A Massless-Point-Charge Model for the Electron

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"It is rather remarkable that the modern concept of electrodynamics is not quite 100 years old and yet still does not rest firmly upon uniformly accepted theoretical foundations. Maxwell's theory of the electromagnetic field is firmly ensconced in modern physics, to be sure, but the details of how charged particles are to be coupled to this field remain somewhat uncertain, despite the enormous advances in quantum electrodynamics over the past 45 years. Our theories remain mathematically ill-posed and mired in conceptual ambiguities which quantum mechanics has only moved to another arena rather than resolve. Fundamentally, we still do not understand just what is a charged particle" [1, p.367]. As a partial answer to the preceeding quote, this paper presents a new model for the electron that combines the seminal work of Puthoff [2] with the theory of the Planck vacuum (PV) [3], the basic idea for the model following from [2] with the PV theory adding some important details.

The Abraham-Lorentz equation for a point electron can be expressed as [4, p.83]

$$m\ddot{\mathbf{r}} = (m_0 + \delta m)\,\ddot{\mathbf{r}} = \frac{2e^2}{3c^3}\frac{d\ddot{\mathbf{r}}}{dt} + \mathbf{F}\,, \tag{1}$$

where

$$\delta m = \frac{4e^2}{3\pi c^2}\int_0^{k_{c*}} dk = \frac{4\alpha m_*}{3\pi^{1/2}} \tag{2}$$

is the electromagnetic mass correction; $e\,(= e_*\sqrt{\alpha}\,)$ is the observed electronic charge; α is the fine structure constant; e_* is the true or bare electronic charge; $k_{c*}\,(= \sqrt{\pi}/r_*)$ is the cutoff wavenumber for the mass correction [2, 5]; m_* and $r_*\,(= e_*^2/m_*c^2)$ are the mass and Compton radius of the Planck particles in the PV; m and m_0 are the observed and bare electron masses; and $\mathbf{F}$ is some external force driving the electron. One of the e_*s in the product $e^2\,(= \alpha e_*^2)$ comes from the free electronic charge and the other from the charge on the individual Planck particles making up the PV. The bare mass is defined via

$$m_0 = m - \delta m \approx -\alpha m_* \tag{3}$$

the approximation following from (2) and the fact that $\alpha m_* \gg m$. In other words, the bare mass is equal to some huge *negative* mass αm_*, an unacceptable result in any classical or semiclassical context.

The problem with the mass in (1) and (3) stems from assigning, ad hoc, a mass to the point charge to create the point electron, a similar problem showing up in quantum electrodynamics. The PV theory, however, derives the string of Compton relations [5]

$$r_* m_* c^2 = r_c m c^2 = e_*^2 \tag{4}$$

that relate the mass m and Compton radius $r_c\,(= e_*^2/mc^2)$ of the various elementary particles to the mass m_* and Compton radius r_* of the Planck particles constituting the negative energy PV. Since the same bare charge e_* is associated with the various masses in (4), it is reasonable to suggest that e_* is massless, implying that the electron charge is also massless. A massless-point-charge electron model is pursued in what follows.

The Puthoff model for a charged particle [2, 5] starts with an equation of motion for the mass m_0

$$m_0\ddot{\mathbf{r}} = e_*\mathbf{E}_{zp}\,, \tag{5}$$

where m_0, considered to be some function of the actual particle mass m, is eliminated from (5) by substituting the damping constant

$$\Gamma = \frac{2e_*^2}{3c^3 m_0} \tag{6}$$

and the electric dipole moment $\mathbf{p} = e_*\mathbf{r}$, where $\mathbf{r}$ represents the random excursions of the point charge about its average position at $\langle\mathbf{r}\rangle = 0$. The force driving the charge is $e_*\mathbf{E}_{zp}$, where $\mathbf{E}_{\rm zp}$ is the zero-point electric field [5, Appendix B]

$$\mathbf{E}_{zp}(\mathbf{r},t) = e_*\mathrm{Re}\sum_{\sigma=1}^{2}\int d\Omega_k \int_0^{k_{c*}} dk\, k^2\,\widehat{\mathbf{e}}_\sigma(\mathbf{k})\,\sqrt{k/2\pi^2}\,\times$$
$$\times\exp\left[i\left(\mathbf{k}\cdot\mathbf{r} - \omega t + \Theta_\sigma(\mathbf{k})\right)\right] \tag{7}$$

and $\omega = ck$. The details of the equation are unimportant here, except to note that this free-space stochastic field depends only upon the nature of the PV through the Planck particle charge e_* and the cutoff wavenumber k_{c*}.

