based on this diagram is simply that the gravitational effects have caused the wave front to rotate away from the sun at a definite angle Θ which is identified with the angle of "light deflection." Both Einstein[2] in GR and Schiff[1] employed Huygens' Principle to evaluate this angle:

$$\mathrm{d}\Theta = \frac{1}{c'}\frac{\mathrm{d}c'}{\mathrm{d}y}\mathrm{d}x\,. \qquad \text{(XV-6)}$$

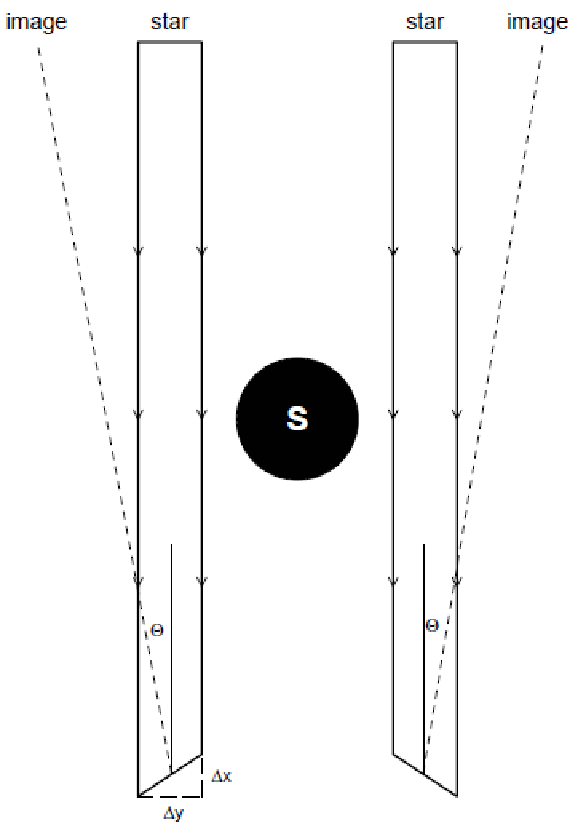
In this formula, c' is the speed of light measured by the observer (not the local value of c measured consistently by the observer at position P). It is obtained using the scaling relations in Table 1. The differential change $\mathrm{d}\Theta$ is then obtained as the ratio of $(\mathrm{d}c'/\mathrm{d}y)/c'$ multiplied with the corresponding distance dx traveled by the light ray along the x axis in time dt.

Accordingly, *all that is required is that the speed of the light ray change with its lateral distance y from the sun*. To compute the derivative dc'/dy, it is clearly necessary to compare the speeds of two different light rays separated laterally by an amount dy. If it is assumed that the corresponding values of c' differ by dc', it is clear that the respective distances along the x axis in the two cases over time dt will also differ. As shown in Fig. 1, the angle which the line connecting the two rays makes with the corresponding one for their initial positions at infinity is thus dΘ = dc' dt/dy. Since the total distance traveled is dx=c'dt, dΘ is seen to satisfy eq. (XV-6). *There is nothing in this derivation which assumes that either light path is curved*, only that the speeds by which the light travels along them is different.

There is a simple interpretation of this result. The line connecting the current positions of the two light rays simulates a *wave front* in the terminology of Huygens. When the light reaches the observer, the direction from which it has come is judged by extending the normal to this wave front backward in space. Integration of dΘ in eq. (XV-6) over the entire path therefore gives the amount by which the light *appears* to have been deflected from the straight-line path actually followed (Fig. 1). The finite differences approach[10] for the execution of Schiff's uniform scaling method[1] has shown that this angle has a value of 1".7517 for light coming from infinity which grazes the outer edge of the sun's surface on its way to the Earth, identically the same value as obtained by Einstein [11] in 1915 using a method of successive approximations.

Schiff also notes that *exactly half this value* results when the scaling of radial distance in eq. (XV-3) is ignored, the same result obtained by Einstein[12] in his early attempts at calculating the angle of deflection.[13.] Schiff also points out that, in agreement with his scaling assumptions, Eddington[14] had shown that both the scaling of time and radial distance must be taken into account in order to successfully obtain the angle of light deflection.

After Schiff's paper had appeared, a "fourth test of general relativity" was suggested by Shapiro[15,16] to verify the GR prediction "that the speed of propagation of a light ray decreases as it passes through a region of increasing gravitational potential." There is therefore little room for doubt that Shapiro's time-delay predictions can be obtained with Schiff's simpler computational method with the same level of accuracy as with the GR relations he used explicitly in his work.[15,16] It is therefore reasonable to conclude that Schiff's assumption of a *strictly straight-line trajectory* is fully consistent with experience using GR. His method is just a simpler approach to applying GR in practice. What is far less clear is how this experience is *in any way compatible with the ubiquitous claims*[17,18] *that GR relies on the principle of curved space-time to arrive at its predictions.*



$$\Theta = \frac{\Delta x}{\Delta y} = \int \frac{dc'dt}{dy} = \int \frac{1}{c'}\frac{dc'}{dy}dx$$

Fig. 1 Schematic diagram showing light rays emitted by stars to follow straight-line trajectories as they pass near the sun. Because of gravitational effects, the speed of the light rays c' is known to increase with gravitational potential, with the effect that the corresponding Huygens wave front gradually rotates away from the sun. As discussed in the text, the normal to a given wave front points out the direction from which the light appears to have come, causing the star images to be displaced by an angle Θ during solar eclipses.

The above calculations are relevant to the discussion of black holes. Soldner[19] published his calculations on the gravitational bending of light in 1804. Even before that, there was speculation[20] by Michell that an object might be so massive that it would become impossible for light to escape from its surface. As discussed above, the argumentation in GR is fundamentally different than in the Newtonian approach to gravity, but the belief still persists that such "black holes" exist and that they do not allow light to pass from them. Hawking[21] has argued that high-energy radiation can still escape from the surface of a black hole, however.

In the previous discussion it has been shown that all known experiments regarding the phenomenon of gravitational light deflection can be explained quantitatively by assuming that light always travels in a perfectly straight line. It is therefore of interest to see how the theory of black holes is affected by making this assumption. First of all, it should be noted that this position is still consistent with Newton's ISL provided that one takes account of the fact that the acceleration due to gravity from the g field on an object varies with the state of motion of the observer. Ascoli[22] has concluded that when an object is moving with speed v relative to the local observer, its acceleration due to gravity is damped by a factor of $\gamma^{-2} = 1 - v^2 c^{-2}$. A consistent derivation of this result will be given in Chapter XVI. This relation has been used successfully in the calculations mentioned above for the precession angle of Mercury's perihelion.[23,24] In the case of light, for which the local value of v is always c, *this damping factor is exactly zero, so that no acceleration is to be expected*. Thus this result is consistent with both Schiff's approach[1] and the underlying theory of the calculations of the precession of Mercury's orbit.

According to this view, light can pass as closely as possible to the surface of a black hole without being deflected. The apparent shift in the position of the image of the light source will be very much larger than it is for the sun, however. Moreover, there is no gravitational effect keeping light from escaping the interior of a black hole, so γ rays are expected to be observed, and not only those originating outside the boundary of the black hole. It should not be forgotten thereby that there is a quite high probability for photons to be absorbed because of the high density of matter, however, so on this basis the description as a blackbody is certainly appropriate. It is also clear that the speed of light will be quite small in the interior of a black hole because of the gravitational time dilation, and a very large red shift for light escaping from it is also expected for an observer located at a relatively high gravitational potential. The key point remains, however, that none of these effects need involve true gravitational deflection, as they are all consistent with a perfectly straight-line trajectory. The phenomenon of gravitational lensing is also expected on this basis, provided the light source is located directly behind the black hole. The image of the light source would be significantly distorted relative to that which would be detected in the absence of the black hole (see Fig. 1)

Keywords: *Black holes*, *Einstein's GR, Finite differences calculation, First Principles, Gravitational red shift, Hafele-Keating experiments, Hawking, Huygens' Principle, Law of Causality, Lorentz transformation LT, Radial velocity scaling, Rotation of wave front, Schiff scaling method, Shapiro Forth Test of GR, Straight line motion of light, Uniform Scaling method, Variation of light speed with gravity*

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XVI. UNIFORM SCALING CALCULATIONS OF MERCURY ORBIT

The method employed by Schiff[1] discussed in Chapter XV was successful in predicting the angle of displacement of the images of stars during solar eclipses. However, Schiff gave two reasons why his scaling method cannot be extended to the crucial test of "the precession of the perihelion of the orbit Mercury." He quoted Einstein[2] to buttress his position on the first of these, specifically Einstein's conclusion that the accurate description of orbital precession requires *that the equation of motion* (the geodesic equation) of the planet be provided as input to the theory. Schiff also noted that Eddington[3] was in complete agreement on this point. In other words, Newton's Inverse Square Law (ISL), which in the 17^{th} century spectacularly provided the first successful method for predicting planetary orbits, would not be useful in obtaining the desired correction to the classical theory to explain the precession anomaly.

The Uniform Scaling method is perfectly equivalent to Schiff's, also as discussed in Chapter XV, but it will be shown in the following that it can be successfully adapted in a straightforward manner[4] to achieve the latter objective with the same level of accuracy attained by GR.[2]

The starting point is Newton's original gravitation theory which makes use of the ISL and the acceleration due to gravity g. It should be noted that Schiff was able to describe the motion of light rays as they pass close to the sun without ever invoking g is his calculation. That raises the question as to why the latter can be completely ignored in the application involving light rays.

The answer to this question can be found by examining the formula for g:

$$g = \frac{GM_s}{R^2}, \tag{XVI-1}$$

This equation is known to be valid for any local observer P, regardless of his state of motion or his location in a gravitational field. In view of the main premise of the Uniform Scaling method, it is reasonable to look for a conversion factor for g to the units of some observer O located in a different rest frame. According to Table 1 in Chapter XII, the kinetic scale factor in question is Q, which suggests that R in eq. (XVI-1) should be multiplied with Q =γ (v) in order to obtain the appropriate value in the units of an observer moving with speed v relative to the object. That means as a consequence that

$$g(O) = Q^{-2} g(P), \tag{XVI-2}$$

since R is in the denominator in eq. (XVI-1).

This conclusion is clearly relevant to the fact that g does not appear in the trajectory calculations for a light wave. Since γ=∞ for a light wave moving with speed c, it follows that g(O)=0 under this condition. *This is of course consistent with the fact that the light is always assumed to move in the same straight line throughout the entire calculation.* This finding is also in agreement with Newton's Third Law. There is no effect of the sun's gravitational field on the light wave because it has a gravitational mass of zero. The fact that g=0 at the location of the light wave means in turn that it cannot exert a gravitational force on the sun or any other object. There is thus an "equal and opposite" null effect in this application of the Third Law.

The situation is obviously different for a planet. There is a non-zero value of g on the surface of the planet, and thus it would seem to be essential to include g in the calculations describing the planet's orbit around the sun. The above argument for the scaling of g therefore indicates that the force caused by the gravitational field of the sun in the eyes of the observer O anywhere in the universe depends on the speed v of the planet relative to the sun, i.e. the value of g to be used in the trajectory calculation is g (O) in eq. (XVI-2). It should also be noted that Sard[5] notes that Ascoli[6] had previously come to the same conclusion, namely that $g(O)=\gamma^{-2}(v)g(P)$ using the present notation.

The gravitational scale factor for g also needs to be determined. Schiff made a distinction between the scaling of distances measured tangential to the gravitational field and those radial to it. He assumed that radial distances should be scaled with an extra factor of S, as shown in eqs. (XV-2,3). Since R in eq. (XVI-1) is radial to the field, in analogy to what has been proposed for the kinetic scale factor Q, it is reasonable to assume that the gravitational scale factor for g is S^{-2} (negative exponent because R is in the denominator in the equation). It should be noted, however, that the kinetic scaling of R is justified by empirical calculations, so Schiff's argument that the choice is based on the length contraction effect of SR[7] is not essential in this regard. In the following discussion, a method for calculating the trajectory of Mercury in its orbit around the sun will be outlined in which it is *provisionally* assumed that g (P) at the position of the planet is to be scaled by a factor of $Q^{-2}S^{-2}$, i.e.

$$g(O) = Q^{-2}S^{-2}g(P). \qquad \text{(XVI-3)}$$

A. Computational Procedure

The following procedure has been adopted to compute the trajectories of objects moving in a gravitational field based on the above considerations. It is assumed that the initial velocity u_o and position P of the object are known relative to a primary (stationary) observer O located at infinity (A_o=1). A coordinate system is adopted such that the sun (in the general case, the gravitational source) is at the origin and it is assumed that O is co-moving with the Sun. The value of the scaling quantity A_p is calculated according to eq. (XII-1) from which the key ratio $S = \frac{1}{A_p}$ is obtained. This allows O to compute the *local* velocity u_p measured by another observer (P) who is also co-moving with the sun but is located at the same gravitational potential as the object (planet). Based on the above discussion, O has to take into account the difference in clock rates for the two observers. Since P's clock runs $\frac{A_p}{A_o} = A_p$ times *slower* than O's (see Table 1), his value of the object's velocity is A_p times greater ($A_p>1$), i.e., $u_p=A_pu_o$. This conversion is only made to obtain an initial value for u_p. In succeeding time cycles, the value of u_p obtained at the end of the previous cycle will be used for this purpose.

The next step is to compute the acceleration exerted on the object by the gravitational field of the source. To this end it is assumed that the ISL is valid for an observer P who is at the same gravitational potential and is at rest with respect to the object. The corresponding value $g(O)$ used by O is given by eq. (XVI-3), i.e. by using the current value of u_p in conjunction with the ISL value at the location of the object.

The above information allows one to compute the change of velocity of the object over a small time interval Δt in O's system of standard units. To do this, however, he must use Schiff's procedure to convert u_p to the corresponding value in his units (u_o), as indicated in Table 1. This means he must first resolve u_p into its transverse and radial components, u_p^t and u_p^r, and then *divide* these values by A_p and A_p^2, respectively. It should be noted that this is not just the inverse of the scaling procedure used above to obtain the initial value of u_p from u_o, in which case we would simply divide all components uniformly by A_p. The reason for making this distinction will be discussed below, but first let us compute the change in the object's velocity from O's perspective as:

$$\Delta \boldsymbol{u}_o = \boldsymbol{g}(O)\Delta t(O), \tag{XVI-4}$$

with g(O) radial to the gravitational field. The velocity at the end of the time interval is then obtained by employing the *velocity addition rule RVT* in eqs, (V-1a-c). This is an important point since use of simple vector addition of Δu_o to the original value of u_o in each time cycle causes significant accumulation of error over a complete orbital period.

The final velocity $\boldsymbol{u}'_o$ is then scaled using Schiff's procedure to obtain the corresponding local value $\boldsymbol{u}'_p$, that is, by multiplying the radial component by A_p^2 and the transverse by A_p. The distance Δs_o travelled by the object in the current time cycle from O's perspective is computed by multiplying the average velocity $\boldsymbol{u}_o^a = \dfrac{(\boldsymbol{u}_o + \boldsymbol{u}'_o)}{2}$ by $\Delta t(O)$. The direction taken is that of the average *local* velocity $\boldsymbol{u}_p^a = \dfrac{(\boldsymbol{u}_p + \boldsymbol{u}'_p)}{2}$, however, not that of $\boldsymbol{u}_o^a$. Note that since there is no gravitational acceleration of light in Schiff's method for computing the angular displacement of star images,[1] the magnitude of $\boldsymbol{u}_p^a$ is always equal to c in this case and its direction is constant as the light passes by the sun. Taking the direction the light to be the same as that of $\boldsymbol{u}_o^a$ in that application leads to inaccuracies in both the trajectory and the displacement angle. The final location of the object $\boldsymbol{P}'$ at the end of the cycle is thus computed as

$$\boldsymbol{P}' = \boldsymbol{P} + \left(\frac{\boldsymbol{u}_p^a}{u_p^a}\right)\Delta s_o . \qquad \text{(XVI-5)}$$

It is important to see that all observers who are co-moving with O must measure exactly the same value for $\boldsymbol{P}'$ according to Table 1. They will only disagree on the amount of elapsed time for this portion of the object's trajectory because their respective clocks run at different rates depending on their position in the gravitational field [$\Delta t(\mathrm{P}) = \dfrac{\Delta t(O)}{A_p}$]. In essence, *O*'s location at infinity makes him the ideal neutral observer. He and he alone can apply Schiff's scaling procedure to obtain the object's trajectory in his system of units (A_o=1), and this information can then be converted to the units of any other observer simply by knowing the latter's value of A_p.

In the specific computational approach adopted in the present discussion, there is another matter that needs to be clarified, however. Both u_o and u_p are continuous functions of time, but only one of them can remain the same in going from the end of one time cycle to the beginning of the next. This is because the distance of the object from the source is constantly changing, and therefore the value of the scaling parameter A_p generally varies between successive cycles. In view of the success of Schiff's approach to the calculation of the displacement of star images caused by the gravitational field of the sun, in which case both the magnitude and the direction of the local light velocity u_p are held constant throughout, it seems preferable at the beginning of each cycle to set u_p equal to the value of $\boldsymbol{u}'_p$ at the end of the previous one, as already mentioned. In so doing, one must accept the fact that this choice generally precludes the existence of a similar equality between the corresponding values of u_o and $\boldsymbol{u}'_o$ for the primary observer in going from one time cycle to the next, but this is inconsequential because in the last analysis these quantities as defined are only an artefact of Schiff's method.

B. Results of the Calculations

The above procedure has been applied to the calculation of the relativistic contribution to the advancement angle of the perihelion of planetary orbits around the sun. At the start of the calculation the position and velocity of the planet are taken from experiment (based on the observed values for the mean radius r and eccentricity e of a given orbit). The solar mass is taken to be $1.99\text{x}10^{30}$ kg and the mass of the planet is not required, consistent with the unicity principle. The time interval $\Delta t(O)$ for each cycle in the numerical procedure has been varied in all cases to insure that a proper degree of convergence is obtained for the calculated results (quadruple precision has been used in all computations).

The value of the precession angle in the present treatment is close to the observed value, but the discrepancy was large enough to consider changes that might be made to improve the level of agreement. It was found that the desired level of accuracy is obtained when the exponent of S for g (O) in eq. (XVI-3) is varied from -2 to -3:

$$g(O) = Q^{-2} S^{-3} g(P). \qquad \text{(XVI-6)}$$

The value of the precession angle Θ of the perihelion of Mercury's orbit around the sun obtained from the altered treatment is 43".0033/cy, in good agreement with both the currently accepted experimental value for this quantity of 43".2 ± 0".9/cy [8] and that computed by Einstein from GR of 43".0076/cy[2,9]. In the latter work he obtained a closed expression[9,10] which indicates that the precession angle in general is proportional to M_s and inversely proportional to both r and $(1-e^2)$. Tests have therefore been carried out for different values of the latter three quantities, and very good agreement with the predictions of GR has been found in all cases. Indeed, since the amount of computer time required increases with r, most of the tests carried out are for a hypothetical planet with one-thousandth of Mercury's radius and therefore a period of revolution around the sun of only 240 s. When the solar mass is increased by a factor of 10.0, it is found that the value of Θ is 10.0012 times greater. If the mean radius is cut in half, Θ is found to increase by a factor of 1.9990. Similarly good agreement with GR is obtained if the radius is changed by factors of 10 and 100. Finally, when e is changed from its experimental value of 0.2056 for Mercury to 0.10, the value of Θ is found to be 0.9677 times smaller, as compared to the predicted factor of 0.9674.

The change of the exponent of S for g(O) in eq. (XVI-6) merits some further discussion. Once one decides that R_p must be scaled differently in the ISL than in computing the actual location of the object, however, another possibility emerges, namely that M_s also needs to be scaled to obtain g (O) from $g(P)$. For this purpose it is instructive to consider how the inertial mass m_I scales with the gravitational potential of the observer, namely as S^{-1} (as shown in Table 1). If one assumes that the gravitational mass M_s in eq. (XVI-1) is scaled in this manner, the result for g (O) in eq. (XVI-6) is obtained,

There is precedence for such an admittedly *ad hoc* procedure, namely in the scaling of the radial component of the velocity in eq. (XV-5). Schiff[1] attributed the different scaling of the radial and tangential components of the velocity to the FLC of SR,[7], but one can just as well look at the distinction as being desirable based on purely empirical considerations, namely in this way one accounts for the missing factor of 0.5 in the value of the light bending angle obtained in Einstein's early investigation in 1911.[11] At least the choice of the scaling factor for g (O) in eq. (XVI-6) conforms to the general pattern in Table 1of using only integral values of the Q and S exponents.

It should be noted that the A_p factors in the present treatment have been computed in two different ways: by means of eq. (XII-1) in each time-step, or by making use of the proportionality relationship:

$$\frac{\gamma(u_p)}{A_p} = \frac{\gamma(u_o)}{A_o}, \tag{XVI-7}$$

as the object's distance from the gravitational source is varied (assuming that no other forces are present). The derivation of this result assumes that the gravitational mass m_G of an object is equal to its inertial mass m_I (weak equivalence principle), and otherwise makes use of the ISL and the well-known result of SR[7] for the energy E of an object,

$$E = m_I c^2 = \gamma(u)\,\mu c^2, \tag{XVI-8}$$

where μ is its proper mass, u is its speed and $\gamma(u) = \left(1 - \frac{u^2}{c^2}\right)^{-0.5}$. If one assumes that eq. (XVI-8) holds locally at both R_o and R_p, it follows from the energy conservation principle that for macroscopic bodies the exact ratio is $\frac{\gamma(u_o)}{\gamma(u_p)}$, where u_o and u_p are the respective speeds of the object measured locally as it falls (rises) between R_p and R_o. The corresponding ratio of the respective S factors is $(1/A_p)/(1/A_o) = A_o/A_p$. In other words, the exact definition of A_p must ensure that eq. (XVI-7) holds. The corresponding two values of Θ agree to within a factor of 1.000093, with that obtained with the latter definition being higher. This result thus clearly supports the conclusion that the whole concept of gravitational scaling is rooted in the conservation of energy principle.

One can summarize the above results as follows. The present theoretical approach obtains results that are consistent with all known measurements of perihelion precession angles, *including those of earth and Venus*. They are also in nearly quantitative agreement with the predictions of GR for the same quantities. The procedure employed can be viewed as a generalization of Schiff's method[1] for computing the displacement angle of star images during solar eclipses (strictly speaking, what is actually calculated via Huygens' principle is the angle by which the wave front of the light rotates relative to its starting orientation at the star[12.13]). Corresponding tests have been carried out with the present procedure for an object moving with local speed c, and excellent agreement with Schiff's (and therefore Einstein's) result has been obtained, including the dependence of this angle on the mass of the gravitational source and the distance of closest approach by the light. A more detailed discussion of these results for the displacement of star images is given elsewhere[12].

C. Summary

For more than a century physicists have held steadfastly to the belief that it is impossible to construct a viable gravitational theory based on Newton's ISL and Einstein's SR. The present work has shown instead that such a theory can be obtained within the framework of the Uniform Scaling method described in Chapters X-XII. The computational approach employed by Schiff[1] in 1960 operates on the principle that observers located at different gravitational potentials will disagree in a well-defined manner about the velocities of objects, as well as on the values of elapsed times and distances travelled by them. His scaling procedures have been adopted in the Uniform Scaling method.

Schiff was able to quantitatively predict the angle by which light appears to be bent during solar eclipses. The reason that he was unable to extend this method to the description of the advancement angle of the perihelion of the orbit of Mercury and other planets can be traced directly to his failure to recognize that Newton's classical gravitational theory (ISL) needs to be considered directly in such calculations. In particular, it is necessary that the acceleration due to gravity g must also be scaled so as to take explicit account of its effect on planetary trajectories. The pertinent scale factor is shown in eq. (XVI-6) and makes clear why g never occurs in Schiff's light bending treatment. It is because $Q=\gamma=\infty$ since the local value of the light speed is always c and therefore, the scaled value of g is equal to 0 in this case. This is of course not so with planets and thus their velocities must be augmented continuously by adding $g\Delta t$ to their current value. Once this is taken care of, the angle of advancement of the Mercury orbit is predicted with the same level of accuracy as is obtained with GR[2]. The various components of velocity (transverse and radial) are scaled in the same manner as proposed by Schiff in his original work.[1]

The trajectory calculations provide a justification for employing a coordinate system in Euclidean space in which all objects of the universe can be located uniquely. All observers *who are not in* *relative motion to one another*[14] must agree on this basis with regard to the instantaneous position of each of these objects. As long as one takes proper account of the fact that the units of time, velocity and acceleration vary with one's position in a gravitational field, in accord with Table 1 of Chapter XII, it is then possible to carry out trajectory calculations exclusively in Euclidean space. The necessary adaptation can be accomplished by inserting a small number of statements in a comparatively simple computer program[15] which otherwise treats planetary motion strictly on the basis of Newton's ISL.

The development of a comprehensive gravitational theory that relies on the local validity of the ISL inevitably raises questions about whether such forces can be transmitted instantaneously across long distances. Newton himself rejected such an interpretation in the strongest terms, but this did not keep him from using the ISL to solve longstanding problems in astrophysics. The fact remains, however, that the above computer program uses time intervals as small as 10^{-4} s to calculate the change in velocity of a planet caused by the sun which is as much as $7x10^{10}$ m distant. It is a matter of opinion whether GR succeeds in eliminating the need for "action at a distance" by introducing the concept of "curved space-time." The present work indicates that the units of physical quantities vary in a precisely predictable manner with the distance of a given location from the gravitational source, suggesting that something like a distance-dependent stationary field *exists at all times* and therefore does not need to be transmitted to have its effect on any object that is located at that point in space. It has demonstrated that, with proper attention to detail, it is possible to obtain a level of accuracy in trajectory calculations that is comparable to that of GR by merging the ISL with the Uniform Scaling method through the gravitational scaling of the above physical units. This experience speaks for the validity of the assumptions that form the basis for arriving at this synthesis, and at least underscores the practicality of the ISL that Newton so skillfully exploited during his lifetime.

Uniform scaling is applicable to any pair of observer-object pairs in the universe. The conversion factors depend exclusively on two separate parameters in each case, Q for kinetic scaling and S for graviational (see Table 1 of Chapter XII). It is possible to compute these quantities on the basis of a minimum of information regarding the states of motion and locations in a gravitational field of both participants. The conversion factor is always a product of Q^n and S^p, where the exponents p and n are integers that are specific to each physical property. For example, the time T measured on a satellite needs to be multiplied with Q/S in order to convert it to the unit of time used by an observer on the earth's surface. An amount of energy E for the object is equal to QS E in the observer's units. The acceleration due to gravity g measured locally on a planet (or a light ray) has a value of $Q^{-2}S^{-3}$ g for the observer.

