Fitzgerald Contraction, Larmor Dilation, Lorentz Force, Particle Mass and Energy as Invariants of Galilean Electrodynamics

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By means of the generalized, Galilei covariant Maxwell equations for inertial frames $\Sigma(\mathbf{r},t,\mathbf{w})$ with substratum velocity $\mathbf{w}$, Fitzgerald contraction $\ell = \ell_o[1-(\mathbf{v}-\mathbf{w})^2/c_o^2]^{1/2}$ of rods, Larmor dilation $\tau = \tau_o[1-(\mathbf{v}-\mathbf{w})^2/c_o^2]^{-1/2}$ of clock periods, and velocity dependence of particle mass $m = m_o[1-(\mathbf{v}-\mathbf{w})^2/c_o^2]^{-1/2}$ are shown to be Galilei-invariant vacuum substratum effects, where $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \mathrm{inv}$ is the respective object velocity relative to the substratum frame $\Sigma^\circ(\mathbf{r}^\circ,t^\circ,\mathbf{0})$. The Lorentz force transferred through the substratum is Galilei-invariant, $\mathbf{F} = e[\mathbf{E}^\circ + \mathbf{w}\times\mathbf{B} + (\mathbf{v}-\mathbf{w})\times\mathbf{B}] = e(\mathbf{E}^\circ + \mathbf{v}^\circ\times\mathbf{B}^\circ) = \mathrm{inv}$. The kinetic energy $K(\mathbf{v}^\circ)$ of high-velocity particles is given by the Galilei-invariant mass-energy relation $K(\mathbf{v}^\circ) + E_o = m(\mathbf{v}^\circ)c_o^2$, where $E_o = m_o c_o^2$ (mass-energy equivalence). The Galilean measurement process in inertial frames $\Sigma(\mathbf{r},t,\mathbf{w})$ is explained considering physical length contraction of measuring rods and rate retardation of measuring clocks, as well as synchronization of clocks in absolute time. Crucial experiments underlying Galilean electrodynamics are discussed briefly.

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Introduction

The concepts of Maxwell, Fitzgerald, Larmor, Hertz, Heaviside, and others concerning the propagation of electromagnetic (EM) waves in the "luminiferous ether" hidden in the vacuum (Whittaker 1954) have been vindicated through recent experiments. The experiment of Penzias and Wilson demonstrates that the universe is filled with a uniform and isotropic (at large) 2.7° K microwave background (Penzias and Wilson 1965). Measuring this background EM radiation (excitation of vacuum substratum) makes the verification of an absolute reference frame Σ° (its origin and directions of coordinate axes can be chosen arbitrarily) possible everywhere in the universe. If in an observation frame the cosmic microwave radiation is found to be isotropic in intensity, then this frame is an absolute space frame Σ°. In inertial frames Σ which move relative to Σ° with a constant velocity $\mathbf{u}^\circ$, the observed microwave radiation is anisotropic, as first shown by Conklin (1969) and Henry (1971), i.e., these are not absolute space frames. These experimental facts alone refute the special theory of relativity (STR) which rests, inter alia, on the experimentally unconfirmed hypotheses that (i) all inertial frames are physically equivalent and (ii) no distinguished reference frame exists (Whittaker 1954).

The nonobservation of the ether in the Michelson-Morley experiment is due to a compensation of the length contraction (first proposed by Fitzgerald (Whittaker 1954)) and time dilation (first proposed by Larmor (Whittaker 1954)) effects in the ether flow on the Earth. In spite of this, the Michelson-Morley experiment has been used to this date to justify the STR postulates of the nonexistence of the ether and a preferred inertial frame Σ° (with EM wave carrier at rest). Builder (1958a,b) and Janossy (1953, 1964, 1967, 1971) further developed the length contraction and time dilation concepts in the ether, and arrived at the conclusion that their "physical relativity theory" is in agreement with the STR. This reasoning is strange since the STR is based on the assumption of the validity of Maxwell's equations in all inertial frames, or the physically equivalent assumptions of (i) the constancy of the velocity of light c_o in all inertial frames, or (ii) the absence of an EM wave carrier in the vacuum. The STR proposes that all physical effects are relative to the observer, i.e., they depend on the velocity $\mathbf{v}$ of the microscopic or macroscopic system relative to the observer. Its main accomplishment is the replacement of the unique physical reality of any physical system, and even of space and time, by a multitude of contradicting system "perspectives" limited only by the number of actual or imagined observers.

For the above reasons, it became necessary to reinvestigate the relativistic foundations of modern physics, from the point of view of absolute space and time and an ether (Wilhelm 1984, 1985a). The latter concepts lead to generalized, Galilei (G) covariant Maxwell equations, which are based on two experimentally supported hypotheses, namely the validity of (i) the ordinary Maxwell equations in the EM wave carrier frame Σ° and (ii) the Galilean transformations for the absolute space and time coordinates between arbitrary inertial frames, $\Sigma(\mathbf{r},t,\mathbf{w}) \leftrightarrow \Sigma'(\mathbf{r}',t',\mathbf{w}')$, with substratum velocities $\mathbf{w}$ and $\mathbf{w}'$, where $\mathbf{u} = \mathbf{w}-\mathbf{w}'$ is the velocity of Σ' relative to Σ (Wilhelm 1984, 1985). We show that rod contraction, clock retardation, Lorentz force, particle mass and energy are not relative to the (noninteracting) observer (Σ, $\mathbf{v}$) but relative to absolute space and the vacuum substratum (Σ°, $\mathbf{v}-\mathbf{w}$). These G-invariant effects ($\mathbf{v}-\mathbf{w}=\mathbf{v}^\circ=$ inv) are in accord with experience, since the physical state of a system can be changed by moving it relative to the substratum and the masses of the universe (sources of physical interactions). Herein, "G-invariant" or "= inv" always means "G-invariant with respect to choice of the inertial frame of observation." The formulae of the STR are recovered as a special case (i) rigorously valid in the substratum frame $\Sigma^\circ(\mathbf{w}=\mathbf{0})$ or (ii) approximately in quasi-ether frames $\Sigma(|\mathbf{w}| \ll c_o)$, such as terrestrial frames with substratum velocity $w \approx 3\times10^5$ m/s $\ll c_o$ (Conklin 1969; Henry 1971). The conclusions of other authors (Builder 1958a,b; Janossy 1953, 1964, 1967, 1971) that the ether and absolute space-time concepts support special relativity cannot be confirmed since $\mathbf{v}-\mathbf{w} \neq \mathbf{v}$ for all inertial frames $\Sigma \neq \Sigma^\circ$.

