

Invariance of the Tetrad Postulate as a Fundamental Principle of Unified Field Theory

by

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Abstract

The tetrad postulate is proven to be an invariant of the general coordinate transformation in Cartan Riemann geometry. In Einstein Cartan Evans (ECE) unified field theory this inference implies that the ECE Lemma and wave equation are covariant in such a way that only the tetrad eigenfunction changes upon general coordinate transformation. The phase of the eigenfunction therefore changes by the addition of a dimensionless factor that is independent of distance and time. This factor is the origin of non-local effects in general relativity. There is no contradiction in concept between the local theory of general relativity and the non-local nature of this factor, because the latter is obtained by the fundamental principle of relativity, coordinate covariance. The invariance of the tetrad postulate is adopted as a fundamental principle to replace the gauge principle in ECE theory. A discussion is given of several experimental effects which can be described by this non-local factor, non-local in the sense that it does not depend on time and distance.

Keywords: Invariance of the tetrad postulate, ECE unified field theory, non-locality, coordinate transformation, general relativity.

1.1 Introduction

It is well known that the tetrad postulate [1] is the link between Cartan geometry, inferred in 1922, and Riemann geometry, inferred in the early nineteenth century. Without the tetrad postulate Cartan cannot be translated into Riemann as required for self consistency [2–10]. The tetrad postulate is

proven rigorously in refs. [1] to [10] and is a consequence of the fundamental definition of the second rank mixed index tensor known as the tetrad:

$$V^a = q_\mu^a V^\mu. \quad (1.1)$$

Here V^a is a vector in Minkowski space-time and V^μ a vector in the base manifold. The tetrad is q_μ^a , and has two indices, a and μ . It is therefore a second rank tensor whose covariant derivative is defined [1–10] to be:

$$D_\mu q_\nu^a := \partial_\mu q_\nu^a + \omega_{\mu b}^a q_\nu^b - \Gamma_{\mu\nu}^\lambda q_\lambda^a \quad (1.2)$$

where $\Gamma_{\mu\nu}^\lambda$ is the gamma connection of Riemann geometry and $\omega_{\mu b}^a$ the spin connection of Cartan geometry. The well known Christoffel connection is a special case of the gamma connection when the lower two indices are symmetric:

$$\Gamma_{\mu\nu}^\lambda = \Gamma_{\nu\mu}^\lambda \quad (1.3)$$

and when the torsion tensor is zero:

$$T_{\mu\nu}^\lambda = \Gamma_{\mu\nu}^\lambda - \Gamma_{\nu\mu}^\lambda = 0. \quad (1.4)$$

The “tetrad postulate” [1–10] is a direct consequence of the fact that a vector field is independent of the coordinate system in which it is expressed. “Tetrad postulate” is therefore something of a misnomer because it is in fact a fundamental property:

$$D_\mu q_\nu^a = 0 \quad (1.5)$$

independent of all connections [1–10].

In Section 1.2 it is shown that Eq. (1.5) is invariant under the general coordinate transformation, in other words the tetrad postulate is true in any frame of reference and is a fundamental property of general relativity. This property is adopted in Section 1.2 as a fundamental principle of Einstein Cartan Evans (ECE) field theory [2–10] and replaces the gauge principle by Ockham’s Razor. In consequence of this invariance principle the ECE Lemma and wave equation are shown in Section 1.2 to be covariant under the general coordinate transformation as required by general relativity. Furthermore the Lemma and wave equation are covariant in such a way that only the tetrad eigenfunction changes under the general coordinate transformation. The eigenoperator and eigenvalues do not change.