The proportionality relationships expressed in the conversion factors for each property are to be regarded as *Laws of Physics*. Just as with the Laws of Thermodynamics and Newton's Laws of Motion, these relationships cannot be derived on the basis of so-called "First Principles." Instead, they have been developed so as to agree with the results of all available experimental information. Their main purpose is to encourage the development of further tests to verify their accuracy. One quite positive feature of the present set of conversion factors is that they leave all accepted laws of physics intact. This experience is closely connected with Galileo's RP. It can be modified as follows on this basis: *The laws of physics are the same in each inertial system, but the units on which they are based can and do vary from one rest frame to another.* From the vantage point of each observer, the rest frame of a given object is characterized by specific values of Q and S. It is interesting to note that both S and Q would be equal to 1 in all applications if the speed of light is assumed to be infinite. All of the relativistic corrections to Newton's gravitational theory are due to his failure to realize that the speed of light is finite.

The rationale behind the Uniform Scaling method is very simple. It assumes that when the observer sees an object move into a particular rest frame, the interactions which are required to produce the effects indicated by the respective Q and S conversion factors *are already there.* They were there before the object arrived and they remain after it has left. There is an *aura* produced by each active mass that is responsible for the effects indicated via the pertinent S scale factor. The same holds true for each ORS from which the speed of the object is to be inserted in the UTDL of eq. (IX-1) in order to evaluate Q. No gravitational waves are necessary for these conditions to be present at any given time. *It is useless to claim that the aura does not exist, any more than it is to assert that a specific experiment supposedly proves that there are gravitational waves moving with finite speed*.

Is the isotropic scaling method equal to that of GR? Despite the previous history of nearly universal belief in GR, there is only one way to answer this question *objectively*. It is necessary to find an experiment which clearly distinguishes between the predictions of the two theories. A good place to start such an investigation is to ask whether light travels a perfectly straight line in free space. Or does it instead follow a curved path in agreement with the ubiquitous diagrams produced by GR proponents that show a ball rolling into a well to illustrate the fundamental nature of "relativistic space-time?" That one uses Euclidean coordinates while the other employs their Riemannian counterpart should not make any difference whatsoever. Since when does the changing of coordinates in a differential equation lead to different results? No, optimally the change should just make it easier to obtain the unique solution.

In addition, however, Schiff has also outlined another such possible distinguishing experiment[16,17]. He pointed out that a naive application of the kinematics of special relativity in the form of Thomas's precession[18] of the electron's orbit around a nucleus leads to a qualitatively different prediction for the rate of precession of the component of spin in the plane of the earth's orbit than is predicted by GR. The GR precession frequency is actually indicated *to be in the opposite sense* as that indicated by the Newtonian law of gravitation. The theory outlined above is perfectly in line with Thomas spin precession, so there is a clear distinction between it and GR in this respect.

Keywords: *Schiff, Einstein's GR, Eddington, Mercury orbit precession, Newton's ISL, Gravitational scaling of g, Free fall proportionality of A and γ, Null value of g for light, Newton's Third Law, Computation of Mercury orbit, Results for angle of precession, Ascoli, Quadruple precision, FLC of SR, Weak equivalence principle, Uniform Scaling method, Action at a distance, Curved space-time in GR, Laws of Physics, Possible aura of scale factors, Conflict over rate of precession of earth's orbit*

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XVII. LIGHT REFRACTION AND QUANTUM MECHANICS

The discussion in the preceding chapters has dealt almost exclusively with interactions in free space. There is an exception in Chapter II, however, in which the Fresnel-Fizeau light damping experiment[1] was shown to be instrumental in causing physicists to search for a replacement for the classical velocity transformation (GVT). The refraction of light in water is a key element of that research.

Light refraction has had a great impact on the development of physical theory over a period of several millennia. The theory of light *reflection* was clearly understood by the ancient Greek philosophers following the work of Hero of Alexandria, but the explanation for light refraction eluded them. The latter is also a phenomenon that is easily observed with the naked eye and yet it took until the early 17th century before it was first possible to formulate a mathematical expression (Snell's Law of Sines) that successfully described it on a quantitative basis. Shortly thereafter, Newton[2] used light refraction to illustrate his Second Law and to support his corpuscular theory of light. However, his views clashed with those of Huygens and other proponents of the wave theory of light, especially in that the two theories led to opposite predictions of the change in the speed of light as it enters water from air.

In the following discussion it will be shown that the previous evaluation of Newton's theory has overlooked some very positive aspects. Its failure to correctly predict the decrease in the speed of light in water is not actually proof of the inadequacy of his assumption regarding the composition of light in terms of particles. Rather, it was the lack of a proper distinction between the momentum and speed of what we now refer to as photons. To begin this discussion, a review will be made of the salient features of the two competing theories and how they led to their opposing predictions of the speed of light in water.

A. Comparison of the Corpuscular and Wave Theories

Newton's theory of light refraction[2] was strongly influenced by the work of Snell in the early 17th century, particularly the latter's Law of Sines which established the relationship between the angles of incidence and refraction of light rays as they pass between two different transparent media (see Fig. 2):

$$n_1 \sin\theta_1 = n_2 \sin\theta_2, \tag{XVII-1}$$

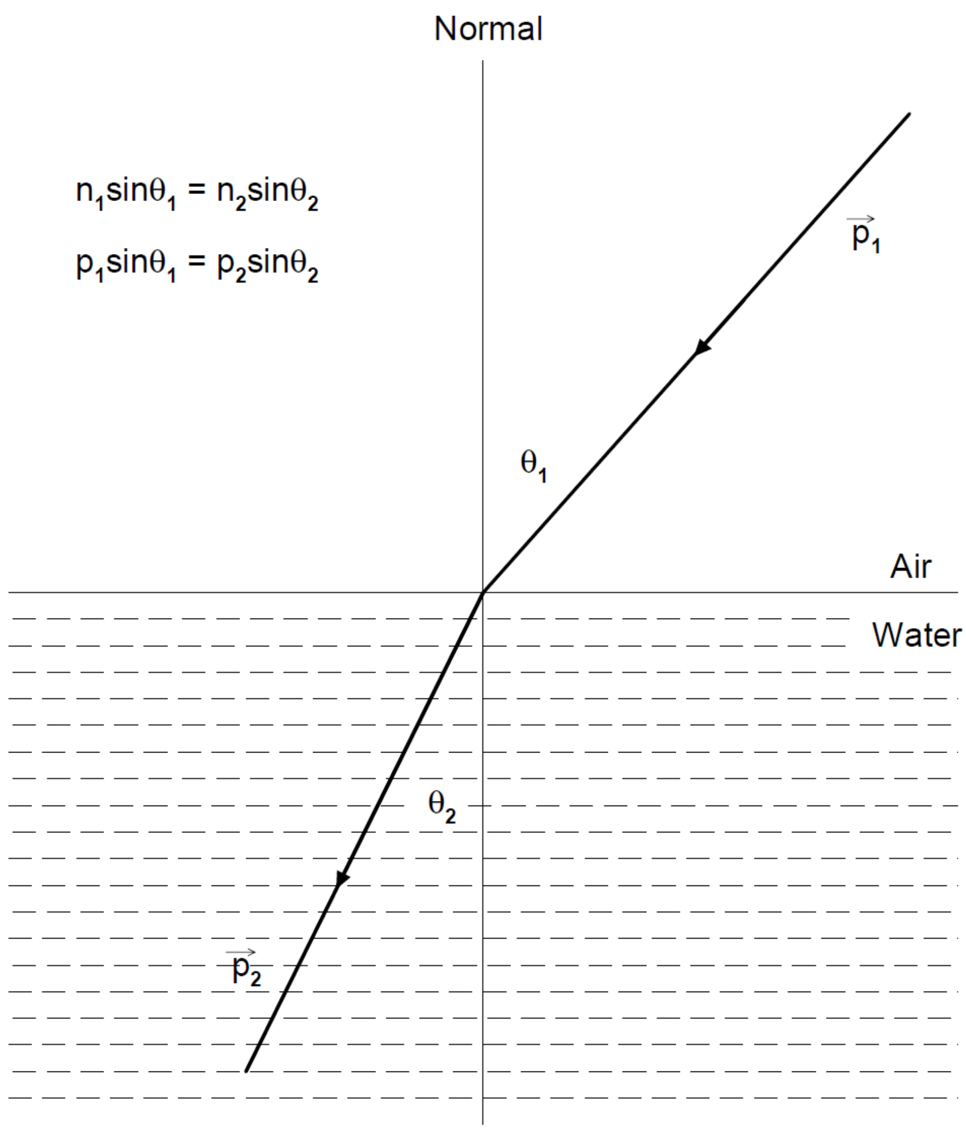

Fig. 2. Diagram showing the refraction of light at an interface between air and water. The relation between the angles of incidence θ_1 and refraction θ_2 in terms of the refractive indices n_i (Snell's Law of Sines) of the two media was viewed by Newton as a clear application of his

Second Law of Kinematics, according to which the component of the "corpuscle" momentum p_i parallel to the interface must be conserved (where n_1 and n_2 are the refractive indices of the two media).

Newton argued that the light consists of particles that are subject to his Second Law. It was assumed that the light rays travel in straight lines within each medium and therefore that there are no unbalanced forces in either region. By further assuming that the light refraction is caused by a force F=dp/dt normal to the interface, he concluded that the momentum p of the particles in a tangential direction must be conserved and therefore that the following equation must be satisfied:

$$p_1 \sin\theta_1 = p_2 \sin\theta_2, \qquad \text{(XVII-2)}$$

which is obviously similar in form to eq. (XVII-1). Comparison of the two equations thus leads to the following proportionality between the momentum of the particles and the index of refraction of the corresponding light rays:

$$\frac{p_1}{p_2} = \frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}. \qquad \text{(XVII-3)}$$

Although eq. (XVII-3) only deals with momentum (a term not used in *Opticks* [2], it was used by Newton to make his famous prediction about the speed of light in water. He concluded that since the index of refraction for water is greater than that for air, it must follow that the speed of light must be larger in water as well. This conclusion gained increased significance at the time because it placed his corpuscular theory of light in direct conflict with the wave theory of Huygens and others on this question.

In the wave theory of light it was assumed that Snell's Law of Sines implies that the speed of light decreases as it passes from air into water. This conclusion was based on the assumption that the speed of light in a medium is equal to c/n. The change in angle could be explained[3] by assuming that the distance separating spherical wave fronts decreases as the light passes into a region of higher index of refraction (Fig. 2). According to this model, the wavelength $\lambda = 2\pi/k$ of the light waves changes in direct proportion to $\sin\Theta$, with the result:

$$\frac{\lambda_2}{\lambda_1} = \frac{k_1}{k_2} = \frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1}. \qquad \text{(XVII-4)}$$

At the same time, it was assumed that the frequency $\nu = \omega/2\pi$ is completely independent of the refractive index for a given medium, so that the corresponding speed of light c_i must be inversely proportional to n_i, i.e.:

$$c_i = \lambda_i \nu = \frac{\omega}{k_i} = \frac{c}{n_i}. \qquad \text{(XVII-5)}$$

where by definition $n_i=1$ in free space.

B. Hamilton's Canonical Equations and the Group Velocity of Light

In 1850 Foucault measured the speed of light in water and it was clear that his results stood in irreconcilable contradiction to Newton's prediction. Newton lost the argument, but it is interesting to see why. Since the angles of incidence and refraction (see Fig. 2) were not changed in multiple passes of light rays through the same media, it could safely be assumed that the energy of the hypothesized particles of light remains constant. The fact that the light is bent downward upon entering a medium of higher density indicates that the potential V acting on the particles must be attractive, i.e. it decreases after crossing such an interface. Combining these two facts led unmistakably to the conclusion that the kinetic energy T of the light particles must be *greater* in the denser medium. Assuming that T was proportional to the square of the velocity, in accordance with the then accepted dynamical theory, thus led to the prediction that the speed of light must be greater in water than in air, which is incorrect.[4] *Proceeding on the principle* *that an assumption which is contradicted by observation is false, it was thereupon concluded that this result refuted the particle theory of light once and for all.*

Examination of the above argument shows that another error of a different kind was made, however, which ultimately invalidates the latter conclusion. In the first place, the kinetic energy of the photon does not satisfy the non-relativistic relation employed therein. When the correct formula is used, one is still led to conclude that the momentum of the photon increases in going to the denser medium, but since the mass of such particles cannot safely be assumed to be constant in a proper relativistic treatment, *it no longer follows that the velocity of light must increase* as *well.* The conclusion that light rays cannot simply be streams of photons because a purely mechanical treatment of the refraction phenomenon leads to a false prediction on this basis *is therefore not justifie*d. On the other hand, if it is assumed not only that light consist of particles but also that their collective motion conforms to a definite statistical distribution, a different result is obtained from the refraction analysis.[5]

Foucault's measurement of the speed of light in water was quite generally accepted as a complete victory for the proponents of the wave theory of light, but in later years more accurate experiments[6-8] showed that its prediction in eq. (XVII-5) is not completely verified either. Instead, the following dependence of the light speed v_g on the derivative of the refractive index with respect to wavelength was indicated:

$$v_g = \frac{c}{n_g} = \frac{c}{n} + \left(\frac{\lambda c}{n^2}\right)\frac{\mathrm{d}n}{\mathrm{d}\lambda}. \qquad \text{(XVII-6)}$$

The presence of the correction term on the right-hand side of this equation has been justified[7] in terms of dispersion effects that are expected to occur when light enters a different refractive medium. Application was made of Rayleigh's theory of sound[9,10] and its explanation of how beats arise when waves of slightly different wavelength are allowed to interfere.

It is important to return to the question of the assumed dispersion effects, but before doing this, it is instructive to consider how Newton could have so misjudged the effects of light refraction on the speed of light. Such a discussion becomes all the more relevant when it is realized that 55 years after Focault's experiments had been reported, Einstein[11] effectively resurrected the particle theory of light by virtue of his interpretation of the photoelectric effect.

With centuries of hindsight, however, it is not difficult to find other indications that Newton was on the right track after all. Primary among these is the conclusion that results when eq. (XVII-3) of the particle theory is brought into connection with eq. (XVII-4) of the wave theory. As already discussed, the latter predicts that the wavelength of light is inversely proportional to the refractive index of the medium, whereas the former concludes that the momentum of the associated particles of light is directly proportional to the same quantity. Combination of these two theoretical relationships leads directly to another, namely:

$$\frac{p_1}{p_2} = \frac{\lambda_2}{\lambda_1} = \frac{k_1}{k_2}, \qquad \text{(XVII-7)}$$

which in turn can be reformulated in terms of a specific proportionality constant:

$$p = \frac{h}{\lambda} = \left(\frac{h}{2\pi}\right)k\,. \qquad \text{(XVII-8)}$$

Stark[12] was apparently the first to arrive at eq. (XVII-8) for light in free space He was influenced by a meeting in which Planck's radiation law was a key topic of discussion.[13] The proportionality constant h in eq. (XVII-8) is the same as Planck[14] used nine years earlier to introduce his quantum hypothesis and the corresponding relation between energy E and frequency ν:

$$E = h\nu = \left(\frac{h}{2\pi}\right)\omega. \qquad \text{(XVII-9)}$$

Its present-day value is 6.625×10^{-34} Js.

It is a matter of historical fact that the proponents of the corpuscular and wave theories of light did not obtain eq. (XVII-8) on the basis of their studies of light refraction, but that does not change the conclusion that this goal could readily have been achieved over 200 years earlier by simply combining eq. (XVII-3) with eq. (XVII-4). The reason that Newton and Huygens did not make this connection is most probably because they did not recognize the validity of the other's model for the composition of light and thus were not disposed to making use of any of its respective predictions. The fact that eq. (XVII-8) can be derived in a straightforward manner from the two "opposing" theories of light refraction is nonetheless a key observation in theoretical physics. It shows that Stark's recognition of the relation between the momentum of particles of light and the wavelength of the corresponding radiation actually *serves as an important confirmation of both theories*, in particular that of Newton, since it has often been claimed to have been contradicted by the experimental data for light refraction.

None of the above changes the fact that Newton did make a critical error in predicting that the speed of light is greater in water than in air. The reason was not his corpuscular theory, however. Rather, it was his inability to compute the light speed in a manner which was consistent with his Second Law. The decisive impulse in this direction was provided by Hamilton and his canonical equations of motion,[15] published 130 years after Newton's *Opticks*. The key equation in the present context is:

$$\frac{\mathrm{d}E}{\mathrm{d}p} = v \,. \qquad \text{(XVII-10)}$$

Somewhat ironically, eq. (XVII-10) can be derived in a straightforward manner[15,16] on the basis of Newton's Second Law and the definition of work/energy dE as F dr=dp (dr/dt)=dp v. The result in eq. (XVII-10) follows from the above scalar product dp v by virtue of a geometric argument.[15]

The first step in arriving at the correct dependence of the speed of light in refractive media is to apply eq. (XVII-10) to obtain the relation between the energy and momentum of the particles of light in free space. Newton had shown in *Opticks*[2] that white light is decomposed into its component colors when it passes through a glass prism. He concluded that this phenomenon is caused by the varying accelerations experienced by the particles of light associated with different colors when they enter a refractive medium. Since white light travels great distances from the sun without undergoing an analogous decomposition, it follows by the same reasoning that the speed of light has the same constant value c for all corpuscles/photons in free space. As a result, the desired relation can be obtained by integration of eq. (XVII-10) for the special case of v=c while setting the constant of integration to zero, namely as:

$$E = pc\,. \tag{XVII-11}$$

The same equation was used by Stark[12] to derive eq. (XVII-8) from Planck's radiation law[14] in eq. (XVII-9).

The next step is to generalize eq. (XVII-11) for the case of photons in a medium of refractive index n. Because p is proportional to n in Newton's particle theory, it follows that p can be replaced quite generally in refractive media by p/n without changing the original equality relationship. Furthermore, because of its association with the color of the light, the energy E of the photons can reasonably be assumed to be unaffected as they pass between different refractive media. Consequently, the most straightforward choice for the general version of eq. (XVII-11) is:

$$E = \frac{pc}{n}\,. \tag{XVII-12}$$

It should be emphasized that eq. (XVII-12) is not a new (*ad hoc*) hypothesis, but rather a *new deduction* based on formerly well-known hypotheses, in particular Newton's eq. (XVII-3).

The speed v of the photons is then obtained from eq. (XVII-10) by calculating the derivative of the energy E with respect to momentum p as:

$$v = \frac{c}{n_g} = \frac{\mathrm{d}E}{\mathrm{d}p} = \frac{c}{n} - \left(\frac{pc}{n^2}\right)\frac{\mathrm{d}n}{\mathrm{d}p}. \tag{XVII-13}$$

Substitution of the p=h/λ relation of eq. (XVII-8) then leads directly [since d(λp) = pdλ + λdp)] to the observed expression for the velocity of light given in eq. (XVII-6). The corresponding formula for the group refractive index n_g in eq. (XVII-13) can be obtained as:

$$n_g = \frac{\mathrm{d}(pc)}{\mathrm{d}E} = \frac{\mathrm{d}(nE)}{\mathrm{d}E} = n + E\left(\frac{\mathrm{d}n}{\mathrm{d}E}\right) = n + \nu\left(\frac{\mathrm{d}n}{\mathrm{d}\nu}\right). \tag{XVII-14}$$

It is also worth noting that Planck's radiation law in eq. (XVII-9) is obtained by combining eq. (XVII-5) of the wave theory of light with eq. (XVII-12):

$$\frac{E}{p} = \frac{c}{n} = \frac{\omega}{k} = \lambda\nu\ . \tag{XVII-15}$$

Substitution of the relation between momentum and wavelength in eq. (XVII-8) gives:

$$\frac{E}{p} = \frac{E\lambda}{h} = \lambda\nu\ , \tag{XVII-16}$$

which upon cancellation and rearrangement yields eq. (XVII-9*). The revolutionary concept of quantization in Planck's law is therefore already clearly present in Newton's particle theory of light. Furthermore, this version is applicable to light in refractive media, not just in free space.* Planck based his discovery on a statistical treatment of the entropy of blackbody radiation[14], but the same result is obtained from the corpuscular theory and its treatment of light refraction when used in conjunction with Hamilton's canonical equations.[15]

In summary, when one uses the correct definition for velocity (Hamilton's equation), Newton's corpuscular theory is found to be in quantitative agreement with experiment, including most especially with Foucault's determination of the speed of light in water. Newton's error is seen to be his implied assumption that the inertial mass m = p/v of the corpuscles/photons is the same in all media.[16] By contrast, the value obtained from eq. (XVII-12) for p and eqs. (XVI-6,13) for v is:

$$m = \frac{p}{v} = \frac{\frac{nE}{c}}{\frac{c}{n_g}} = nn_g \frac{E}{c^2} = nn_g \frac{h\nu}{c^2}. \tag{XVII-17}$$

The mass of Newton's corpuscles increases as the square of the refractive index, which means it is roughly 1.7 times larger in water than in air, thereby causing him to overestimate the corresponding speed of light in the former medium by this factor. Note that the above formula indicates that Einstein's mass/equivalence formula is only valid in free space.

C. Light Dispersion in the Wave Theory

After the measurement of the speed of light in water had been made, it became necessary to understand why the value of $c_i = c/n_i$ in eq. (XVII-5) estimated using the original wave theory required the wavelength-dependent correction shown in eq. (XVII-6). Rayleigh[9,10] pointed out that the distinction could be explained on the basis of a well-known characteristic of sound whereby waves of slightly different frequency $\omega+\Delta\omega$ and $\omega-\Delta\omega$ are superimposed. The result is a succession of wavelets with variable amplitude. The corresponding wave function is:[17]

$$\Psi = 2A\cos\left(\omega t - kx\right)\cos\left(\Delta\omega t - \Delta kx\right). \tag{XVII-18}$$

The amplitude distribution curve moves with speed $v_g = \Delta\omega/\Delta k$, which is referred to as the group velocity. For light waves in a transparent medium, $\omega = kc/n$, which upon differentiation leads directly to eq. (XVII-6).

To justify this approach, it is necessary to assume that whenever monochromatic light from free space enters a transparent medium, i.e. where no absorption occurs, a) waves of slightly differing ω and k values are always formed and b) it is the speed of the resulting wave groups that is determined in experiments designed to measure the speed of light in the medium. As discussed in earlier work,[18] this interpretation of the correction term in eq. (XVII-6) making use of an analogy to sound waves raises significant questions. For example, it needs to be recognized that, unlike the case for sound, the $\Delta\omega$ and Δk quantities have never been observed for light waves. This conclusion implies that such differences are just too small to be detected, but that raises another question: *how can one measure the speed of the wave groups in actual experiments when their period and wavelength are essentially infinitely long?* Moreover, it also needs to be explained why the frequency and wavelength of the monochromatic light are observed, but their corresponding (phase) velocity indicated in the other factor in eq. (XVII-18), i.e. c_i=c/n_i in eq. (XVII-5), is never measured in refractive media.

The analogous situation is unlike any of the classical applications of Rayleigh's theory to sound and water waves. When two musical instruments are slightly out of tune, both the average tone and the characteristic beat frequency are easily audible. When a rock is dropped into a pond, both wavelets and wave groups are clearly visible. In short, the supposed "dispersion" of monochromatic light waves as they enter a refractive medium has never actually been observed and may in fact be purely hypothetical.

In the particle theory, the assumption is that all the photons in monochromatic light of a given frequency have exactly the same energy and momentum in any medium. The second term on the right-hand side in eq. (XVII-13) comes directly from their momentum dependence within a given medium because of the definition of the light speed in terms of the derivative in eq. (XVII-10). There is no requirement that photons of different frequency somehow must be generated because of the interaction with the refractive medium. The model simply assumes (Fig. 2) that the momentum value increases with refractive index n, but that the energy of each photon is not altered as it passes from one transparent medium to another.

Keywords: *Corpuscular theory of light, De Broglie formula, E=pc/n general formula for light, Experimental formula for light speed, Foucault light speed measurement, Fresnel-Fizeau experiment, Hamilton's de/dp=v equation, Index of refraction n, Light dispersion interpretation, Light refraction diagram (Fig. 2), New derivation of Planck's law, Newton's Opticks, Newton's Second Law, Photoelectric effect, Planck's energy-frequency law, Proportionality of p to n, Rayleigh's theory of sound, Rebuttal of dispersion application, Refraction of light in water, Relativistic variation of mass, Snell's Law of Sines, Stark p=h/λ formula for light*

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XVIII. EXPERIMENTAL TESTS OF THE PARTICLE THEORY OF LIGHT

Experimental support for Newton's particle model comes from observations of time-correlated single-photon counting (TCSPC). Muiño et al.[1] measured the speed of light in water and in air using this technique. Statistical distributions of the photons have been obtained as a function of their time of flight over a given distance. The pattern of these distributions is very similar in the above two media. It simply takes longer for the maximum in the distribution to advance through water than it does for air, and on this basis an accurate value of the ratio of the light speeds in the two media was obtained which is in good agreement with the value expected from eq. (XVII-6). This experience indicates that individual photons are uniformly slowed as they move into a region of higher index of refraction, and that they all continue to move at the same slower speed as long as they are present in the refractive medium. In summary, the TCSPC experiments[1] show no evidence for the dispersion of light in refractive media that is claimed in the modified wave theory.[2,3] On the other hand, they are quite consistent with the Newtonian view that all photons in monochromatic light are completely indistinguishable regardless of the transparent medium in which they are currently found.

The above discussion shows that the particle theory of light is quite capable of describing light refraction on a quantitative basis, contrary to what has been previously assumed because of Newton's failure to predict the speed of light in water. The question thus arises whether it is possible to explain all experimental observations of light phenomena in terms of such an atomistic theory. The prevailing view among physicists is that there is a wave-particle duality such that matter behaves as particles in some experiments and as waves in others. This approach was introduced by de Broglie[4] and can be viewed as a compromise between the two theories, but duality is not an intuitive concept and it precludes concrete experimental verification.