G-covariant electrodynamics has been applied with success to radiation phenomena including Cerenkov radiation (removal of relativistic paradoxes) (Wilhelm 1985, 1990a,b, 1991, 1992a), anomalous unipolar induction in corotating conductor-magnet systems (Wilhelm 1992b), and a consistent formulation of G-covariant quantum mechanics in EM fields (Wilhelm 1985b). Here, we apply the generalized Maxwell equations (Wilhelm 1984, 1985a) to a physical, paradox-free explanation of length contraction, clock retardation, Lorentz force, particle mass, energy, and dynamics at high velocities. Galilean electrodynamics is supported by the cosmic microwave experiments (Penzias and Wilson 1965; Conklin 1969; Henry 1971), the effects of Sagnac (1913) and Aharonov-Bohm (Aharonov and Bohm 1959), the dielectric Cerenkov effect (Wilhelm 1992a), and anomalous induction in homopolar generators without relative motion between conductor and magnet (Wilhelm 1992b; Kennard 1917; Mueller 1987). In a forthcoming communication, G-covariant electrodynamics will be shown to explain all known EM experiments, including the interferometer experiments of Fizeau and Hoek on the speeding up and slowing down of EM waves by moving dielectric media (Wilhelm 1993).

Physical Length Contraction

A particle of charge e moving with a constant velocity $\mathbf{v}$ in an arbitrary inertial frame $\Sigma(\mathbf{r},t,\mathbf{w})$ with z-axis chosen to be parallel to the invariant vector $\mathbf{v}-\mathbf{w}=\mathbf{v}^\circ$, excites in the vacuum substratum a transient EM field, the electric potential of which is given by Wilhelm (1990a)

$$\Phi(\mathbf{r},t) = \frac{e}{4\pi\varepsilon_o}\left[1-\frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\right]^{-1/2} \times \left\{(x-v_x t)^2+(y-v_y t)^2+\frac{(z-v_z t)^2}{1-\frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}}\right\}^{-1/2} \tag{1}$$

The surfaces of constant electric potential $\Phi(x,y,z,t)$ of the uniformly moving ($\mathbf{v}$) charge in the inertial frame $\Sigma(\mathbf{r},t,\mathbf{w})$ with ether velocity $\mathbf{w}$ are the ellipsoids of revolution about the z-axis

(Wilhelm 1990a)

$$(x-v_xt)^2+(y-v_yt)^2 + \frac{(z-v_zt)^2}{1-\frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}} = \text{const} > 0 \tag{2}$$

which are centered at the instantaneous position $\mathbf{r} = \mathbf{v}t$ of the charge. In Equation (2), the z-axis is in the direction of the G-invariant vector

$$\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \text{inv} \tag{3}$$

which represents the charge velocity relative to the ether (same value for observers in all inertial frames). It is seen that the ellipsoid axis parallel to the invariant charge velocity $\mathbf{v}^\circ$ (z-direction) in the ether is shortened by the dimensionless factor

$$\left[1-\frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\right]^{1/2} = \frac{1}{\gamma} > 0, \quad |\mathbf{v}-\mathbf{w}| < c_o \tag{4}$$

Since matter consists of positive (nuclei) and negative (electrons) charges, the contraction (4) of their equipotential surfaces (2) in the direction $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \text{inv}$ causes, in equilibrium, a Fitzgerald contraction of the extension $\ell(0)$ of bodies in the direction of their velocities $\mathbf{v}^\circ = \mathbf{v}-\mathbf{w}$ relative to the ether:

$$\ell(0) = \ell_o\left[1-\frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\right]^{1/2} = \text{inv} \tag{5}$$

By Equation (3), the body extension $\ell(0)$ is a G-invariant, i.e., has the same extension for observers in different inertial frames. The formula (5) indicates that length contraction of bodies is not relative to the observer (STR) but has absolute meaning relative to the vacuum substratum. A rod has its largest length ℓ_o when at rest in the ether (Σ°) and a shorter length $\ell < \ell_o$ when moving with a velocity $\mathbf{v}^\circ$ relative to the ether frame Σ° (or with a velocity $\mathbf{v} = \mathbf{v}^\circ + \mathbf{w}$ in an inertial frame Σ).

The corresponding STR formula $\ell(0) = \ell_o[1-v^2/c_o^2]^{1/2}$, where $\ell_o = \ell(\mathbf{v}=\mathbf{0})$ is the "proper" length measured in the body frame, has given rise to paradoxes, since observers with different velocities relative to the body are supposed to measure different extensions for one and the same body. E.g., for two identical rods attached to two physically equivalent inertial frames Σ and Σ' (moving with constant relative velocity $\mathbf{u}$), the observer in Σ claims that his rod has the length ℓ_o and that in Σ' the length $\ell = \ell_o[1-u^2/c_o^2]^{1/2}$, whereas the observer in Σ' asserts that his rod has the length ℓ_o and that in Σ the length $\ell' = \ell_o[1-u^2/c_o^2]^{1/2}$. This contradiction is exacerbated by the fact that the STR cannot decide which of the two identical rods is longer or shorter, since the two inertial frames are completely equivalent in the empty STR vacuum.

Such physical impossibilities do not exist in G-covariant electrodynamics, since two identical rods moving with a constant velocity $\mathbf{u}$ relative to each other have different velocities $\mathbf{v}^\circ_{1,2}$ relative to the ether and, therefore, different invariant lengths ℓ and ℓ'. The STR suggestion that the length of a rod depends on its velocity $\mathbf{v}$ relative to the observer is physically untenable, if only

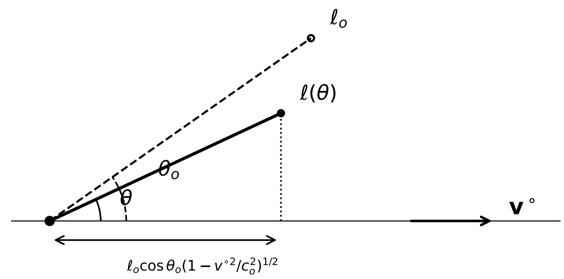

Figure 1: Contracted rod $\ell(\theta)$ forming angle θ with absolute velocity $\mathbf{v}^\circ$.

for the reason that the observer velocity is arbitrary and the observer does not interact with the rod.

Let us calculate the length $\ell(\theta)$ of a contracted rod that forms an arbitrary angle θ with its velocity $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ$ relative to the ether (Σ°) as depicted in Figure 1. By Equation (5) and Figure 1 ($\|$ designates projection in the direction of $\mathbf{v}^\circ$)

$$\ell_\| = \ell_o \cos\theta_o \cdot \left[1-\frac{v^{\circ 2}}{c_o^2}\right]^{1/2} \tag{6}$$

$$\ell^2 = \ell_\|^2 + (\ell_o \sin\theta_o)^2 \tag{7}$$

$$\tan\theta = \left[1-\frac{v^{\circ 2}}{c_o^2}\right]^{-1/2} \tan\theta_o \tag{8}$$

where θ_o is the angle the uncontracted rod forms with the direction of $\mathbf{v}^\circ$, Figure 1. By elimination

$$\cos^2\theta_o = \frac{\cos^2\theta}{1-\left(\frac{v^{\circ 2}}{c_o^2}\right)\sin^2\theta} \tag{9}$$

$$\ell = \ell_o\left[1-\left(\frac{v^{\circ 2}}{c_o^2}\right)\cos^2\theta_o\right]^{1/2} \tag{10}$$

From Equations (9) and (10) the length of a contracted rod, moving under an angle θ with its velocity $\mathbf{v}^\circ$ relative to the ether frame Σ°, follows as

$$\ell(\theta) = \ell_o\left[\frac{1-\frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}}{1-\frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\sin^2\theta}\right]^{1/2} = \text{inv} \tag{11}$$

By Equation (9) and $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \text{inv}$, the length of a rod moving with an arbitrary inclination relative to its absolute velocity $\mathbf{v}^\circ$ in the ether is a G-invariant, i.e., has the same length for observers in different inertial frames. In particular, $\ell(0) = \ell_o[1-(\mathbf{v}-\mathbf{w})^2/c_o^2]^{1/2}$ and $\ell(\pi/2) = \ell_o$.

