NEW ECE THEORY AND APPLICATIONS TO PHOTON MASS

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ABSTRACT

A new type of ECE theory is developed in which Proca type structures can be derived directly from the tetrad postulate of Cartan geometry. These structures have applications to electromagnetism and gravitation, and the interaction thereof. They also have applications to a new type of particle theory to be developed. The Proca structure is applied to photon mass theory and Euler Bernoulli structures are derived for resonance amplification of energy from spacetime interpreted in terms of photon mass. A novel Poynting theorem is derived.

Keywords: New ECE theory, Proca equations, photon mass.

UFT 245

1. INTRODUCTION

The Proca equations {1 - 10} were introduced in the mid thirties on the postulate of photon mass developed mainly by de Broglie and his well known school of thought. This school differs considerably from what is known as "standard" physics. Notably, the de Broglie school adheres to finite photon mass, the "standard" physics asserts in a most obscure manner that there is a particle without mass. Clearly, the concept of photon mass used by both schools is naive. There is much more to photon mass than meets the eye. In this paper the problem is analysed afresh in terms of a new type of ECE theory whose main advantage is its ability to derive Proca structures directly from the most fundamental theorem of geometry, the tetrad postulate of Cartan and his school of thought in mathematics. It is shown in Section 2 that the tetrad postulate leads directly and elegantly to both the wave and field equation of Proca. This result is true in electromagnetism and gravitation, and also in particle theory, in which the Proca equation has been mainly applied. In "standard" physics the Proca equation is ignored because it is not U(1) gauge invariant and effectively repudiates the whole of Higgs theory. The latter is regarded by the de Broglie / AIAS school as pseudoscience: the "cult science" of Feynman or "pathological science" of Langmuir. In Section 2 it is shown that the new ECE theory is a well defined part of the original ECE of 2003 developed in this series of two hundred an forty five papers to date. A novel Poynting theorem is derived and Euler Bernoulli resonance structures deduced. The photon mass is defined in a novel way, and the Yukawa potential discarded as unphysical. The photon mass means different things when derived from different experiments and different assumptions.

In Section 3 the novel Proca structures are developed in terms of the vacuum theory of Eckardt and Lindstrom.

2. NEW ECE THEORY AND PROCA STRUCTURES.

In the original ECE theory of 2003 {1 - 10} the electromagnetic field tensor is a vector valued two - form of Cartan geometry:

$$F^a_{\mu\nu} = f^a_{\mu\nu} - f^a_{\nu\mu} + \omega^a_{\mu b} A^b_\nu - \omega^a_{\nu b} A^b_\mu \quad -(1)$$

where A^a_μ is the electromagnetic potential, a vector valued one - form, and where $\omega^a_{\mu b}$ is the Cartan spin connection. Eq. (1) is based directly on the first Cartan structure equation with the hypotheses:

$$A^a_\mu = A^{(0)} q^a_\mu , \quad F^a_{\mu\nu} = A^{(0)} T^a_{\mu\nu} . \quad -(2)$$

The new ECE theory of this paper defines the subsidiary electromagnetic field:

$$f^a_{\mu\nu} = \partial_\mu A^a_\nu . \quad -(3)$$

Consider the tetrad postulate of Cartan geometry {1 - 11}:

$$D_\mu q^a_\nu = \partial_\mu q^a_\nu + \omega^a_{\mu b} q^b_\nu - \Gamma^\lambda_{\mu\nu} q^a_\lambda = 0 \quad -(4)$$

where $\Gamma^\lambda_{\mu\nu}$ is the gamma connection and q^a_μ the Cartan tetrad. Define:

$$\omega^a_{\mu\nu} = \omega^a_{\mu b} q^b_\nu , \quad \Gamma^a_{\mu\nu} = \Gamma^\lambda_{\mu\nu} q^a_\lambda \quad -(5)$$

and it follows that the tetrad postulate is:

$$\partial_\mu q^a_\nu = \Gamma^a_{\mu\nu} - \omega^a_{\mu\nu} := \Omega^a_{\mu\nu} . \quad -(6)$$