It is possible to make a different interpretation of de Broglie's principle, however, which is far more consistent with Newton's atomistic views[5]. It relies primarily on the association of a wave with a statistical distribution of many particles: *Some experiments are so precise (photoelectric and Compton effects, the refraction of light and single photon counting) that they reveal the elementary nature of matter in terms of particles, while others (interference and diffraction as the primary examples) are only capable of giving information about the statistical distribution of particles in space and time.*

Support for this statement of the duality principle is found in the Born interpretation[6] of the quantum mechanical wave function Ψ. The absolute square of this function plays a similar role as the intensity in the wave theory of light. In this view, $\Psi\Psi^*$ is a statistical distribution function that gives highly reliable information about large samples of a given entity such as an electron or photon, but is incapable of providing detailed information about the current location of any one of them. For example, in an interference experiment, if the intensity of the beam is small and detection is made with a device such as a photographic plate, the distribution observed early in the counting procedure will vary significantly from one trial to another. However, if the experiment is continued for a sufficiently long period of time in each case, the pattern of detected objects will always stabilize to agree completely with quantum mechanical predictions based on the $\Psi\Psi^*$ magnitude for the associated microscopic system. Most importantly, experiments of this type[7] demonstrate that if the intensity is lowered sufficiently, it is always possible to detect single particles on an individual basis, both for electrons and for photons. This is probably the strongest argument for an atomistic theory of matter and the association of statistical distributions of particles with a quantum mechanical wave packet.

In this view, a single atom, electron or photon is *not* vibrating with a definite frequency and wave length. Rather, the values of λ and ν in eqs. (XVII-8,9) are the parameters in Ψ that specify the statistical distribution that many identical particles of this kind possess as an ensemble. As in other applications of statistics, *the corresponding distributions may be quite inadequate for predicting the behavior of individuals, but they provide an unerring guide for trends within very large populations.* The quantum mechanical wave packet thus bears the same relationship to a particle as the histogram does to a member of a sample whose statistical distribution it represents. The latter is a real object, whereas the former is only a mathematical abstraction. A light wave is certainly real, but in analogy to an ocean wave containing many water molecules, it is a collective body whose elementary constituents are single photons.

The speed of light is also altered when it passes through a gravitational field, and thus it is of interest to compare this phenomenon with light refraction[8]. One significant difference is that there is an abrupt change in speed when light passes through an interface separating two different transparent media (Fig. 2 of Chapter XVII), whereas the acceleration is much more gradual when it passes by a massive body. One might tentatively conclude from this difference that light rays follow a curved trajectory in the former case, as opposed to the sharp change in slope that occurs when they enter water from air.

Einstein's prediction of the displacement of star images has generally been interpreted as an indication that light is bent by gravitational interactions, but there are also reasons for doubting this assessment, as discussed in Chapter XV. The angle of displacement was computed in Einstein's work, not the actual trajectory of the light rays. The key assumption is that the speed of light c' decreases as the rays pass closer to the sun.[10] Huygens' principle [eq. XV-6)] is then used to evaluate the angle of displacement θ by integration over the path between the star at infinity and the earth. Schiff has used a simple analytical approach[10] to compute θ and he obtained the same result as Einstein did using the considerably more complicated theory of general relativity (GR).[9]

Experimental evidence for the variation of the speed of light with distance from the sun was obtained by Shapiro et al.[11]. Radar signals were transmitted from earth to either Mercury or Venus and echoes were detected that were retarded by solar gravity. The time delays were expected to increase by almost $2x10^{-4}$ s when the radar pulses pass near the sun.[12] The predicted increase in echo times was observed to within experimental error.[11] The corresponding decrease in the speed of light c' in eq. (XV-6) is also expected to be responsible for the observed displacement of star images during solar eclipses.

In summary, the above considerations show that one can obtain quantitative agreement with the displacement angle Θ by assuming that *there is no deviation of the light rays from their straight-line path* as they travel past a massive body, only a predictable decrease in their speed. The greater time delay of rays closer to the sun causes the associated wave front to rotate (Fig. 1 of Chapter XV), whereby the angle of rotation can be calculated using Huygens' principle. Implicit in these calculations, including Einstein's,[9], is an assumption *that the observer on earth perceives the light from the stars to be approaching along the normal to this wave front*. This conclusion suggests an experiment with light refraction to test the validity of the above assumption,[8,13] as discussed below.

The diagram in Fig. 3 defines the angles of incidence Φ and refraction Φ' as light enters water from free space. The index of refraction of water is defined according to eq. (XVII-3) as n=sinΦ/sinΦ'. Two light rays emanating from the same source are shown as they start out in free space and then cross the interface with water. Depending on the angle of incidence, there is a period of time in which the lower of the two rays is passing through the water while the upper one is still moving in free space. The ratio of the distances that the upper and lower rays travel in this period is clearly the same as that of the corresponding light speeds in the respective media, which in turn is equal to the group refractive index n_g of water..

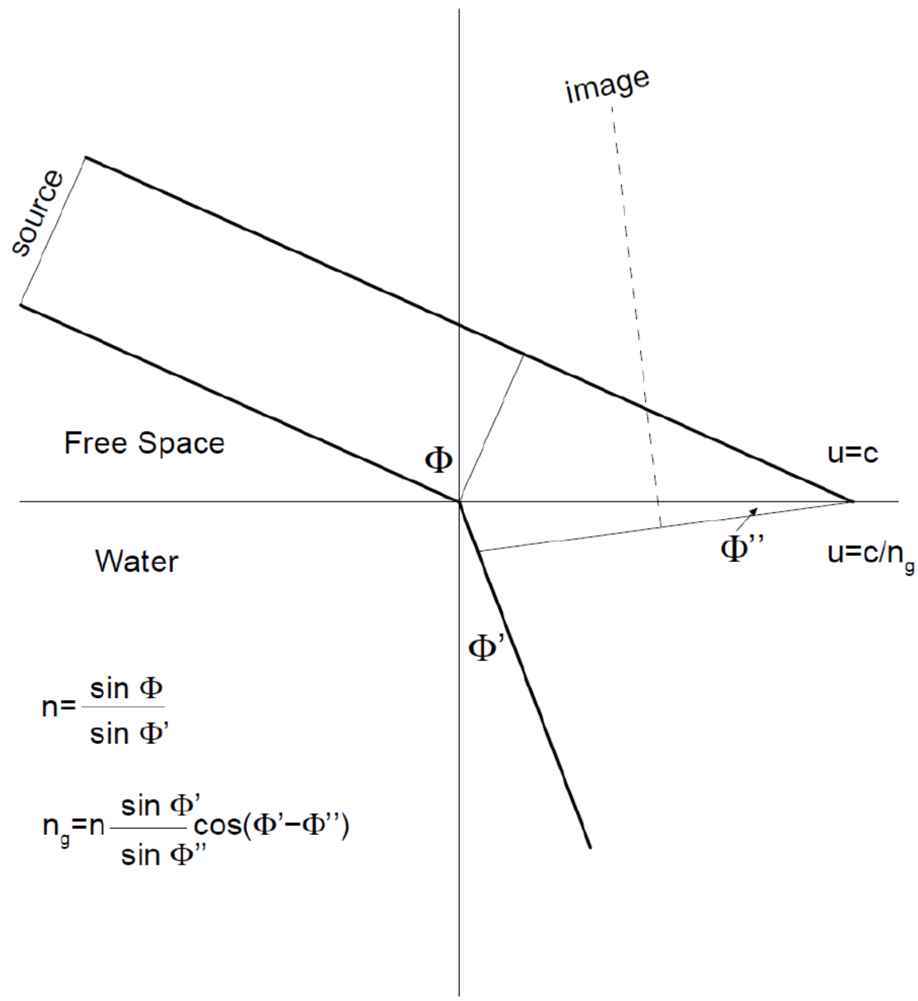

Fig. 3. Angles of incidence Φ and refraction Φ' as light enters water from free space. The corresponding angle Φ" which the wave front makes with the interface upon entering a refracting medium can be determined experimentally by noting the direction from which the image of the light source is *viewed from inside the medium.*

In analogy to the situation illustrated in Fig. 1 for light passing near the sun, the fact that the two light rays move at different speeds in water and air for the above period causes the corresponding wave front connecting them to rotate. The effect is exaggerated in Fig. 3, where the angle of rotation relative to the interface is denoted by Φ”. Also in analogy to the gravitational example, it is assumed that the image of the light source *when viewed from within the water* appears to lie along the normal to this wave front, and therefore to be somewhat displaced from the actual position of the light source. The line passing from a suitable detector immersed in the water to the image outside of it also makes an angle Φ” with the normal to the interface, so its value can be determined with relative ease.

The difference between the two angles Φ’ and Φ” gives a direct measure of the deviation of n_g from the conventional refractive index n. The exact relation obtained using trigonometric identities is, with n=sinΦ/sinΦ’ (Fig. 3):

$$n_g = n\left(\frac{\sin\Phi'}{\sin\Phi''}\right)\cos\left(\Phi' - \Phi''\right). \qquad \text{(XVIII-1)}$$

The two refractive indices also satisfy the relationship:

$$cot\Phi'' = \left(\frac{n_g}{n\sin\Phi'\cos\Phi'}\right) - \tan\Phi'. \qquad \text{(XVIII-2)}$$

If Φ’=Φ”, it follows from both equations that n_g=n. The latter equality was the underlying assumption of the original wave theory which led to its erroneous prediction of the speed of light in water as the phase velocity c_i given in eq. (XVII-5).

The method described above constitutes a direct determination of the group refractive index for monochromatic light.[8,13] It does not require a series of measurements involving different wavelengths of light that allows the determination of dn/dλ in eq. (XVII-6). It is therefore also a method for determining the speed of light in refractive media. It has distinct practical advantages over the classical techniques[14-16] first used to determine this quantity, as well as the more recent procedure[1] involving single-photon counting discussed at the beginning of this chapter.

There are also significant reasons of a more fundamental nature for applying this method for determining light speeds. First of all, it is expected to provide valuable new physiological insight concerning the way in which the human eye and other mechanical devices determine the direction from which the images of objects are perceived to come. At the same time, it should provide verification for the conclusion of the previous chapters that light rays are not actually bent as they pass by a massive body. Instead, they travel in perfectly straight-line trajectories with varying speeds depending on their separation from the body, thereby causing a rotation of the associated wave front.

Keywords: *Born interpretation, De Broglie p=h/λ law, Direct measurement of* n_g*, Einstein's GR, Huygens' Principle, Interference experiments, Light bending myth, Light refraction in water, Muino TCSPC experiment, Newton's particle theory of light, No evidence of light dispersion, Particle–wave duality theory debunking, Physiological insight for determination of light direction, Schiff scaling method*

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XIX. HAMILTON'S CANONICAL EQUATIONS AND $E=mc^2$

The failure of the LT discussed in Chapters III and IV is a consequence of its space-time mixing characteristic. There is no such reliance in the derivation of the $E=mc^2$ mass-energy equivalence relation since it does not involve space and time coordinates. The original derivation of Einstein's $E=mc^2$ formula, which has become his trademark, is based instead upon the description of the dynamics of electromagnetic interactions.[1] He took the position that there were two kinds of inertial mass, and his definition of the *longitudinal mass* variant is essential in his derivation. Planck subsequently suggested[2] that the same result could be obtained by making a generalized definition of inertial mass, namely as $m=\left(1-v^2c^{-2}\right)^{-0.5}\mu v=\gamma\mu v$, where μ is the rest mass of the particle and v is its speed relative to the origin of the electromagnetic force responsible for its acceleration. Einstein readily agreed with Planck[2,3] that it was incorrect to argue that there are two different kinds of inertial mass, but the fact remains that there is a definite element of serendipity in his original $E=mc^2$ derivation.

The object of the present discussion is to show that the mass-energy equivalence relation can be derived without regard to any characteristics of the electromotive force, but rather on the basis of the assumption that *the speed of light in free space has a constant value of c relative to its source.* The light-speed constancy assumption can be traced to the results of the Fizeau/Fresnel light-drag experiment.[4] They showed that light is slowed as it moves through a transparent medium but, by extrapolation of the value of the medium's refractive index n to a unit value, that the observed light speed in the laboratory in the limit of free space should be completely independent of the speed v of the medium, i.e. $c(v)=c$. Maxwell's theory of electricity and magnetism published in 1864 also indicated that the speed of light has the same constant value c in every rest frame. The latter result was clearly at odds with the classical (Galilean) space-time transformation which indicates that speeds should be additive, i.e. $c+v\neq c$. Michelson and Morley[5] used their newly developed interferometer to test this theory, but it merely verified the conclusion that the speed of light is independent of the rest frame through which it moves, in particular that it is directionally independent at all times of the year.

Rather than search for an "ether" to explain the light-speed constancy observations, Voigt[6] suggested that the matter could be explained, as discussed in Chapter II.A, by simply altering the classical transformation in a novel way. In the following discussion, it will be shown that a similar approach can be used to define an energy-momentum transformation that allows one in a straightforward manner to obtain all the key relationships obtained by Einstein and Planck in their original investigations without making use of the characteristics of electromagnetic interactions.

Einstein's approach to the description of the dynamics of an electron or other charged particle was first to consider the transformation properties of Maxwell's equations for electromagnetic interactions. He considered the specific case in which the electron has been accelerated along the x axis as a consequence of the application of an electric field $\mathscr{E}$. He *invoked the Relativity Principle* to argue that the equation of force in the new rest frame is:

$$\mu \frac{\mathrm{d}^2 x'}{\mathrm{d}t'^2} = e'E = e\,, \qquad \text{(XIX-1)}$$

(primed notation has been used for variables in this rest frame).

He then argued that the corresponding equation of force in the original rest frame can be obtained by a Lorentz transformation between the current rest frame and that in which the force has been applied. He pointed out that this transformation indicated that there are two different kinds of inertial mass, longitudinal and transverse. In the present case, the longitudinal inertial mass, which he concluded was equal to $\gamma^3\mu$ according to the above argument, is required since the motion is along the axis of the electric field. The corresponding equation (using unprimed notation for the original rest frame variables) is thus:

$$\frac{\mu\gamma^3 \mathrm{d}^2 x}{\mathrm{d}t^2} = e'E = e\,, \qquad \text{(XIX-2)}$$

He then proceeded to compute the kinetic energy W of the accelerated particle as :

$$W = \int(\mathrm{d}E) = \int(F\mathrm{d}x) = \int(v\mathrm{d}p) = \int(v\mathrm{d}(\text{long.mass}v) = \int(\mu\gamma^3 v\ \mathrm{d}v) = \mu\int(c^2\mathrm{d}\gamma),$$

$$= (\gamma - 1)\,\mu c^2\,, \qquad \text{(XIX-3)}$$

since $d\gamma=\gamma^3 vc^{-2}dv$. The integration is between 0 and infinity, and the longitudinal mass term $\gamma^3(v)$ is treated as a constant in the integration. One thus obtains the $E=mc^2=\gamma\mu c^2$ formula for energy by this route.

Planck was clearly impressed with Einstein's results, but he had some reservations about the way in which he had derived them.[2] Planck was especially sceptical about the need for two different types of inertial mass that Einstein had assumed in order to reach his conclusions. He proceeded instead to make a new generalized definition of momentum as $p=\gamma\mu v$. He then assumed that the electromagnetic force F in Einstein's derivation was equal to dp/dt, in accord with Newton's Second Law. Planck then carried out the differentiation with respect to time in the three spatial directions. For example,

$$\frac{\mathrm{d}p_x}{\mathrm{d}t} = \gamma\mu\frac{\mathrm{d}v_x}{\mathrm{d}t} + \mu v_x\frac{\mathrm{d}\gamma}{\mathrm{d}t} = \gamma\mu a_x + \gamma^3\mu c^{-2} v_x{}^2 a_x$$

$$= \gamma^3\mu a_x\left(1 - v_x{}^2 c^{-2}\right) + \mu v_x{}^2\gamma^3 a_x c^{-2} = \mu a_x\gamma^3\left(1 - v_x{}^2 c^{-2} + v_x{}^2 c^{-2}\right) = \gamma^3\mu a_x\,. \qquad \text{(XIX-4)}$$

The corresponding values in the y and z directions are $\gamma\mu a_y$ and $\gamma\mu a_z$. Einstein had previously referred to the γ^3 and γ factors as longitudinal and transverse masses, respectfully, but he agreed[3] that Planck's derivation was preferable and that there was only one kind of mass after all.

The Voigt space-time transformation[6] can be modified in order to deal directly with the questions considered by Einstein and Planck. The same basic assumption needs to be made as in Voigt's original treatment, namely that the speed of light in free space *relative to its source* is equal to c no matter what the state of motion of the observer might be. Only in this application, speed is not dealt with as a ratio of space and time coordinates. Instead, one defines speed v in terms of Hamilton's Canonical Equations, namely as

$$v = \frac{\mathrm{d}E}{\mathrm{d}p}. \qquad \text{(XIX-5)}$$

As noted above, Planck also made use of this relationship in order to obtain the $E=mc^2$ relationship in eq. (XIX-3) .

In close analogy to Voigt's procedure, one defines the speed of light in free space to have a value of c relative to its source in two different rest frames, i.e.

$$\frac{\mathrm{d}E}{\mathrm{d}p} = \frac{\mathrm{d}E'}{\mathrm{d}p'} = c. \qquad \text{(XIX-6)}$$

The starting point is then Hamilton's transformation in terms of E and p coordinates (note that v is the relative speed of the two rest frames):

$$\mathrm{d}E = \mathrm{d}E' + v\mathrm{d}p_x' \qquad \text{(XIX-7a)}$$

$$\mathrm{d}p_x = \mathrm{d}p_x' \qquad \text{(XIX-7b)}$$

$$\mathrm{d}p_y = \mathrm{d}p_y' \qquad \text{(XIX-7c)}$$

$$\mathrm{d}p_z = \mathrm{d}p_z'. \qquad \text{(XIX-7d)}$$

In order to satisfy the light-speed constancy condition in this case, an extra term with a free parameter a is added to the second equation;

$$\mathrm{d}p_x = \mathrm{d}p_x' + a\mathrm{d}E'. \tag{XIX-8}$$

The value of a is then determined, in complete analogy to Voigt's original procedure, by assuming the above light-speed constancy relation:

$$\frac{\mathrm{d}E}{\mathrm{d}p_x} = c = \frac{\mathrm{d}E' + v\mathrm{d}p_x'}{\mathrm{d}p_x' + a\mathrm{d}E'} = \frac{\frac{\mathrm{d}E'}{\mathrm{d}p_x'} + v}{1 + \frac{a\mathrm{d}E'}{\mathrm{d}p_x'}} = \frac{c+v}{1+ac}$$

One therefore concludes that

$$a = c^{-2}v. \tag{XIX-9}$$

Thus, the second E,p equation is changed thereby to

$$\mathrm{d}p_x = \mathrm{d}p_x' + c^{-2}v\mathrm{d}E'. \tag{XIX-10}$$

After integration of both sets of differential quantities, one obtains the following relation between the squares of the two sets of E and p_x coordinates:

$$E^2 - p_x^2c^2 = \gamma^{-2}\left(E'^2 - p_x'^2c^2\right). \tag{XIX-11}$$

On this basis, it is clear that $E'=p_x'c$ whenever $E=p_xc$, as required.

In order to obtain the corresponding result for motion of the light in any direction ($p^2=p_x^2+p_y^2+p_z^2$),

$$E^2 - p^2c^2 = \gamma^{-2}\left(E'^2 - p'^2c^2\right), \tag{XIX-12}$$

one must either multiply the right-hand sides of both the p_y and p_z equations (i.e. for a perpendicular direction) by a factor of γ^{-1}, or else multiply both the right-hand sides of the E,p_x equations by a factor of γ. Since we cannot change the p_y and p_z relations because they are fixed by Newton's Second Law (note that Voigt[6] did the opposite for his space-time transformation; he multiplied the y and z components with γ^{-1} and left the t and x equations unchanged), we are left with only the latter possibility. The result is:

$$E = \gamma\left(E' + vp_x'\right) \tag{XIX-13a}$$

$$p_x = \gamma\left(p_x' + c^{-2}vE'\right). \tag{XIX-13b}$$

$$p_y = p_y' \tag{XIX-13c}$$

$$p_z = p_z'. \tag{XIX-13d}$$

As a consequence, as required by the light-speed constancy condition,

$$E^2 - p^2c^2 = E'^2 - p'^2c^2. \tag{XIX-14}$$

The inverse transformation can be obtained by interchanging the primed and unprimed quantities and changing the sign of v (Galilean inversion):

$$E' = \gamma\left(E - vp_x\right) \tag{XIX-15a}$$

$$p_x' = \gamma\left(p_x - c^{-2}vE\right). \tag{XIX-15b}$$

$$p_y' = p_y \tag{XIX-15c}$$

$$p_z' = p_z. \tag{XIX-15d}$$

The next step is to consider the inverse transformation from the vantage point of the rest frame in which the accelerating force was applied, in which case, p'=0:

$$E' = \gamma E - \gamma v\left(\gamma c^{-2}vE'\right) = \gamma E - \gamma^2v^2c^{-2}E'. \tag{XIX-16}$$

Thus,

$$E'\left(1 + \gamma^2v^2c^{-2}\right) = E'\gamma^2\left(\gamma^{-2} + v^2c^{-2}\right) = E'\gamma^2 = \gamma E \tag{XIX-17}$$

The conclusion is therefore : E=γE'. Note that the same result is obtained directly from eq. (XIX-13a).

The second of the inverse transformation equations under this p_x'=0 condition is:

$$0 = \gamma\left(p_x - c^{-2}vE\right) = \gamma\left(p - c^{-2}vE\right). \tag{XIX-18}$$

Recalling the definition of momentum in terms of inertial mass m and speed v, this equation leads directly to the mass-energy equivalence relation, since it shows that

$$p = mv = c^{-2}vE\ . \tag{XIX-19}$$

Upon solving for m, we obtain the desired relationship:

$$m = \frac{E}{c^2}. \tag{XIX-20}$$

The key innovation that Planck made to arrive at the above results was to introduce the definition of relativistic momentum as p= γμv. This result can also be easily derived from eq. (XIX-17) as follows (μ is the rest mass of the particle):

$$\frac{E}{E'} = \gamma = \frac{m}{\mu}. \tag{XIX-21}$$

Again, from the original definition of momentum as p=mv, one therefore finds that p=γμv, as was to be shown.

It is important to focus on the E=γE' relation, especially to recall how it was obtained. It results by considering the special case of p'=0. In other words, E' is the rest energy of the particle, i.e. E'=μc^2. However, there are three different speeds that are to be taken into account in the general case. They involve two rest frames in which the particle is stationary at any one time, as well as the other from which the accelerating force originates. The latter has been referred to in previous work as the Objective Rest System or ORS.[7] The former two rest frames move relative to another with speed v, as indicated explicitly in the E-p transformation. It is this speed which is used to define γ (v) in the transformation equations.

Their corresponding speeds relative to the common ORS are given by Hamilton's Canonical Equations as $dE/dp=v_0$ and $dE'/dp'=v_0'$, respectively.

According to the above analysis in terms of the Hamilton-Voigt energy-momentum (E-p) transformation, the energy of a particle in a stationary position within a given rest frame is obtained as $E=\gamma(v_0)\,E_0=\gamma(v_0)\mu c^2$. In other words, one assumes that the particle energy increases relative to its rest value by a factor of $\gamma(dE/dp)$ or $\gamma(dE'/dp')$ to $\gamma(v_0)\mu c^2$ or $\gamma(v_0')\mu c^2$, respectively. This relationship is essential for understanding the overall effect of the application of force to the particle at two different stages of acceleration (note that $v_0=v_0'=c$ in the case of a light pulse, consistent with the derivation of the E-p transformation). It can be expressed in the above notation as a direct proportionality:

$$\frac{E}{\gamma\left(v_0\right)}=\frac{E'}{\gamma\left(v_0'\right)}. \tag{XIX-22}$$

The above equation is closely related to the inverse proportionality relation for elapsed times Δt and $\Delta t'$ measured in the same two rest frames (referred to in Chapter IX as the Universal Time-Dilation Law[8], namely:

$$\Delta t\gamma\left(v_0\right)=\Delta t'\gamma\left(v_0'\right). \tag{XIX-23}$$

Of course, the latter can also be converted into a direct proportionality by using the periods of clocks τ and τ' instead of the corresponding elapsed times. What one concludes then is that energy and time scale in exactly the same manner with the application of force to the corresponding particle.

One can simplify these relationships further by looking upon the various quantities as *units of a physical property*. In other words, what we see is that both the unit of energy and time vary in the same proportion as the particle is accelerated. It is helpful to refer to the proportionality factor as $Q=\gamma(v_0')/\gamma(v_0)$. Thus, $\Delta t'=\Delta t/Q$ and $\tau'=Q\tau$. Similarly, $E'=QE$, using the same value of Q, which will be referred to in the following as the *kinetic scale factor*. More discussion of this point is given in Chapters IX-XI.

Experimental measurements of the inertial mass of an electron[9] are in complete accord with the above analysis. They showed that mass increases with speed relative to the laboratory by the same factor as expected for lifetimes, from which one concludes that the scale factor for this property also varies in direct proportion to Q. Taken together, all these results are found to be consistent with the $E=mc^2$ formula; both E and m scale as Q, while c remains constant. In general, by simply noting its composition in terms of the three fundamental properties of inertial mass, distance and time, one can predict in a quite easy manner the way in which the corresponding scale factor for a given property varies, again as shown in Chapter XI.

It is important to note that the above procedures are perfectly in line with Galileo's Relativity Principle. Even though the units for the various physical properties vary upon application of a force to the particle, the fact remains that there is no way based on *in situ* measurements alone that a stationary observer co-moving with the particle can be aware of such changes. This is because a change in the value of a given property is always perfectly matched by a proportional change in the unit employed to express it. Observers in different inertial systems have every reason to believe that the units they are independently using are standard, even though it can be shown experimentally that they differ from one rest frame to another. They each think that their meter stick has a length of exactly 1.0 m, and that their standard of energy is exactly equal to 1.0 J.

This being the case, it is still true that the passengers locked below the hull of a ship cannot know whether they are underway on a perfectly calm sea or have actually never left the port. Galileo used this example to help contemporaries to accept the truth that the earth is orbiting the sun at the "unbelievable" speed of 30 km per second. The above scaling arguments indicate, however, that there should be an addendum to the Relativity Principle, namely[10]: The laws of physics are the same in every inertial rest frame, *but the units in which they are expressed vary in a completely systematic manner from one frame to another.*

Keywords: *Addendum to RP, Derivation of $E=mc^2$ from EP transformation, $E=mc^2$, Galileo's RP, Hamilton-Voigt EP transformation, LT space-time mixing, Maxwell's theory of electromagnetism, Measurements of inertial Mass variation, Michelson-Morley interference, Objective rst system ORS, Planck definition of momentum, Planck derivation, Speed of light relative to source, UTDL variation for energy and mass, Voigt transformation*

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XX. EINSTEIN'S MISTAKEN USE OF THE RELATIVITY PRINCIPLE

In his derivation of the mass-energy equivalence relation, Einstein[1] invoked the Relativity Principle (RP) to deduce the electromagnetic force equation in the rest frame of the accelerating charged particle. He then used the Lorentz transformation (LT) to obtain the corresponding force equation in the rest frame in which the force was applied. It is generally overlooked thereby that the former rest frame is not freely translating, and therefore that Einstein's claim that the RP is relevant to this situation is not correct. In his 1905 paper, he explicitly states on p.895 (see point #1) that it applies to "freely translating systems," without listing any exceptions beyond this. As a consequence, there is no reason to accept his conclusion about the above force equation as an unavoidable consequence of the RP. In particular, his derivation of the expression for inertial mass is certainly faulty.