Physical Clock Retardation

A clock can be realized by two mirrors held apart by a rod, between which a light signal is reflected back and forth (Janossy

1953). The theory of a light clock moving with an arbitrary angle relative to its absolute velocity was first worked out by Janossy under consideration of anisotropic light propagation (Janossy 1964, 1967). Since the velocity of a light flash in the ether frame $\Sigma^\circ(\mathbf{0})$ is isotropic, $c^\circ(\varphi^\circ) = c_o$, the velocity of this light flash in an arbitrary inertial frame $\Sigma(\mathbf{w})$ with ether velocity $\mathbf{w}$ is anisotropic, $\mathbf{c}(\varphi) = \mathbf{w} + \mathbf{c}^\circ(\varphi^\circ)$. Accordingly

$$c(\varphi) = (c_o^2 - w^2 \sin^2\varphi)^{1/2} + w\cos\varphi,\ 0 \le \varphi \le \pi \tag{12}$$

where φ is the angle between the light velocity $\mathbf{c}(\varphi)$ and the ether velocity $\mathbf{w}$. In particular, $c(0,\pi) = c_o \pm w$ (propagation downstream and upstream relative to the ether flow) and $c(\pi/2) = (c_o^2 - w^2)^{1/2}$. The corresponding velocities $c_\pm(\theta)$ for light propagation up (+) and down (–) the rod are by Figure 1 (Janossy 1964, 1971)

$$c_\pm(\theta) = (c_o^2 - v^{\circ 2}\sin^2\theta)^{1/2} \mp v^\circ\cos\theta,\ 0 \le \theta \le \pi \tag{13}$$

where $\theta = \pi - \varphi$ is the angle between the contracted rod and its velocity $\mathbf{v}^\circ$ relative to the ether.

The period of the light signal reflected back and forth between the mirrors of the light clock moving with a velocity $\mathbf{v}^\circ$ relative to the ether is, for an arbitrary rod-angle θ

$$\tau = \frac{\ell(\theta)}{c_+(\theta)} + \frac{\ell(\theta)}{c_-(\theta)} \tag{14}$$

Hence

$$\tau = \frac{2\ell_o}{c_o}\frac{\left[1 - \dfrac{v^{\circ 2}}{c_o^2}\sin^2\theta\right]^{1/2}}{1 - \dfrac{v^{\circ 2}}{c_o^2}} \tag{15}$$

or

$$\tau = \frac{\tau_o}{\left[1 - \dfrac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\right]^{1/2}} = \text{inv} \tag{16}$$

$$\tau_o = \frac{2\ell_o}{c_o} \tag{17}$$

by substitution of $c_\pm(\theta)$ from Equation (13) into Equation (14) and $\ell(\theta)$ from Equation (11) into Equation (15), respectively. Equation (16) gives the period of a light clock with arbitrary orientation θ, and velocity $\mathbf{v}^\circ$ in the ether. The corresponding rate of the light clock moving under an arbitrary rod angle θ with its velocity $\mathbf{v}^\circ$ relative to the ether is

$$\nu = \nu_o\left[1 - \frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\right]^{1/2} = \text{inv} \tag{18}$$

The clock period (16) and clock rate (18) are independent of the orientation of the clock in space since the period is derived from a 2-way light path in the clock. The period τ and rate ν are G-invariants, i.e., a given clock has the same period and the same rate for observers in different inertial frames.

The G-invariance of the clock period or rate is the necessary condition for the absolute nature of time in all inertial frames, $t = t' = t^\circ = \text{inv}$. The spatial independence of time is readily verified in the ether frame Σ°, since light propagates there isotropically with the speed c_o. Hence, in the ether frame Σ° we can synchronize fixed clocks B with a fixed clock A by means of light signals through the relation

$$\Sigma^\circ(\mathbf{0}):\ t_2 = t_1 + \Delta t,\ \Delta t = \tfrac{1}{2}(t_3 - t_1) \tag{19}$$

where t_2 is the local time with which the clock at B has been set, at the instant the light signal emitted at the local time t_1 by the clock at A arrived at B. Whereas t_3 is the local time recorded by the clock at A at the instant the light signal reflected by B arrived. Since in the ether frame Σ° the light travel time for the paths A→B or B→A is measured as $\Delta t = \frac{1}{2}(t_3 - t_1)$, the absolute time t exists simultaneously at the fixed points A and B, if the B-clock is set to the known time t_2 at the instant when it receives the light signal emitted from A at time t_1.

Synchronization of fixed, distant clocks is more involved in inertial frames $\Sigma(\mathbf{w})$ with ether flow, since in this case light propagates anisotropically with velocity $c(\varphi)$ between the fixed locations A and B of the clocks by Equation (12). In an arbitrary inertial frame $\Sigma(\mathbf{w})$, clocks at points B are synchronized with a clock at A as before through light signals via the relation

$$\Sigma(\mathbf{w}):\ t_2 = t_1 + \Delta t(\varphi) \tag{20}$$

$$\Delta t(\varphi) = \frac{\overline{AB}}{c(\varphi)} \tag{21}$$

where the contracted ($\mathbf{w} \ne \mathbf{0}$) distance $\overline{AB}$ between the clocks at A and B is measured by means of measuring rods. The light velocity $c(\varphi)$ is given by Equation (12) where φ is the angle between the direction A→B of the light signal and the ether velocity $\mathbf{w}$ in $\Sigma(\mathbf{w})$, e.g., $c(\varphi) = c_o \pm w$ if A→B is parallel or antiparallel to $\mathbf{w}$. It is seen that the ether velocity $\mathbf{w}$ has to be known by magnitude and direction for clock synchronization in inertial frames $\Sigma(\mathbf{w})$ with anisotropic light propagation.

The clock formulae (16) and (18) are of fundamental importance, since they indicate that only a clock which moves relative to the EM wave carrier, $\mathbf{v}^\circ = \mathbf{v} - \mathbf{w} \ne \mathbf{0}$, has a dilated period $\tau > \tau_o$ and retarded rate $\nu < \nu_o$, i.e., these effects are the result of the clock's interaction with the ether. A clock with a velocity $\mathbf{v} = \mathbf{w}$ in the inertial frame $\Sigma(\mathbf{w})$ has the highest rate, $\nu = \nu_o$, corresponding to a clock at rest in the ether, $\mathbf{v}^\circ = \mathbf{0}$.