In Section 1.3 this property of the Lemma and wave equation is interpreted in terms of a dimensionless factor added to the phase of the eigenfunction

under general coordinate transformation. For example, if the original phase is considered to be:

$$\begin{aligned}\phi &= \kappa^\mu x_\mu \\ &= \omega t - \kappa Z\end{aligned}\tag{1.6}$$

the phase after general coordinate transformation is

$$\phi' = \kappa^\mu x_\mu + \alpha\tag{1.7}$$

where α is independent of x^μ , i.e. independent of time and distance. Here κ^μ is the wave-number four vector:

$$\kappa^\mu = \left(\frac{\omega}{c}, \boldsymbol{\kappa} \right)\tag{1.8}$$

and x_μ the coordinate four-vector:

$$x_\mu = (ct, -\mathbf{r})\tag{1.9}$$

where ω is angular frequency, t is time, Z is a coordinate for propagation along the Z axis and κ the wave-number magnitude. Therefore α is “non-local” in the sense that it is independent of x^μ . There is no contradiction with the local theory of relativity, because α is generated by a coordinate transformation - one of the fundamental principles of general relativity itself. Non-locality is defined therefore as the distance and time independence of α , a feature introduced through coordinate transformation of the ECE wave equation, the fundamental wave equation of physics.

In Section 1.4 it is shown that α is responsible for several experimental effects and a discussion is given of the shortcomings of gauge theory. The invariance of the tetrad postulate is adopted in preference to the gauge principle in generally covariant unified field theory.

1.2 Frame Invariance of the Tetrad Postulate

The general coordinate transformation in Riemann geometry for a tensor of any rank is [1-10]:

$$T_{\nu'_1 \dots \nu'_l}^{\mu'_1 \dots \mu'_k} = \left(\frac{\partial x^{\mu'_1}}{\partial x^{\mu_1}} \dots \frac{\partial x^{\mu'_k}}{\partial x^{\mu_k}} \right) \left(\frac{\partial x^{\nu_1}}{\partial x^{\nu'_1}} \dots \frac{\partial x^{\nu_l}}{\partial x^{\nu'_l}} \right) T_{\nu_1 \dots \nu_l}^{\mu_1 \dots \mu_k}\tag{1.10}$$

and the most basic property of general relativity is that the tensor transform as in Eq. (1.10). Otherwise it is not a tensor. For this reason the gamma connection is not a tensor [1] as is well known. A tensor in one frame of

reference must be a tensor in any other frame of reference, moving arbitrarily with respect to the original frame. The Christoffel connection, for example, transforms [1] as:

$$\Gamma_{\mu'\lambda'}^{\nu'} = \frac{\partial x^\mu}{\partial x^{\mu'}} \frac{\partial x^\lambda}{\partial x^{\lambda'}} \frac{\partial x^{\nu'}}{\partial x^\nu} \Gamma_{\nu\lambda}^\mu - \frac{\partial x^\mu}{\partial x^{\mu'}} \frac{\partial x^\lambda}{\partial x^{\lambda'}} \frac{\partial^2 x^{\nu'}}{\partial x^\mu \partial x^\lambda} \quad (1.11)$$

and because of the second term on the right hand side, does not transform as a tensor.

The spin connection on the other hand [1] transforms as a vector under the general coordinate transformation:

$$\omega_{\mu'b}^a = \left(\frac{\partial x^\mu}{\partial x^{\mu'}} \right) \omega_{\mu b}^a \quad (1.12)$$

and the tetrad transforms as:

$$q_{\mu'}^a = \left(\frac{\partial x^\mu}{\partial x^{\mu'}} \right) q_\mu^a. \quad (1.13)$$

In these transformations the a and b indices are kept constant, but the μ index is transformed. For pure rotational motion [2–10]:

$$\omega_{\mu b}^a = -\frac{\kappa}{2} \epsilon_{bc}^a q_\mu^c \quad (1.14)$$

so, self-consistently:

$$\omega_{\mu'b}^a = -\frac{\kappa}{2} \epsilon_{bc}^a q_{\mu'}^c. \quad (1.15)$$

This property means that Eq. (1.14) is generally covariant as required by general relativity. Eq. (1.14) is therefore a true tensorial equation and is a key equation in the derivation [2–10] of the ECE spin field. This equation can be constructed only in Cartan geometry, otherwise, as we have seen, the connection does not transform as a tensor. General covariance in the spin connection and tetrad must be defined as in Eqs. (1.12) and (1.13) for self-consistently.