Eq. (3) follows directly from the subsidiary postulate:

$$f^a_{\mu\nu} = A^{(0)} \Omega^a_{\mu\nu} . \quad -(7)$$

Differentiate both sides of Eq. (7) to obtain:

$$\partial^\mu \partial_\mu q^a_\nu = \Box q^a_\nu = \partial^\mu \Omega^a_{\mu\nu} \quad -(8)$$

and define R as follows:

$$\partial^\mu \Omega^a_{\mu\nu} := -R q^a_\nu . \quad -(9)$$

With postulates (2) and (7) Eq. (9) gives the Proca field equation:

$$\partial^\mu g^a_{\mu\nu} + R A^a_\nu = 0 \quad -(10)$$

It follows from the definition (8) that:

$$(\Box + R)\, q^a_\mu = 0. \quad -(11)$$

This is the 2003 ECE wave equation. With Eq. (2), Eq. (11) becomes the ECE generalization of the Proca wave equation:

$$(\Box + R)\, A^a_\mu = 0 \quad -(12)$$

first derived in 2003.

It is seen that the Proca field and wave equations are subsidiary structures of the more general nonlinear structure (1) of the first Cartan structure equation of geometry. The B(3) field that is the basis of the ECE unified field theory is defined by:

$$B^a_{\mu\nu} = -ig\left(A^c_\mu A^b_\nu - A^c_\nu A^b_\mu\right) = \omega^a_{\mu b} A^b_\nu - \omega^a_{\nu b} A^b_\mu \quad -(13)$$

and is derived from the nonlinear part of the complete field tensor (1). In the B(3) theory:

$$\omega^a_{\mu b} = -ig A^c_\mu \epsilon^a{}_{bc} . \quad -(14)$$

Now define for each polarization index a:

$$g^{\mu\nu} = \partial^\mu A^\nu - \partial^\nu A^\mu \quad - (15)$$

It follows {1 - 10} that:

$$\partial^\rho g^{\mu\nu} + \partial^\nu g^{\rho\mu} + \partial^\mu g^{\nu\rho} = 0. \quad - (16)$$

This equation is the same as:

$$\partial^\mu \tilde{g}_{\mu\nu} = 0 \quad - (17)$$

where the tilde denotes the Hodge dual. It follows that :

$$\partial^\mu \tilde{g}_{\mu\nu} = 0 \quad - (18)$$

which is the homogeneous field equation of the Proca structure. Note that Eq. (6) allows the possibility of explaining the Aharonov Bohm effects with the assumption:

$$\Gamma^a_{\mu\nu} = \omega^a_{\mu\nu}. \quad - (19)$$

With this assumption the potential is non zero when the field is zero.

In UFT157 on www.aias.us the following relation was derived for each polarization index a:

$$j^\mu = -\frac{R}{\mu_0} A^\mu \quad - (20)$$

where the charge current density in S. I. Units is:

$$j^\mu = (c\rho, \underline{J}) \quad - (21)$$

and where the four potential in S. I. Units is:

$$A^\mu = \left(\frac{\phi}{c}, \underline{A} \right). \quad -(22)$$

Here μ_0 is the vacuum permeability and ϵ_0 the vacuum permittivity. So:

$$\rho = -\epsilon_0 R \phi \quad -(23)$$

and

$$\underline{J} = -\frac{R}{\mu_0} \underline{A} \quad -(24)$$

where ρ is the charge density, ϕ the scalar potential, $\underline{J}$ the current density and $\underline{A}$ the vector potential. A list of S. I. Units is given as follows:

$$\begin{aligned} \mu_0 &= J s^2 C^{-2} m^{-1} \\ \epsilon_0 &= J^{-1} C^2 m^{-1} \\ E &= J C^{-1} m^{-1} \\ B &= J s C^{-1} m^{-2} \\ A &= J s C^{-1} m^{-1} \end{aligned} \quad -(25)$$

$$\rho = C m^{-3}, \quad \phi = J C^{-1} = \text{volt}, \quad J = C m^{-2} s^{-1}$$

where $\underline{E}$ is electric field strength in volts per metre and $\underline{B}$ is magnetic flux density in units of tesla. The complete set of equations of the Proca structure is therefore:

$$f^a_{\mu\nu} = A^{(0)} \left(\Gamma^a_{\mu\nu} - \omega^a_{\mu\nu} \right) \quad -(26)$$