The corresponding STR formula, $\nu = \nu_o[1 - v^2/c_o^2]^{1/2}$, which predicts that the clock frequency varies with the velocity $\mathbf{v}$ relative to the observer, is the source of paradoxes. E.g., for two identical clocks attached to two physically equivalent inertial frames Σ and Σ' (relative velocity $\mathbf{u}$), the observer in Σ claims that his clock has the highest rate ν_o and the rate of the clock in Σ' is only $\nu = \nu_o[1 - u^2/c_o^2]^{1/2}$. Whereas the observer in Σ' asserts that his clock has the fastest rate ν_o, and the rate of the clock in Σ is only $\nu = \nu_o[1 - u^2/c_o^2]^{1/2}$. This contradiction is unresolvable, since the STR provides no means to decide which of the identical clocks runs slower or faster. Such "paradoxes" do not exist in G-covariant electrodynamics, since the clocks in Σ and Σ' have different velocities $\mathbf{v}^\circ_{1,2}$ relative to the ether, and therefore, run at different invariant rates by Equation (18). E.g., the twin who moves faster relative to the ether ages slower, whereas the twin who moves with a lesser velocity relative to the ether ages at a faster rate.

Lorentz Force and EM Potentials

The force acting on a point charge e moving with an arbitrary non-uniform velocity $\mathbf{v}(t)$ in an EM field $\mathbf{E},\mathbf{B}$ of the inertial frame $\Sigma(\mathbf{r},t,\mathbf{w})$ with ether velocity $\mathbf{w}$ is, in G-covariant electrodynamics

$$\mathbf{F} = e(\mathbf{E}+\mathbf{v}\times\mathbf{B}) \tag{22}$$

$\mathbf{F} = \mathbf{F}' = \text{inv}$ is G-invariant since $\mathbf{E}+\mathbf{v}\times\mathbf{B} = \text{inv}$ and $e = \text{inv}$ in G-transformations $\Sigma \leftrightarrow \Sigma'$ (Wilhelm 1985a). A superficial interpretation of Equation (22) might suggest that this so-called Lorentz force is relative to the observer (STR), since it appears to depend only on the charge velocity $\mathbf{v}(t)$ relative to the observer of $\Sigma(\mathbf{r},t,\mathbf{w})$.

For the latter reason, Equation (22) is rewritten in a form which reveals the absolute nature (ether effect) of the Lorentz force relative to the vacuum substratum, namely

$$\mathbf{F} = e[\mathbf{E}+\mathbf{w}\times\mathbf{B}+(\mathbf{v}-\mathbf{w})\times\mathbf{B}] \tag{23}$$

where

$$\mathbf{E}+\mathbf{w}\times\mathbf{B} = \mathbf{E}^\circ = \text{inv} \tag{24}$$
$$\mathbf{B} = \mathbf{B}^\circ = \text{inv} \tag{25}$$
$$\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \text{inv} \tag{26}$$

are G-invariants (Wilhelm 1985a). Equations (23)–(26) clearly show that the Lorentz force $\mathbf{F} = \mathbf{F}^\circ = \text{inv}$ is an ether excitation, i.e., a force transferred onto the charge through the vacuum substratum. $\mathbf{F}$ is not relative to the observer (STR), since in Equation (23) $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \text{inv}$ is the charge velocity relative to the ether, and the remaining fields in Equation (23) are ether excitations by Equations (24)–(25).

Similarly, the absolute nature (ether effect) of the Lorentz force becomes obvious if we introduce the EM potentials through $\mathbf{E} = -\nabla\Phi - \partial\mathbf{A}/\partial t$, $\mathbf{B} = \nabla\times\mathbf{A}$. These relations are G-invariant, since they can be rewritten in the form (Wilhelm 1985a)

$$\mathbf{E}+\mathbf{w}\times\mathbf{B} = -\nabla(\Phi-\mathbf{w}\cdot\mathbf{A}) - \left(\frac{\partial}{\partial t}+\mathbf{w}\cdot\nabla\right)\mathbf{A} \tag{27}$$

$$\mathbf{B} = \nabla\times\mathbf{A} \tag{28}$$

where

$$\Phi-\mathbf{w}\cdot\mathbf{A} = \Phi^\circ = \text{inv} \tag{29}$$
$$\mathbf{A} = \mathbf{A}^\circ = \text{inv} \tag{30}$$

and

$$\nabla = \nabla^\circ = \text{inv},\ \frac{\partial}{\partial t}+\mathbf{w}\cdot\nabla = \frac{\partial}{\partial t^\circ} = \text{inv} \tag{31}$$

in G-transformations (Wilhelm 1985a). Insertion of Equations (27) and (28) into Equation (23) yields the Lorentz force in terms of the EM potentials,

$$\mathbf{F} = e\left[-\nabla(\Phi-\mathbf{w}\cdot\mathbf{A}) - \left(\frac{\partial}{\partial t}+\mathbf{w}\cdot\nabla\right)\mathbf{A} + (\mathbf{v}-\mathbf{w})\times(\nabla\times\mathbf{A})\right] \tag{32}$$

or

$$\mathbf{F} = e\left[-\nabla\Phi - \frac{\partial\mathbf{A}}{\partial t} + \mathbf{v}\times(\nabla\times\mathbf{A})\right] \tag{33}$$

since $\nabla(\mathbf{w}\cdot\mathbf{A}) = \mathbf{w}\cdot\nabla\mathbf{A} + \mathbf{w}\times(\nabla\times\mathbf{A})$ and the ether velocity $\mathbf{w}$ is uniform. By Equations (29)–(31), the G-invariance of the Lorentz force is apparent in Equation (32), whereas it is concealed in Equation (33). The representation (32) again demonstrates that the Lorentz force is not relative to the observer (STR), but relative to the ether, since $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ$ is the charge velocity relative to the substratum frame Σ°.

The above considerations also demonstrate that the "generalized" electric field $\mathbf{E}+\mathbf{w}\times\mathbf{B} = \mathbf{E}^\circ = \text{inv}$ has a more fundamental meaning than the "ordinary" electric field $\mathbf{E} \neq \mathbf{E}^\circ$, which is not invariant in G-transformations [Equation (22)]. Since the Lorentz force is an ether excitation, it has the same value in all inertial frames Σ. Without the vacuum substratum, the Lorentz force could not exist, since the ether is the medium through which the force $\mathbf{F}$ is transferred onto the charge e. The STR concept according to which EM force fields exist in an empty vacuum without EM field carrier reveals a lack of understanding of elementary physics.