If the Lorentz transformation [1] of special relativity is applied:

$$\omega_{\mu b'}^{a'} = \Lambda^a_{a'} \Lambda^b_{b'} \omega_{\mu b}^a - \Lambda^c_{b'} \partial_\mu \Lambda^{a'}_c \quad (1.16)$$

but:

$$q_{\mu'}^{a'} = \Lambda^{a'}_a q_\mu^a \quad (1.17)$$

and so Eq. (1.14) is not covariant under the Lorentz transformation. This finding is consistent with the fact that Eq. (1.14) is not an equation of translation, it is an equation of rotation. The Lorentz transform applies only to one frame translating at a constant velocity with respect to another (the limit of special relativity). This is the case for the Maxwell Heaviside (MH) field theory - a theory only of special relativity. Applying the Lorentz transform to MH theory is internally inconsistent therefore because MH theory deals with rotational motion as is well known. ECE theory is therefore the correct way to describe electrodynamics because ECE is correctly and generally covariant, not just Lorentz covariant. We have just illustrated this with respect to Eq. (1.14). Every equation of Cartan geometry is generally covariant, so every equation of ECE theory is generally covariant.

The frame invariance of the tetrad postulate is the property:

$$D_\mu q_\nu^a = (D_\mu q_\nu^a)' = 0 \quad (1.18)$$

under the general coordinate transformation. This is proven as follows, but firstly some basic definitions are given. The partial derivative transforms generally as [1]:

$$\partial_{\mu'} = \frac{\partial x^\mu}{\partial x^{\mu'}} \partial_\mu. \quad (1.19)$$

A vector in the base manifold transforms generally as:

$$V^{\mu'} = \left(\frac{\partial x^{\mu'}}{\partial x^\mu} \right) V^\mu \quad (1.20)$$

The Lorentz transform is the special case:

$$x^{\mu'} = \Lambda^{\mu'}{}_\mu x^\mu. \quad (1.21)$$

The symmetric metric transforms generally as a second rank tensor:

$$g_{\mu'\nu'} = \left(\frac{\partial x^\mu}{\partial x^{\mu'}} \right) \left(\frac{\partial x^\nu}{\partial x^{\nu'}} \right) g_{\mu\nu}. \quad (1.22)$$

The covariant derivative of Riemann geometry is defined as

$$D_\mu V^\nu = \partial_\mu V^\nu + \Gamma_{\mu\lambda}^\nu V^\lambda \quad (1.23)$$

and is DEFINED as a tensor, so that:

$$D_{\mu'} V^{\nu'} := \left(\frac{\partial x^\mu}{\partial x^{\mu'}} \right) \left(\frac{\partial x^{\nu'}}{\partial x^\nu} \right) D_\mu V^\nu. \quad (1.24)$$

This definition means that the Christoffel connection cannot be a tensor as we have argued already. The general mixed index tensor transforms as:

$$T_{b'\nu'}^{a'\mu'} = \Lambda^{a'}_a \frac{\partial x^{\mu'}}{\partial x^\mu} \Lambda^b_{b'} \frac{\partial x^\nu}{\partial x^{\nu'}} T_{b\nu}^{a\mu} \quad (1.25)$$

if both the Latin and Greek indices are transformed. However, the general coordinate transformation of the spin connection and tetrad are DEFINED [1] by Eqs. (1.12) and (1.13) as we have argued. Therefore the tetrad postulate transforms generally as:

$$D_{\nu'} q_{\mu'}^a = \left(\frac{\partial x^\nu}{\partial x^{\nu'}} \right) \left(\frac{\partial x^\mu}{\partial x^{\mu'}} \right) D_\nu q_\mu^a = 0 \quad (1.26)$$

because:

$$D_\nu q_\mu^a = 0 \quad (1.27)$$

Q.E.D.

Therefore the tetrad postulate is an invariant of Cartan Riemann geometry under the general coordinate transformation. We adopt this property as a fundamental principle to replace the gauge principle.