$$\partial^\mu f^a_{\mu\nu} + R A^a_\nu = 0 \quad -(27)$$

$$(\square + R) q^a_\mu = 0 \quad -(28)$$

$$\partial^\mu F^a_{\mu\nu} = \square A^a_\nu = -R A^a_\nu = \mu_0 j^a_\nu \quad -(29)$$

$$\partial^\mu \tilde{f}^a_{\mu\nu} = 0 \quad -(30)$$

$$j^\mu = -\frac{R}{\mu_0} A^\mu \quad -(31)$$

Now define the field tensor ($g_{\mu\nu}$) and its Hodge dual as:

$$g_{\mu\nu} = \begin{bmatrix} 0 & E_x/c & E_y/c & E_z/c \\ -E_x/c & 0 & -B_z & B_y \\ -E_y/c & B_z & 0 & -B_x \\ -E_z/c & -B_y & B_x & 0 \end{bmatrix} ; \quad \tilde{g}_{\mu\nu} = \begin{bmatrix} 0 & B_x & B_y & B_z \\ -B_x & 0 & E_z/c & -E_y/c \\ -B_y & -E_z/c & 0 & E_x/c \\ -B_z & E_y/c & -\frac{E_x}{c} & 0 \end{bmatrix} \quad -(32)$$

These definitions give the inhomogeneous Proca field equations under all conditions, including the vacuum:

$$\underline{\nabla} \cdot \underline{E} = \rho / \epsilon_0 = -R\phi \quad -(33)$$

$$\underline{\nabla} \times \underline{B} - \frac{1}{c^2}\frac{\partial \underline{E}}{\partial t} = \mu_0 \underline{J} = -R\underline{A} \quad -(34)$$

and the homogenous field equations:

$$\underline{\nabla} \cdot \underline{B} = 0 \quad -(35)$$

$$\underline{\nabla} \times \underline{E} + \partial \underline{B} / \partial t = \underline{0} \quad -(36)$$

under all conditions.

The solution of Eq. (33) is:

$$\phi = \frac{1}{\epsilon_0} \int \frac{\rho}{|\underline{x} - \underline{x}'|} d^3 \underline{x}' \quad -(37)$$

and from Eqs. (33) and (37):

$$\phi = -\frac{\rho}{\epsilon_0 R} = \frac{1}{\epsilon_0} \int \frac{\rho}{|\underline{x} - \underline{x}'|} d^3 \underline{x}' \quad -(38)$$

so:

$$\int \frac{\rho}{|\underline{x} - \underline{x}'|} d^3 \underline{x}' = -\frac{\rho}{R} \quad -(39)$$

where:

$$R = -q_a^{\nu}\, \partial^{\mu}\left(\Gamma^{a}_{\mu\nu} - \omega^{a}_{\mu\nu}\right). \quad -(40)$$

Therefore:

$$\int \frac{\rho(\underline{x}')\, d^3\underline{x}'}{|\underline{x} - \underline{x}'|} = \frac{\rho}{q_a^{\nu}\, \partial^{\mu}\left(\omega^{a}_{\mu\nu} - \Gamma^{a}_{\mu\nu}\right)}. \quad -(41)$$

The original Proca equations of the mid thirties assumed that:

$$q_a^{\nu}\, \partial^{\mu}\left(\omega^{a}_{\mu\nu} - \Gamma^{a}_{\mu\nu}\right) = \left(\frac{m_0 c}{\hbar}\right)^2 \quad -(42)$$

where m_0 is a rest mass. For electromagnetic fields in the vacuum this was assumed to be the photon rest mass, so the Proca equations were assumed to be equations of a boson with finite mass. More generally in particle physics this can be any boson. In Proca theory therefore the electromagnetic field is associated with a massive photon (i.e. a photon that has mass). As shown in this paper the massive photon is a direct consequence of the tetrad postulate of geometry. Therefore the original Proca equations of the thirties assumed:

$$\phi = \frac{1}{\epsilon_0}\left(\frac{\hbar}{m_0 c}\right)^2 \rho. \quad -(43)$$

It follows that:

$$\int \frac{\rho\, d^3\underline{x}'}{|\underline{x} - \underline{x}'|} = \left(\frac{\hbar}{m_0 c}\right)^2 \rho. \quad -(44)$$