Velocity Dependence of EM Mass and Momentum

A projectile moving in air generates a sonic wave field with energy U_s, the mass equivalent $m_s = U_s/c_o^2$ of which is negligible (even at hypersonic speeds) in comparison with the mass of this macroscopic body. On the other hand, a charged particle such as an electron or proton moving with a velocity $\mathbf{v}^\circ$ in the vacuum substratum excites an EM field in the substratum, the energy of which increases like $U \propto [1-v^{\circ 2}/c_o^2]^{-1/2}$. The mass equivalent $m = U/c_o^2$, even for a charge at rest in the ether, is large enough to explain the rest masses of elementary charged particles. For this reason, the EM mass of Lorentz and Abraham cannot be ignored (STR), in particular since elementary particles may be quasi-singular excitations of the vacuum substratum.

Let $\rho_o(\mathbf{r}^\circ)$ be the charge density field of an extended charged particle of net charge e, when the latter is at rest in the ether. If this particle moves with uniform velocity $\mathbf{v}^\circ = v^\circ\mathbf{a}_z^\circ$ in the ether frame $\Sigma^\circ(\mathbf{r}^\circ,t^\circ,\mathbf{0})$, it has a space charge field (Wilhelm 1990a)

$$\rho^\circ(\mathbf{r}^\circ,t^\circ) = \gamma\rho_o(x^\circ,y^\circ,\bar{z}^\circ) \tag{34}$$

where

$$\bar{z}^\circ = \gamma(z^\circ - v^\circ t^\circ),\ \gamma = [1-v^{\circ 2}/c_o^2]^{-1/2} \tag{35}$$

due to the contraction of the charge cloud in the direction of charge motion $\mathbf{v}^\circ$, Equation (5). Equation (34) satisfies the condition for uniform particle motion, $(\partial/\partial t^\circ + \mathbf{v}^\circ\cdot\nabla^\circ)\rho^\circ = 0$, and the constraint

$$\int_{-\infty}^{+\infty}\rho^\circ(\mathbf{r}^\circ,t^\circ)d^3r^\circ = \int_{-\infty}^{+\infty}\rho_o(x^\circ,y^\circ,\bar{z}^\circ)dx^\circ dy^\circ d\bar{z}^\circ = e \tag{36}$$

Since $\partial/\partial t^\circ = -v^\circ\partial/\partial z^\circ$ and $dz^\circ = \gamma d\bar{z}^\circ$, the wave equation for the scalar potential $\Phi^\circ(\mathbf{r}^\circ, t^\circ)$, which originates in the particle charge density $\rho^\circ(\mathbf{r}^\circ, t^\circ)$, reduces to the Poisson equation (Wilhelm 1990a)

$$\left[\frac{\partial^2}{\partial x^{\circ 2}} + \frac{\partial^2}{\partial y^{\circ 2}} + \frac{\partial^2}{\partial \bar{z}^{\circ 2}}\right]\Phi^\circ = -\frac{\gamma\rho_o(x^\circ, y^\circ, \bar{z}^\circ)}{\varepsilon_o} \qquad (37)$$

by Equation (34). Hence, the electric potential of the particle charge distribution moving with uniform velocity $\mathbf{v}^\circ$ is of the form

$$\Phi^\circ(\mathbf{r}^\circ, t^\circ) = \gamma\Phi_o(x^\circ, y^\circ, \bar{z}^\circ) \qquad (38)$$

where $\Phi_o(\mathbf{r}^\circ)$ is the corresponding solution for the charge distribution resting in Σ°. By Equation (38), the electric field components of the moving charge distribution $\rho^\circ(\mathbf{r}^\circ, t^\circ)$ are of the form

$$E^\circ_{x,y}(\mathbf{r}^\circ, t^\circ) = \gamma^2 E_{ox,y}(x^\circ, y^\circ, \bar{z}^\circ)$$
$$E^\circ_z(\mathbf{r}^\circ, t^\circ) = \gamma E_{oz}(x^\circ, y^\circ, \bar{z}^\circ) \qquad (39)$$

Equations (34), (38), and (39) constitute the self-similar solution with similarity variable $\bar{z}^\circ = \gamma(z^\circ - v^\circ t^\circ)$ for the extended charged particle in uniform motion with velocity $\mathbf{v}^\circ$ in the ether frame $\Sigma^\circ(\mathbf{r}^\circ, t^\circ, \mathbf{0})$. Note that the charge distribution $\rho_o(\mathbf{r}^\circ)$ for the particle at rest in Σ° is arbitrary.

The momentum of the EM field of the moving charge is $\mathbf{p}^\circ = c_o^{-2}\iiint \mathbf{E}^\circ \times \mathbf{H}^\circ\, d^3r^\circ$ where $\mathbf{H}^\circ = \varepsilon_o\mathbf{v}^\circ \times \mathbf{E}^\circ$ in the ether frame Σ° (Wilhelm 1990a). Accordingly

$$\mathbf{p}^\circ = \frac{\varepsilon_o}{c_o^2}\int_{-\infty}^{+\infty} \mathbf{E}^\circ \times (\mathbf{v}^\circ \times \mathbf{E}^\circ)\, d^3r^\circ \qquad (40)$$

If we make the plausible assumption that the charge distribution $\rho_o(\mathbf{r}^\circ)$ of the particle at rest in Σ° has spherical symmetry, then its electric field $\mathbf{E}_o(\mathbf{r}^\circ)$ is spherically symmetric, too, and we obtain

$$\mathbf{p}^\circ = \frac{4}{3}\frac{U_o}{c_o^2}\left[1 - \frac{v^{\circ 2}}{c_o^2}\right]^{-1/2}\mathbf{v}^\circ \qquad (42)$$

where

$$U_o = \frac{\varepsilon_o}{2}\int_{-\infty}^{+\infty} E_o^2(\mathbf{r}^\circ)\, d^3r^\circ \qquad (43)$$

is the electric field energy of the particle of charge density $\rho_o(\mathbf{r}^\circ)$ at rest in the ether, Σ°.

Thus, we arrive at the following formula for the momentum of the EM field of the extended charged particle moving with uniform velocity $\mathbf{v}^\circ$ in the ether frame $\Sigma^\circ(\mathbf{r}^\circ, t^\circ, \mathbf{0})$:

$$\mathbf{p}^\circ = m^\circ(\mathbf{v}^\circ)\mathbf{v}^\circ \qquad (44)$$

where

$$m^\circ(\mathbf{v}^\circ) = \frac{m_o}{\left[1 - \frac{v^{\circ 2}}{c_o^2}\right]^{1/2}} \qquad (45)$$

$$m_o = \frac{4}{3}\frac{U_o}{c_o^2} \qquad (46)$$

is the EM mass of the charged particle moving resp. at rest in the ether. The factor $\frac{4}{3}$ of the rest mass m_o can be shown to be 1 if stresses holding the charge together are taken into consideration (Fermi 1923).

