The Radiation Reaction of a Point Electron as a Planck Vacuum Response Phenomenon

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The polarizability of the Planck vacuum (PV) transforms the bare Coulomb field e_*/r^2 of a point charge into the observed field e/r^2, where e_* and e are the bare and observed electronic charges respectively [1]. In uniform motion this observed field is transformed into the well-known relativistic electric and magnetic fields [2, p.380] by the interaction taking place between the bare-charge field and the PV continuum. Given the involvement of the PV in both these transformations, it is reasonable to conclude that the negative-energy PV must also be connected to the radiation reaction or damping force of an accelerated point electron. This short paper examines that conclusion by comparing it to an early indication [3] that the point electron problem may involve more than just a massive point charge.

The nonrelativistic damping force

$$\frac{2e^2}{3c^3}\frac{d\ddot{\mathbf{r}}}{dt} \tag{1}$$

is the one experimentally tested fact around which the classical equations of motion for the point electron are constructed. The relativistic version of the equation of motion due to Dirac [3] can be expressed as [4, p.393]

$$m\,a^\mu = \frac{2e^2}{3c^3}\frac{v^\alpha(v_\alpha\dot{a}^\mu - \dot{a}_\alpha v^\mu)}{c^2} + F^\mu \tag{2}$$

where $\mu = 0, 1, 2, 3$; v^μ and a^μ are the velocity and acceleration 4-vectors; the dot above the acceleration vectors represents differentiation with respect to the proper time; and F^μ is the external 4-force driving the electron. The first term on the right side of (2) is the relativistic damping-force 4-vector that leads to (1) in the nonrelativistic limit. In the derivation of (2) Dirac stayed within the framework of the Maxwell equations; so the m on the left side is a derived electromagnetic mass for the electron.

In deriving (2) Dirac was not interested in the physical origin of the damping force (1) — he was interested in a covariant expression for the damping force that recovered (1) in the nonrelativistic limit, whatever it took. In the derivation he utilized a radiation-reaction field proportional to the difference between retarded and advanced fields [4, p.399]:

$$\frac{F^{\mu\alpha}_{\text{ret}} - F^{\mu\alpha}_{\text{adv}}}{2} \longrightarrow \frac{2e}{3c^3}\frac{(v^\mu\dot{a}^\alpha - \dot{a}^\mu v^\alpha)}{c} \tag{3}$$

where $F^{\mu\alpha}_{\text{ret}}$ and $F^{\mu\alpha}_{\text{adv}}$ are, respectively, the retarded and advanced electromagnetic field tensors for a point charge. The right side of (3) is the left side evaluated at the point electron. It is significant that this field difference is nonsingular at the position of the electron's charge, for the Maxwell equations then imply that the origin of the damping force and the field (3) *must be attributed to charged sources other than the electron charge* since that charge's Coulomb field diverges as $r \to 0$. This conclusion implies that a third entity, in addition to the electron charge and its mass, is the cause of the damping force.

It can be argued that this third entity is the omnipresent PV if it is assumed that the electron charge interacts with the PV in the near neighborhood of the charge to produce the damping force. Under this assumption, the advanced field in (3) represents in a rough way *the reaction field from the PV converging on the charge*. (To the present author's knowledge, there exists no other simple explanation for this convergent field.) Thus the superficial perception of the advanced field in (3) as a cause-and-effect-violating conundrum is changed into that of an acceptable physical effect involving the PV.

The Wheeler-Feynman model for the damping force [5] [4, pp.394–399] comes to a conclusion similar to the preceding result involving the PV. In their case the third entity mentioned above is a completely absorbing shell containing a compact collection of massive point charges that surrounds the point electron. The total force exerted on the electron by the absorber is [4, eqn.(21–91)]

$$e\sum_{i=1}^{n}\frac{F^{(i)}_{\text{ret}\,\mu\alpha}\,v^\alpha}{c} + \frac{2e^2}{3c^3}\frac{(v_\mu\dot{a}_\alpha - \dot{a}_\mu v_\alpha)\,v^\alpha}{c^2} \tag{4}$$

where $F^{(i)}_{\text{ret}\,\mu\alpha}$ is the retarded field tensor due to the i-th charged particle in an absorber containing n particles, and where the v_μs and a_μs are defined in (2). (The reader should note that the index i on the sum is defined somewhat differently here than in [4].) A central property of the electron-plus-absorber system is that there is no radiation outside that system. That is, the disturbance caused by the accelerated electron is confined to a neighborhood (the electron-plus-absorbed) surrounding the electron.

In summary, the importance of the PV theory to (1) and its covariant cousin in the Dirac radiation-reaction equation

(2) is that it explains the advanced field in (3) as a convergent field whose source is the PV. Also, it is interesting to note that the Wheeler-Feynman model for the damping force tends to support the PV model, where the free-space absorber is a rough approximation for the negative-energy PV in the vicinity of the accelerated electron charge.

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