From Eqs. (38) and (44):

$$\phi(\mathrm{vac}) = \frac{1}{\epsilon_0}\left(\frac{\hbar}{m_0 c}\right)^2 \rho(\mathrm{vac}) \quad -(45)$$

giving the photon rest mass as:

$$m_0^2 = \left(\frac{\hbar}{c}\right)^2 \frac{1}{\epsilon_0} \frac{\rho(\mathrm{vac})}{\phi(\mathrm{vac})} = 1.4 \times 10^{-74} \frac{\rho(\mathrm{vac})}{\phi(\mathrm{vac})} \quad -(46)$$

If it is assumed that the vacuum charge density is about the same order of magnitude as the vacuum scalar potential, the order of magnitude of the photon rest mass is:

$$m_0 \sim 10^{-37}\ \mathrm{kgm.} \quad -(47)$$

A list of experiments used to detect photon mass is given in ref. (12), and the result (46) is in agreement with the experimental photon mass. So it is concluded that there exists a vacuum charge current density which is about the same order of magnitude as the vacuum four potential.

Conservation of charge current density for each polarization index a means that:

$$\partial_\mu j^\mu = 0. \quad -(48)$$

From Eqs. (48) and (31):

$$\partial_\mu A^\mu = 0. \quad -(49)$$

In the "standard" physics Eq. (49) is known as the Lorenz condition, an arbitrary assumption. In the Proca theory the Lorenz condition is a direct result of the conservation of charge current density, one of the fundamental conservation theorems of physics. In the Proca theory the four potential is physical and so the U(1) gauge invariance of the "standard" physics is no longer true. In consequence the Higgs theory collapses.

From the well known radiative corrections {1 - 10} it is known experimentally that the vacuum contains charge current density. So it follows directly from Eq. (31) that it must contain a four potential, the vacuum four potential associated with photon mass. Therefore there are vacuum fields which in the non linear ECE theory of Eq. (1) include the longitudinal B(3) field {1 - 10}. The latter therefore exists in the vacuum and is linked to photon mass theory and Proca theory. In the "standard" physics the assumption of zero photon mass means that vacuum fields are purely transverse. This is geometrical nonsense, and leads to the unphysical E(2) little group as is well known {1 - 10}. So the "standard" physics is unphysical. In consequence there is no Higgs boson. The vacuum four potential is:

$$A^\mu(\mathrm{vac}) = \left(\frac{\phi(\mathrm{vac})}{c}, \underline{A}(\mathrm{vac}) \right) \quad -(50)$$

It follows that a circuit can pick up the vacuum four potential via the inhomogeneous Proca equations:

$$\underline{\nabla} \cdot \underline{E} = -R\,\phi(\mathrm{vac}) \quad -(51)$$

and

$$\underline{\nabla} \times \underline{B} - \frac{1}{c^2} \frac{\partial \underline{E}}{\partial t} = -R\,\underline{A}(\mathrm{vac}) \quad -(52)$$

In this process total energy is conserved through the relevant Poynting theorem derived as follows. Multiply Eq. (52) by $\underline{E}$:

$$\underline{E} \cdot (\underline{\nabla} \times \underline{B}) - \frac{1}{c^2} \underline{E} \cdot \frac{\partial \underline{E}}{\partial t} = -R\,\underline{E} \cdot \underline{A}(\mathrm{vac}) \quad -(53)$$

Use:

$$\underline{E} \cdot (\underline{\nabla} \times \underline{B}) = -\underline{\nabla} \cdot (\underline{E} \times \underline{B}) + \underline{B} \cdot \underline{\nabla} \times \underline{E} \quad -(54)$$

and Eq. (36) to find the Poynting theorem of conservation of total energy density:

$$\frac{\partial W}{\partial t} + \underline{\nabla} \cdot \underline{S} = \frac{R}{\mu_0} \underline{E} \cdot \underline{A}\,(\text{vac}). \quad -(55)$$

The electromagnetic energy density in joules per cubic metre is:

$$W = \frac{1}{2}\left(\epsilon_0 E^2 + \frac{1}{\mu_0} B^2\right) \quad -(56)$$

and the Poynting vector is:

$$\underline{S} = \frac{1}{\mu_0} \underline{E} \times \underline{B}. \quad -(57)$$

Eq. (56) defines the electromagnetic energy density available from the vacuum, more accurately spacetime. This process is governed by the Poynting theorem (55) and therefore there is conservation of total energy. There is electromagnetic energy density in the vacuum.