Equations (44) and (45) are fundamental results, which show that the EM momentum and the EM mass of a charged particle are G-invariants:

$$\mathbf{p}^\circ(\mathbf{v}^\circ) = \mathbf{p}(\mathbf{v} - \mathbf{w}) = \text{inv} \qquad (47)$$
$$m^\circ(\mathbf{v}^\circ) = m(\mathbf{v} - \mathbf{w}) = \text{inv} \qquad (48)$$

since $\mathbf{v} - \mathbf{w} = \mathbf{v}^\circ = \text{inv}$ is the particle velocity relative to the vacuum substratum. Accordingly, $\mathbf{p}$ and m of a moving charged particle have the same value for observers in all inertial frames Σ. Thus, $\mathbf{p}$ and m are absolute ether effects, since the EM field of a moving charged particle is an excitation of the ether.

For comparison, the corresponding STR formulae are quoted, $\mathbf{p} = m(\mathbf{v})\mathbf{v}$ and $m(\mathbf{v}) = m_o[1 - v^2/c_o^2]^{-1/2}$; these depend on the particle velocity $\mathbf{v}$ relative to the observer (Σ). The unsoundness of the STR mass and momentum concepts is obvious, since they imply that $\mathbf{p}(\mathbf{v})$ and $m(\mathbf{v})$ vary with the velocity $\mathbf{v}$ relative to the observer, i.e., vary with the velocity of the observer, who does not interact with the particle.

Energy and Mass at High Velocities

The mass-energy equivalence $E_o = m_o c_o^2$, where E_o is energy in any form including EM energy, can be derived without recourse to STR space-time concepts (Lewis 1908). In G-covariant electrodynamics, we start with the invariant formula (45) for the velocity dependent mass of a high-velocity particle in the form

$$m^2\left(c_o^2 - v^{\circ 2}\right) = m_o^2 c_o^2 \qquad (49)$$

where

$$m = m(\mathbf{v}^\circ) = \text{inv} \qquad (50)$$

by Equation (45) has the same value in all inertial observation frames Σ. The differential of Equation (49) is

$$v^{\circ 2}dm + m\mathbf{v}^\circ \cdot d\mathbf{v}^\circ = c_o^2 dm \qquad (51)$$

Since the mass $m(\mathbf{v}^\circ)$ of a particle at high energies depends on the particle velocity $\mathbf{v}^\circ$ relative to the ether frame Σ°, the kinetic energy of a particle has to be defined by

$$K = K(\mathbf{v}^\circ) \qquad (52)$$

K has the same value in all inertial frames Σ, since $\mathbf{v}^\circ = \mathbf{v} - \mathbf{w} = \text{inv}$. Substitution of Equation (51) yields the fundamental kinetic energy-mass formulae for high-velocity particles:

$$K = mc_o^2 - m_o c_o^2 \qquad (55)$$

or

$$K = m_o c_o^2\left\{\left[1 - \frac{v^{\circ 2}}{c_o^2}\right]^{-1/2} - 1\right\} \qquad (56)$$

or

$$K + E_o = mc_o^2 \qquad (57)$$

where

$$E_o = m_o c_o^2 \qquad (58)$$

Equation (55) determines the kinetic energy $K(\mathbf{v}^\circ)$ of high energy particles with velocity-dependent mass $m(\mathbf{v}^\circ)$ in Galilean physics. Equation (58) indicates that (i) a mass m_o, which is at rest in the ether (Σ°), is equivalent to an energy $E_o = m_o c_o^2$ in any form, and (ii) an energy E_o in any form has an equivalent mass $m_o = E_o/c_o^2$.

Note that $K \cong \frac{1}{2} m_o v^{\circ 2}$ for $v^\circ \ll c_o$ by Equation (56), i.e., K does not reduce to the classical kinetic energy $K_{cl} = \frac{1}{2} m_o v^2$ at low velocities v of the body in the frame of observation Σ. However, $K \approx \frac{1}{2} m_o v^2$ equals the classical expression for $w \ll v \ll c_o$.

Galilean Measuring Process

Since the length $\ell = \ell_o[1-(\mathbf{v}-\mathbf{w})^2/c_o^2]^{1/2}$ of a measuring rod and the rate $\nu = \nu_o[1-(\mathbf{v}-\mathbf{w})^2/c_o^2]^{1/2}$ of a measuring clock are invariants (same value for observers in all inertial frames), the measurement of length (Δz) or time (Δt) intervals appears to be simple in Galilean physics. However, in comparing experimental results with the presented equations of high-velocity electrodynamics, we must take into consideration that the quantities $\Delta z_m > \Delta z$ and $\Delta t_m < \Delta t$ measured (m) by means of standard rods and clocks in an inertial frame $\Sigma(\mathbf{r}, t, \mathbf{w})$ with ether flow $\mathbf{w}$ are not the true measures (Δz, Δt), since the measuring rods are contracted and the measuring clocks are retarded in Σ. Accordingly, if measuring rods and clocks, moving with a velocity $\mathbf{v}$ in the frame of observation Σ are used, the following corrections have to be made:

$$\Delta z = \Delta z_m \left[1 - \frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\right]^{1/2} = \Delta z^\circ = \text{inv} \tag{59}$$

$$\Delta t = \frac{\Delta t_m}{\left[1 - \frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\right]^{1/2}} = \Delta t^\circ = \text{inv} \tag{60}$$

Note that the z-axis of the observation frame $\Sigma(\mathbf{r}, t, \mathbf{w})$ is in the direction of length contraction, $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \text{inv}$ ($\Delta x_m = \Delta x$, $\Delta y_m = \Delta y$). The units of length (meter = m) and time (second = s) would have to be defined by means of a "standard rod" and "standard clock" at rest in the ether frame $\Sigma^\circ(\mathbf{r}^\circ, t^\circ, \mathbf{0})$.

As a first illustration of the required corrections of the measured values, consider a rod of true length $\Delta z^\circ = 1$ m and a clock of true period $\Delta t^\circ = 1$ s at rest in the ether frame $\Sigma^\circ(\mathbf{r}^\circ, t^\circ, \mathbf{0})$. When these instruments are moved to an inertial frame $\Sigma(\mathbf{r}, t, \mathbf{w})$ with ether flow $\mathbf{w}$ and compared there with a standard rod and a standard clock, the ratios of the true to measured (m) values are (correction factors)

$$\frac{\Delta z}{\Delta z_m} = \left[1 - \frac{w^2}{c_o^2}\right]^{1/2} < 1 \tag{61}$$

$$\frac{\Delta t}{\Delta t_m} = \left[1 - \frac{w^2}{c_o^2}\right]^{-1/2} > 1 \tag{62}$$

In these relations, $\mathbf{v} = \mathbf{0}$ since the measuring standards and the objects measured are at rest in the frame of observation Σ.

Another example is the measurement of the 2-way velocity of light in an inertial frame $\Sigma(\mathbf{r}, t, \mathbf{w})$ with ether velocity $\mathbf{w}$ by means of a stationary clock at "O" and a stationary mirror at "M", where O and M are fixed positions on an optical table which are connected through an optical tube (light path) containing vacuum as depicted in Figure 2. Since Σ moves with a velocity $\mathbf{u}$ relative to the ether frame Σ°, the ether streams with a velocity $\mathbf{w} = -\mathbf{u}$ in Σ, i.e., through the optical tube OM and table, and the measuring instruments (Figure 2).