A direct consequence of this principle is that the ECE Lemma transforms as:

$$\square q_\mu^a = R q_\mu^a \quad (1.28)$$

$$\square' q_{\mu'}^a = R' q_{\nu'}^a \quad (1.29)$$

meaning that the Lemma is generally covariant as required. The transformation in Eq. (1.29) simplifies as follows. It is known that R is a scalar curvature [2–10], so that:

$$R = R'. \quad (1.30)$$

It is defined by:

$$R = -kT \quad (1.31)$$

where k is Einstein's constant and where T is another scalar quantity, the index reduced canonical energy momentum density defined by:

$$T = g^{\mu\nu} T_{\mu\nu} \quad (1.32)$$

where $T_{\mu\nu}$ is the canonical energy-momentum tensor. Furthermore the d'Alembertian is also frame invariant:

$$\square = \partial^\mu \partial_\mu = \square' = \partial^{\mu'} \partial_{\mu'} \quad (1.33)$$

so the Lemma transforms generally as follows:

$$\square q_\mu^a = R q_\mu^a \longrightarrow \square q_{\mu'}^a = R q_{\mu'}^a. \quad (1.34)$$

The wave equation transforms generally as follows:

$$(\square + kT) q_\mu^a = 0 \longrightarrow (\square + kT) q_{\mu'}^a = 0. \quad (1.35)$$

In electrodynamics the potential field is defined through the ECE ansatz as:

$$A_\mu^a = A^{(0)} q_\mu^a \quad (1.36)$$

where $cA^{(0)}$ has the units of volts. Here c is the speed of light, a constant of relativity. Therefore the fundamental wave equation of electrodynamics is:

$$(\square + kT) A_\mu^a = 0 \quad (1.37)$$

and under general transformation becomes:

$$(\square + kT) A_{\mu'}^a = 0. \quad (1.38)$$

When the electromagnetic field becomes independent of all other fields (notably, but not only, the gravitational field) the following limit is defined by the ECE principle of equivalence, a generalization of the Einstein principle of equivalence for the gravitational field:

$$kT = \left(\frac{mc}{\hbar} \right)^2 \quad (1.39)$$

Here m is the mass of the photon, and \hbar is the quantum of action or angular momentum. In this limit Eq. (1.37) is a generalization of the Proca equation [2–10]:

$$\left(\square + \left(\frac{mc}{\hbar} \right)^2 \right) A_\mu^a = 0. \quad (1.40)$$

For each index a (a polarization) Eq. (1.40) is the Proca equation. There is no difficulty in deriving the Proca equation from the fundamental principle (1.18) given the ECE Ansatz (1.36). In contrast the Proca equation cannot be derived from the gauge principle [11] as is well known. However, photon mass is essential to the Einstein Hilbert (EH) theory of the deflection of light by gravity, a theory known to be precise to one part on a hundred thousand after experiments by NASA Cassini in the solar system. Therefore the gauge principle should be abandoned and replaced by the invariance principle (1.18).

For fermionic fields [2–10] the general coordinate transform is:

$$(\square + kT)\psi = 0 \longrightarrow (\square + kT)\psi' = 0 \quad (1.41)$$

and for gravitational fields [2–10] it is:

$$(\square + kT)q_\mu^a = 0 \longrightarrow (\square + kT)q_{\mu'}^a = 0. \quad (1.42)$$

The field equations [2–10] of ECE theory are also generally covariant. Adopting a short-hand notation in which indices are left out for clarity, the electromagnetic field transforms generally as:

$$F = D \wedge A = d \wedge A + \omega \wedge A \quad (1.43)$$

$$F' = (D \wedge A)' = (d \wedge A)' + (\omega \wedge A)' \quad (1.44)$$

The homogeneous field equation transforms as:

$$d \wedge F = \mu_0 j \longrightarrow (d \wedge F = \mu_0 j)'. \quad (1.45)$$

The inhomogeneous field equation transforms as:

$$d \wedge \tilde{F} = \mu_0 J \longrightarrow (d \wedge \tilde{F} = \mu_0 J)'. \quad (1.46)$$

