On the Vacuum Induced Periodicities Inherent to Maxwell Equations

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The hypothesis that the Planck's vacuum is inherent to all physical laws, given that it interact with massless elementary electrical charges, is examined exploring gauge invariance. It is then found that Compton's and de Broglie's periodicities, parameters of distinct vacuum induced fluctuations, are inherent to Maxwell equations.

Electromagnetic fields, in principle, are produced by electrical charges (and its movements), which are permanently actuated by the Planck's vacuum [1]. In this sense, it is expected that Maxwell's equations contain some (hidden) information about vacuum induced fluctuations.

The above hypothesis will be examined, firstly, considering the well-known redefinitions of the electromagnetic potentials that leaves the Maxwell equations unchanged, i.e.

$$\mathbf{A} \to \mathbf{A} + \nabla\chi, \quad \phi \to \phi - \partial_t\chi, \tag{1}$$

where χ is a scalar function (not as arbitrary as it may seem), together with the Lorenz condition (SI units)

$$c^{-2}\partial_t\phi + \nabla \cdot \mathbf{A} = 0, \tag{2}$$

which is not a condition (nor a gauge) but a physical law [2].

In order to preserve the local conservation law (2) under the redefinitions (1), χ must obey

$$\nabla^2\chi - c^{-2}\partial_{tt}\chi = 0, \tag{3}$$

as can be seen in the reference [3, p.2̇39]. This wave equation (and the assumptions to get it) suggests that electrical charges – regardless of their ordinary translational motions – present *local* periodical space-time evolutions at the light speed c. It means that massless elementary electrical charges (MEECs), everywhere, incorporate the local space-time evolution of the incoming zero-point radiation (ZPR). Apart randomness, this interpretation agrees with the Schrödinger's *zitterbewegung* [4]; i.e., electrons describe random curvilinear paths (Compton's angular frequency) at the light speed.

Aiming to proof that the periodicity of the *local* Eq.(3) is indeed the Compton's one, the observed motion will be introduced through the simple (but rich in content) relation

$$\mathbf{A} = \left(\phi/c^2\right)\mathbf{v}, \tag{4}$$

which relates the potentials of a free charged particle moving with velocity $\mathbf{v}$, as can be verified from the corresponding current density $\mathbf{J} = \rho\mathbf{v}$, where ρ is charge density, together with

$$\nabla^2\mathbf{A} - c^{-2}\partial_{tt}\mathbf{A} = -\mu_o\mathbf{J}, \quad \nabla^2\phi - c^{-2}\partial_{tt}\phi = -\rho/\epsilon_o. \tag{5}$$

Following the same steps that led to Eq.(3), to preserve the form of Eq.(4) – relativistic energy-momentum relation (per unit charge) – under the redefinitions (1), χ must obey

$$\nabla\chi + c^{-2}\partial_t\chi = 0. \tag{6}$$

Assuming that the inferred periodicity of χ obeys the standard phase $\omega t - \mathbf{k}\cdot\mathbf{x}$, the Eq.(6) implies

$$-\mathbf{k} + (\omega/c^2)\mathbf{v} = 0, \tag{7}$$

from which we obtain the *improper* phase velocity

$$v_p = \omega/|\mathbf{k}| = c^2/v; \tag{8}$$

i.e., the phase velocity of the inherent de Broglie wave.

The above result implies that ω is the Compton's angular frequency ($\gamma m_o c^2/\hbar$), and $|\mathbf{k}|$ is the de Broglie wave number ($\gamma m_o v/\hbar$), where γ is the Lorentz factor [5].

Notice, the periodicity of the (co-moving) Eq.(3) is therefore $m_o c^2/\hbar$, as inferred in connection with *zitterbewegung*.

The improper nature of v_p and its close relation with inertia [6] are indicative of vibrations triggered by "imminent" violations of the radiation speed limit (ZPR absorbed-emitted by MEECs) when the ordinary motion takes place (quantum wave-packet), as suggested in the reference [5].

Keep the form of Eq.(4), considering the non-uniqueness of $\mathbf{A}$ and ϕ, is convenient for comparing $e\mathbf{A} = (e\phi/c^2)\mathbf{v}$, calculated in the domain d of the extended charge e producing the potentials, with the relativistic relation $\mathbf{p} = (E/c^2)\mathbf{v}$. It means admitting that $\mathbf{p} = [e\mathbf{A}]_d$ and $E = [e\phi]_d$. This, besides agreeing with the classical electron radius as well as with the canonical momentum of a charged particle in an external field, in the sense that $\mathbf{P} = e\mathbf{A}_{tot} = e\mathbf{A} + e\mathbf{A}_{ext} = m\mathbf{v} + e\mathbf{A}_{ext}$, implies that the mass E/c^2 is of electromagnetic origin [7].

References

1. de la Peña L., Cetto A. M., Hernandez A. V. The Emerging Quantum The Physics Behind Quantum Mechanics. Springer, 2015.
2. Jefimenko O. D. Presenting electromagnetic theory in accordance with the principle of causality. *European Journal of Physics*, 2004, v. 25, 287–296.
3. Jackson J. D. Classical Electrodynamics. 3rd ed., John Wiley and Sons Inc., 1999.
4. Dirac P. A. M. The Principles of Quantum Mechanics. 4ed. Oxford University Press, 1958.
5. Ogiba F. On the Quantum-relativistic Behavior of Moving Particles. *Progress in Physics*, 2016, v. 12, n. 4, 325–328.
6. Wignall J. W. G. De Broglie waves and the nature of mass. *Foundations of Physics*, 1985, v. 15, n. 2, 207–227.
7. Griffiths D.J. Electromagnetic Momentum. *American Journal of Physics*, 2012, v. 80, n. 7, 7–18.