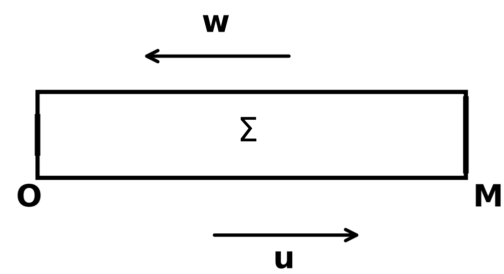

Figure 2: Inertial frame Σ (with fixed optical tube OM, clock at O, mirror at M, and ether velocity $\mathbf{w}$) moving with velocity $\mathbf{u} = -\mathbf{w}$ relative to the substratum.

Laying standard rods end to end with the optical tube OM, the distance OM is measured as Δz_m "m". Due to length contraction of the measuring rods in Σ, the true distance OM is in Σ

$$\Delta z = \Delta z_m \left[1 - \frac{w^2}{c_o^2}\right]^{1/2} \tag{63}$$

Using the standard clock at O, the travel time for both the forward light signal, O$\to$M, and the return light signal, M$\to$O, is measured as Δt_m "s". Due to retardation of the measuring clock, the true travel time is in Σ

$$\Delta t = \Delta t_m \left[1 - \frac{w^2}{c_o^2}\right]^{-1/2} \tag{64}$$

If the experiment were conducted with the same setup in the ether frame Σ° (isotropic light propagation), the velocity of light could be determined by means of the formula $c_o = 2\Delta z^\circ/\Delta t^\circ$, since the light signal is a disturbance of the light carrier. In the inertial frame $\Sigma(\mathbf{r}, t, \mathbf{w})$ under consideration, the 1-way velocities for signal propagation O$\to$M upstream ($\to$) and M$\to$O downstream ($\leftarrow$) relative to the ether flow $\mathbf{w}$ in the tube OM are (Figure 2)

$$c_o - w = \frac{\Delta z}{\Delta t_\rightarrow} \tag{65}$$

$$c_o + w = \frac{\Delta z}{\Delta t_\leftarrow} \tag{66}$$

These 1-way light velocities are not determined since the travel times for the forward signal, $\Delta t_\rightarrow$, and the return signal, $\Delta t_\leftarrow$, cannot be measured individually by means of one clock only. The total travel time for the forward and return signals measurable by the clock at O is

$$\Delta t = \frac{\Delta z}{c_o - w} + \frac{\Delta z}{c_o + w} = \frac{2\Delta z c_o}{c_o^2 - w^2} \tag{67}$$

Substitution of the true experimental measures from Equations (63) and (64) into Equation (67) gives for the measurement of the 2-way velocity of light in Σ:

$$c_o = \frac{2\Delta z_m}{\Delta t_m} \tag{68}$$

This surprising result indicates that the 2-way velocity of light, in an inertial frame Σ with ether flow $\mathbf{w}$, can be directly obtained from the measured values Δz_m and Δt_m, without any corrections whatsoever. Equation (68) is rigorously valid, since the length contraction and time dilation effects produced by the ether flow $\mathbf{w}$ have canceled out! Michelson and Morley conceived this formula "instinctively", and thus correctly measured the 2-way velocity of light (Michelson and Morley 1887).

To this date, the STR supporters have shown that they do not understood the physics behind Equation (68), since they misinterpret it in a trivial way by concluding that there can be no anisotropic light propagation $c_{\rightarrow} = c_o - w$ and $c_{\leftarrow} = c_o + w$ in Σ and, therefore, no ether or EM wave carrier, $\mathbf{w} \equiv \mathbf{0}$. This conclusion is not only a physical mistake, but an obvious logical blunder, as well.

Conclusions

The deductions presented here are based on G-covariant electrodynamics, i.e., on concepts of absolute space and time (meaning independent of the observer). Since the 3-dimensional space $\{x,y,z\}$ and the 1-dimensional time-line $\{t\}$ are infinite, real space and real time cannot be contracted and dilated, respectively, relative to the observer (STR) or relative to the ether. Maxwell's theory and its G-covariant generalization (Wilhelm 1984, 1985a) are Eulerian field theories, in which the spatial coordinates $\mathbf{r} = (x,y,z)$ and time coordinate t are independent variables, i.e., $\partial\mathbf{r}/\partial t = \mathbf{0}$ and $\partial t/\partial\mathbf{r} = \mathbf{0}$. The relativity principle, according to which one and the same (spherical) vacuum light signal propagates not only in the inertial frame $\Sigma(\mathbf{r},t,\mathbf{w})$ of its source but in all conceivable (∞^3) inertial frames $\Sigma'(\mathbf{r}',t',\mathbf{w}')$ with the same velocity c_o is represented in the STR through the invariants (Minkowski 1909)

$$x^2+y^2+z^2-c_o^2t^2 = 0 = x'^2+y'^2+z'^2-c_o^2t'^2 \tag{69}$$

which are connected through zero. Equation (69) led Minkowski (1909) to the prediction, "henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a union of both shall have an independent existence." In reality, these novel "space-time" concepts are based on a confusion of the Lagrangian coordinates $\xi(t)$, $\eta(t)$, $\zeta(t)$ of the spherical wave fronts with the Eulerian space variables x,y,z. Accordingly, the STR assertion of the interrelation of space and time has no physical meaning and, hence, no bearing on physics (Alfvén 1977).

These general comments on the physical irrelevance of the STR are further substantiated by the specific physical results presented, which are summarized as follows.

Nonrelativity of Space. A rod moving with a velocity $\mathbf{v}$ in an arbitrary inertial frame $\Sigma(\mathbf{r},t,\mathbf{w})$, i.e., with a velocity $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \text{inv}$ relative to the ether, experiences a length contraction $\ell = \ell_o[1-(\mathbf{v}-\mathbf{w})^2/c_o^2]^{1/2} = \text{inv}$ (same value for all observers in inertial frames), as a result of its interaction with the ether.

Nonrelativity of Time. A clock moving with a velocity $\mathbf{v}$ in an arbitrary inertial frame $\Sigma(\mathbf{r},t,\mathbf{w})$, i.e., with a velocity $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \text{inv}$ relative to the ether, experiences a rate retardation $\nu = \nu_o[1-(\mathbf{v}-\mathbf{w})^2/c_o^2]^{1/2} = \text{inv}$ (same value for all observers in inertial frames).

Nonrelativity of Mass. The mass of a charged particle moving with a velocity $\mathbf{v}$ in an arbitrary inertial frame $\Sigma(\mathbf{r},t,\mathbf{w})$, i.e., with a velocity $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \text{inv}$ relative to the ether, increases like $m = m_o[1-(\mathbf{v}-\mathbf{w})^2/c_o^2]^{-1/2} = \text{inv}$ (same value for all observers in inertial frames).