In these equations the homogeneous current j transforms as:

$$j = \frac{A^{(0)}}{\mu_0} (R \wedge q - \omega \wedge T) \longrightarrow j' \quad (1.47)$$

where R is the curvature form and T is the torsion form. Here μ_0 is the vacuum permeability, and:

$$j' = \frac{A^{(0)}}{\mu_0} (R \wedge q - \omega \wedge T)'. \quad (1.48)$$

The inhomogeneous current J is the Hodge dual of j and also transforms covariantly. In electrodynamics the basic invariance principle (1.18) becomes:

$$D_\mu A_\nu^a \longrightarrow (D_\mu A_\nu^a)' = 0. \quad (1.49)$$

In contrast [1] gauge theory is superfluous by Ockham's Razor, because it introduces an internal vector space that is an abstract concept, not a geometrical concept. The internal space is not related to the base manifold geometrically in gauge theory. The internal vector space of gauge theory is defined [1] as "...an independent addition to the manifold." The fibre bundle of gauge theory is the mathematical union of base manifold and the internal vector space. The gauge transform is the transform of a field defined in the fiber bundle. The gauge principle is that physical quantities are invariant under a gauge transform in the fiber bundle. Gauge theories are invariant under a gauge transform. Without having to go into any further detail of gauge theory it is seen that it is based on an additional postulate not present in Cartan Riemann geometry. This postulate is not needed by Ockham's Razor in ECE theory, where everything is defined geometrically and where the tangent bundle [1–10] replaces the fiber bundle. As we have seen, ECE theory successfully generalizes the Proca equation, and also reduces [2–10] to the EH theory in the limit of zero torsion. Gauge theory cannot produce the Proca equation, and so ECE is preferred to gauge theory for this reason as well as by Ockham's Razor.

1.3 Non-Locality from the Invariance Principle

The invariance principle adopted in this paper produces the transformation (1.35), where the flat space-time index a is kept constant [1]. (The principle is also correct if a is varied, but as explained in ref. [1], a is kept constant by definition when a general coordinate transform is applied, for example, to the spin connection. This is a matter of definition.) So the only variable that changes under the transformation (1.35) is the base manifold index μ . The basic mathematical property is that only the eigenfunction changes. The eigenvalues kT remain the same and the d'Alembertian operator is also invariant under the transformation. These properties derive from the invariance of the tetrad postulate, a basic geometrical property of Cartan geometry. Therefore the mathematical problem is to find eigenfunctions that have the

property (1.35). If it is assumed that the eigenfunction is a function multiplied by a phase factor, a simple solution may be found to the problem (1.35). Therefore it is assumed that the eigenfunction is:

$$q_\mu^a = q_\mu^a(0)e^{ix^\mu \kappa_\mu}. \quad (1.50)$$

The photon mass m appearing in the Proca equation, for example, is known experimentally to be non-zero (Eddington type of experiment, or NASA Cassini) but m is very small in magnitude. Therefore the Proca equation is well approximated by the d'Alembert equation. In free space the latter is generalized in ECE theory to:

$$\square A_\mu^a = 0. \quad (1.51)$$

The plane wave solutions to this equation are:

$$\mathbf{A}^{(1)} = \mathbf{A}^{(2)*} = \frac{A^{(0)}}{\sqrt{2}}(\mathbf{i} - \mathbf{j})e^{i(\omega t - \kappa Z)} \quad (1.52)$$

and it is seen that the phase factor in this case is:

$$\phi = \exp(i(\omega t - \chi Z)). \quad (1.53)$$

Under the coordinate transformation (1.35) these solutions must change in such a way that the phase factor becomes:

$$\phi' = e^{i\alpha} \phi \quad (1.54)$$

where α cannot depend on time (t) or distance (Z). This is because the eigenvalues of the Proca equation must be the same after transformation (1.35). If α depended on t and Z they would change after transformation. In this sense the transformation (1.35) when applied to the Proca equation produces a “non-local” factor α . A “local” theory of general relativity (i.e. the ECE field theory) has produced this result in a manner that is consistent with general covariance. A “local” theory, or field theory, is one on which an effect is transferred through a spacetime (x^μ) dependent field of force. A non-local effect is usually thought of as an action at a distance type effect. The ECE theory now shows that the terms “local” and “non-local” are entirely arbitrary, and should no longer be used. In Section 1.4 this result is applied to some experimental effects which in the standard model are usually thought of as being “non-local”, for example the Aharonov Bohm effects, quantum entanglement and so on. It is also shown in Section 1.4 that experiments that are impossible to describe with the Maxwell Heaviside theory are explained straightforwardly in ECE theory with the invariance principle introduced in

this paper. Examples include the Sagnac effect and the Faraday disk generator. The gauge theory of the Aharonov Bohm effect in the standard model is mathematically incorrect [2–10] as well as conceptually nearly impossible to apply or understand.