The fact is that the question of transverse and longitudinal masses was settled once and for all by Planck's intercession (see Chapter XIX), so there is no need to further discuss that conclusion. There still remains another consequence of Einstein's version of the RP which merits discussion, however. This has to do with the value of the speed in the momentary rest frame of the accelerated electron. According to the Hamilton-Voigt transformation given in eqs. (XIX-15a-d), the energy measured in this rest frame is equal to $\gamma\mu c^2$ and the corresponding inertial mass is γ, whereby the argument v for γ in both cases is the *speed of the particle relative to the rest frame (ORS) in which force was applied.* The corresponding momentum is $p=\gamma\mu v$.

The standard relativistic treatment of electromagnetic interactions is based on the premise that the components of the electric E and magnetic B field vectors transform according to the following equations[2] (c is the speed of light in free space, 299792458 ms^{-1}):

$$E_x' = E_x \qquad\qquad B_x' = B_x$$

$$E_y' = \gamma\left(E_y - vc^{-1}B_z\right) \qquad B_y' = \gamma\left(B_y + vc^{-1}E_z\right) \qquad \text{(XX-1)}$$

$$E_z' = \gamma\left(E_z + vc^{-1}B_y\right) \qquad B_z' = \gamma\left(B_z - vc^{-1}E_y\right)$$

Einstein derived this set of relations[1] by assuming that Maxwell's equations must be invariant to a Lorentz transformation (LT) of spatial and time coordinates between different rest frames. It was further assumed that the components of the electromagnetic force F on charged particles e are given in terms of the above field components by the Lorentz Force equation:

$$\mathbf{F} = e\left(\mathbf{E} + c^{-1}\mathbf{vxB}\right). \qquad \text{(XX-2)}$$

In this equation it has been generally assumed that v is the velocity of charged particles relative to the observer, a point which will prove worthy of further discussion subsequently.

There is ample evidence[3] that the Lorentz Force satisfies the equation of motion expected from Newton's Second Law, namely:

$$e\left(\mathbf{E} + \mathbf{v}c^{-1}\mathbf{xB}\right) = \frac{\mathrm{d}\left(\gamma\mu\mathbf{v}\right)}{\mathrm{d}t}, \qquad \text{(XX-3)}$$

i.e. the force F equals the time rate of change for the relativistic momentum p=γμv, with $\gamma = (1-v^2c^{-2})^{-0.5}$ and μ is the rest mass of the particle/electron. Nonetheless, as will be seen from the following concrete example which makes use of this equation, there is still an uncertainty in the definition of v therein when the observer is located in a different rest frame than that of the laboratory in which the force is applied.[4]

Consider the effects of an electromagnetic field with only the two components, E_x and B_y, acting on an electron. From the point of view of an observer located at the origin of the field, the electron will initially move along the x axis. This is because the force F in eq. (XX-2) only depends on E_x at the instant the field is applied since the value of v=0 negates any effect from the corresponding magnetic field component B_y. This situation changes as time goes by and the electron is accelerated to non-zero speeds. The vxB term in eq. (XX-2) gradually produces a force component in the z direction, causing the electron to veer away from its initial path. Depending on the relative strengths of the constant values of E_x and B_y, the amount of deflection can be quite significant over time. This situation is easily reproduced in the laboratory and there is no doubt that it is consistent with the Lorentz Force law.

Next consider the same example from the perspective of an observer co-moving with the electron. Since the speed v of the electron relative to the observer is zero at all times, it follows according to the transformation law of eq. (XX-1) as well as eq. (XX-2) that the *magnetic field has no effect.* As a result one expects that, from the perspective of this observer, *the electron continues indefinitely along a straight line parallel to the x axis.* This predicted trajectory is therefore clearly distinguishable from that discussed first from the vantage point of the laboratory observer.

This difference raises the question of whether it is reasonable to expect that the electron would appear to follow a different path for the two observers. No one has ever ridden along with an accelerated electron or other charged particle to verify that the predicted straight-line trajectory would actually be found by such an observer. Since the curved path expected from the laboratory perspective is routinely observed, however, it would therefore seem on the contrary *that the straight-line result is pure fiction,* an artefact of a physically unrealistic theory.

Does this example prove that Galileo's RP does not apply to electromagnetic interactions? Clearly not. The reason is because there is another quite straightforward way to satisfy both Maxwell's equations and the RP at the same time, namely to insist that all observers, regardless of their state of motion, *see exactly the same results of any given interaction*. In particular, the hypothetical observer co-moving with the accelerated electron must record the same curved trajectory as is viewed from the laboratory perspective.[4]

The measured values for the parameters of the electron's path may still differ for the two observers, however. This is *because the units in which they express their respective measured values may not be the same.* We know, for example, from the time-dilation experiments[5-7] mentioned in Chapter VIII that the clocks they employ to measure elapsed times can run at different rates. This fact does not change the above conclusion about the trajectory of the electron in the above example, however. There is no reason to doubt that all observers should agree that a curved path is followed as a consequence of the interaction of crossed electric and magnetic fields.

There is a detail that needs to be considered in both Maxwell's equations and the Lorentz Force Law which is crucial for deciding how to apply the RP to electromagnetic interactions, however. It is the interpretation of the velocity that appears in both expressions. At some point in history, physicists came to the consensus that v is the velocity of the electrons or other charged particles *relative to the observer* in any given interaction. This decision has quite important consequences vis-a-vis the measurement process in general. It means that the results of any measurement are thought to depend on the perspective of the observer. *Measurement is subjective*, according to this view in other words.

This was an astonishing departure from the prevailing attitude of physicists in the preceding centuries. It was previously taken for granted that measurement had an *absolute character* and that all observers could agree on values such as the length and weight of an object. A confusing aspect of measurement was clearly that each observer could express his measured results in a different set of units and therefore obtain *different numerical values* for the same quantity.

However, this eventuality did not change the fact that people could always agree on which of two lengths or weights was larger. More quantitatively, it could safely be assumed that the ratio of two measured values of the same type must be independent of the choice of units (see the discussion of the PRM in Chapter I). *Measurement was both rational and objective* and thus, if carried out properly, could serve as a fair basis for trading practices. Yet now, physicists were claiming that quantities such as electric and magnetic fields vary with the state of motion of the observer.

There is a clear alternative interpretation of the velocities which appear in Maxwell's equations and the Lorentz Force Law, however, one which eliminates the need to assume that observers can disagree on the trajectories of particles affected by these interactions. It is simply necessary to assume that the variable v in these equations is the velocity of the electron *relative to the rest frame in which the electromagnetic field originates*. This is a quantity which all observers can agree upon at least in principle. Just changing the unit in which velocity measurements are expressed can have no effect on the measured trajectory of the particle. In particular, an observer co-moving with the electron in the example of the previous section can therefore use Maxwell's equations and the Lorentz Force Law to conclude that the path being followed is exactly the same as reported by his counterpart located at the origin of the electromagnetic field, except perhaps for a difference in the sets of physical units in which each expresses his results.

The above interpretation allows for a much less restrictive interpretation of the RP. It is not necessary that the form of the physical law describing this or any other interaction be invariant to a particular space-time transformation in an arbitrarily chosen rest frame. In the case of electromagnetic interactions, it is only necessary that the same laws, in this case Maxwell's equations and the Lorentz Force Law, apply in any rest frame, *including that where the electron currently exists*. The electron's velocity v relative to the origin of the interaction uniquely determines the magnitudes of the electric and magnetic fields as well as the corresponding force acting on it. By contrast, the velocity of the electron relative to the observer himself plays no direct role in determining such quantities, thereby removing any element of subjectivity from the process. All observers, regardless of their own state of motion, must agree on the results of the interaction, except that they will generally not agree on the numerical values of their measurements because of differences in their respective choice of physical units.

It therefore suffices if the law in question faithfully predicts the results of the interaction in any given rest frame, regardless of the observer's current state of motion. Phipps[8] has pointed out that Ampère's original law of ponderomotive force action exerted by an infinitesimal element of neutral current $I_2 d\vec{s}_2$ upon another element $I_1 d\vec{s}_1$, has the form.[9-10]

$$\vec{F}_{21(Ampere)} = \frac{\mu_0}{4\pi}\frac{I_1 I_2 \vec{r}}{r^3}\left[\frac{3}{r^2}\left(\vec{r}\cdot d\vec{s}_1\right)\left(\vec{r}\cdot d\vec{s}_2\right) - 2\left(d\vec{s}_1 \cdot d\vec{s}_2\right)\right], \tag{XX-4}$$

where $\vec{r} = \vec{r}_1 - \vec{r}_2$ is the relative position vector of the elements and ($\mu_0 / 4\pi$) is a units factor yielding force in N for current in amperes. Note that the force is symmetrical between 1 and 2 subscripts, and proportional to $\vec{r}$. Thus, it rigorously obeys Newton's third law of equality and co-linearity of action-reaction between current elements, which requires $\vec{F}_{21} = -\vec{F}_{12}$ on a detailed element-by-element basis. It has nonetheless generally been rejected by physicists in favor of the Lorentz Force Law because of its transformation properties not shared by eq. (XX-4). The latter, when similarly expressed, takes the form[9]

$$\vec{F}_{21(Lorentz)} = \frac{\mu_0}{4\pi}\frac{I_1 I_2}{r^3}\left[-\left(d\vec{s}_1 \cdot d\vec{s}_2\right)\vec{r} + \left(d\vec{s}_1 \cdot \vec{r}\right)d\vec{s}_2\right] \tag{XX-5}$$

It is asymmetrical in subscripts 1 and 2, and not proportional to $\vec{r}$, so that it disobeys Newton's third law in two ways. More details about this topic may be found in Phipps's original work[8]. The point to be emphasized in the present discussion is that there is no reason to reject eq. (XX-4) once one agrees that the velocities of the electrons in the current elements I_1 and I_2 are to be measured relative to the rest frame in which the electromagnetic field originates.

Keywords: *Contradiction when v assumed relative to observer, Correct definition of v, Curved path of electron, Einstein's use of RP, Lorentz invariance condition, Meaning of v in Lorentz force equations, Newton's Third Law End of Paper, Objectivity of measurement, Phipps discussion of Ampere's Force, Principle of Rational Measurement PRM, Standard electromagnetism equations*

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XXI. MINKOWSKI'S FOUR-VECTOR FOLLY

There is a similar problem with subjectivity in the Lorentz transformation (LT) given below:

$$\Delta t' = \gamma\left(\Delta t - v\Delta x c^{-2}\right) = \gamma\eta^{-1}\Delta t \qquad \text{(XXI-1a)}$$

$$\Delta x' = \gamma\left(\Delta x - v\Delta t\right) \qquad \text{(XXI-1b)}$$

$$\Delta y' = \Delta y \qquad \text{(XXI-1c)}$$

$$\Delta z' = \Delta z \, . \qquad \text{(XXI-1d)}$$

These equations are given in terms of intervals of space Δx, Δy and Δz and time Δt and their primed counterparts, i.e. $\Delta x = x_2 - x_1$, $\Delta x' = x_2' - x_1'$ etc. for two events [c is the speed of light, v is the relative speed of the participating inertial systems S and S' moving along a common x,x' coordinate axis and $\gamma = (1 - v^2c^{-2})^{-0.5}$]. In addition, the quantity η is defined as $(1 - vc^{-2}\Delta x/\Delta t)^{-1}$. In Einstein's original derivation1,[1] Δx/Δt is the velocity component (u_x) of an object in uniform translation as viewed by a stationary observer in S.

One of the key predictions of the LT is that a moving clock will always appear to run slower than its identical counterpart at rest (Chapter III). Thus, once again, SR[1] claims that the results of measurements are a matter of perspective. Each observer thinks that it is the other's clock that has the slower rate. There has been much debate over the last century about whether such a situation is physically realizable. As already mentioned in the Chapter III, however, experiments which have been carried out to test this prediction have proven decidedly negative in this respect. In the Hafele-Keating study,[2,3] for example, it has been demonstrated that the atomic clocks on the airplane flying eastward run slower than those left behind at the origin of the flight, whereas those moving in the westerly direction run faster than both of the latter. The GPS methodology discussed in Chapter XIII relies on the assumption that an atomic clock on a satellite runs slower than its identical counterpart on the ground once one takes account of gravitational effects.

It has been shown in Chapter VI that there is an alternative space-time transformation[4-6] (referred to as the Newton-Voigt transformation NVT) which satisfies both of Einstein's postulates of SR and assumes, in contrast to eq. (XXI-1a) of the LT, that the measured elapsed times of the two observers in S and S' are strictly proportional to one another:

$$\Delta t' = \frac{\Delta t}{Q} \tag{XXI-2a}$$

$$\Delta x' = \eta\left(\Delta x - v\Delta t\right) \tag{XXI-2b}$$

$$\Delta y' = \frac{\eta \Delta y}{\gamma Q} \tag{XXI-2c}$$

$$\Delta z' = \frac{\eta \Delta z}{\gamma Q}. \tag{XXI-2d}$$

The parameter Q in the NVT equations is fixed for any pair of inertial systems (see Chapter XI). In a typical case it is defined in terms of the speeds v_0 and v_0' of S and S' relative to a specific rest frame.[7]. In the Hafele-Keating study, the earth's center of mass serves as this unique system, for example.

The point to be emphasized in the present discussion is that the symmetric relationship between elapsed times expected from the LT has always been contradicted in actual experiments. The assumption of clock-rate proportionality in the NVT of eqs. (XXI-2a-d) has been quantitatively verified in both the Hay et al.[8] and Hafele-Keating studies. *Time dilation is exclusively asymmetric and space and time are unequivocally distinct entities* (see Chapter VIII). The conclusion from the empirical data is unequivocal. The LT is invalid and all of its predictions therefore need to be carefully reconsidered. This includes most especially the idea that space and time are inextricably mixed.[9,10] Newton was right and Einstein was wrong.[11]

Minkowski's four-vector approach depends wholly on the LT. This was the point that Einstein was making when he dismissed it[12] as “superfluous learnedness.” All that is done is to put SR in the framework of linear/affine spaces. One defines the spatial variables in the LT of eqs. (XXI-1a-d) as follows: $x_1=\Delta x$, $x_2=\Delta y$, $x_3=\Delta z$. Then, instead of using elapsed time directly, a fourth vector is defined as $ic\Delta t$. The Lorentz invariance condition is obtained by summing the squares of the four LT relations,

$$\Delta x'^2 + \Delta y'^2 + \Delta z'^2 - c^2\Delta t'^2 = \Delta x^2 + \Delta y^2 + \Delta z^2 - c^2\Delta t^2 . \qquad \text{(XXI-3)}$$

In terms of the Minkowski four-vector $x=(x_1,x_2,x_3,x_4)$, this equation becomes a relation between scalar products:

$$x \bullet x = x' \bullet x' \qquad \text{(XXI-4)}$$

The beautiful simplicity of eq. (XXI-4) doesn't change the fact that the LT on which it is based is invalid.[9,10] There is a corresponding invariance relationship for the NVT. Expressed in its most symmetric form, it is:

$$\eta' Q'^{-1}\left(\Delta x'^2 + \Delta y'^2 + \Delta z'^2 - c^2\Delta t'^2\right) = \eta Q^{-1}\left(\Delta x^2 + \Delta y^2 + \Delta z^2 - c^2\Delta t^2\right). \qquad \text{(XXI-5)}$$

In this expression η' is obtained from η by Galilean inversion, i.e. by interchanging the primed and unprimed variables and changing the sign of v so that $\eta'=(1+vc^{-2}\ \Delta x'/\Delta t')^{-1}$. It has been pointed out in Chapter II that the following identity[13] holds for these two quantities:

$$\eta\eta' = \gamma^2 . \qquad \text{(XXI-6)}$$

In order to satisfy the RP it is also necessary that QQ'=1, i.e. that eq. (XXI-2a) is consistent with its inverse, $\Delta t=Q\Delta t'=\Delta t'/Q'$. As a result, eq. (XXI-5) has the equivalent form:

$$\left(\Delta x'^2 + \Delta y'^2 + \Delta z'^2 - c^2\Delta t'^2\right) = \varepsilon^2\left(\Delta x^2 + \Delta y^2 + \Delta z^2 - c^2\Delta t^2\right). \qquad \text{(XXI-7)}$$

with $\varepsilon=\eta(\gamma Q)^{-1}$. The LT has a corresponding value of $\varepsilon=1$ in eq. (XXI-3). Inverting eq. (XXI-7) shows that $\varepsilon\varepsilon'=1$ is the condition for satisfying the RP, i.e. where ε' is obtained in the usual way (Galilean inversion) from ε by interchanging primed and unprimed variables and reversing the sign of v.

The NVT is thus seen to *satisfy the RP condition but not* $\varepsilon^2=1$. This is a significant distinction for the four-vector formalism. It means that the set of 4x4 matrices a_{ij} describing the LT form a group. It should be noted, however, that this relationship only holds if the velocity vectors in the pairs of a_{ij} matrices lie in the same direction. The corresponding set of matrices for the NVT do not form a group, however. That is a physically irrelevant point, however, since there is no *a priori* reason that the true space-time transformation should exhibit group properties.

An attractive feature of Minkowski's formalism is that the LT transformation matrix $A=a_{ij}$ is orthogonal, i.e. its transpose A' satisfies the relationship:

$$A' = A^{-1}. \tag{XXI-8}$$

It also can be used in a similarity transformation for the four-tensor F of the electromagnetic field[14]:

$$F' = AFA', \tag{XXI-9}$$

i.e., where F' has the same form in the other rest frame.

It needs to be emphasized, however, that a comparable set of relationships is obtained when one uses the NVT of eqs. (XIX-2a-d) to form the Minkowski matrix, $B=\varepsilon A$, with $\varepsilon=\eta(\gamma Q)^{-1}$. The same relationship between the electric and magnetic fields is obtained with the NVT as with the LT because of the homogeneity of Maxwell's equations (for the same reason that both transformations satisfy the light-speed postulate.[1,15-16]). In this case, $B'=\varepsilon'A'$ and $\varepsilon'=\eta'(\gamma Q')^{-1}$. One therefore obtains the equivalent matrix relationships as in eqs. (XXI-8,9) since $\varepsilon\varepsilon'=1$:

$$B' = B^{-1}. \qquad \text{(XXI-10)}$$

$$F' = BFB'. \qquad \text{(XXI-11)}$$

There is a distinction between the four-vector approach and ordinary linear spaces that needs to be taken into account, however. There is an axiom in the strictly mathematical definition which states that in order for a set to qualify as a linear space it must have a *unique zero element.* This condition is not satisfied in the Minkowski definition because all light-vectors have zero magnitude by definition in eq. (XXI-3), i.e. each side has a null value. This state of affairs has a more serious consequence when it comes to defining the four-tensors that are used to represent the NVT and other space-time transformations in general. In the case of the NVT, this situation manifests itself because there are two mathematically equivalent linear combinations of the x_i vectors to define the time vector x_4'. One has already been discussed in connection with the B matrix above. The fourth row has two non-zero elements in the *B* transformation matrix, similarly as for *A*, from which it differs by the constant factor $\varepsilon=\eta(\gamma Q)^{-1}$. An alternative matrix *C* is obtained if eq. (XXI-2a) is used instead. In that case the fourth row contains only a single non-zero element, namely $c_{44}=Q^{-1}$. The other three rows are identical to those in *B*. The fourth column of the transpose matrix C' therefore also has only one non-zero element, $c_{44}'=Q'^{-1}$. As a consequence, one finds that the condition equivalent to eq. (XXI-10) for the *B* matrix does not apply to *C*, i.e. $C'\neq C^{-1}$.

If one carries out the transformation of Maxwell's equations in the conventional manner employed by Einstein,[1] it is clear that the results are exactly the same whether one uses eq. (XXI-2a) directly or eq. (XXI-1a) with the right-hand side multiplied with $\varepsilon=\eta(\gamma Q)^{-1}$, or for that matter with any other value of ε. As mentioned above, this equivalence is guaranteed by the homogeneity of Maxwell's equations. The difference between the results of the matrix operations in the Minkowski formalism simply points out the necessity of choosing a specific form for the transformation equations in order to obtain the desired result. This situation is already evident from the fact that a particular factor, namely ic, for Δt and Δt' must be used to satisfy eq. (XXI-4). On the one hand, this specificity does not prevent one from obtaining the "right answers" using the four-vector formalism, but on the other, it supports Einstein's critique of the method as being unnecessarily complicated ("superficial").

The case of an electron being acted upon by an electromagnetic field is an example of a more general situation in which a particle undergoes acceleration as a result of a locally applied force. The energy E and momentum p of the particle also combine to form a four-vector which satisfies the following relationship in SR[1] between different rest frames:

$$E^2 - p^2c^2 = E'^2 - p'^2 c^2 = \mu^2 c^4 , \qquad \text{(XXI-12)}$$

where μ is the rest mass of the particle. This equation can be derived from the experimental results obtained by Bucherer [17] for the variation of the mass m of accelerated electrons with speed v relative to the laboratory:

$$m = \gamma\left(v\right)\mu . \qquad \text{(XXI-13)}$$

When combined with Einstein's mass-energy relation,[1] this equation can be converted to

$$E = mc^2 = \gamma\mu c^2 = \gamma E_0 , \qquad \text{(XXI-14)}$$

where E_0 is referred to as the rest energy of the particle. Squaring eq. (XXI-14) leads back to eq. (XXI-12) since

$$E^2\gamma^{-2} = E^2\left(1 - v^2c^{-2}\right) = E^2 - E^2v^2c^{-2} = E^2 - \left(E^2c^{-4}\right)v^2c^2 = E^2 - m^2v^2c^2 = \qquad \text{(XXI-15)}$$

$$E^2 - p^2c^2 = E_0{}^2 = \mu^2c^4 = E'^2 - p'^2 c^2 .$$

Note that E' and p' in the last term correspond to a different rest frame than the original and therefore to a different value of the particle's speed (v') relative to the laboratory.

There are two points to be emphasized in the above derivation. First, eqs. (XXI-13,14) refer to measurements made from the perspective of the laboratory in Bucherer's experiments,[17] i.e. v and γ (v) are determined relative to this rest frame. Second, the situation is the same as for electromagnetic interactions, as discussed in Chapter XX. The *speed of the observer relative to the particle is irrelevant* in determining the values of E, m and p. All observers see the same *absolute* values of these quantities. If the observer has also undergone acceleration relative to the origin/laboratory, his standard unit of mass will differ from that employed in the laboratory.

The situation is the same as for time dilation. One needs to know the speed v' of the observer relative to the origin of the interaction as well as the speed v of the particle relative to the same rest frame. The conversion factor between the observer's unit of mass and that employed in the laboratory rest frame is the same (Q) as for time dilation. In this case, eqs. (XXI-13,14) must be replaced by the relations:

$$m = Q\mu \qquad \text{(XXI-16)}$$

$$E = QE_0 , \qquad \text{(XXI-17)}$$

This is a critical distinction for the four-vector formalism, however. The E,p four-vector no longer satisfies the scalar product relation in eq. (XXI-12) when Q≠γ. This only occurs when the *observer is stationary in the rest frame where the force causing the particle acceleration occurs*, which is the case in Bucherer's experiments.[17] On the other hand, Q=1 for the observer co-moving with the electron, so he will obtain the rest values of E and m, i.e. E_0 and μ. His value for the momentum p will be μv, however, where v is the velocity of the electron relative to the laboratory, not simply p=0. This conclusion is again consistent with the discussion in Chapter XX for electromagnetic interactions. Momentum is determined by the velocity of the particle relative to the rest frame in which the relevant force was applied, *not by the speed of the observer relative to either the particle or this origin.* The same situation holds for clock rates in the Hafele-Keating experiments.[2,3]

Note that all observers must agree on the value of v to be consistent with the light-speed constancy postulate.[18] This also means that the unit of distance must change in the same manner with rest frame as time and mass, i.e. with the same conversion factor Q. Accordingly, the conversion factor for speed, the ratio of distance to elapsed time, is $Q^0=1$. More details concerning conversion factors for other physical properties are given in Chapter XI.

As a final topic in this chapter, consider the four-vector relationship for frequencies ν and wavelengths γ. For this purpose it is convenient to use the definitions of circular frequency ω=2πν and wave vector k=2π/λ. There is again an invariance condition for the associated scalar product, in this case:

$$\omega^2 - k^2c^2 = 0\,. \qquad \text{(XXI-18)}$$

This relationship only holds for light in free space, however, in which case ω/k=λν=c. It has special significance[19] because of the quantum mechanical relationships for photons: E=hν and p=h/λ. There is thus a close connection between the E,p and ω,k four-vectors for this case.

Keywords: *Bucherer mass experiment, Conflict with linear space theory, Einstein transformation of Maxwell's equations, Galilean inversion, General role of parameter Q, GPS methodology. Hafele-Keating airplane study, Hay et al. experiment, Lorentz transformation equations, LT as basis for Minkowski's theory, Minkowski's four-tensor relationship, Minkowski's four-vector approach, Momentum definition, Newton-Voigt transformation, RP condition, Scaling parameter Q, SR subjectivity,* $\eta'\eta=\gamma^2$ *identity*

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XXII. THE MYTH OF FITZGERALD-LORENTZ LENGTH CONTACTION

One of the most staunchly believed predictions of SR is FitzGerald-Lorentz length contraction. It was originally derived[1] on the basis of the Galilean space-time transformation in an attempt to make it compatible with experiments that indicated that the speed of light is the same for all observers independent of their state of motion relative to the source. Accordingly, it was argued that the length of objects decrease when they are accelerated, and by varying amounts depending on their orientation. Einstein[2] derived exactly the same relationships based on the LT.

The Uniform Scaling method, as discussed in Chapter X, on the contrary assumes that the lengths of objects *expand isotopically* when they are accelerated. The justification for this position is based on the observed constancy of the speed of light. Consider an experiment in which the speed of light is determined in the laboratory rest frame S by measuring the elapsed time T that a light pulse takes to move the entire length of a metal rod of length L located there. The speed of the light pulse is found to be equal to L/T=c, as expected.