Nonrelativity of Velocity. The Lorentz force of the EM field acting on a charge e moving with a velocity $\mathbf{v}(t)$ in an arbitrary inertial frame $\Sigma(\mathbf{r},t,\mathbf{w})$ depends only on the velocity $\mathbf{v}-\mathbf{w} = \mathbf{v}^\circ = \text{inv}$ of the charge relative to the ether.

The effects of high particle velocities are important for velocities $v > 10^{-1}c_o$. The G-invariant formulae for rod length, clock rate, and particle mass reduce, in quasi-ether frames (negligible $\mathbf{w}$), to:

$$\ell = \ell_o\left[1-\frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\right]^{1/2} \cong \ell_o\left[1-\frac{v^2}{c_o^2}\right]^{1/2},\ w \ll v \tag{70}$$

$$\nu = \nu_o\left[1-\frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\right]^{1/2} \cong \nu_o\left[1-\frac{v^2}{c_o^2}\right]^{1/2},\ w \ll v \tag{71}$$

$$m = \frac{m_o}{\left[1-\frac{(\mathbf{v}-\mathbf{w})^2}{c_o^2}\right]^{1/2}} \cong \frac{m_o}{\left[1-\frac{v^2}{c_o^2}\right]^{1/2}},\ w \ll v \tag{72}$$

These approximations are the corresponding STR relations, which hold exactly in the ether frame, $\mathbf{w} = \mathbf{0}$. Equations (70)–(72) explain why the STR gives approximately correct results on the Earth (quasi-ether frame), where particle velocities $v > 10^{-1}c_o$ relative to the observer are practically the particle velocities relative to the ether, too, since $\mathbf{v}-\mathbf{w} \cong \mathbf{v}$ for $w \ll v$.

By Equations (23), (44), and (47), the equation of motion of a particle of rest mass m_o (in the ether), charge e, and velocity $\mathbf{v}(t)$ in an EM field $\mathbf{E},\mathbf{B}$ is, in an arbitrary inertial frame $\Sigma(\mathbf{r},t,\mathbf{w})$:

$$\frac{d[m(\mathbf{v}-\mathbf{w})]}{dt} = e[\mathbf{E}+\mathbf{w}\times\mathbf{B}+(\mathbf{v}-\mathbf{w})\times\mathbf{B}] \tag{73}$$

This fundamental equation is G-invariant, since $\mathbf{v}(t)-\mathbf{w} = \mathbf{v}^\circ(t^\circ) = \text{inv}$, $\mathbf{E}+\mathbf{w}\times\mathbf{B} = \mathbf{E}^\circ = \text{inv}$, $\mathbf{B} = \mathbf{B}^\circ = \text{inv}$, and $d[\mathbf{v}(t)-\mathbf{w}]/dt = d\mathbf{v}^\circ(t^\circ)/dt^\circ = \text{inv}$. The corresponding relativistic equation holds exactly for $\mathbf{w} = \mathbf{0}$ (ether frame) and approximately for $w \ll v(t)$ (quasi-ether frames).

This investigation completes the work initiated by Fitzgerald and Larmor (Whittaker 1954), which has been interrupted since 1905.

References

Aharonov, Y., and Bohm, D., 1959, Significance of electromagnetic potentials in quantum theory, *Phys. Rev.* 115:485.

Alfvén, H., 1977, Cosmology: Myth or science? in: *Cosmology, Philosophy, and Theology*, Eds. W. Yourgrau and A.D. Breck, Plenum, New York.

Builder, G., 1958a, Ether and relativity, *Aust. J. Phys.* 11:279.

Builder, G., 1958b, The constancy of the velocity of light, *Aust. J. Phys.* 11:457.

Conklin, E.K., 1969, Measurement of absolute velocity of Earth, *Nature* 222:971.

Fermi, E., 1923, Correction of a contradiction between the electrodynamic and relativistic theories of the electromagnetic mass, *Nuovo Cimento* 25:159.

Henry, P.S., 1971, Isotropy of 3°K background, *Nature* 231:516.

Janossy, L., 1953, Physical interpretation of the Lorentz transformation, *Ann. Physik* 11:293.

Janossy, L., 1964, Reflections on the problem of measuring the velocity of light, *Acta Phys. Hung.* 17:421.

Janossy, L., 1967, The paradoxes of the relativity theory, *Atom. Ener. Rev.* 5:159.

Janossy, L., 1971, *Theory of Relativity Based on Physical Reality*, Akadémiai Kiadó, Budapest.

Kennard, E.H., 1917, Unipolar induction: Another experiment and its significance as evidence for the existence of the ether, *Phil. Mag.* 33:179.

Lewis, G.N., 1908, A revision of the fundamental laws of matter and energy, *Phil. Mag.* 16:705.

Michelson, and Morley, E.W., 1887, The relative velocity of the Earth in the luminiferous ether, *Am. J. Sci.* 34:333.

Minkowski, H., 1909, Space and time, *Physik. Zeitschr.* 10:104.

Mueller, F.J., 1987, Seat of unipolar induction, in: *Progr. Space-Time Phys.*, Ed. J.P. Wesley, B. Wesley Publ., Blumberg, Germany.

Penzias, A.A, and Wilson, R.W., 1965, Measurement of the excess antenna temperature at 4080 Mc/s, *Astrophys. J.* 142:419.

Sagnac, G., 1913, The luminiferous ether demonstrated by the effect of relative motion of the ether in an interferometer in uniform rotation, *C.R.* 157:708.

Whittaker, E.T., 1954, *A History of the Theories of Aether and Electricity*, Nelson, London.

Wilhelm, H.E., 1970, Hydrodynamic model of quantum mechanics, *Phys. Rev.* D1:2278.

Wilhelm, H.E., 1984, Covariant electrodynamics of conducting media, *Fusion Techn.* 6:174.

Wilhelm, H.E., 1985a, Covariant electromagnetic theory for inertial frames with substratum flow, *Radio Sci.* 20:1006.

Wilhelm, H.E., 1985b, Galilei covariant quantum mechanics in electromagnetic fields, *Int. J. Math. and Math Sci.* 8:589.

Wilhelm, H.E., 1990a, Covariant electrodynamics in vacuum, *Z. Naturforsch.* 45a:736.

Wilhelm, H.E., 1990b, Electromagnetic field of accelerated charges in inertial frames with substratum flow, *Z. Naturforsch.* 45a:749.

Wilhelm, H.E., 1991, Shock waves and Cerenkov radiation in electromagnetic substratum, *Int. J. Math and Math Sci.* 14:769.

Wilhelm, H.E., 1992a, Dielectric Cerenkov effect in inertial frames with substratum flow, *Gal. Electrodyn.* 3:28.

Wilhelm, H.E., 1992b, Explanation of anomalous unipolar induction in corotating conductor-magnet arrangements, *Apeiron* 13:17.

Wilhelm, H.E., 1993, Electrodynamics of moving media with applications to the experiments of Fizeau and Hoek, *Apeiron* 15:1.