1.4 Application of the Invariance Principle to some Experimental Effects

The phase transformation [2–10]:

$$\phi' = e^{i\alpha}\phi \quad (1.55)$$

generates the Dirac Wu Yang phase from the conventional phase of the Maxwell Heaviside field theory. This is precisely the result (1.54) of the invariance transformation (1.35). Since α is arbitrary (it has no dependence on t or Z) this transformation is not gauge invariant. This contradicts [2–10] the usual assumption in the standard model that the MH theory is a U(1) invariant gauge field theory. It has been shown [2–10] that MH theory is incorrectly applied to the Aharonov Bohm (AB) effects. This is a basic mathematical flaw that has crept into the textbooks. This flaw is shown straightforwardly [2–10] by considering the conventional Stokes Theorem in differential form notation:

$$\oint_{dS} A = \int_S d \wedge A. \quad (1.56)$$

The U(1) gauge transform is:

$$A \longrightarrow A + d\chi \quad (1.57)$$

and

$$\oint_{dS} d\chi = \int_S d \wedge d\chi = 0 \quad (1.58)$$

from the Poincaré Lemma:

$$d \wedge d\chi := 0. \quad (1.59)$$

The Stokes Theorem (1.56) is true [2–10] in non simply connected spaces as well as simply connected spaces. This basic mathematical fact can be found

in a good textbook on vectors such as [12]. In the standard model description of the AB effects it is incorrectly asserted that:

$$\oint_{dS} d\chi \neq 0 \quad (1.60)$$

because of non simply connected topology. The correct (ECE) description of the of the AB effects [2–10] is given by the Stokes Theorem with covariant derivative:

$$\oint_{DS} A = \int_S D \wedge A \quad (1.61)$$

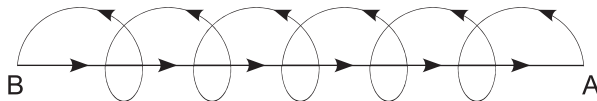
where the field is defined as:

$$F = D \wedge A := d \wedge A + \omega \wedge A \quad (1.62)$$

in a shorthand indexless notation [2–10] used for clarity and simplicity. The electromagnetic phase in generally covariant electrodynamics takes the general form:

$$\phi = \exp \left(ig \oint_{DS} A^{(3)} \right) = \exp \left(ig \int_S B^{(3)} \right) \quad (1.63)$$

This equation was interpreted as an integration around a helix [2–10]: in



which the only non-zero contribution is along the line B to A .

In vector notation, the AB effects are described by:

$$\phi = \exp \left(ig \int \mathbf{B}^{(3)} \cdot \mathbf{k} dAr \right) = \exp \left(g^2 \int \mathbf{A}^{(1)} \times \mathbf{A}^{(2)} \cdot \mathbf{k} dAr \right) \quad (1.64)$$

where:

$$\mathbf{B}^{(3)*} = -ig \mathbf{A}^{(1)} \times \mathbf{A}^{(2)} \quad (1.65)$$

is the ECE spin field [2–10]. Without the spin field there is no satisfactory explanation of the electromagnetic phase or AB effects. The spin field is

therefore a basic property of optics and electrodynamics. The magnetic flux (in weber) observed in an AB effect such as that due to a static magnetic field (Chambers experiment) is, in ECE theory:

$$\Phi = \oint_{DS} A + \int_S \omega \wedge A. \quad (1.66)$$

Experimentally, it is arranged that:

$$\oint_{DS} A = 0 \quad (1.67)$$

but a shift in the interference pattern of electron beams occurs due to:

$$\Phi = A^{(0)} \int_S \omega \wedge q \quad (1.68)$$

i.e. due to the spin connection of space-time itself. The AB effect therefore shows that space-time is spinning.