The relevant electromagnetic field tensor is:

$$f^a_{\mu\nu} = \partial_\mu A^a_\nu \quad -(58)$$

so either:

$$\underline{E} = -\underline{\nabla}\phi \quad -(59)$$

or:

$$\underline{E} = -\frac{\partial \underline{A}}{\partial t}. \quad -(60)$$

The antisymmetry of the Cartan torsion {1 - 10} means that the complete non-linear field of Eq. ( ) is antisymmetric:

$$F^a_{\mu\nu} = -F^a_{\nu\mu} = f^a_{\mu\nu} - f^a_{\nu\mu} + \omega^a_{\mu\nu} - \omega^a_{\nu\mu} \quad -(61)$$

The Cartan torsion is defined by:

$$T^{a}_{\mu\nu} = q^{a}_{\lambda} \cdot T^{\lambda}_{\mu\nu} \quad -(62)$$

where the antisymmetric torsion tensor $T^{\lambda}_{\mu\nu}$ is defined by the commutator of covariant derivatives:

$$[D_\mu, D_\nu] V^\rho = -T^{\lambda}_{\mu\nu} D_\lambda V^\rho + R^{\rho}{}_{\sigma\mu\nu} V^\sigma . \quad -(63)$$

The torsion tensor is defined by the difference of antisymmetic connections:

$$[D_\mu, D_\nu] V^\rho = -\left(\Gamma^{\lambda}_{\mu\nu} - \Gamma^{\lambda}_{\nu\mu}\right) D_\lambda V^\rho + R^{\rho}{}_{\sigma\mu\nu} V^\sigma \quad -(64)$$

and the tetrad postulate means that:

$$\Gamma^{a}_{\mu\nu} = -\Gamma^{a}_{\nu\mu} = \partial_\mu q^{a}_{\nu} + \omega^{a}_{\mu\nu} . \quad -(65)$$

It follows that the antisymmetry in Eq. (1) is defined by:

$$\partial^{a}_{\mu\nu} + \omega^{a}_{\mu b} A^{b}_{\nu} = -\left(\partial^{a}_{\nu\mu} + \omega^{a}_{\nu b} A^{b}_{\mu}\right) . \quad -(66)$$

If Eq. (60) is used for the sake of argument then the Poynting theorem becomes:

$$\frac{\partial W}{\partial t} + \underline{\nabla} \cdot \underline{S} = -\frac{1}{2}\frac{R}{\mu_0}\frac{\partial}{\partial t}\left(A^2(vac)\right) \quad -(67)$$

From Eq. (24):

$$\underline{A}(vac) = -\frac{\mu_0}{R} \underline{J}(vac) \quad -(68)$$

so we arrive at:

$$\frac{\partial W}{\partial t} + \underline{\nabla} \cdot \underline{S} = -\frac{1}{2}\mu_0 R \frac{\partial}{\partial t}\left(\frac{J^2(vac)}{R}\right) \quad -(69)$$

which shows that the vacuum energy density and vacuum Poynting vector are derived from the time derivative of the vacuum current density squared divided by R.

In practical applications we are interested in transferring the electromagnetic energy density of the vacuum to a circuit which can use the energy density. In an isolated circuit consider the equation:

$$\Box A_\mu^a = \mu_0 j_\mu^a \quad -(70)$$

When the circuit interacts with the vacuum:

$$j_\mu^a \rightarrow j_\mu^a + j_\mu^a(vac) \quad -(71)$$

so the Proca equations become:

$$\Box A_\mu^a = \mu_0\left(j_\mu^a + j_\mu^a(vac)\right) \quad -(72)$$

and

$$\partial^\mu F_{\mu\nu}^a = \mu_0\left(j_\mu^a + j_\mu^a(vac)\right) \quad -(73)$$

The Coulomb law is modified to:

$$\underline{\nabla} \cdot \underline{E} = \frac{1}{\epsilon_0}\left(\rho(circuit) + \rho(vacuum)\right) \quad -(74)$$

and the equation governing the scalar potential is:

$$(\Box + R)\phi = \frac{\rho(vac)}{\epsilon_0} \quad -(75)$$

The d'Alembertian operator is defined by:

$$\Box = \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \nabla^2 . \quad -(76)$$

