Electromagnetic theory and transformations between reference frames: A rebuttal

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Abstract:
In a previous article published on viXra (http://viXra.org/abs/1505.0140), I proposed a modified version of Hertz-Phipps electromagnetism, an alternative theory to Maxwell's electromagnetism invariant under Galilean transformations. The aim was to stimulate interest and further analysis by the physics community.
Upon careful reconsideration, the proposed theory has proven inadequate as a physically realistic description.

Introduction:
Prof. Franco Selleri's book Weak Relativity (Melquiades Editions, ISBN 978-88-6218-711-4) presented a coherent alternative description of space and time, challenging my earlier conviction that Minkowski's space-time structure was inevitable. This prompted me to reevaluate alternative hypotheses for the description of space and time in physics.

Since adopting a different conception of space and time requires abandoning Lorentz transformations, and since Maxwell's equations are covariant under those transformations, it follows that the Maxwellian description of electromagnetic phenomena must also be reconsidered.
This led me to explore alternative electromagnetic theories not bound to Minkowski space-time. Inspired by Thomas E. Phipps, Jr.'s theory in his 2006 book Old Physics for New (Apeiron, ISBN 0-9732911-4-1), I attempted to formulate a Galilean-invariant theory of electromagnetism.
I presented this proposal on viXra (http://viXra.org/abs/1505.0140) in the hope of encouraging further discussion. Since this did not occur, I decided to critically evaluate the theory myself.

Recap of Maxwell's Electromagnetism in Vacuum
Maxwell's equations in vacuum are:
(1):

$$\nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0}$$

(2):

$$\nabla \cdot \vec{B} = 0$$

(3):

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

(4):

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$$

where ***E*** is the electric field, ***B*** is the magnetic flux density, ***ρ*** is the charge density, ***J*** is the current density, ε_0 is the permittivity of free space, and μ_0 is the permeability of free space.
These equations, together with the Lorentz force law (5):

$$\vec{F} = q\left(\vec{E} + \vec{v} \times \vec{B}\right)$$

where ***q*** is the charge of a particle and ***v*** is its velocity, provide a complete description of classical electromagnetism in vacuum.
Maxwell's equations are covariant under Lorentz transformations, which means they take the same form in all inertial reference frames in the framework of special relativity.

Recap of Hertz-Phipps Electromagnetism in Vacuum

Hertz-Phipps equations in vacuum are:
(1H):

$$\nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0}$$

(2H):

$$\nabla \cdot \vec{B} = 0$$

(3H):

$$\nabla \times \vec{E} = -\frac{d\vec{B}}{dt}$$

(4H):

$$\nabla \times \vec{B} = \mu_0 \ \vec{J}_m + \mu_0 \varepsilon_0 \frac{d\vec{E}}{dt}$$

similar to Maxwell's, but using the total time derivative instead of partial derivatives.
The total time derivative is defined as the limit of the ratio between the variation of a quantity along the trajectory of a detector particle and the corresponding time interval, as the interval approaches zero. Let xp(t), yp(t), zp(t) denote the coordinates of the detector (a classical point particle) in frame S.
Then, applying the chain rule:

$$\frac{d}{dt} = \frac{\partial}{\partial t} + \vec{v}_d \cdot \nabla$$

where $\boldsymbol{v_d}$ is the velocity of the detector experiencing the fields in the inertial reference frame ***S***.
Employing the total time derivative operator in the field equations implies evaluating temporal variations not at fixed points in ***S***, but at points moving with the detector's instantaneous velocity.
Thus, temporal variations are evaluated in the non-inertial (but non-rotating) reference frame $\boldsymbol{S_d}$, moving with velocity $\boldsymbol{v_d}$ relative to ***S***.
The Hertz-Phipps force law is (5H):

$$\vec{F} = q \ \vec{E}$$

In the Hertz-Phipps formulation, the force on a charged particle depends only on the electric field at the particle's location, and not on the magnetic flux density. The motion of the detector relative to the fields in the observer's reference frame is taken into account, indirectly, by means of the total time derivative in the equations.
The use of the total time derivative makes the Hertz-Phipps equations invariant under Galilean transformations.
The current density $\vec{J}_m$ in ***S*** is interpreted as the current density "seen" by a detector moving with velocity $\boldsymbol{v_d}$ in ***S***.
The current density $\vec{J}_m$ relates to the Maxwellian current density $\vec{J}$ by (6H):

$$\vec{J}_m = \vec{J} - \rho \ \vec{v}_d$$

Inadequacy of Hertz-Phipps Theory and Attempts at Correction

The Hertz-Phipps theory incorrectly predicts the forces between circuits carrying steady currents.
To address this, I explored a modification in which the divergence of the electric field perceived by the detector depends on an equivalent charge density ρ_m, a function of the detector-source relative velocity.
This implies that stationary charges might experience forces from steady currents. The interaction between fields and lattice charges must be considered. In such a model, predictions regarding forces between static circuits match Maxwell's results.
Additional modifications were considered to account for possible instantaneous interaction components. However, these were unrelated to the core inconsistencies of the theory.