Subsequently, the same experiment is carried out with exactly the same result (consistent with RP) in an accelerated rest frame S' that is now moving uniformly; this occurs at the same gravitational potential as before so as to eliminate any possible effect of gravity on the clock rate. It is known that the clock rate in S' has slowed because of time dilation by a factor of Q>1 relative to its original value in S. Thus, the time measured on the *laboratory clock* S must now be QT>T since it is equal to T on the S' clock. Nonetheless, the observed value of the light speed is still equal to c, as is to be expected based of the light-speed postulate. Moreover, the same result is obtained independent of the orientation of the metal rod, also as expected. The only way to explain this result is to assume that the length of the rod itself has increased from a value of L to QL based on the measuring device employed in the laboratory. In this way the light speed is determined to be QL/QT =c for all orientations of the rod.

Arguments presented in various textbooks[3,4] published over the past 60 years come to a conclusion regarding the validity of the FLC which is completely opposite to that reached in the present work, so it is important to understand why. An example is considered in which a vehicle travels between two fixed points, analogous to the case above in which when a light pulse travels the entire distance along a metal rod. In both versions of the theory, two observers located in different rest frames S and S' are assumed to measure the same value for the speed u of the vehicle. There is also no disagreement in the conclusion that the observer in S' with the slower clock measures a shorter elapsed time for the journey and therefore a *smaller* value for the distance. The point of disagreement comes because the textbooks conclude from this that there is length contraction in S'. The opposite is true, as shown below.

Each observer sees the same event, and thus the *absolute* value for the distance travelled is exactly the same for both. The reason that their *numerical* values differ is clearly a consequence of the fact that *the unit of length* in which they express their respective findings is not the same. Measured values of any physical quantity *are inversely proportional to the size of the unit* employed by the observer. It therefore follows that the unit of length in S' must be *greater* than that in S; that's why a *smaller* value for the distance has been measured by the S' observer. The measuring rod has therefore *expanded* in the rest frame where time dilation has occurred, i.e. S'.

Moreover, the textbook versions[3,4] fail to mention that the amount of the supposed contraction is the same in all directions. Nowhere in the textbook argument is it necessary to state the direction of travel, only its speed. This is because the distance measurements are made with clocks and thus the *ratio* of the respective numerical values is always the same as for their clock rates since they agree on the speed of travel. If the speed of the vehicle is u along the x direction and Q= γ (u), the Uniform Scaling method therefore concludes that

$$t' = \frac{t}{\gamma} \tag{XXII-1a}$$

$$x' = ut' = \frac{ut}{\gamma} = \frac{x}{\gamma} \tag{XXII-1b}$$

$$y' = \frac{y}{\gamma}, \tag{XXII-1c}$$

i.e. that the slowing down of the S' clocks, as shown in eq. (XXII-1a), is accompanied by isotropic length expansion of the measuring rods at rest in S', as shown in eqs. (XXII-1b,c). In the above example, the period of the clock serves as the unit of length. The slower the rate of the clock, the greater is its period and therefore the greater is the unit of length.

The LT and SR[1,2] conclude by contrast that

$$x' = \gamma x \tag{XXII-2a}$$

$$y' = y, \tag{XXII-2b}$$

One only has to compare the predictions in eqs. (XXII-1b-c)) with those of the FLC in eqs. (XXII-2a,b) to see that the two approaches actually come to opposite conclusions.

One of the great advances in Einstein's original paper[2] was the prediction of the transverse Doppler effect. Ives and Stillwell were able to obtain the first experimental confirmation over 30 years later.[5] The wavelength of radiation emitted from a moving source was recorded on a photographic plate. Comparison with the wave pattern obtained with an identical source at rest in the laboratory demonstrated that the predicted shift to the red had occurred. The ordinary first-order non-relativistic Doppler effect was eliminated by averaging over the wavelengths obtained from opposite directions. The constancy of the speed of light was invoked to conclude that a lowering in the frequency of the radiation by the same fraction had occurred, and this in turn was seen[6] to be a consequence of time dilation in the moving rest frame. The accepted explanation for this result is that the frequency observed in the laboratory is the same as would be measured if proper clocks at rest there *had been moved to the rest frame of the source without having their rates affected by time dilation.* The RP also indicates that observers co-moving with the light source would not notice the change in frequency because all timing devices in that rest frame are slowed by exactly the same fraction, as assumed in the Uniform Scaling method.

The above argument is based on the assumption that the value of the speed of light relative to its source is always equal to c. As discussed in Chapters X-XI, the Uniform Scaling method assumes on the basis of the RP that all *relative speeds between any two objects* will also be the same for all observers, not just the light speed relative to the source.

It is interesting that the analogous chain of reasoning has generally not been applied to wavelengths. Since the transverse Doppler wavelength is longer than the corresponding value observed from an identical light source at rest in the laboratory, it follows by the same logic that *wavelengths increase upon acceleration.* Furthermore, the amount of the change is independent of the direction from which the radiation comes, i.e. after making the first-order correction in each case. The fact that this effect is not noticed by co-moving observers again forces a conclusion from the RP, namely *diffraction gratings* used to measure the wavelengths must have increased in dimension by exactly the same fraction in all directions as the wavelengths. In short, the conclusion from Einstein's two postulates and the transverse Doppler effect is that isotropic length expansion accompanies time dilation in the rest frame of the moving source, exactly the same result as for the example of a vehicle moving between fixed points discussed above. If the FLC were correct, the laboratory observer should find a decrease in the transverse wavelength by varying amounts depending on the direction of approach of the light waves from the moving source, but something quite different results in actual practice.

In more recent times experience with measuring wavelengths and frequencies has led to a movement to change the way in which the standard of length is defined. It became clear that frequencies can be measured with much higher accuracy than wavelengths and that this presented a fundamental limitation in obtaining the value of the speed of light.[7] It was thereupon decided by international convention that the constant c should be defined to have a fixed value of 299792458 ms^{-1}. Consequently, the meter is now defined as the distance travelled by light in free space in c^{-1} s. It is no longer necessary to prove that a length measurement made with an atomic clock is equivalent to what would have been obtained using a standard metal bar or wavelength of light. The definition shifts the burden of proof in the other direction to demonstrate that laying a particular measuring rod against an object gives the same result as determining the amount of time required for light to traverse it.

The most interesting feature of the meter definition in the present context is that it leads to a definite conclusion as to how the dimensions of objects vary with the amount of time dilation in a given rest frame. If clocks run slower in S' because of time dilation, it is clear that the distance travelled by light in c^{-1} s is *longer* there than that measured in S based on clocks that still run at the faster rate. Once again, this conclusion must hold independent of the direction the light travels. The meter is longer in S' where time dilation has occurred. The observer in S can determine this using local clocks by measuring how much faster they run than their counterparts in S'. According to the FLC, a "meter stick" at rest in S' must appear contracted to the observer in S, and by varying amounts depending on its orientation to their relative velocity v. It is impossible to reconcile this prediction with the meter definition, whereas it meshes perfectly with the expectations of the NVT and the Uniform Scaling method.

The arguments in the preceding section also have relevance to the underlying technology of the Global Positioning System (GPS). Although this technique is designed to measure distances on the earth's surface, it can also be adapted to make a definitive test of the FLC. A key objective in the overall procedure is to place atomic clocks on satellites that run at the same rate as their counterparts on the ground.[8] This is done by "pre-correcting" the frequency of a given clock to account for changes that are expected to occur as a result of its being put into orbit on a GPS satellite. The distance between the latter and a position on the ground is computed by measuring the elapsed time for a light signal to pass between them. This is possible to a suitable approximation by comparing the local time of arrival on the satellite clock with that measured on the ground clock at the time the signal was sent.

The same technique can be applied to measure the change in length of a metal bar as it is placed in orbit. Prior to launch the elapsed time for light to traverse the metal bar is found to be Lc^{-1} s on the ground clock, indicating that the length of the bar is L m at this point in the experiment. The pre-corrected clock runs $Q>1$ times faster while it is still on the ground and thus finds a corresponding time of QLc^{-1} s (effects of the gravitational red shift are neglected at this stage in the argument). The length of the bar is also L m on this basis because the effective speed of light has been artificially changed to cQ^{-1} ms^{-1} by virtue of the aforementioned rate adjustment.

The metal bar and the pre-corrected clock are then put into orbit and the measurement is repeated. Consistent with the RP, no change in the length measurement is found on the satellite. The elapsed time for light to traverse the bar is still QLc^{-1} s. However, because of the effects of time dilation, it is known that the onboard clock now runs at exactly the same rate as the clock on the earth's surface. The elapsed time on the latter clock has therefore increased by the same factor of Q from Lc^{-1} s to QLc^{-1} s. The speed of light on the satellite is still equal to c for the observer on the ground. The conclusion is therefore that the bar has *expanded* as a result of being accelerated into orbit; its length has increased from L m to QL m. Moreover, the increase in length is the same in all directions because the local time measurement on the satellite is completely independent of the orientation of the metal bar to the observer on the ground. The observer on the satellite is unaware of this change, which simply means that the lengths of all objects on the satellite have increased by the same factor (uniform scaling of distance and time).

The effects of the gravitational red shift do not change the above result. To include them it is necessary to compute the value of the pre-correction factor in a different manner. An increase in altitude causes clock rates to increase by a factor of $S>1$ (see Table 1 of Chapter XII), so that an unadjusted satellite clock runs SQ^{-1} times *faster* in orbit than its identical counterpart on the ground ($S>Q$)[8]. Consequently, the value of the pre-correction factor must be changed from Q to QS^{-1} relative to the above example. The elapsed time measured on the adjusted satellite clock for light to traverse the metal rod is thus $\Delta T'=QL(Sc)^{-1}$ s, both prior to launch and later when orbit has been achieved (RP). This means that the corresponding time on the ground clock has changed from Lc^{-1} s to $\Delta T'$, i.e. it has increased by the factor of QS^{-1}. *However, the speed of light on the satellite has a different value than in the first example, namely Sc m/s.* The length of the metal rod on the orbiting satellite is therefore obtained as $Sc\ \Delta T' = QL$ m on the ground clock. The result is seen to be completely independent of the altitude of the satellite's orbit. As before, the length of the metal rod on the satellite increases by the same amount in all directions. This result is consistent with the general finding first enunciated by Einstein[9] in 1907 that the lengths of objects are invariant to changes in the gravitational potential in which they are located. However, the speed of light does increase at higher altitude by virtue of the corresponding increase in light frequencies there, which explains why ΔT' must be multiplied with Sc in the above example.

Yet another way to analyze the relationship between time dilation and length variations is to consider how the units of distance and time change with acceleration. Use of the LT precludes the introduction of physical units in different rest frames. It states that observers will differ as to which clock is running slower, for example, and this makes it impossible to define unique conversion factors to go from one system of units to another. Experience with atomic clocks[10-11] shows that in actual practice it is possible to predict the ratios of clock rates quantitatively with no ambiguity about which clock is running slower or faster. As a result, it is possible to assign a separate unit of time to each inertial system. For example, in the above discussion, one can define the unit in S to be 1 s. Because the clocks in S' run γ times slower, this means that the corresponding unit in S' is γ s.[6]

Since the observers in S and S' agree on the values of all relative velocities, in accordance with the predictions the Uniform Scaling method, it follows that the unit of velocity is the same for both rest frames, i.e. 1 ms^{-1} in each case. The corresponding unit of distance is completely determined because of these assignments because distances are products of velocity and elapsed times. As a result, the unit of length in S is 1 m, but it is γ m in S'. Both the units of time and distance are larger in S' than in S, which, as already been stated above , means that the numerical values of distances measured in S are always greater than the corresponding numerical values in S'. Since the physical unit of length is the meter stick (or at least it used to be) in each rest frame, it follows that it is larger in S' where time dilation has occurred relative to S. The unit of length is the same in all directions, so this means that the effect is isotropic. All these arguments are valid when times and distances are measured within the context of the Uniform Scaling method. They show once again that time dilation and isotropic length expansion go hand-in-hand in relativity theory as long as one avoids using the LT to establish such relationships.

Keywords: *Deductions based on RP, Definition of the value of light speed, Effect of acceleration on diffraction gratings, Einstein derivation based on LT, FitzGerald-Lorentz length contraction FLC, Galilean space-time transformation, GPS test 10, Gravitational red shift, Inconsistent interpretation of wavelength changes, Invariance of length for gravitational changes, Isotropic length expansion, Misleading textbook arguments, New light speed Postulate. NVT, Pre-correction feature, Time dilation, Transverse Doppler effect, Uniform scaling method, Unit of length 8*

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XXIII. EINSTEIN'S BIAS AGAINST THE GVT

The equality of the relative velocity of two objects for different observers is the basis for concluding that isotropic length expansion accompanies the slowing down of clocks. In previous work,[1] it has been shown that the latter equality relationship results from use of the RVT. As discussed in Chapter V, the RVT relates the velocity components u_i and u_i' of an object from the standpoint of observers in two different rest frames (S and S') that are moving with relative speed v along the x axis of the coordinate system. The three equations for the respective x, y, z components are repeated below:

$$u_x' = \left(1 - \frac{vu_x}{c^2}\right)^{-1} \left(u_x - v\right) = \eta\left(u_x - v\right) \qquad \text{(XXIII-1a)}$$

$$u_y' = \gamma^{-1}\left(1 - \frac{vu_x}{c^2}\right)^{-1} u_y = \eta\gamma^{-1}u_y \qquad \text{(XXIII-1b)}$$

$$u_z' = \gamma^{-1}\left(1 - \frac{vu_x}{c^2}\right)^{-1} u_z = \eta\gamma^{-1}u_z\,, \qquad \text{(XXIII-1c)}$$

where $\gamma=(1-v^2/c^2)^{-0.5}$ and c is the speed of light in free space. Note the occurrence of the quantity $\eta=(1-vu_x/c^2)^{-1}$ in each case. It is a function of both the relative speed v of S and S' as well as the parallel component u_x of the object's velocity relative to v.

To demonstrate the velocity equality relationship in a suitably general case, let us assume that one object also moves along the x axis with speed u_1 ($u_{1y}=u_{1z}=0$) relative to an observer O at rest in S, while the second travels in a different direction with velocity components u_{2x} and u_{2y} relative to him. The first goal is to determine the relative velocity u_{21} of these two objects from O's perspective. To do this we use the RVT of eqs. (XXIII-1a-c), Accordingly, we find that (i.e., with set v equal to u_1):

$$u_{21x} = \frac{u_{2x} - u_1}{1 - \frac{u_{2x}u_1}{c^2}} \qquad \text{(XXIII-2a)}$$

$$u_{21y} = \frac{u_{2y}}{\gamma(u_1)\left(1 - \frac{u_{2x}u_1}{c^2}\right)}. \qquad \text{(XXIII-2b)}$$

In effect, we are computing the velocity of the second object from the vantage point of another observer (O”) *who is at rest with respect to the first object* and is therefore also moving with velocity u_1 relative to O.

The next step is to compute the relative velocity of the two objects (u_{12}’) from the vantage point of observer O’ at rest in S’. We first need to compute the corresponding velocities of each object relative to O’ based on their known velocity components relative to O. The RVT allows us to do this:

$$u_{1x}\text{'} = u_1\text{'} = \frac{u_1 - v}{1 - \frac{vu_1}{c^2}} \qquad \text{(XXIII-3a)}$$

$$u_{2x}\text{'} = \frac{u_{2x} - v}{1 - \frac{vu_{2x}}{c^2}} \qquad \text{(XXIII-3b)}$$

$$u_{2y}\text{'} = \frac{u_{2y}}{\gamma(v)\left(1 - \frac{vu_{2x}}{c^2}\right)}. \qquad \text{(XXXIII-3c)}$$

The final step is then to compute u_{21}’ and compare the results with u_{21} in eqs. (XXIII-2a-b). To do this we look upon O” as the “moving” observer relative to O’. Using the RVT again and the velocity components from eqs. (XXIII-3a-c), the result is:

$$u_{21x}\text{'} = \frac{u_{2x}\text{'} - u_1\text{'}}{1 - \frac{u_{2x}\text{'}u_1\text{'}}{c^2}}$$

$$= \frac{u_{2x} - v}{1 - \frac{v u_{2x}}{c^2}} - \frac{u_1 - v}{1 - \frac{v u_1}{c^2}}$$

$$= \frac{u_{2x} - v}{1 - \frac{v u_{2x}}{c^2}} - \frac{u_1 - v}{1 - \frac{v u_1}{c^2}}$$

$$x\left(1 - \frac{(u_1 - v)(u_{2x} - v)}{c^2\left(1 - \frac{v u_1}{c^2}\right)\left(1 - \frac{v u_{2x}}{c^2}\right)}\right)^{-1}$$

$$= c^2\left[\left(u_{2x} - v\right)\left(1 - \frac{v u_1}{c^2}\right) - \left(u_1 - v\right)\left(1 - \frac{v u_{2x}}{c^2}\right)\right] \qquad \text{(XXIII-4)}$$

$$x\left[c^2\left(1 - \frac{v u_1}{c^2}\right)\left(1 - \frac{v u_{2x}}{c^2}\right) - u_1 u_{2x} + v u_1 + v u_{2x} - v^2\right]^{-1}$$

$$= \frac{c^2\left(u_{2x} - u_1\right)\left(1 - \frac{v^2}{c^2}\right)}{c^2 - u_1 u_{2x} - v^2 + \left(\frac{v^2 u_1 u_{2x}}{c^2}\right)}$$

$$= \frac{u_{2x} - u_1}{1 - \frac{u_1 u_{2x}}{c^2}}$$

$$= u_{21x},$$

$$u_{21y}' = \frac{u_{2y}'}{\gamma(u_1')\left(1 - \frac{u_{2x}' u_1'}{c^2}\right)}$$

$$= c^2 u_{2y}\left(1 - \frac{v^2}{c^2}\right)^{0.5}\left[1 - \frac{(u_1 - v)^2}{c^2\left(1 - \frac{v u_1}{c^2}\right)^2}\right]^{0.5} \qquad \text{(XXIII-5)}$$

$$x\left(1-\frac{u_{2x}v}{c^2}\right)^{-1}\left[c^2-\frac{(u_1-v)(u_{2x}-v)}{\left(1-\frac{vu_1}{c^2}\right)\left(1-\frac{vu_{2x}}{c^2}\right)}\right]^{-1}$$

$$=c^2u_{2y}\left(1-\frac{v^2}{c^2}\right)^{0.5}\left(\frac{c^2+\frac{v^2u_1{}^2}{c^2}-u_1{}^2-v^2}{c^2-2vu_1+\frac{v^2u_1{}^2}{c^2}}\right)^{0.5}$$

$$x\left(\frac{\left(1-\frac{vu_{2x}}{c^2}\right)\left(c^2-u_1u_{2x}\right)\left(1-\frac{v^2}{c^2}\right)}{\left(1-\frac{vu_1}{c^2}\right)\left(1-\frac{vu_{2x}}{c^2}\right)}\right)^{-1}$$

$$=c^2u_{2y}\frac{\left(\frac{c^2-u_1{}^2}{c^2}\right)^{0.5}}{c^2-u_1u_{2x}}$$

$$=\frac{c^2u_{2y}}{\gamma(u_1)\left(c^2-u_1u_{2x}\right)}=\frac{u_{2y}}{\gamma(u_1)\left(1-\frac{u_1u_{2x}}{c^2}\right)}$$

$$=u_{21y}\,.$$

It is thus seen that O and O' agree on both the direction and the speed with which the two objects are moving relative to one another, as was to be shown.

There is something quite basic to be noted in the above derivation, however. It was pointed out in Chapter V that the GVT must be applied in any case (denoted by Type A) where two observers in relative motion compare their measured velocities of the same object. The procedure of "distance reframing" has been used to prove that the RVT is *not* applicable in such cases. Therefore, the above derivation using the RVT is of no consequence, despite the fact that it does conclude by obtaining agreement with the equal relative velocity tenet of the Uniform

Scaling method. What is particularly noteworthy is that a fair amount of algebraic manipulations is necessary to achieve this result.

The situation is much more transparent when the GVT is used instead. First, we assume that the two observers in S and S' are separated by velocity v. There is no restriction about either the magnitude or the direction of this *vector*. Next we assume that there are two objects. They move with respective velocities u_1 and u_2 relative to S and u_1' and u_2' relative to S'. Again there are no restrictions with regard to the speed or direction of these velocity vectors.

The velocities of the two objects u_{21} and u_{21}' relative to one another are then computed. To do this we first need to recognize based on the GVT that the values of the velocity of any object are related as follows: $u_i'=u-v$. This general relationship is confirmed by the distance reframing procedure applied over a definite time T, i.e. $u_i'T=(u_i-v)T$. By definition, $u_{21}=u_2-u_1$ and $u_{21}'=u_2'-u_1'$. Combining the latter definition with the general relation $u_i'=u_i-v$ then leads to $u_{21}'=u_2'-u_1'=(u_2-v)-(u_1-v)=u_2-u_1=u_{21}$, as was to be proven. Note that all the above are relationships between vectors and they are independent of any restrictions regarding either the magnitude or the direction of any one of the vectors.

The above derivation with the GVT is both incredibly simple to execute and also astounding to recognize that it has been kept from the physics community for over a century. Most importantly, its result is perfectly in agreement with all known experiments. It is also consistent with Galileo's RP and the true light speed postulate, namely that the speed of light relative to its source anywhere in the universe has the same value of c = 299792458 ms^{-1}.

The far more difficult question to answer is this: How was Einstein able to convince the world that it is incorrect to use vector addition to solve problems involving high velocities. A part of the answer is that there is a definite group of experiments (of Type B) for which it is necessary to assume that the speed of light is the same for all observers. This was Voigt's contribution to the field. Despite the fact that his new space-time transformation does not satisfy Galileo's RP; it is nonetheless consistent with the RVT. The Fresnel-Fizeau experiment and Thomas spin precession are two well-known examples which require this assumption. As noted in Chapter V, such Type B experiments do not involve the measurements of the same object by two different observers in relative motion to one another. Instead, GVT/vector addition is required for all such (Type A) experiments. For Type B experiments by contrast, the object is to be considered under different conditions by the same observer.

Keywords: *Equality of velocity measurements, Role of vector addition in relative velocity determinations, RVT equations, Type A experiments, Use of GVT to prove equal velocity rule, Use of RVT to demonstrate equal velocity rule. Voigt contribution*

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XXIV. LEWIS-TOLMAN MASS PREDICTION

One of the most significant developments in relativity theory in the early 20th century was the prediction of mass dilation by Lewis and Tolman.[1] Bucherer was able to confirm their prediction experimentally[2] by studying the motion of charged particles in a transverse magnetic field. Their arguments were based on Einstein's SR which had been published several years earlier,[3] particularly on the phenomenon of time dilation that had first been enunciated in this work. In the following discussion the assumptions that were employed to arrive at the prediction of mass dilation will be reviewed and compared with others that have since been used to describe other aspects of relativity theory.

The basic content of the theoretical arguments presented by Lewis and Tolman can be understood with the help of the diagram in Fig. 4. An elastic collision between two identical objects A and B is considered from the vantage point of two observers O_1 and O_2, respectively. The observers are located in inertial systems S_1 and S_2, and the direction of their relative motion is along the x axis. Object A is initially at rest in S_1 before the collision, whereas object B is initially at rest in S_2. The collision process is designed to be perfectly symmetrical for the two observers. Each one sees one of the objects moving along the y axis in his rest frame, A by O_1 and B by O_2, making a collision with the other object after it travels a distance y relative its initial rest position. That object then returns to its initial position with exactly the same speed in each case. The other object appears to be traveling at (high) speed u along the x (horizontal) direction, but with a small (vertical) component so that it makes a glancing collision with the former object. After the collision, the other object continues moving along the x axis in the same direction as before, but returns with a vertical component in the opposite direction. The underlying idea is that object A will simply appear to move up and down in the y direction by O_1, whereas object B will appear to do the same for O_2.

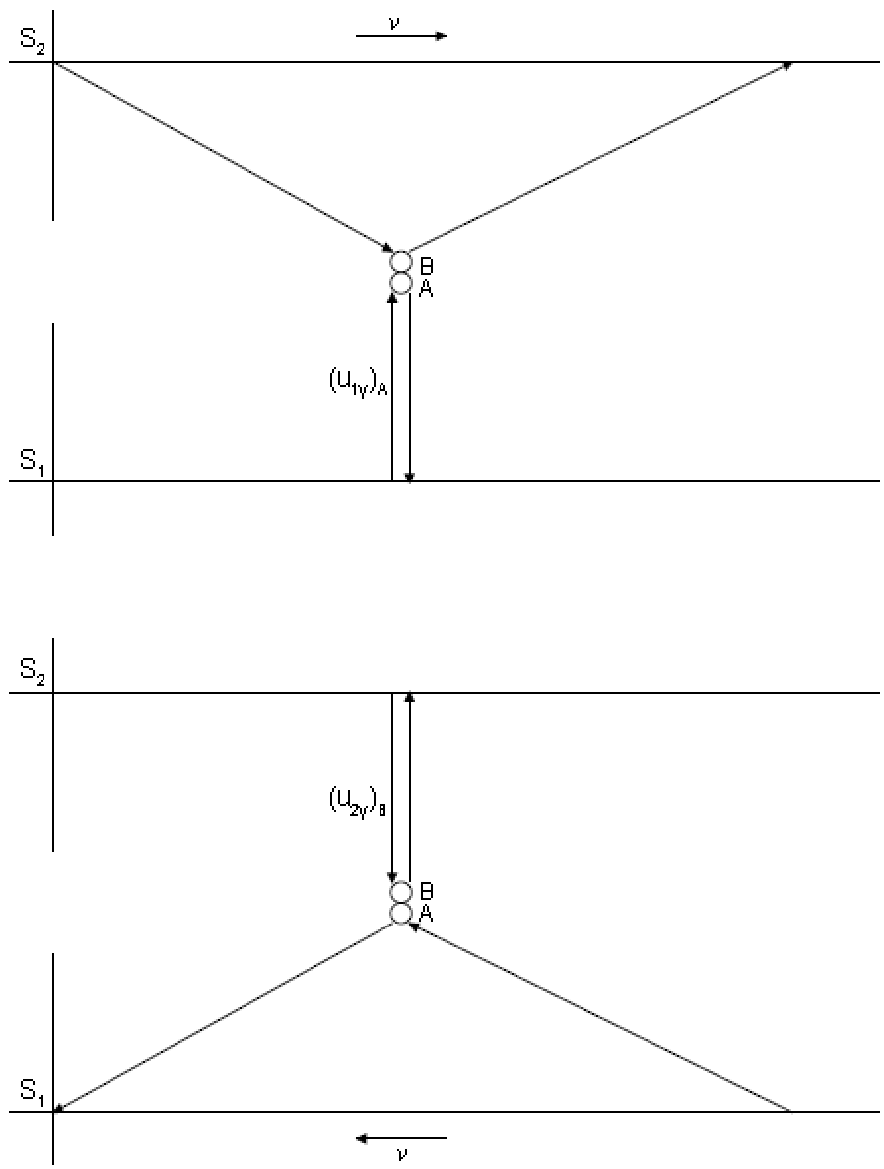

Fig. 4. Lewis-Tolman model for the elastic collision of two objects that were originally at rest in different inertial systems S_1 and S_2 that are moving with speed u relative to one another. The upper half of the diagram shows the collision as viewed by an observer at rest in S_1 (note that S_2 is moving to the right for him). The lower half shows the same collision as viewed by an observer at rest in S_2 (he views S_1 moving to the left).