The time dependent part of ϕ of the circuit is therefore defined by:

$$\frac{1}{c^2}\frac{\partial^2 \phi}{\partial t^2} + R\phi = \frac{\rho}{\epsilon_0}(\text{vacuum}) . \quad -(77)$$

The most fundamental unit of mass of the circuit is the electron mass m_e, whose rest angular frequency is defined by the de Broglie wave particle dualism:

$$R_e = \left(\frac{m_e c}{\hbar}\right)^2 = \frac{\omega_e^2}{c^2} = q^{\nu}_{a}\,\partial^{\mu}\left(\omega^{a}_{\mu\nu} - \Gamma^{a}_{\mu\nu}\right) \quad -(78)$$

So Eq. (77) becomes:

$$\frac{\partial^2 \phi}{\partial t^2} + \omega_e^2 \phi = \frac{c^2 \rho}{\epsilon_0}(\text{vacuum}) \quad -(79)$$

which is an Euler Bernoulli resonance equation provided that:

$$\frac{c^2 \rho}{\epsilon_0}(\text{vacuum}) = A\cos\omega t . \quad -(80)$$

The solution of the Euler Bernoulli equation:

$$\frac{\partial^2 \phi}{\partial t^2} + \omega_e^2 \phi = A\cos\omega t \quad -(81)$$

is well known to be

$$\phi(t) = \frac{A\cos\omega t}{(\omega_e^2 - \omega^2)^{1/2}} . \quad -(82)$$

At resonance:

$$\omega_e = \omega \quad -(83)$$

and the circuit's scalar potential become infinite for all A, however tiny in magnitude. This allows the circuit design of a device to pick up practical quantities of electromagnetic energy density from the vacuum by resonance amplification. The condenser plates used to observe the well known Casimir effect can be incorporated in the circuit design as in previous work by Eckart, Lindstrom and others.

From Eqs. (20) and (23):

$$\frac{c^2 \rho(vac)}{\epsilon_0} = -c^2 R\, \phi(vac). \quad -(84)$$

If we consider the space part of the scalar potential ϕ then:

$$\Box \rightarrow -\nabla^2 \quad -(85)$$

and for each polarization index a the Proca wave equation reduces to:

$$\nabla^2 \phi = \left(\frac{mc}{\hbar}\right)^2 \phi. \quad -(86)$$

The Laplacian in polar coordinates is defined by:

$$\nabla^2 \phi = \frac{\partial^2 \phi}{\partial r^2} + \frac{2}{r}\frac{\partial \phi}{\partial r} \quad -(87)$$

so there is a solution to Eq. (86) known as the Yukawa potential:

$$\phi = \frac{B}{r} \exp\left(-\left(\frac{mc}{\hbar}\right) r\right) \quad -(88)$$

This solution was used in early particle physics but was discarded as unphysical. The early experiments to detect photon mass {12} all assume the validity of the Yukawa potential. However, the basic equation:

$$\Box A_\mu = \mu_0 j_\mu \quad -(89)$$

also has the solutions:

$$\phi = \frac{e}{4\pi\epsilon_0}\left(\left(1-\underline{n}\cdot\frac{\underline{v}}{c}\right)|\underline{r}-\underline{r}'|\right)^{-1}_{t_r} \quad -(90)$$

and

$$\underline{A} = \frac{\mu_0 e \underline{v}}{4\pi}\left(\left(1-\underline{n}\cdot\frac{\underline{v}}{c}\right)|\underline{r}-\underline{r}'|\right)^{-1}_{t_r} \quad -(91)$$

which are the well known Liénard Wiechert solutions. Here t_r is the retarded time defined by:

$$t_r = t - \frac{1}{c}|\underline{r}-\underline{r}'|, \quad c = \frac{|\underline{r}-\underline{r}'|}{t-t_r} \quad -(92)$$

Therefore the static potential of the Proca equation is given by Eq. (90) with:

$$\underline{v} = \underline{0} \quad -(93)$$

and the static vacuum charge density in coulombs per cubic metre is given by:

$$\rho(vac) = -\left(\frac{mc}{\hbar}\right)^2 \frac{1}{4\pi}\left(\frac{e}{|\underline{r}-\underline{r}'|}\right)_{t_r} \quad -(94)$$

which is the Coulomb law for any photon mass.