Recap of modified Hertz-Phipps electromagnetism

(n1):

$$\vec{E} = \vec{E}_1 + \vec{E}_2$$

(n2):

$$\vec{B} = \vec{B}_1 + \vec{B}_2$$

(n3):

$$\nabla \cdot \vec{E}_1 = \frac{\rho_m}{\varepsilon_0}$$

(n4):

$$\nabla \times \vec{E}_1 = 0$$

(n5):

$$\nabla \cdot \vec{E}_2 = 0$$

(n6):

$$\nabla \times \vec{E}_2 = -\frac{d\vec{B}}{dt}$$

(n7):

$$\nabla \cdot \vec{B}_1 = 0$$

(n8):

$$\nabla \times \vec{B}_1 = \mu_0 \ \vec{J}_m$$

(n9):

$$\nabla \cdot \vec{B}_2 = 0$$

(n10):

$$\nabla \times \vec{B}_2 = \mu_0 \varepsilon_0 \frac{d\vec{E}}{dt}$$

(n11):

$$\vec{J}_m^{+} = \rho_+ (\vec{v}_+ - \vec{v}_d)$$

(n12):

$$\vec{J}_m^{-} = \rho_- (\vec{v}_- - \vec{v}_d)$$

(n13):

$$\vec{J}_m = \vec{J}_m^{+} + \ \vec{J}_m^{-}$$

(n14):

$$\rho_m^{+} = \rho_+ \left(1 + \frac{|\vec{v}_+ - \vec{v}_d|^2}{2\,c^2}\right)$$

(n15):

$$\rho_m^{-} = \rho_- \left(1 + \frac{|\vec{v}_- - \vec{v}_d|^2}{2\,c^2}\right)$$

(n16):

$$\rho_m = \rho_m^{+} + \ \rho_m^{-}$$

The use of an "apparent" charge dependent on the detector's state of motion is suggested by the analysis of a simple ideal experimental configuration. Let us consider a source consisting of an infinitely long straight wire carrying a steady current. We choose as a detector a point charge *q* placed at a certain distance from the wire and with an initial velocity $\mathbf{v_0}$ parallel to the wire.

According to Maxwell's electromagnetism, in $\mathbf{S_L}$, i.e., the laboratory reference frame in which the wire is stationary, the source is described as a region characterized by: $\boldsymbol{\rho = 0}$ and $\mathbf{J \neq 0}$.
In the space around the wire, we will have: $\mathbf{E = 0}$ and $\mathbf{B \neq 0}$.
The Lorentz force **F** exerted on the detector charge by the source through the fields is: $q\,\vec{v}_0 \times \vec{B}$ (oriented perpendicular to the wire).
If we change the reference frame and adopt, for example, the reference frame instantaneously at rest with the detector charge (i.e., the reference frame in which $\mathbf{v_0}$ is zero), the force component associated with the magnetic field vanishes. The force to which the detector is subjected must then be justified by the electric component; therefore, in this reference frame, the source no longer appears neutral.
A covariant description of the fields requires a covariant description of the sources.
The different description of a current-carrying conductor in different reference frames is made possible, recalling the conservation of electric charge, by the non-conservation of spatial intervals predicted by Lorentz transformations when changing reference frames.

According to Hertz-Phipps electromagnetism, which respects Galilean transformations (and therefore invariant lengths and volumes), the source is described in a way that is (generally) dependent on the detector's motion (through $\mathbf{v_d}$) but invariant with respect to the change of reference frame.
Expressing the force that the detector should perceive according to Hertz-Phipps theory through the potentials, we have:

$$\vec{F} = q\left(-\nabla\varphi - \frac{\partial \vec{A}}{\partial t}\right) - q(\vec{v}_d \cdot \nabla)\vec{A}$$

Applying this expression to the considered example, we will have: $\vec{F} = -q(\vec{v}_0 \cdot \nabla)\vec{A}$.
Since this force has no component perpendicular to the wire, one might think that this component (experimentally observable) could instead be associated with the scalar potential.
To this end, the scalar potential must be non-zero even in a context of neutrality.
It is possible to achieve this by making the potential a function of the detector's velocity.
For this function to be invariant under a change of reference frame, the velocities that appear in this function cannot be velocities referred to the observer (which can be chosen arbitrarily) but must only be invariant velocities (thus relative velocities of detector and sources).

Clear Inadequacy of the Amended Theory

The hypothesis lends itself to serious objections.
It was assumed that electric charges in an infinitesimal volume element **dV** (producing positive densities ρ_+ and negative densities ρ_-) are subject to orderly motion, with positive charges sharing velocity $\vec{v}_+$, and negative charges sharing velocity $\vec{v}_-$.
Only the average drift velocities of charge carriers were considered relevant for the analysis.
The question arises: why consider only average velocities of charge carriers, rather than instantaneous velocities? The only convincing justification would be a statistical cancellation of effects associated with different instantaneous velocities of individual charge carriers.
However, if expressions (N14) and (N15) are valid for instantaneous velocities, quadratic functions prevent cancellation of effects due to thermal motion of charges.
If expressions (N14) and (N15) were valid at the microscopic level, the instantaneous velocities of lattice charges and conduction electrons, which have different velocity distributions due to their different masses

and coupling to thermal lattice vibrations, would result in observable electric fields with a temperature dependence even in macroscopically neutral conductors.
However, experiments have never detected such electric fields. Neutral conductors, regardless of their temperature, do not produce measurable electric fields in their surroundings.
This discrepancy between the predictions of the modified theory and experimental observations clearly demonstrates that expressions (N14) and (N15) cannot be valid at the microscopic level, and the hypothesis of an apparent charge dependent on the detector's motion is unsustainable.

Conclusion

While the modified Hertz-Phipps theory offered an interesting alternative framework, it ultimately fails to align with experimental observations. In particular, the introduction of an apparent charge dependent on detector motion leads to predictions—such as temperature-dependent electric fields in neutral conductors—that are not borne out by empirical data. Therefore, despite its initial theoretical appeal, the model must be rejected as a realistic physical theory.