The top part of Fig. 4 shows how the collision plays out for O_1. For him, object A moves upward with speed v_{1y}, makes the collision with B, and then returns with the same speed. The time for the object to move before the collision occurs is T_0, and hence $(v_{1y})_A = y/T_0$. The bottom part shows the collision from the perspective of O_2. He finds that object B moves downward with speed $(v_{2y})_B=y/T_0$ before returning to him in the opposite direction. The assumption is therefore that $(v_{1y})_A=(v_{2y})_B$ in Fig. 4.

Let us now consider how the motion of object B appears to the observer in S_1. It is here that Lewis and Tolman[1] begin to make use of some of Einstein's conclusions in his original work.[3] First, they assumed that because of time dilation in S_2, the time T of the downward flight of object B must be longer than T_0 by a factor of $\gamma = (1-u^2/c^2)^{-0.5}>1$. Secondly, because of the Fitzgerald-Lorentz contraction effect (FLC[3]), the distance travelled by B over this period is equal to y from the observer's vantage point in S_1, that is, *the same distance as measured by the observer in S_2.* This is because the direction of the object's motion is *perpendicular* to that of the relative motion of S_1 and S_2. As a result, Lewis and Tolman concluded that, from the viewpoint of the observer in S_1, the speed of object B is *γ times less* than that of object A, that is, $(v_{1y})_B = y/T=\gamma^{-1}y/T_0=\gamma^{-1}(v_{1y})_A$.

It is at this point in the discussion that conservation of momentum is brought in. If we assume that the respective y components of the momentum of the two objects must be equal in order for object A to return to its starting position (as measured by O_1) with the same speed as before $[(v_{1y})_A]$, it follows that the inertial mass of object B (also as measured by O_1) must be *larger* than that of object A by the same factor of γ. In short, according to the predictions of SR[3], the two objects must not have the same inertial mass, even though it has been assumed that the *in* *situ* mass of A measured by O_1 is exactly the same as the *in situ* mass of B measured by O_2. This conclusion led Lewis and Tolman to predict[1] that *the inertial mass of any object must increase by a factor of γ (u) when it is accelerated from a rest position to speed u relative to the observer.*

The fact that the above argument led to a successful experimental verification of mass dilation does not prove, however, that the underlying theory is correct. Careful inspection of the Lewis-Tolman justification for their prediction shows clearly that it is fundamentally flawed. It relies on the assumption that the relative velocity of object B to its rest position in S_2 is different for the two observers, i.e. $(v_{2y})_B \neq (v_{1y})_B$. If one takes the special case that particle B is a photon, this means that O_1 and O_2 do not agree that the speed of light is equal to c for both of them. This assumption therefore contradicts Einstein's second postulate of relativity,[3] as well as the Uniform Scaling method[4,5] (see Table 1 in Chapter XII), which states that the speed of light in free space relative to its source is the same for all observers at the same gravitational potential.. Moreover, the same feature holds for any relative velocity of the particle.[4,5]

The LT of SR is responsible for two assumptions of the Lewis-Tolman model, namely time dilation and the FLC, whereby the latter states that O_1 and O_2 must agree[3] on the distance y travelled by B since it is in a direction which is perpendicular to their separation velocity u.

The problem in this regard ultimately goes back to the fact that distance, time and velocity are not completely independent from one another, whereas the LT treats them as such. Specifically, if one claims that two observers *agree* on the distance travelled by an object and also on its speed relative to some starting point, then they cannot also claim that they *disagree* on the amount of elapsed time it took for it to arrive at its destination.

There is an even easier way to demonstrate that the LT is inconsistent. Consider the example of two lightning strikes occurring in the rest frame S_2. According to the arguments employed by

Lewis and Tolman[1], if the time difference between the two strikes observed by O_2 is ΔT_2, the corresponding time difference observed by O_1 will be $\Delta T_1=\gamma\Delta T_2$ because of time dilation in S_2. The LT also predicts something else,[3] however, namely that ΔT_2 can be equal to zero, i.e. the two lightning strikes can occur simultaneously for O_2 whereas the time difference ΔT_1 can be different than zero for O_1. This prediction of the LT is referred to as "remote non-simultaneity." Yet substitution of $\Delta T_2=0$ in the above equation leads one directly to the conclusion that $\Delta T_1=\gamma\Delta T_2=0$, from which one must conclude that the lightning strikes do indeed occur simultaneously (see Chapter III) for O_1 as well as for O_2 .[6-8] There is thus a clear contradiction, proving that the LT is not valid since both assumptions are derived from it. Once again, it is seen that the LT does not provide a sound basis for the Lewis-Tolman prediction of mass dilation.

The prediction of mass dilation and its experimental verification was one of the first successful applications of Einstein's 1905 theory. As discussed above, however, it is ironic that the basis for the prediction is itself faulty. The question that will be discussed below is whether the Lewis-Tolman model can nonetheless be reformulated to give a proper understanding of the role of momentum conservation in high-energy dynamics.

To begin with, it is essential that one do away with the assumption that the two observers O_1 and O_2 of the collision system can disagree on the relative speed of either of the objects A or B with respect to its starting point in Fig. 4. In other words, as discussed in detail above, $(v_{1y})_B=(v_{2y})_B$ and $(v_{1y})_A=(v_{2y})_A$, not the inequality assumed by Lewis and Tolman in their discussion. When the objects in the former equations are photons, it is clear that the above equalities are essential in order to maintain consistency with the light-speed postulate on which the LT is based, but they also hold for any type of massive particle.[5]

In order to illustrate how the conservation-of-momentum principle should operate under the Lewis-Tolman conditions, it is helpful to consider the case where the speeds of both particles are the same, i.e. $(v_{1y})_A = (v_{1y})_B$. Because of the above general equalities this means that $(v_{2y})_A = (v_{2y})_B$ as well. The masses of A and B must therefore also be equal, i.e. $m_{1A} = m_{1B}$, in order for momentum to be conserved.

It is helpful to consider the Bucherer experiment[2] with accelerated electrons in order to understand how the above condition can be met. It is known from experiment that the laboratory observer (O_1) finds that the inertial mass of the electron increases in direct proportion to γ (u), where u is the speed of the electron in the laboratory. If μ is the rest mass of the electron, it therefore follows that O_1 measures the mass of the accelerated electron to be $m_1 = \gamma(u)\mu$. It is thus clear that momentum will *not* be conserved in the example of Fig. 4 if the *rest masses* of A and B are the same because then $m_{1A} \neq m_{1B}$.

It is therefore clear how to guarantee momentum conservation in the Lewis-Tolman model when $(v_{1y})_A = (v_{1y})_B$. One simply has to choose the rest mass of B (μ_B) to be smaller than that of A(μ_A), specifically, so that $\mu_B = \gamma^{-1}\mu_A$. In that way, it is guaranteed that the masses of A and B will be equal when they begin the collision process.

Such an approach is analogous to the "pre-correction technique" employed[9,10] in the Global Positioning System navigation procedure (see Chapter XIII). It is used to adjust the rates of atomic clocks *prior to launch* so that after attaining orbit, they run at the same rate as clocks on the ground. In this case, it is the effect of time dilation which slows the rate of the satellite clocks to produce the desired equality, whereas mass dilation accomplishes the desired equalization of masses A and B in the Lewis-Tolman model.[1]

As with non-relativistic collisions, however, it is not necessary that the speeds of the two particles be equal in order to satisfy the conservation-of-momentum principle. Any ratio of the two speeds is possible, not just that indicated by the Lewis-Tolman assumption based on time dilation.. If one chooses $(v_{1y})_A=X(v_{1y})_B$, for example, momentum can be conserved by having the relationship between the two rest masses of the two particles be $\mu_B=X\gamma^{-1}\mu_A$. After mass dilation occurs in S_2, the mass of B will then be X μ_A, thereby cancelling out the difference in A and B's relative speed. Clearly, the same cancellation occurs regardless of whether $X<1$ or $X<1$.

It is obvious from this discussion that Lewis and Tolman's original argument[1] is specious; it is not true that the amount of mass dilation is solely determined by the supposed effect of time dilation in S_2 on the ratio of the relative speeds of A and B. Instead, the ratio X of the two relative speeds can be determined completely at random. Time dilation has nothing whatsoever to do with this choice. The key point is that the ratio of rest masses must be chosen to exactly compensate for this difference in relative speeds. Nonetheless, Lewis and Tolman were able to deduce correctly that *the factors* for time and mass dilation are exactly the same in the model shown in Fig.4, namely γ (u). In the last analysis, this is the result of primary significance in their investigation as a whole.

An important aspect of the Lewis-Tolman model is its relevance to interactions with light. As discussed in detail above, $(v_{1y})_B=(v_{2y})_B$ and $(v_{1y})_A=(v_{2y})_A$, not the inequality assumed by Lewis and Tolman in their discussion. The question that needs to be discussed in the present context is how conservation of momentum can be assured when the particles in question are photons (incidentally, Lewis coined the word "photon[11]" in a famous argument supporting Newton's assertion that light consists of particles). As before in the previous discussion, it is essential in that case that some adjustment be made to insure that mass dilation causes the necessary equalization of the two masses in the collision. This can be done by choosing the frequency ν_0 (B) of the light emanating from a source at rest in S_2 to be *lower* than the standard value ν_0 (A) originating from the corresponding source at rest in S_1. Specifically, the condition must be ν_0 (B)=ν_0(A)/γ. Because of time dilation in S_2, it can be assumed that the frequency measured in S_1 will be smaller by a factor of γ, so that its value will be $\nu_0(A)/\gamma^2$. At the same time, both the energy and momentum of the photon measured in S_1 will be larger than the corresponding values for the photon in S_2 by a factor of γ, just as are masses of particles that are stationary there. These seemingly contradictory relationships are resolved by noting that the unit of angular momentum and therefore also of Planck's constant h is γ^2 larger[12] in S_2 than in S_1. In this way, the measured values of the energy and momentum of photon B in S_1 will be $h\nu_0(A)$ and h $\nu_0(A)/c$, respectively, as required to conserve both momentum and energy in the collision.

Finally, there is another key area where Lewis and Tolman were misled by the LT. They assumed that the amount of time dilation and therefore the ratio of the elapsed times measured by O_1 and O_2 is always equal to $\gamma(u)$. *Each observer* was assumed to measure a smaller elapsed time by this factor than his counterpart in the other rest frame. This means that one must believe that the clock at rest in the other rest frame must run slower by this factor than that at rest in his own rest frame (Einstein's Symmetry Principle).[3]

Experiment tells an entirely different story, however. In their study of circumnavigating atomic clocks, for example, Hafele and Keating[13,14] found that the elapsed time registered on a given clock *decreases as its speed u increases relative to the earth's center of mass (ECM)*. This means that the clock on the eastward-flying airplane ran slower than that moving in the opposite direction in their study. If the speeds of the two clocks are u_1 and u_2, respectively, it was found that the ratio of the two elapsed times $\Delta T_1/\Delta T_2$ for the same portion of the journey (after suitable correction for gravitational effects on the clock rates[14] was equal to $Q=\gamma(u_2)/\gamma(u_1)$. The measured ratio is not $\gamma(u)$ (where u is the relative speed of O_1 and O_2; see Fig. 4), contrary to what is assumed by Lewis and Tolman[1] in their model.

The same inverse proportionality between elapsed times and γ (u) was found in an earlier study employing x-ray detectors and absorbers.[15] In that case, Sherwin pointed out[16] that this result was inconsistent with the *symmetric* prediction based solely on the Lorentz transformation. Because the above ratio Q applies in the description of all known timing studies as yet carried out experimentally, it is appropriate to refer to the corresponding equation as the Universal Time-dilation Law (UTDL)[17] discussed in Chapter IX. Note also that the conversion factor for O_2 $[\gamma(u_1)/\gamma(u_2)=1/Q]$ when carrying out measurements for clocks at rest in S_1 is the reciprocal of that for O_1 when the reverse comparison is made. The symmetry that Einstein envisioned is therefore contradicted by the experimental data underlying the UTDL.

The success of the Lewis-Tolman model in predicting the phenomenon of relativistic mass dilation is a textbook example showing that an experimental confirmation does not constitute proof of the theory on which it was based. The authors formulated their arguments under the assumption that the LT is completely valid. They concluded on this basis that two observers can differ on the speed v_{iy} of a given particle relative to its starting point in the collision system they proposed. Years later, the experimental confirmation of time dilation in muon decay experiments[18] was firmly based on the opposite conclusion, namely that observers in different rest frames must be in complete agreement on the speed of the accelerated particles.

Applying their model for photons also makes it clear that something is wrong with the LT, since it forces one to overlook the light-speed postulate on which the transformation is clearly based. In addition, its prediction of remote non-simultaneity does not mesh with the proportionality characteristic of time dilation, both of which effects are derived squarely from the Lorentz transformation.

Perhaps the most insightful aspect of the Lorentz-Tolman model is its assertion that time dilation and mass dilation change in direct proportion to one another. The quantitative factor that governs these changes has been found from numerous timing experiments to increase with the speed u of the object relative to a definite rest frame. In the Hafele-Keating study[13,14] employing circumnavigating atomic clocks, this rest frame has been shown to be the earth's center of mass. The elapsed time for a given portion of the journey was always found to be inversely proportional to $\gamma(u)$, in accordance with the UTDL.[17] The ratio Q of elapsed times is determined to be equal to $\gamma(u_2)/\gamma(u_1)$ when the object clock moves with speed u_2 while the observer's moves with speed u_1. A simple way to look upon Q is as a conversion factor between different units of time in the two rest frames. The same factor holds for the ratios of units of inertial mass and also for energy and momentum. A consistent picture emerges for the conversion factors of units for all other physical properties. Each factor turns out to be an integral power of Q, as determined by the composition of each property in terms of the standard quantities of time, distance and inertial mass.[8]

Keywords: *Applicability of the UTDL, Bucherer experiment, Conservation of momentum, FLC erroneous application, GPS pre-correction technique, Hafele-Keating airplane experiment, Improper assumption about light speeds, Inertial mass scaling, Lewis coining of photon, Lewis-Tolman conjecture, Lewis-Tolman diagram, Lightning strike analogy (End Paper 6), Planck's constant scaling, Reciprocal relation for scale factors, Relativistic collision theory, Same scaling of mass and time, Simultaneity and time dilation, SR-LT predictions, Time dilation*

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XXV. THE DOPPLER EFFECT AN D THE SPEED OF SOUND

The study of wavelike phenomena has been a subject of great interest in physics dating back at least to the work of Huygens in the late 17th century. A wave is characterized by a definite frequency and wavelength. The latter is defined as the distance separating successive wave crests whereas the frequency is the number of wave crests passing a certain point in space in a given amount of time.

One of the basic questions about frequencies and wavelengths is how they are affected by motion of the source relative to the observer. In 1842 Doppler gave a detailed description of a phenomenon that was well known in everyday life, namely the fact that the pitch of sound waves becomes higher when the source approaches the observer and then decreases after the source has passed and begins moving away from him. He showed that it is a first-order effect depending on the *ratio* of the speed of the observer relative to the location of the source of the sound waves to that of the sound waves themselves relative to this source. The analogous effect is also observed for light waves.

The speed of light and sound waves in free space *relative to their sources* is obtained as the product of the associated frequency and wavelength of the associated radiation; this is referred to as the phase velocity v_p of the waves and must be carefully distinguished from the actual speed v of the waves relative to a given observer. The question that will be discussed below *is how the relative motion of the observer to the source affects the value of the phase velocity of the waves measured by him.* Consider the following application of the Doppler effect. A fire truck in the station starts his siren. The sound waves it emits have a frequency of ν_O and a wavelength of λ_O. The corresponding speed (phase velocity) relative to a stationary observer is therefore $v_O=\nu_O\lambda_O=\lambda_O/\tau_O$, where $\tau_O=1/\nu_O$ is the corresponding period of the waves.

The truck then exits the station and starts moving toward the observer until it reaches a constant speed v. The period $\tau=1/\nu$ of the sound waves (i.e. the time it takes for successive wave crests to pass a given point) that now reach the observer has therefore decreased to a value of $[(v_O-v)/v_O](1/\nu_O)=(1-v/v_O)\tau_O$, in accord with the formula for the Doppler effect. At the same time, the corresponding wavelength of the waves reaching the observer has been reduced to $\lambda=(1-v/v_O)\lambda_O$. As a consequence, the *phase velocity* of the waves reaching the observer is unchanged from its initial value since $\lambda\nu=\lambda/\tau=\lambda_O/\tau_O=\lambda_O\nu_O=v_O$.

The above example raises a critical question, however. What is the situation when it is the *observer who is moving* relative to a fire truck with the same speed v? Conventional wisdom has it that it does not matter: the frequency, wavelength and speed of sound will supposedly all be exactly the same in both cases. This position misses a basic point about frequencies, however, *namely the number of wave crests emitted per unit time by the source is independent of the motion of the observer.* Einstein made this point in his elucidation of the gravitational red shift.[1] It would be a violation of the Law of Causality to claim that the motion of the observer can have an effect on the frequency of the waves emitted by the source.

Consequently, it does make a crucial difference in the calculation of the *phase velocity* of the waves whether it is the source or the observer which is in motion relative to the original rest frame. In the case first discussed, the frequency ν of the waves measured by the observer is changed as per the Doppler effect, whereas in the opposite case where the source does not move, the frequency of the emitted waves remains unaffected by the motion of the observer.

The situation with wavelength variations is qualitatively different, however. All that matters in either case is the relative speed of the source to the observer. The waves are compressed into the intervening space of the medium through which they move. As a result, the same formula for wavelengths holds in the second case as well, namely $\lambda=(1\text{-}v/v_O)\lambda_O$. As a consequence, since the observed frequency is equal to the source frequency ν_O, the phase velocity of the waves is simply proportional to the wavelength, i.e. $\lambda\nu_O=(1\text{-}v/v_O)\lambda_O\nu_O=v_O\text{-}v$, unlike the first case in which the phase velocity of the waves measured by the observer is v_O.

The case in which the source remains stationary while the observer moves toward it raises an interesting physiological point. Since the brain registers a change in pitch as the observer increases his relative speed to the source, *the effect cannot be caused by the frequency of the waves* since it remains constant throughout. As long as musicians in an orchestra are stationary, it is clear that the frequency of a tuning fork determines the desired pitch for the various instruments, but the corresponding wavelength changes in exact proportion to this frequency. Therefore, it is also clear that one might just as well say that it is the wavelength which is involved in the tuning process. If the musicians/observers were to move away from the tuning fork at constant speed, however, this would not affect the frequency of the sound emitted. It would nevertheless change the pitch of the sound used in the tuning process because the motion affects its wavelength.

The two examples discussed above emphasize that the measurements of wavelengths and frequencies do *not* allow for an unambiguous decision as to the value of *the actual speed of the sound waves relative to the observer.* Even though the speed at which observer and source are separating from one another *is exactly the same,* the speed of sound deduced (falsely) on the basis of measured wavelengths and frequencies, that is, the phase velocity v_p, *is different depending on whether it is the observer or the source that is moving relative to the original rest frame of both.* If the source moves toward the observer, then the conclusion is that the speed of sound. i.e. the phase velocity, is v_O (Doppler effect), whereas if it is the observer who is moving toward the source whose waves are moving toward the observer, the answer is v_O-v. In the former case one can say that it is the phase velocity of sound relative to the source that is being measured on the basis of the measured frequency and wavelength of the waves, whereas in the latter case, it is the phase velocity of the sound waves relative to the observer.

The main point of this discussion is that the phase velocity v_P is something distinct from the actual speed v of the waves. Speed is defined in general as the distance travelled by an object in unit time. The same (distance reframing) approach is taken here as in Chapter IV where it has been shown that Einstein's version of the light postulate[2] is untenable.[3] Take the case where *the source moves away from the observer* and the waves are moving in the same direction. The waves travel a distance of v_OT while the source itself moves a distance of vT relative to the observer in a given time T. The total distance is then v_OT+vT, so the speed relative to the observer, whether he moves from the original position or not, is *by definition* equal to v_O+v. If the waves move *toward t*he observer on the other hand, while the source is again moving away from the observer, the distance traveled by the waves relative to him is v_OT-vT, i.e. the corresponding speed relative to him is clearly v_O-v.

In the above calculation of the actual speed of the waves, it is immaterial whether it is the source or the observer that is moving relative to the original position of the latter, only that the relative speed to each other for both is v. The magnitudes of the speed are obtained using ordinary *vector addition.* One can easily generalize the method of calculation for the case when the waves do not travel in the same direction as that in which source and observer separate from one another. Vector addition is the modern name for what is traditionally called *the Galilean or classical space-time transformation.* In other words, it is that transformation which can be used in all cases to compute the actual speed/velocity of the sound waves relative to the observer's current position.

The point that is easily missed and is perhaps the most perplexing aspect of the whole discussion is that the phase velocity of the waves is not always equal to their actual speed. Using vector addition in the case where the observer moves toward the source of the sound waves which are moving toward him, the computed speed of the waves relative to him is v_O+v. In the calculation based on wavelength and frequency for the same case, however, the *phase velocity* of the sound waves is v_O-v (because the wavelength decreases while the frequency stays the same). This is just an example which shows that *the phase velocity is not always the same as the actual speed* of the waves relative to the observer, which is v_O+v in this case. Moreover, as discussed in Chapter V, the same argument with vector addition and the distance reshaping procedure also applies to light in free space, in which case the speed of sound v_O is simply replaced by c, i.e. the speed of light relative to its source.

Keywords: *Definition of frequency and wavelength, Doppler effect, Galilean velocity transformation GVT, Huygens wave theory, Lack of frequency variation with motion of observer, Law of Causality applied by Einstein, Phase velocity of waves, Pitch of sound waves, Use of linear rephrasing to compute speed of waves, Variation of wavelengths with relative motion*

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XXVI. THE SOUND BARRIER AND THE DE BROGIE RELATION

Sonic booms occupy a special place in the history of the physical sciences. It is a phenomenon which has been experienced in everyday life. They can be heard while walking down the street without the aid of special equipment. The sound barrier responsible for them represented a special challenge to airplane pilots which was first overcome in a memorable flight by Yeager in 1947. Anyone could experience them first-hand during a supersonic flight of the Concorde over the Atlantic.

Yet, no consistent explanation for their existence has ever been given by theoretical physicists. It seems highly unlikely that relativity theory is required for this purpose since the speeds involved are much smaller than for light in free space. They originate at relatively low altitudes above the earth, so the effects of gravitational fields can safely be ignored in searching for an answer as well. Maxwell's theory of electromagnetism seems irrelevant since no electrical or magnetic fields appear to play any significant role. Does the theory of quantum mechanics provide a possible clarification? Or does the more modern theory of quantum chromodynamics solve this puzzle? The discussion below is aimed at removing the uncertainty about why sonic booms occur.

When an airplane passes a certain point, it produces sound waves with a constant speed v which possess a wavelength λ_0 and frequency ν_0. As the plane heads into the waves with speed w relative to their origin, the waves are compressed together, thereby resulting in a reduction in wavelength, as determined quantitatively by the Doppler effect, to have a value of $\lambda=(1-w/v)\lambda_0$. The frequency of the waves that reach the airplane is not affected, however, i.e. $\nu=\nu_0$, by its motion, since the same number of wave crests is emitted from the source per unit of time regardless of the value of w. The same argument about constant frequencies was given by

Einstein[1,2] in conjunction with his prediction of the gravitational red shift for light waves emitted near the sun's surface. When the airplane accelerates and the value of its speed $w<v$ relative to the original source of the sound waves increases, the wavelength λ decreases in accord with the Doppler formula but neither the speed v nor the frequency ν of the waves changes as a result.

As the value of w gets quite close to v, i.e.to Mach 1 in the scientific literature, it is clear from the Doppler formula that the value of the wavelength gradually approaches zero. At this point in the discussion, it is important to recall the Davisson-Germer electron diffraction experiment.[3] It was found that the result of passing 54 ev electrons through a nickel crystal is a wave pattern whose wavelength is quantitatively consistent with the de Broglie[4] quantum mechanical relation between momentum p and wavelength: $p=h/\lambda$, where $h=6.625x10^{-34}$ Js. Planck's constant h also appears in the relation[5] between energy E and frequency ν, i.e. $E=h\nu$. Both relations are believed to be completely general, applying to both photons and particles with non-zero rest mass μ. In the present case, one is dealing with what one can loosely describe as "air molecules" as the carrier of the sound waves instead of electrons as in the Davisson-Germer example. In reality, air is composed of both O_2 and N_2 molecules plus small amounts of rare gases and CO_2. In the present discussion it is permissible to treat them as molecules with an average value of μ.

So, what happens as the airplane approaches Mach 1? First of all, since the wavelength λ is close to zero, the momentum p of the carrier molecules becomes unbounded ($p=\infty$) according to the de Broglie relation $p=h/\lambda$. The value of p changes with time during acceleration. As a result, a force F is generated by the motion, which in accord with Newton's Second Law is equal to the time derivative of the momentum, i.e. $F = dp/dt$. The direction of this force is the same as that in which the airplane is headed.

What happens to this force? It clearly can have no effect on the molecules themselves since it has been generated *internal* to their motion. This is consistent with the fact that the speed of sound remains constant throughout, i.e. $dv/dt=0$. Moreover, their energy E also does not change, which is consistent with the Planck relation[5] since the frequency of the sound waves is also not affected by the motion of the airplane. Instead, the force acts on its surroundings, which would account for the sonic boom phenomenon, and also on the gyrations experienced by the airplane in the Mach 1 range.