This means that photon mass does not affect the Coulomb law, known to be one of the most precise laws in physics. Similarly the photon mass does not affect the Ampère Maxwell law or Ampère law. This is observed experimentally {12} within high contemporary experimental precision, so it is concluded that the usual Liénard Wiechert solution is the physical solution, and that the Yukawa solution is mathematically correct but not physical. On the other hand the "standard" physics ignores the Liénard Wiechert solution, and other solutions, and asserts arbitrarily that the Yukawa solution must be used in photon mass theory. The use of the Yukawa potential means that there are deviations from the Coulomb and Ampère laws. These have never been observed so the "standard" physics concludes that the photon mass is zero for all practical purposes zero. This is an entirely arbitrary conclusion based on the anthropomorphic claim of zero photon mass, an invalid, circular argument. The theory of this paper shows that the Coulomb and Ampère laws are true for any photon mass, so the latter cannot be determined from these laws. In other words these laws are not affected by photon mass in the sense that their form remains the same. For example the inverse square dependence of the Coulomb law is the same for any photon mass. The concept of photon mass is not nearly as straightforward as it seems, for example UFT244 shows that Compton scattering when correctly developed gives a photon mass much different from Eq. (47). There are unresolved questions in particle physics, because UFT244 has shown violation of conservation of energy in the basic theory of particle scattering.

3. VACUUM THEORY OF ECKARDT and LINDSTROM.

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3. Vacuum Theory of Eckardt and Lindstrom

An earlier version of the ECE electromagnetic vacuum [13] was defined by the absence of electric and magnetic fields throughout all of space at one particular time. This requires

$$F^{a\,(vac)}_{\mu\nu} = 0\ . \tag{95}$$

Equation (1) then becomes

$$f^{a\,(vac)}_{\mu\nu} - f^{a\,(vac)}_{\nu\mu} + \omega^{a}{}_{\mu b} A^{b\,(vac)}_{\nu} - \omega^{a}{}_{\nu b} A^{b\,(vac)}_{\mu} = 0\ . \tag{96}$$

The ECE equations of antisymmetry, resulting from an antisymmetric $\Gamma^{a}{}_{\mu\nu}$ are

$$f^{a\,(vac)}_{\mu\nu} + f^{a\,(vac)}_{\nu\mu} + \omega^{a}{}_{\mu b} A^{b\,(vac)}_{\nu} + \omega^{a}{}_{\nu b} A^{b\,(vac)}_{\mu} = 0\ . \tag{97}$$

Adding equations (96) and (97) gives

$$f^{a\,(vac)}_{\mu\nu} + \omega^{a}{}_{\mu b} A^{b\,(vac)}_{\nu} = 0\ . \tag{98}$$

Comparing this with equation (4) requires

$$\Gamma^{a\,(vac)}_{\mu\nu} = 0\ . \tag{99}$$

From equation (29) it is apparent that for a vacuum defined by equation (95)

$$R = 0\ , \tag{100}$$

indicating the absence of charge accumulations and current flow. Equation (29) then gives the vacuum wave equations as

$$\Box A^{a\,(vac)}_{\mu} = 0\ . \tag{101}$$

Equation (27) provides a more interesting structure using the constraint of equation (98)

$$\partial^{\mu}\left(\omega^{a}{}_{\mu b} A^{b\,(vac)}_{\nu}\right) = 0\ . \tag{102}$$

In vector notation, this equation gives

$$\frac{1}{c^2}\frac{\partial}{\partial t}\left(\omega^a_{0b}\phi^{b(vac)}\right) - \underline{\nabla}\cdot\left(\boldsymbol{\omega}^a_b\phi^{b(vac)}\right) = 0\ , \tag{103}$$

$$\frac{1}{c^2}\frac{\partial}{\partial t}\left(\omega^a_{0b}\boldsymbol{A}^{b(vac)}\right) - \left(\underline{\nabla}\cdot\boldsymbol{\omega}^a_b\right)\boldsymbol{A}^{b(vac)} - \boldsymbol{\omega}^a_b\cdot\underline{\nabla}\boldsymbol{A}^{b(vac)} = 0\ . \tag{104}$$