The dimensionless phase that accompanies the observed magnetic flux is:

$$\phi = \frac{e}{\hbar} \Phi. \quad (1.69)$$

So the AB effect is a phase shift due to spinning space-time. Other effects of this type [2–10] include the Sagnac effect and the Faraday disk generator. These are therefore effects of general relativity whereas MH is a theory of special relativity. Recall that the 1905 theory of special relativity by Einstein was derived from MH theory in tensor form (Lorentz and Poincare) and therefore from the work of Heaviside. The latter was the first to express the complicated quaternionic Maxwell theory in straightforward vector form, and he also developed vector theory in general. In MH theory, (standard model), if:

$$\oint A = 0 \quad (1.70)$$

then:

$$\Phi = \int_S F = \oint_{dS} A = 0 \quad (1.71)$$

and there is no phase shift:

$$\phi = 0. \quad (1.72)$$

So there is no AB effect in MH theory.

In ECE theory, the phase shift of the AB effect is non-zero and given in shorthand notation by:

$$\phi = \frac{eA^{(0)}}{\hbar} \int_S \omega \wedge q. \quad (1.73)$$

The invariance transform produced in this paper gives valuable additional insight into the origin of the AB effect (and other effects) because ϕ of Eq. (1.73) may be identified with α of Eq. (1.7). These effects are produced by spinning space-time, and the phase factor:

$$\phi_S = e^{i\alpha} \quad (1.74)$$

may be considered as a rotation generator [2–10], a generator of space-time rotation. It has been argued in Section 1.3 that this phase factor is the result of the invariance of the tetrad postulate under general coordinate transformation. Spin transformation due to a spin or rotation generator is a special case of a general coordinate transformation. Note carefully that a spin transformation cannot occur in special relativity, and so cannot occur in MH theory. The reason is that MH is Lorentz covariant, and the Lorentz transformation does not apply to rotation [1]. In special relativity [1] there can be only spacetime coordinate translations:

$$x^\mu \rightarrow x^\mu + a^\mu \quad (1.75)$$

or a Lorentz boost due to the constant TRANSLATION of one frame with respect to another:

$$x^\mu \longrightarrow \Lambda^{\mu'}_{\nu} x^\nu. \quad (1.76)$$

Rotation generators occur in the Lorentz and Poincaré groups [2–10] but these are defined in Minkowski space-time in which there is no spin connection. In summary therefore the AB effects are described by a spin connection and by the rotation generator (1.74). These are both concepts of Cartan geometry which do not appear in special relativity.

The Sagnac effect has been considered [2–10] as a phase transformation due to:

$$\omega_1 t \longrightarrow (\omega_1 \pm \Omega) t \quad (1.77)$$

where Ω is the angular frequency of the platform rotation and ω_1 the angular frequency of light going around the platform in an interferometer. The Sagnac effect is essentially the time delay:

$$\Delta t = 2\pi \left(\frac{1}{\omega_1 - \Omega} - \frac{1}{\omega_1 + \Omega} \right) \quad (1.78)$$

and this is also the ring laser gyro effect known to great precision. The corresponding phase factor transformation in the Sagnac effect is:

$$\phi = \exp(i\omega t) \longrightarrow \exp(\pm i\Omega t) \phi \quad (1.79)$$

and $\pm\Omega t$ can now be identified with α of Eq. (1.74). The Sagnac effect is easily understood therefore as being due to the invariance of the tetrad postulate. There is no explanation for the Sagnac effect in MH theory (U(1) gauge theory) because the MH equations are invariant under rotation.

A similar simple explanation is given for the Faraday disk generator [2–10], which can now be understood as being due to the invariance of the tetrad postulate of ECE theory and Cartan geometry. Therefore these experimental effects are due to the basic property of vector fields embodied in the tetrad postulate. Again, there is no explanation for the Faraday disk generator (1831) in the MH theory, and this is again due to the fact that space-time spin is not considered in MH theory. Finally, quantum entanglement [2–10], the “archetypical non-local effect” is now understood by the factor α applied to the Schrödinger equation, which is a limit of the ECE wave equation. It is well known that the standard model description of entanglement is enormously convoluted - based on the flawed Bohr Heisenberg uncertainty. There are so many interpretations of standard model quantum mechanics now as to render them all meaningless contrivances of subjectivity, rather than the rigorous objectivity evident in ECE theory.

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