Yet, if the speed of the molecules continues to have the same value v as before, how can the momentum p change so substantially? This is theoretically possible from the definition of momentum as $p=mv$ *only* if the relativistic mass m of the carrier molecules is also unbounded ($m=\mu$ times ∞). It needs to be recognized, however, that this condition is inconsistent with Einstein's original prediction:[6]

$$m = \left(1 - v^2 c^{-2}\right)^{-0.5} \mu = \gamma\mu\,, \qquad \text{(XXVI-1)}$$

since v is finite and c is the speed of light in free space (299792458 ms^{-1}). It should be noted that the latter equation is closely akin to Einstein's famous mass/energy equivalence relation:

$$E = mc^2\,. \qquad \text{(XXVI-2)}$$

By squaring both sides of eq. (XXVI-1) and multiplying by c^4, while defining the rest energy E_0 to have a constant value of μc^2, the result is:

$$E^2 - p^2c^2 = E_0{}^2\,, \qquad \text{(XXVI-3)}$$

which is another key relation in Einstein's theory.[6] Thus, if the interpretation in terms of the de Broglie and Planck relations is correct, it becomes necessary *in this application* to disregard key results of Einstein's theory of relativity.

There is precedent for combining relativity theory with applications of the de Broglie and Planck quantum mechanical relations. It is found in the phenomenon of light refraction, as discussed in Chapter XVII. Stark[7,8] was the first to use the p=h/λ relation with respect to light in free space, before de Broglie generalized it to all forms of matter. He made use of Planck's E=hν relation:

$$p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda} . \qquad \text{(XXVI-4)}$$

Stark also concluded on this basis that particles of light (photons[9]) in free space have inertial mass since by definition, p=mv = mc in the present case:

$$m = \frac{p}{v} = \frac{E}{vc} = \frac{h\nu}{c^2} . \qquad \text{(XXVI-5)}$$

For light in a refractive medium, the value of the photon's mass changes to (n and n_g are the refractive index and group refractive index, respectively of the medium):

$$m = \frac{p}{v} = \frac{\frac{nh\nu}{c}}{\frac{c}{n_g}} = \frac{nn_g h\nu}{c^2} . \qquad \text{(XXVI-6)}$$

Accordingly, the value of mc^2 in this case is:

$$mc^2 = nn_g h\nu = nn_g E . \qquad \text{(XXVI-7)}$$

As a result, it is clear that *Einstein's mass-energy equivalence relation of eq. (XXVI-2) does not hold in this case*. In short, the above argument about the origin of sonic booms is also consistent with what is known about light refraction.

Keywords: *Davisson-Germer experiment 8, De Broglie p=h/λ quantum mechanical relation, Doppler effect, Einstein's E=mc² relation, Infinite mass creation, Mach 1, Newton's Second Law, Sonic booms, Stark photon momentum, Yeager supersonic flight*

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XXVII. THEORY OF THE BIG BANG

There seems to be general agreement among physicists that the universe originated with a massive explosion which has come to be known as the Big Bang. Astronomical measurements carried out at the present time show clearly that the current universe consists of a huge number of galaxies which are moving away from earth at varying speeds. Edmund Halley in 1720 asked the very basic question of why the sky is dark at night. This was followed by the Olbers' Paradox, according to which it was argued that the reason the night sky is not filled with light is because the galaxies are constantly in outward motion. Moreover, the universe must be limited in space.

Some two centuries after Halley's question, Edwin Hubble was able to make the theory of the "expanding universe" much more quantitative by measuring the distances separating the various galaxies from the earth. This information was combined with measurements of the red shifts of lines of the same galaxies which were obtained by Hubble's colleague, Milton Humason. From a purely qualitative point of view, these data showed that the galaxies are moving away from the earth, in agreement with the general conclusion of an expanding universe. There was a more quantitatively significant result from the Hubble-Humason collaboration, however. It was found that the ratio of the distance of a given galaxy to its speed relative to earth is nearly the same in all cases for which measurements are available. This ratio has come to be known as Hubble's Constant. It has a value of approximately 10^5 ly /(mi/s). Accordingly, when $H = 10^5$ is defined as above in standard units of s ly/mi, the distance L is measured in mi and the speed v in mi/s, the following equation can be assumed to be valid to a good approximation :

$$L = HXv \,, \tag{XXVII-1}$$

where X is the number of miles in a light year (5.8786×10^{12} mi/ly).

The fact that the galaxies are all undergoing acceleration raises the question of how great the acceleration A of a particular galaxy is at the current time. If attention is centered on a single galaxy, it is possible to use standard formulas from differential calculus which assume a *constant* acceleration value A for its motion *away from the Earth*. Since HX=L/v in eq. (XXVII-1) is a constant throughout the universe, it follows that the ratio $\Delta L/\Delta v$ of a given galaxy over an elapsed time Δt will essentially be the same as L/v, i.e. that H (or HX) will not change appreciably over this period of time. Accordingly, the current values of the speed v of the galaxy and its distance from earth L can be combined to obtain an estimate of A, as follows:

After time Δt has elapsed relative to some as yet unspecified initial time t_0 on the basis of the standard formulas of differential calculus, one obtains a change in speed of $\Delta v = A\Delta t$ and corresponding change of distance of $\Delta L = A\Delta t^2/2$ relative to their respective current values of v and L, respectively. Elimination of Δt then leads to the following relation between A, Δv and ΔL:

$$A = \frac{\Delta v^2}{2\Delta L} \qquad \text{(XXVII-2)}$$

Substitution of $HX = \Delta L/\Delta v = L/v$ in eq. (XXVII-2) then yields:

$$A = \frac{\Delta v}{2HX} = \frac{\Delta v}{t_X} \qquad \text{(XXVII-3)}$$

with $t_X = 2HX = 1.176\text{x}10^{18}$ s$=3.726\text{x}10^{10}$ y.

It is interesting to note that eq. (XXVII-2) is consistent with a determination of the acceleration due to gravity g in a local field. In that case, a freely falling object of mass m will attain a kinetic energy of 0.5 mv^2 when it has reached a speed v at a distance L from the origin relative to a standing start. At this point in time, the decrease in gravitational energy according to standard Newtonian theory is mgL. Equating these two energy values leads to an equivalent result to that for the acceleration A in eq. (XXVII-2), namely $g=v^2/2L$.

One way to interpret the above results is simply to assume that t=0 refers to the time of the Big Bang. The first application of eq. (XVIII-3) to be considered is for the present time frame when the speed of the given galaxy has reached its current value of v, i.e. it is assumed that $\Delta v=v$. As an example, consider the galaxy Hydra, which is known to have a speed of approximately $3.8\text{x}10^4$ mi/s. Substitution of this speed gives a value for Hydra's current acceleration of $3.23\text{x}10^{-14}$ mi/s^2. This amounts to $1.1706\text{x}10^{-10}$ ft/s^2. This value can be compared to the value of g at the surface of Earth of approximately 32 ft/s^2, which is $2.73\text{x}10^{11}$ times larger.

It needs to be emphasized that A refers to a "residual acceleration." It is the result of a nearly equal competition between gravitational forces and the inertial forces which originated in the Big Bang explosion. It is clear from eq. (XXVII-3), however, *that gravity is losing the battle at every stage.* The acceleration A obviously causes the galaxy to slightly increase its speed, but as this happens, the value of A increases as well since it is always proportional to v. The changes are extremely small in all cases but they are always in the same direction, with the galaxies all heading farther out into space at an ever increasing rate. Moreover, it is clear that eq. (XXVII-3) is perfectly consistent with the concept of an *expanding universe*. The farther out the galaxy, the faster it moves in every case. This combined motion preserves the constancy of H, at least over a relatively small period of time. This result is not surprising considering how eq. (XXVII-3) has been derived.

Another key point about the derivation of eq. (XXVII-3) is the assumption that A is constant. In one sense, this assumption is not strictly correct because the derivation leads to the conclusion that A varies in direct proportion to the speed of the galaxy v. Yet, in practice this means that A will decrease by only 10% for a galaxy that is 100 times closer to earth than Hydra with a speed which is 10 times less than Hydra's, that is, one whose value of L is 3.8×10^7 ly = 2.23×10^{20} mi. Surely, that amount of variation over this large range is commensurate with the above constancy assumption since Hydra's current value of A is only 1.17×10^{-10} ft/s^2.

Another area in which eq. (XXVII-3) can prove instructive is in resolving the question of the age of the universe. Since $\Delta v = A\Delta t$, one can compute the value of the elapsed time Δt relative to t=0 by considering the case at the present time when the speed of the galaxy (it doesn't matter which one because the formulas are applicable to all) is equal to v. Substitution of this value in eq. (XXVII-3) then allows the amount of time since t=0 to be computed in order for the speed of the galaxy to have reached the current value of v:

$$A = \frac{\Delta v}{t_x} = \frac{v}{t_x} = \frac{A\Delta t}{t_x}, \tag{XXVII-4}$$

whereupon elimination of A yields the interesting result:

$$\Delta t = t_x, \tag{XXVII-5}$$

that is, the elapsed time needed to attain the *present* galaxy velocity of v *is exactly* t_x*=37.26 billion years.*

There is a problem with the above determination, however. As we go backward in time, the value of Hubble's constant decreases. By the time t=0 is reached, it has a value of zero. It would therefore be more realistic to employ an average value of this constant over the entire period of time. For example, it would be reasonable to estimate this quantity as the average of Hubble's constant from its present value of t_x to the final value of zero. In other words, it is more realistic to use $0{,}5t_x$ in the denominator of eq. (XXVII-3) than t_x. This would mean that the sum of all Δv values would add up to the current value of v *twice as quickly as before*. That would mean in turn that the time of the universe is estimated to be only $0{,}5t_x = 18.63$ billion years in this calculation. That value fits in much better with the estimated experimental value of $t_u = 16$ billion years. The discrepancy of 2.6 billion years can be put down to the inaccurate average value of $0.5t_x$ assumed above, so this result is an indication that eq. (XVII-3) for computing the acceleration of each galaxy is in reasonable agreement with experiment.

The elapsed time Δt for the galaxy to reach its current value of L in mi can also be calculated with the aid of eq. (XXVII-3):

$$\Delta L = L = HXv = \frac{A\Delta t^2}{2} = \frac{v}{2t_x}\Delta t^2 , \qquad \text{(XXVII-6)}$$

whereby the current value of the galaxy's speed v in mi/s has been assumed in this equation. The question arises whether the same value of the elapsed time ($\Delta t = t_x$) as above results from solving this equation. To show that it does, one only needs to eliminate v from eq. (XXVII-6) and solve for Δt^2 (see the definition of t_x given directly after eq. (XXVII-3):

$$\Delta t^2 = 2HXt_x = t_x^{\ 2} \qquad \text{(XXVII-7)}$$

The simple mathematical nature of the characteristics of constant acceleration can be used to good advantage in another important way. As motion of the galaxy proceeds, one can use the formulas to compute both the changes in its distance and speed, Δv and ΔL, for a given amount of time Δt, in terms of the present acceleration value $A = v/t_x$ from eq. (XXVII-3):

$$\Delta v = A\Delta t = \frac{v\Delta t}{t_x} , \qquad \text{(XXVII-8)}$$

$$\Delta L = \frac{A\Delta t^2}{2X} = \frac{v}{2Xt_x}\Delta t^2 . \qquad \text{(XXVII-9)}$$

The factor X has been included in eq. (XXVII-9) to account for any potential change in units. For example, if ΔL is to be given in ly, then X is the conversion factor required to change from ly to mi [see the definition after eq. (XXVII-1)] when the speed v has the unit of mi/s (note that both t_x and Δt have the unit of s). Since $\Delta L/\Delta v = L/v$ over at least a short period of elapsed time [see the discussion after eq. (XXVII-1)], it follows that the corresponding change ΔH in the Hubble Constant is equal to $\Delta L/\Delta v$; hence, from eqs. (XXVII-8,9) one obtains:

$$\Delta H = \frac{\Delta L}{\Delta v} = \frac{\dfrac{v}{2Xt_x}\Delta t^2}{\dfrac{v\Delta t}{t_x}} = \frac{\Delta t}{2X}. \qquad \text{(XXVII-10)}$$

The concept of constant accelerations for the galaxies leads very easily to the results of eqs. (XXVII-8,9) for the dependence of their speeds v and separations L from present-day earth. In particular, v varies as the first power of Δt and ΔL as the square thereof. Consequently, it comes as no surprise that the ratio of distance to speed, which is Hubble's Constant, turns out to be directly proportional to Δt.

The term "constant" for this quantity clearly refers to the fact that the value of the ratio is, at least to a good approximation, the same for all galaxies *at the current time.* What eq. (XXVII-10) indicates, however, is that Hubble's Constant is *time-dependent* and is definitely not constant in this respect. In other words, if one goes backward in time, the *distance L decreases faster* than the corresponding value of v for each galaxy. The universe gradually shrinks as we look backward in time to the point at which the universe started.

It is possible to use eq. (XXVII-3) to predict the speed of a given galaxy at a later time Δt, namely as the sum of the current speed v and the increased speed $\Delta v = A\ \Delta t = v\ \Delta t/t_x$. To be accurate, however, the elapsed time Δt must be relatively short. This is because eq. (XXVII-3) assumes that H is constant, which means that $t_x = 2HX$ must be nearly constant as well. This is a key consideration if the goal is to use the equation to predict changes in speed since the Big Bang occurred. For example, if one would like to compute the speed of the galaxy at a time half-way between the present and the time of the Big Bang, it is reasonable to assume from eq. (XXVII-10) that the value of H at that time is only one-half of its current value. Therefore, in applying eq. (XXVII-3), one has to alter it by replacing t_x by $t_x/2$ = HX to obtain the value of Δv over this period of time. The failure to do so, would mean that the value of Δv is underestimated by a factor of two,

Based on the above considerations, it is reasonable to assume that Hubble's Constant varies linearly with time t, whereby t=0 corresponds to the time of the Big Bang explosion:

$$H(t) = \frac{Ht}{t_q}. \tag{XXVII-11}$$

According to this formula, Hubble's constant would reach its current value of H=100000 ly s/mi, i.e. when $t=t_q$; t_q is preferred to the estimated average value of $0.5t_x$=HX. It would have a null value at the time of the Big Bang (t=0). Consistent with this relation for Hubble' s constant, it would be reasonable to also assume a linear dependence for galaxy speeds as suggested by eq. (XXVII-8):

$$v(t) = \frac{vt}{t_q}, \tag{XXVII-12}$$

whereby v is taken to be the current value of the speed in each case.

Along the same line of argument, the corresponding formula for distances is:

$$L(t) = L\left(\frac{t}{t_q}\right)^2. \tag{XXVII-13}$$

The t^2 dependence in this case is consistent with eq. (XXVII-9). It also causes the ratio of L to v (Hubble's Constant) to be perfectly consistent with eq, (XXVII-11). Finally, the analogous argument also suggests that acceleration a is linearly dependent on t:

$$a(t) = \frac{at}{t_q}, \tag{XXVII-14}$$

which is consistent with eq, (XXVII-3).

There are three main cosmological theories to explain the origin of the universe.[1] The steady-state theory certainly does not mesh well with all the evidence of a Big Bang explosion. The second assumes that the Big Bang not only occurred, but that its force continues to the present day to push the known galaxies farther into space, eventually taking them all the way to infinity, however that may be defined. The third theory assumes on the contrary that the universe is oscillating between explosion and collapse.

The latter theory is based in large part on belief in Einstein's theory of general relativity (GR) which he introduced in 1916.[2] According to Einstein, the gravitational pull on massive bodies can be expressed as a curvature of space.[3] His first ideas on this subject appear to go back to a paper he published in 1911.[4] He felt that he could use his 1905 version of relativity theory (SR[5]) to explain the apparent displacement of star images during solar eclipses. This attempt gave a result for the angle in question which was only half as large as believed experimentally, but this error was removed in his GR paper five years later. According to his biographer,[6] Einstein realized he needed to know something about Riemannian geometry to carry out his program, and so he contacted his friend, Marcel Grossmann, in 1912 to obtain the necessary instruction. This ultimately led to his 1916 paper on GR and his successful calculation of the angle of light "bending." It has been shown in Chapter XV, however, that what actually occurs is a *displacement of star images, not the bending of light.*

It is commonly believed in the astrophysical community that the only way to satisfactorily explain the displacement of star images and related phenomena is by way of GR. Nothing could be further from the truth (see Chapter XV). In 1960 Schiff published a method[7] which *assumed* *that light travels in a perfectly straight line.* His method makes use of a conclusion that Einstein made about the speed of light in his 1907 paper[8] in which he enunciated the Equivalence Principle. He used his 1905 theory[5] to claim that *the speed of light decreases as it gets closer to a massive body such as the sun.*

Einstein's conclusion was verified in 1964 by Shapiro[9] in what the latter referred to as a "fourth test of general relativity." Shapiro proved that radar pulses are indeed slowed when they pass close to planets. What Schiff showed with his paper is that light rays only *appear* to be bent by passing close to the sun. They each move at different speeds, however, becoming ever slower the closer they come to the sun. As a consequence, *the wave front of the light rays is rotated*. The angle of rotation is what is measured during solar eclipses.

In Schiff's view,[7] the bending of light can easily be explained without making any assumptions about "curved space-time." It should also be noted, however, that Schiff admitted that his method did not satisfactorily explain another key phenomenon, namely the advancement of the perihelion of Mercury's orbit (see Chapter XVI). This failure clearly detracted from the attempt to convince physicists that his method was a genuine competitor with GR. In more recent studies,[10-13] however, Schiff's method has been extended so that it has become applicable to the Mercury orbit as well, and with comparable accuracy as is obtained with GR.

The latter work has gone largely unnoticed by the astronomical community, however. As a result, a great deal of credence is given to GR, including to its famous cosmological predictions. It is claimed, for example, that the degree of curvature in space may be sufficient to cause the expansion of the universe to slow down and ultimately, if there is sufficient mass, even to reverse course. Once one sees that there is another way to quantitatively explain the key effects of the displacement of star images and the precession of Mercury's perihelion, however, it becomes imperative to much more thoroughly scrutinize the predictions of GR in this regard.

The great advantage of the Uniform Scaling approach is that it makes no assumptions whatsoever based on either GR[2] or Schiff's method.[7] Rather, it simply combines the experimental fact of Hubble's Constant with the quantitative relations that one uses to describe the motion of ordinary objects that are under the influence of a *constant acceleration*. The results are shown in eqs. (XXVII-11-14) for the galaxy speeds, separations and accelerations, respectively.

The calculations with the present model given above indicate that that the speed v(T) of any given galaxy grows *linearly* with time, as well as does the corresponding acceleration value. This is completely incompatible with both the steady-state universe model as well as the oscillating universe prediction of GR. The result is not dependent in any way on the value of the total mass of the universe, but is based instead entirely on the experimental evidence provided by measurements of the value of Hubble's Constant. Gravitational and inertial forces are assumed to be in continuous competition with one another, but no concrete information regarding the strength of either is required to obtain the final results of the theory. It is clear, however, that the strength of the inertial forces always outweighs that of gravitation, in complete agreement with the expanding universe theory of cosmology.

Keywords: *A is proportional to velocity, Big Bang (alternate Page 7), Cosmological theories, Dependence of L,v changes on elapsed time, Displacement of star images during solar eclipses, Edmund Halley, Einstein curved space theory from GR, Einstein's SR, Estimate of time of Big Bang, Expanding universe theory, Gravitational rotation of wave fronts of light, Hubble Constant, Humason, Hydra example, Linear dependence on time since Big Bang, Newtonian ISL, Olbers' Paradox, Residual acceleration A, Schiff's scaling method, Shapiro experiment, Theory of constant acceleration from calculus, Uniform Scaling method*

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XXVIII. CONCLUSION

The Lorentz transformation (LT) is the cornerstone of Einstein's relativity theory. What the great majority of physicists have not understood is that it is fatally flawed. One can easily see this from a critical examination of the light speed postulate on which it is based (see Chapter IV). Consider the following case in which a light source leaves the laboratory with speed v at the same time that it emits a light pulse in the same direction. Einstein's postulate LSP) in the theory of Special Relativity (SR) states that the speed of the light pulse is c for *both* the stationary observer in the laboratory as well as relative to the source. One can see that this is an untenable assumption by calculating the respective distances separating the light pulse from each rest frame after a certain time T has passed. The value of this distance is seen *to be cT in each case.* But this is impossible, since the source and stationary observer *are no longer at the same position in space.* In arriving at this conclusion, it clearly does not matter how great T is, whether it is just a few milliseconds or many thousands of years. In summary, *Einstein's light speed postulate is completely unrealistic.*

There is also another effective way to use the above ("distance reframing") procedure. Consider again what happens when some time T has elapsed since the light source began to move with speed v. After this time has passed the source is found at a distance vT from the stationary observer, while the light pulse is again located at a distance cT from the source. The corresponding distance separating the light pulse from the stationary observer is obtained by simply adding these two partial distances together, in which case the answer is clearly vT+cT. We don't need Newton or Galileo to deduce this value, nor the ancient Greek and Roman philosophers. It involves the same "theory" as we use to measure the length of a room with a meter stick. We measure out the various portions of the room in meters and just add the results.

Since the motion of the light pulse and source occur at the same time T, it is possible by definition to calculate the speed of the light pulse relative to the stationary observer, namely as the ratio of the distance travelled to the amount of elapsed time, i.e. as (vT+cT)/T=v+c. This result is exactly what one obtains when one applies the classical (Galilean) velocity transformation (GVT). It therefore stands in clear contradiction to another of Einstein's conclusions from SR, namely that the GVT does not apply to light or other fast moving objects. The GVT is known in standard mathematical language as the *vector addition* of velocities.

Moreover, it can be stated without fear of contradiction that, just as for vector addition, it applies to motion in all three (not four!) spatial directions. It was used by Bradley in the 17th century to deduce a key aspect of astronomical measurements, namely the aberration of starlight from infinity. Einstein concluded on the basis of his light speed postulate that the angle of aberration is $\tan^{-1}(\gamma v/c)$, whereas the correct value that Bradley obtained by vector addition is $\tan^{-1}(v/c)$. The maximum speed observable speed in free space is not c as SR would have one believe, but rather 2c when two light pulses approach each other head-on. Each pulse travels a distance of cT in time T, so their total closing distance is 2cT. There is no reason to doubt this,

As discussed in Chapter III, another problem with the LT is that its space-time mixing characteristic violates the Law of Causality. Consistent with Newton's First Law, one expects that an inertial clock cannot change its rate spontaneously, that is, without the application of some unbalanced external force. The ratio of the rates of any two inertial clocks must therefore be constant. This means that the elapsed times Δt and Δt' measured for a given event must always occur in the same ratio (Q) as their rates, i.e. Δt'=Δt/Q. This equation is referred to as Newtonian Simultaneity because it is evident therefrom that if the events occur simultaneously for one of the clocks (Δt'=0), they must also be simultaneous based on the other (Δt=0). The attribution to Newton is appropriate because of his longstanding belief that events occurring anywhere in the universe must always occur at the same time. The equation is also referred to as the Clock-rate Corollary to Newton's First Law. The failure of the LT to satisfy this physical requirement is therefore proof that it violates the Law of Causality.

Einstein was aware of the fact, first pointed out by Poincaré, that the LT predicts that events do not always occur simultaneously for two observers in relative motion to one another (remote non-simultaneity or RNS). His famous example of two lightning strikes on opposite sides of a train as it passes by the station platform was intended to bolster belief in RNS. Examination of his argument, however, shows that is based on his LSP which has been shown above to be unreliable. When the GVT is used to analyze the problem instead, however, the strikes are found to occur simultaneously.

The impetus for treating the speed of light differently than for other objects can be traced to the Fresnel-Fizeau light-damping experiment in the early 19^{th} century. It leads to the conclusion that the speed of light in a medium with a refractive index close to n=1 is independent of the medium's speed v in the laboratory; c(v)=c. It was recognized that this behavior is inconsistent with the GVT. After the Michelson-Morley experiment carried out in 1887 appeared to be in agreement with the above relation, Voigt suggested that a suitable transformation could be obtained by simply introducing a free parameter into the GVT equations. His result was inconsistent with Galileo's Relativity Principle (RP), however. Larmor and Lorentz were able to modify Voigt's transformation so as to remove this objection and Einstein used the resulting transformation, the LT, in developing his version of relativity theory, i.e. SR.

The point which has not been appreciated is that this success in no way removes the necessity of using the GVT for other purposes. In Chapter V, the distinction has been made between experiments of Type A, in which two observers in relative motion obtain different values for the speed of light emitted from a given source, from those of Type B in which a single observer measures the light speed *under two different conditions*, such as occurs in the Fresnel-Fizeau light-damping experiment. For the latter purpose, one must use the relativistic velocity transformation (RVT), which is easily derived from both the Voigt transformation and the LT. The ranges of applicability for the GVT and RVT are seen to be mutually exclusive.

The Newton-Voigt transformation (NVT) shown in Chapter VI is consistent with the $\Delta t' = \Delta t/Q$ relation (Newtonian Simultaneity) and, unlike both the LT and the Voigt transformation, is therefore consistent with the Law of Causality. The corresponding (different from the LSP) light speed postulate assumes that the speed of light in free space is always equal to c *relative to its source,* independent of the states of motion of both the observer and the light source; the NVT also satisfies this requirement. It also satisfies the condition required by the Galilean RP. This is proven on the basis of an identity derived in Chapter VI, namely $\eta\eta' = \gamma^2$. Previously, it has been assumed incorrectly by most physicists that the LT is the only space-time transformation that is consistent with the RP. The same identity is also used in Chapter VI to prove that the RVT, which can be derived from the NVT as well, is also consistent with the RP.

In order to apply the NVT in a given case, it is necessary to know not only the relative speed v of the two observers involved in the transformation but also the value of the ratio Q of the rates of their respective clocks. The latter value must be obtained experimentally. The results of the Ives-Stilwell experiment and the various studies of the lifetimes of muons and pions were in agreement with Einstein's time dilation prediction. It was found that the value of Q depends on the speed v of the light source relative to the laboratory, namely as $\gamma(v) = (1 - v^2/c^2)^{-0.5}$.

The Hay-et al. centrifuge experiment with x-ray radiation showed, however, that time dilation is not symmetric. The LT prediction of a red shift being observed in all cases was contradicted in this study, although this was not recognized by the authors. The atomic clock experiments on board circumnavigating airplanes that were carried out by Hafele and Keating a decade later ruled out the possibility that Einstein's 1907 Equivalence Principle satisfactorily explains what occurs in general. In the centrifuge experiment it was found that the clocks on the eastward flying airplane ran slower than those flying westward. The explanation is that the speed v of each clock that determines the clock rate is taken to be relative to the earth's center of mass (ECM). This fact shows that Einstein's Symmetry Principle is not viable and instead that time dilation is an asymmetric phenomenon,

The parameter Q in the Newton Simultaneity formula is thus seen to the ratio of the corresponding $\gamma(v)$ factors. An inverse proportionality therefore exists between a given elapsed time measured with each clock and the associated $\gamma(v)$ factors. This relationship is referred to in Chapter IX as the Uniform Time Dilation Law (UTDL). To apply it in a given case, it is necessary to specify a rest frame, referred to as the *objective rest frame* or ORS, relative to which the speeds of the clocks (v and v') are to be referenced in each case. It is the laboratory in the Hay et al. x-ray study, the ECM in the Hafele-Keating experiment with circumnavigating atomic clocks, or more generally, as the rest frame from which an object has been accelerated. With these definitions, it is possible to define Q as the ratio of $\gamma(v')$ to $\gamma(v)$. The latter is most effectively seen as a *conversion factor* between the rates of the clocks.