Equations (103) and (104) utilize the tetrads

$$\partial^\mu \rightarrow \left(\frac{1}{c}\frac{\partial}{\partial t}, -\underline{\nabla}\right), \tag{105}$$

$$\omega^a{}_{\mu b} \rightarrow \left(\frac{\omega^a_{0\,b}}{c}, -\boldsymbol{\omega}^a_b\right), \tag{106}$$

$$A^a_\mu \rightarrow \left(\frac{\phi^a}{c}, -\boldsymbol{A}^a\right). \tag{107}$$

For $\nu = 0$, equation (102) becomes

$$\frac{1}{c}\frac{\partial}{\partial t}\left(\frac{\omega^a_{0b}}{c}\frac{\phi^{b(vac)}}{c}\right) - \underline{\nabla}\cdot\left(\frac{\boldsymbol{\omega}^a_b\phi^{b(vac)}}{c}\right) = 0 \tag{108}$$

which is equation (103).

For $\nu = 1,2,3$, equation (102) becomes

$$\frac{1}{c}\frac{\partial}{\partial t}\left(\frac{\omega^a_{0b}}{c}\boldsymbol{A}^{b(vac)}\right) - \frac{\partial}{\partial x^i}\left(\omega^a{}_{i\,b}\boldsymbol{A}^b\right) = 0\ . \tag{109}$$

Note that

$$\frac{\partial}{\partial x^i}\left(\omega^a{}_{i\,b}\boldsymbol{A}^b\right) = \frac{\partial\omega^a{}_{i\,b}}{\partial x^i}\boldsymbol{A}^b + \omega^a{}_{i\,b}\frac{\partial\boldsymbol{A}^b}{\partial x^i} = \left(\underline{\nabla}\cdot\boldsymbol{\omega}^a_b\right)\boldsymbol{A}^{b(vac)} + \boldsymbol{\omega}^a_b\cdot\underline{\nabla}\boldsymbol{A}^{b(vac)}\ . \tag{110}$$

Substituting this into equation (109) gives equation (104).

We notice from [13] that the vacuum supports a topological charge density given by

$$\frac{\rho_{top}}{\varepsilon_0} = -\underline{\nabla}\cdot(\boldsymbol{\omega}\phi) \tag{111}$$

for a single polarization index with

$$\nabla^2\phi = -\frac{\rho_{top}}{\varepsilon_0} \ . \tag{112}$$

Substituting this into equation (103) for a single index polarization gives, for the scalar potential,

$$\nabla^2\phi + \frac{1}{c^2}\frac{\partial}{\partial t}(\omega_0\phi) = 0 \ . \tag{113}$$

If we assume that, following the developments in [13],

$$\omega_0 = \frac{\partial}{\partial t} log\left(\frac{1}{\phi}\right) , \tag{114}$$

then equation (113) is a standard wave equation for free space:

$$\nabla^2\phi - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\phi = 0 \ . \tag{115}$$

indicating that this indeed is a valid solution for the vacuum in the absence of charge density or current flow.

Finally, Eqs.(103,104) can be compared with the expressions of the energy density of the electromagnetic vacuum field derived in [13]:

$$u_{\phi,ECE} = \frac{1}{2}\varepsilon_0\left(\frac{1}{c^2}(\omega_0\phi)^2 + \sum_i|\omega_i\phi|^2\right), \tag{116}$$

$$u_{A,ECE} = \frac{1}{2\mu_0}\sum_i\left(\frac{1}{c^2}(\omega_0 A_i)^2 + |\omega_i A_i|^2\right). \tag{117}$$

It can be seen that the energy densities are very similar to the square values of Eqs.(103,104), with exception of the mixed product terms and missing derivatives. Eqs.(103,104) represent the Pointing theorem

$$\frac{\partial u}{\partial t} = \frac{\partial}{\partial t}\left(u_{\phi,ECE}+u_{A,ECE}\right) \ = -\underline{\nabla}\cdot\boldsymbol{S} \tag{118}$$

for the energy flow with Pointing vector **S** in the vacuum which had also been defined in [13]. Remember that the energy density in vacuo cannot be defined by electric and magnetic fields because these vanish in this type of macroscopic vacuum theory. Nevertheless the potential fields induce an energy density.

Additional References

[14] H. Eckardt, D. W. Lindstrom, "Solution of the ECE Vacuum Equations", publications section on www.aias.us