It is also possible to prove that the same conversion factor applies to distances. If an object of length L is accelerated, as discussed in Chapter X, *length expansion must accompany time dilation* in order that the speed of light in free space has the same value c in both rest frames, This is the opposite relationship expected based on the FitzGerald length contraction prediction of SR. Moreover, again unlike the case for the FLC prediction, the amount of the expansion must be *independent of the orientation* of the object.

The experiments of Bucherer in 1909 with electrons accelerated to speed v in an electromagnetic field found that the inertial mass of the electrons increased in proportion to $\gamma(v)$. On this basis it can be concluded that inertial mass also scales with factor Q. The conversion factors of all other physical properties can therefore be deduced to have conversion factors which are integral multiples of Q. For example, speed is the ratio of distance to speed, so the conversion factor for speed is $Q/Q=Q^0=1$, that is, it is independent of the state of motion of the observer. This is of course consistent with the light speed postulate stated above, namely that the speed of light in free space relative to its source is always equal to c. The conversion factor for frequency is Q^{-1} based on the fact that it is defined to be the reciprocal of the period of clocks. Accordingly, energy scales as Q since it is defined as the product of inertial mass and the square of speed.

The scaling procedure outlined above is consistent with the Principle of Rational Measurement (PRM) introduced in Chapter I. It is the basis of the Uniform Scaling method as a whole (see Chapter XI). A key aspect of Uniform Scaling is that the reverse conversion factor Q' is always the reciprocal of the original (Q'=1/Q), It is clearly distinguished from Einstein's Symmetry Principle which states that two clocks can both be running slower than each other at the same time.

A consequence of the perfect objectivity of the Uniform Scaling method is that it allows one to deduce the value of Q for any two rest frames (2 and 3) from the respective Q values of another rest frame (1): Q(2,3)=Q(1, 3)/Q(1,2)=Q(2,1)Q(1,3). It should also be noted that the rest frames do not have to be inertial in order to apply the Uniform Scaling method. The Hafele-Keating airplane experiment shows that the UTDL is valid for atomic clocks that are constantly accelerating. The values of the speeds are those measured instantaneously at the current time.

There is an analogous scaling procedure for differences in gravitational potential, as discussed in Chapter XII. In this case the quantity $A_i=GM/c^2r_i$ plays the same role as γ (v) for kinetic scaling. The corresponding conversion factor S is equal to A_o/A_p. The two factors Q and S are independent of one another. This is again seen from the Hafele-Keating study in which the effect of gravity on the clock rates is simply added to the corresponding kinetic effect. This is a key observation since physicists have traditionally believed that the two effects are intertwined. A typical unfounded assertion is that the effects of gravity cannot be "painted" onto SR.

The conversion factors for each property are integral multiples of S, just as in the case of the factors of Q for kinetic scaling. The integers for the fundamental properties of time, inertial mass and distance are -1, -1 and 0, respectively, whereas they are 1, 1 and 1 for the exponents of Q. It is only necessary to know its composition in terms of the three fundamental properties in order to determine the power of S for a given property, similarly as is the case for the power of the corresponding kinetic conversion factor. For example, since speed is the ratio of distance to time, the exponent of S is found to be 0/-1=1 in this case. The composition of energy is inertial mass times the square of speed, hence the gravitational factor exponent in this case is computed to be -1+1+1=1. Because the two types of factors are independent of one another, it is possible to list the value for each property as a product Z of an S factor with the corresponding Q factor. Values for the most important physical properties are listed in Table 1 in Chapter XII. For example the value for energy is Z=QS, while that for time is Q/S.

The role of these conversion factors is to allow the measured results in one rest frame (S') to be converted over to the corresponding units in another (S). For example, if the value of the energy E of an object is measured to be E in rest frame S', the corresponding value in rest frame S is Z=QS E. The relationship in the same two rest frames for Planck's constant h, and for angular momentum in general, is $Zh=Q^2h$. The Uniform Scaling method is consistent with the PRM. *The only reason two observers can legitimately differ on the value of a physical property is if their unit is different.* There is a unique set of kinetic and gravitational scaling factors for any pair of rest frames which enables the conversion of the values of any physical property between them.

The values of Q and S are positive definite and finite in all cases. It is theoretically possible for the unit of length to be much larger in one rest frame than in another. For example, if the factor of Q has a value of 1000, this means that a length of 1.0 m in rest frame S' must have a corresponding value in S of 1.0 km, whereas a length of 1.0 m in S has a corresponding value in S' of only 1.0 mm. There is no experimental evidence that stands in contradiction to these comparisons, nor to the results for any other property. Consistent with what is stated in Chapter I, an assertion that the Uniform Scaling method is not a law of nature has no validity until such contradictory evidence becomes known. The situation is exactly equivalent to the claim that the energy conservation principle is a law of nature.

A law of nature is of no interest to physicists, or to the general public for that matter, unless it has some practical application. This requirement for the Uniform Scaling method, as discussed in Chapter XIII, is satisfied by the Global Positioning System (GPS) navigation method. Uniform scaling for time is applied to the rates of atomic clocks carried on satellites. Both kinetic and gravitational scale factors are used to adjust the rates of satellite clocks to be the same as for their counterparts on the earth's surface or elsewhere. This procedure is essential in order to assure the level of accuracy required for the practicality of GPS. It has been suggested that the "pre-correction" technique used by the GPS engineers could be improved by adjusting the rates by on-board computers based on the predictions supplied by the Uniform Scaling method. It should be clear that Einstein's Symmetry Principle of SR is not capable of providing the necessary information for the adjustment of the clock rates for the simple reason that it rules out the possibility that there is an asymmetric relationship between the rates of atomic clocks located in different rest frames. More generally, the Uniform Scaling methods opens up the possibility of obtaining useful information regarding the rates of atomic clocks located near the moon or other planets.

It is possible to extend the Uniform Scaling method to electromagnetic quantities such as electric charge and electric and magnetic fields. As shown in Chapter XIV, this can be done by taking advantage of ambiguities connected with basic relationships such as Coulomb's Law and the Biot-Savert Law. For example, the units of electric charge and the electric permittivity constant ε_0 can be chosen to have mks values; electric charge can be assigned the unit of Joule (J) whereas ε_0 then has the corresponding unit of Newton (N). Once this assignment is agreed upon, it becomes possible to apply both kinetic and uniform scaling to these two quantities. It should be noted in this context that it is claimed incorrectly in many standard texts that the charge of an electron is simply invariant. The corresponding units for all the other commonly used electromagnetic quantities are shown in Table 2 of Chapter XIV.

In order to successfully determine the effect of gravity on light waves, it is necessary to make an adjustment relative to the scaling factors shown in Table 1. The component of velocity radial to the gravitational field must be scaled with an extra factor of S, also the corresponding value of the distance vector (Chapter XV). This follows the suggestion made by Schiff in his 1960 paper, but it is not the consequence of either the FLC or Einstein's Equivalence Principle as he claimed, rather it is simply an empirical adjustment required to obtain agreement with experimental data.

There is another critical aspect to Schiff's method, however, namely that in his trajectory calculation light always follows the same straight line throughout, and with the same local value of the light speed of c. The finding that the angle of displacement of star images during solar eclipses is non-zero is *not due to the ben*ding *of light waves* because of the use of curvilinear coordinates in the calculation, as GR would have one believe, but rather because of the fact that *the speed of light decreases as it passes by a gravitational mass* (consistent with Table 1). Shapiro's experiments demonstrated what he referred to as the "fourth test of general relativity" by carrying out experiments with radio waves passing by Venus and other planets. As Fig. 1 in Chapter XV shows, the consequence of this gravitational effect is to rotate the wave fronts of the light away from the sun. The quantitative calculation of the angle of displacement then follows based on Huygens' Principle enunciated in the 17th century. as demonstrated by use of finite differences in the calculations.

Schiff, who was an acknowledged expert on GR calculations, acknowledged that his scaling method was not able to explain the other key gravitational effect, the variation of the angle of precession of Mercury's orbit. In Chapter XVI, it is shown that this conclusion was due to his failure to include the effect of g, the acceleration due to gravity, in his calculations. His star displacement image calculation does not include g in any way, so he apparently thought that the Mercury effect should not depend on this either. The correct value of the precession angle is obtained by including g with a particular scale factor: $Q^{-2}S^{-3}$. It needs to be emphasized that this scaling procedure also explains why g does not have to be included in his calculation of the displacement of the images of stars; since the speed of light is c, $Q=\gamma(v)$ is infinite and the value of Q^{-2} in that application is therefore exactly zero.

There is another quantity that needs to be closely considered in this context. Schiff points out that the GR calculation of the Thomas precession of the earth's orbit around the sun leads to a quite unusual result for the component of spin in the plane of the earth's orbit; it is in the *opposite sense and different in magnitude* from what is expected based on the Newtonian Law of Gravity. The calculations of the Uniform Scaling method, on the other hand, are in perfect agreement with the classical Newtonian prediction. Combining this characteristic with its claim that light is bent by the sun provides ample evidence to subject GR to much more careful scrutiny than has been the case in the past century.

The corpuscular/particle theory of light was used by Newton to predict that the speed of light increases when it enters water, contrary to what was assumed on the basis of Huygens' wave theory. When it was found in the 19th century that the light speed does decrease in water, it was widely assumed that this proved beyond any doubt that Newton's particle theory was incorrect and that it needed to be replaced by Huygens' wave theory.

Upon closer examination, however, it is seen that the reason for Newton's error was his assumption that the mass of the particles does not change when they enter water from air. His argument based on the Second Law of Kinetics (see Fig. 2 of Chapter XVII) only supports the conclusion that the *momentum* of the water molecules is directly proportional to the index of refraction n, not their speed. As discussed in Chapter XVII, the fact is that the mass of the light particles is proportional to n^2. This in turn suggests that the speed of light decreases by a factor n when it enters water, in agreement with the wave theory. In other words the two theories actually support each other on this point.

Moreover, the fact that experiment finds that the wavelength λ of light is inversely proportional to n indicates based on the particle theory that $p\lambda$ is a constant. This relationship is seen to be identical with de Broglie's principle, whereupon the above constant is equal to Planck's constant h. One can go a step further, by invoking Hamilton's principle $dE/dp=v$ (which perhaps ironically can be derived from the Second Law). Integration leads to the conclusion that $E=pc$ for light in free space since $v=c$ in this case, which therefore leads to the conclusion that $E=p\lambda\nu=h\nu$, which is Planck's energy/frequency relationship.

Since p is proportional to n, one can generalize the above formula to $E=pc/n$ for light in refractive media. One can further apply Hamilton's principle to obtain the following dependence of light speed on refractive index: $c(n)=c/n-pcn^{-2}dn/dp$. Substitution of $p=h/\lambda$ then leads (see Chapter XVIII) to the experimentally determined relationship between c and $k=2\pi/\lambda$: $c(n)=c/n-kcn^{-2}dn/dk$.

The strongest indication that light is indeed composed of particles comes from Einstein's interpretation of the photoelectric effect, which he also published in his "miracle year" of 1905. It is clear from these results that energy does not *accumulate.* Unless a certain threshold frequency is reached, no metal particle is able to exit the surface. This behavior simply cannot be explained on the basis of the wave theory. A similar situation exists for claims that light waves are dispersed when they enter water from air. An attempt is made to make an analogy with sound waves, but for that argument to be plausible, one would like the light waves to exhibit beats, something which has never been observed. On the other hand, the TCSPC measurements discussed in Chapter XVIII show that the statistical pattern of the photons is merely transported more slowly in water than in air and is otherwise indistinguishable between the two media. This is exactly what one would expect if the photons are simply slowed when they enter water.

There is another experiment with light refraction that could be most illuminating. The diagram in Fig, 3 of Chapter XVIII illustrates how one might be able to measure the speed of light directly in water without relying on wavelength comparisons. By measuring the angle of approach of the light from air *with an apparatus located in the water*, it would be possible to confirm the assumptions made on the basis of the particle theory. This would also lend support to the interpretation of the displacement of star images during solar eclipses, as is indicated in Fig. 1 of Chapter XV.

The energy-mass equivalence relation ($E=mc^2$) does not depend on space and time coordinates and therefore is not affected by either the distance-reframing procedure or the Law of Causality. As pointed out in Chapter XVIII, it is interesting that Einstein arrived at his result through considerations of the Doppler effect and on the basis of the non-relativistic kinetic energy formula: $E=0.5mv^2$.

It has been pointed out, however, that many of the most famous relativistic equations only hold when the observer is located at the ORS position which determines the value of v The UTDL shows that it is only in this case that $Q=\gamma(v)$. Otherwise, the appropriate relationship for inertial mass is $m=Q\mu$, not $\gamma\mu$, and $p=Q\mu v$, not Planck's definition of $p=\gamma\mu v$. Planck applied Newton's Second Law $F=dp/dt$ to obtain $E=mc^2$, whereas this route to $E=mc^2$ is not feasible when the relevant equation is $p=Q\mu v$. At the same time, the $E=mc^2$ relation itself is nonetheless valid because it only requires knowledge of the E/m ratio, in which case the scale factor Q is cancelled out in the appropriate calculation. At the same time, it is also clear that the E/m ratio is not equal to c^2 in the case of refractive media. This is because p is proportional to n while v is inversely proportional to it. The E/m ratio is therefore proportional to the square of the refractive index in this case, and therefore is not equal to c^2.

One of the most widely held tenets of physicists in the field of relativity is that forces must change from one rest frame to another as a result of application of a Lorentz transformation. Consider the following application discussed in Chapter XX which makes use of the Lorentz Force Law: F=e(E+vxB). Assume that the electric field E is pointed along the x direction in which the electron moves while the magnetic field B is perpendicular to it. It is found in the laboratory that the electron initially moves in the x direction. However, shortly thereafter, consistent with the Lorentz Force Law, as its speed increases to a value of v *relative to the laboratory observer*, it begins to veer off in a perpendicular direction since the vxB term is no longer zero. Thereupon, the electron follows an increasingly curved path at ever higher speed.

Next consider how this process is viewed from the vantage point of an observer who is co-moving with the electron. *According to Einstein's theory*, the electron is continually accelerated with him along the x axis of his coordinate system. Its direction can never change according to the Lorentz Force Law since there is supposedly no effect caused by the magnetic field B (since v is assumed to be relative speed of the electron to the observer). As a result, the effect of the magnetic field never kicks in and therefore the electron continues indefinitely on a path in the x direction. *As a consequence, the two observers must disagree as to whether the electron follows a curved path or not.* One has to give up the principle of objectivity of measurement to believe this. There is certainly no way to demonstrate that the two observers *do not agree on the path of the electron.* There is thus a clear choice; either one believes that measurement is objective, or instead that the Lorentz Force Law has a different form in each rest frame.

The present argument stands in direct contradiction to the ubiquitous claims that forces must be invariant to a Lorentz transformation. It needs to be acknowledged instead that, in accord with the RP, *forces must always have the same form in every rest frame*.

A similar situation arises in application of the FLC of SR. The angles of a triangle are different for any two observers in relative motion in this view. But angles are dimensionless quantities, just like numbers, so it is logically impossible that the two observers could disagree on this point either. The only physically plausible position is that in both cases all observers must be in complete agreement on the values of dimensionless quantities, independent of how fast they travel relative to one another. Therefore, this example constitutes indisputable proof not only that the FLC is unphysical but also the tenet that insists that forces must change from one rest frame to another in accord with application of the Lorentz transformation..

A way around this dilemma is to change the definition of v in the above example. Instead of being the speed relative to a given observer, *it should be changed to be the speed relative to the rest frame in which the electromagnetic field originates.* When this is done, the only way the two observers can disagree on the values of their respective measurements is if they use a different set of units in which to express their results. That view is consistent with the Uniform Scaling method as a whole, and thus no adjustment is required in order to be consistent with the expected outcome of the experiment with electromagnetic fields.

One only has to remember that Minkowski's four-vector formalism is based squarely on the LT to realize that it has no basis in reality. As discussed in Chapter XXI, every Minkowski four-vector can be decomposed into a scalar and a conventional vector of three dimensions without the necessity of introducing the imaginary number i into the formalism. According to his biographer, Einstein agreed with this assessment, at least initially, even though he claimed that the ideas had somehow helped him to develop GR at a later time. It is a pity that physics students through the past century have been forced to commit Minkowski's ideas to memory in order to obtain a good grade in their examination. One can only hope that this situation gradually changes in the relatively near future, and that the comparatively straightforward formalism of the Uniform Scaling method takes hold in the world's graduate schools.

A similarly negative assessment applies to the FLC of SR. Once one accepts both light speed constancy and asymmetric time dilation as experimental facts, it follows that length expansion must accompany the slowing down of clocks upon acceleration. In the Uniform Scaling methodology, this relationship is established by assuming that the scale factor for distance is the same as for time (see Table 1). In the past, it has been argued that the narrowing of particle beams that is observed when they are accelerated relative to the laboratory is a manifestation of the FLC. In fact, this is simply another confirmation of de Broglie's principle, namely that the wavelength of the beams is inversely proportional to the momentum of the corresponding particles. The FLC, by contrast, refers to a single distance between two points in space, and hence the experience with particle beams is completely irrelevant in this respect.

The Ives-Stilwell experiment provides a clear example of the FLC's totally misleading predictions. In that case, it is found that the wavelength of the radiation observed in the laboratory *increases* in direct proportion to the standard value observed in the rest frame of the accelerated light source (obtained after eliminating the influence of the first-order Doppler effect). The argument often made by SR proponents is that the FLC simply does not apply to light, even though the same experiment is used to confirm the theory's predictions regarding light frequencies.

In general, it is a mistake to take predictions of the LT at face value. Its RNS claim falls in the same category as the FLC experience. The Newtonian Simultaneity relation ($\Delta t'=\Delta t/Q$) incorporated in the NVT indicates instead that there is absolute simultaneity throughout the universe, in agreement with Newton's position. It also stands in contradiction to the LT prediction of the possibility of time reversal, which was used long ago to supposedly rule out the occurrence of light speeds exceeding c. Experiments with light traveling through absorptive regions in which the index of refraction is less than unity have unquestionably demonstrated that faster-than-c photon speeds do in fact occur in nature. Belief in the LT has prevented physicists from accepting such results at face value, however. On the contrary, Newtonian Simultaneity and the NVT completely rule out the possibility that the sign of one elapsed time can be the opposite of the other's for the simple reason that the scaling factor Q is positive definite.

The negative influence of the LT is shown perhaps most strongly in that it led physicists to reject the use of the GVT in all but low-speed applications. Einstein unquestionably took the lead in this misconception by insisting on his light-speed postulate. As discussed in Chapter IV, the latter is shown to be untenable when attention is centered on the distance travelled by a light pulse relative to two observers who are located at a different position in space (distance reframing procedure). The correct postulate is that the speed of light relative to its source is always equal to c.

The same line of argument shows unequivocally that the speed of the light pulse is indeed determined correctly on the basis of the GVT. The Uniform Scaling method incorporates the latter conclusion by asserting its claim that the *relative* speed of two objects is the same for all observers independent of their respective states of motion. Representing the velocities of a given object as vectors allows one to conclude on the basis of *vector addition* that the *relative* velocity of any pair of objects must be the same for both observers. As discussed in Chapter XXIII, the corresponding three vectors simply form a triangle one of whose legs is connected to the corresponding vectors representing the velocity of the object to their respective positions. From the point of view of logic, it is clear that the decision to exclude the GVT in all cases involving light is based on the belief that since it does not hold for the Fresnel-Fizeau light-damping experiment, it supposedly cannot be accurate for any application involving light. On the contrary, it is shown in Chapter V that there are simply two distinct types of experiments, designated as Type A and B respectively, the former always described accurately by application of the GVT, the latter always by use of the RVT. In other words, the areas of application for the two transformations are *mutually exclusive*.

The Lewis-Tolman conjecture is characterized by a different type of experience with the LT. These authors concluded correctly on the basis of SR that an increase in inertial mass caused by acceleration is directly proportional to the corresponding increase in the periods of clocks. What one finds, however, is that Lewis and Tolman reached this conclusion by ignoring one of the basic premises of SR, namely the constancy of the speed of light in free space. Thus, this is an example where the correct result is obtained *by making two false assumptions* that tend to offset each other.

This is also reminiscent of the experience of the GPS engineers. They simply ignored another of Einstein's tenets, namely the Symmetry Principle, whereby the clocks located on a satellite would supposedlybe running at a slower rate than those on the ground from the vantage point of an observer there, while at the same time from the vantage point of the stationary observer on the satellite, the clocks on the ground would be running slower than those located on the satellite. The Uniform Scaling method by contrast is the byproduct of pure empiricism. It asserts that inertial mass and elapsed times are subject to the same conversion factor because that is what has been found in all experiments to date. As discussed in Chapter I on a general basis, this relationship does *not* rely on deductions that follow from some First Principles, The same holds true for the Conservation of Energy Principle.

The origins of sound and light can both be described in terms of the motion of particles. In the former case, the particles are combinations of different molecules such as the components of air, whereas in the latter they are photons. The speed of the particles relative to the source of the waves is variable in the case of sound waves (v_O), whereas it is always equal to c for light waves. The speed v of both relative to a given observer depends on the speed of the source v_S and is accurately described by the GVT. In the case of sound, $v=v_O+v_S$, whereas for light, $v= c+v_S$. As discussed in Chapter IV, it is possible for v to exceed c whenever the light source moves in the same direction as the emitted light from the vantage point of the observer.

The Doppler effect for wavelengths depends on the speed v_S of the source relative to that of the sound waves, i.e. $\lambda=(1-v_S/v_O)\lambda_0$. When the source moves into the waves, i.e. v_S and v_O have the same direction relative to the observer, the space in which they move is decreased and so the wavelength measured by the observer decreases. The wavelength increases when the opposite is the case.

It does not matter whether it is the source or the observer which is moving in a given reference frame. The situation is different for periods (τ), however. If the source moves into the waves, their period decreases, i.e. $\tau =(1-v_S/v_O)\tau_0$, in accord with the predictions of the Doppler effect. However, if the observer moves into the waves while the source stays in place in a given rest frame, the period of the waves relative to the observer does not change ($\tau=\tau_O$). Were it otherwise, it would constitute a violation of the Law of Causality. Einstein made this point in his study of the gravitational red shift. As a consequence, the phase velocity λ/τ does not equal λ_0/τ_0 in this case, whereas it is unchanged when it is the source that moves. In either case, the speed of the sound waves is not equal to the phase velocity, but rather is equal to $v_O + v_S$ in accord with the GVT.

The manner in which the wavelength of sound changes with the speed of the observer is critical in understanding the origin of sonic booms. As discussed in Chapter XXVI, an airplane is continuously causing sound waves to be created. Their wavelength decreases as the speed of the plane v_S increases. It reaches a null value when $v_S=v_O$. According to the de Broglie $p=h/\lambda$ relation of quantum mechanics, the momentum p of the air molecules becomes infinite at this speed (Mach 1). This increase in p leads to a strong force F in accord with Newton's Second Law of Motion: F=dp/dt. This force can only be applied to the surroundungs of the plane, which explains why a sudden increase in energy occurs there, and this is perceived as a sonic boom.

A model for the motion of galaxies has been developed which is based on Hubble's Constant. There is a standard relation from elementary calculus which predicts the values of the speed v and distance L travelled by an object under the assumption of a constant value A of its acceleration, namely $A=v^2/2L$. Inserting Hubble's Constant H=L/v in this equation leads to the conclusion that $A=\Delta v/\Delta t=v/2H$, i.e. that the acceleration of a given galaxy is proportional to its current speed. The value for Hydra with v=38000 mi/s is only 1,17x 10^{-10} ft/s^2 which is miniscule in comparison to the acceleration due to gravity on the earth's surface of 32 ft/s^2. It is clear that this is only a residual acceleration, but it definitely supports the conclusion that the force of gravity is never able to overcome the effects of the Big Bang explosion.

Further development of the model indicates that Hubble's Constant is gradually increasing with time, rendering it to be something like a "clock of the universe." The galaxy speeds are all increasing linearly with elapsed time t, whereas the corresponding distances from the earth increase as t^2.

The results of the present model are quite consistent with the cosmological theory of an "expanding universe." They do not agree with the "oscillating universe" of GR, nor do they agree with the steady-state model. The Big Bang itself is consistent with the Laws of Thermodynamics. The Second Law states the amount of entropy in the universe is always increasing, and therefore always decreasing when one looks backward in time. The Third Law states that entropy is a positive definite quantity, so it never can go below a null value. Taken together, these two laws indicate that there was a *complete lack of disorder* prior to the Big Bang. This is consistent with null values of v and L for each galaxy predicted by the present model.

Keywords: *Bradley aberration explanation, Bucherer electron mass experiment, Contradiction of covariance rule, Contradiction via distance reframing, Displacement of star images, Einstein light speed postulate LSP, Einstein Symmetry Principle, Einstein's* $E=mc^2$ *relation, Einstein's GR theory, Erroneous assumption of mass variation in water, Erroneous interpretation of v in laws of physics, Faster-than-c light speeds, FLC, FLC debunking, Fresnel-Fizeau light damping, Galilean RP, General E=pc/n relation for light, GPS navigation method, Gravitational rotation of light waves, Hafele-Keating atomic clock study, Hay et al. experiment, Huygens' wave theory of light, Identity* $\eta\eta'=\gamma^2$*, Inclusion of G in Mercury calculation, Isotropic length expansion, Ives-Stilwell proof of isotropic length expansion, Law of Causality, Lorentz Force Law, Lorentz transformation LT, Magnetic scaling, Michelson-Morley experiment, Minkowski mistaken reliance on the LT, Newton's First Law, Newton's particle theory of light, Newton's Second Law, Newtonian Simultaneity relation, NVT, Photoelectric effect as verification of Newton's theory, Poincare, Principle of Rational Measurement PRM, Proposed method of measuring* n_g*, RNS debunking via GVT, RVT, Scaling of electromagnetic properties, Scaling parameter Q, Schiff's scaling method, Separation of kinetic and gravitational effects, Shapiro experiments, TCSPC experiment, Thomas precession of earth's orbit, Time dilation, Uniform Scaling method, UTDL, Verification of the GVT for light, Voigt transformation*