Inserting (6) into (5) leads to the equation of motion

$$\ddot{\mathbf{p}} = \frac{3c^3\Gamma}{2}\,\mathbf{E}_{\rm zp} \tag{8}$$

for the point charge in the massless-charge electron model, where the mass equation of motion (5) is now discarded. The mass m of the electron is then defined via the charge's average kinetic energy [2, 5]

$$m \equiv \frac{2e_*^2}{3c^3} \frac{\left\langle \dot{\mathbf{r}}_2^2 \right\rangle}{c^2\Gamma}, \tag{9}$$

where $\dot{\mathbf{r}}_2$ represents the planar velocity of the charge normal to its instantaneous propagation vector $\mathbf{k}$, and where

$$\left\langle \dot{\mathbf{r}}_2^2 \right\rangle = \frac{3c^4(k_{c*}\Gamma)^2}{2\pi} \tag{10}$$

is the squared velocity averaged over the random fluctuations of the field.

The cutoff wavenumber and damping constant are determined to be [2, 5]

$$k_{c*} = \frac{\sqrt{\pi}}{r_*} \tag{11}$$

and

$$\Gamma = \left(\frac{r_*}{r_c}\right)\frac{r_*}{c} = \left(\frac{1.62\times10^{-33}}{3.91\times10^{-11}}\right)\frac{r_*}{c} \sim 10^{-66}\ [\text{sec}], \tag{12}$$

where the vanishingly small damping constant is due to the large number ($\sim 10^{99}$ per cm^3) of agitated Planck particles in the PV contributing their fields simultaneously to the zero-point electric field fluctuations in (7). This damping constant is assumed to be associated with the dynamics taking place within the PV and leading to the free-space vacuum field (7).

Inserting (11) and (12) into (9) and (10) yields

$$\frac{\left\langle \dot{\mathbf{r}}_2^2 \right\rangle}{c^2} = \frac{3}{2}\left(\frac{r_*}{r_c}\right)^2 \tag{13}$$

and

$$m = \frac{r_* m_*}{r_c} \tag{14}$$

where the result in (14) agrees with the Compton relations in (4). Equation (13) shows the root-mean-square relative velocity of the massless charge to be

$$\frac{\left\langle \dot{\mathbf{r}}_2^2 \right\rangle^{1/2}}{c} = \sqrt{\frac{3}{2}}\left(\frac{r_*}{r_c}\right) \sim 10^{-23} \tag{15}$$

a vanishingly small fraction of the speed of light. The reason for this small rms velocity is the small damping constant (12) that prevents the velocity from building up as the charge is randomly accelerated.

The equation of motion (8) of the point charge can be put in a more transparent form by replacing the zero-point field (7) with [3]

$$\mathbf{E}_{zp} = \sqrt{\frac{\pi}{2}}\,\frac{e_*}{r_*^2}\,\mathbf{I}_{\text{zp}}, \tag{16}$$

where $\mathbf{I}_{\text{zp}}$ is a random variable of zero mean and unity mean square $\left\langle \mathbf{I}_{\text{zp}}^2 \right\rangle = 1$. Making this substitution leads to

$$\ddot{\mathbf{r}} = \sqrt{\frac{9\pi}{8}}\left(\frac{m}{m_*}\right)\frac{c^2}{r_*}\mathbf{I}_{\text{zp}} = \sqrt{\frac{9\pi}{8}}\,\frac{c^2}{r_c}\mathbf{I}_{\text{zp}}, \tag{17}$$

where the factors multiplying $\mathbf{I}_{\text{zp}}$ are the rms acceleration of the point charge. The electron mass m now appears on the *right side* of the equation of motion, a radical departure from equations of motion similar to (1) and (5) that are modeled around Newton's second law with the mass multiplying the acceleration $\ddot{\mathbf{r}}$ on the left of the equation. The final expression follows from the Compton relations in (4) and shows that the acceleration is roughly equivalent to a constant force accelerating the charge from zero velocity to the speed of light in the time r_c/c it takes a photon to travel the electron's Compton radius r_c.

The overall dynamics of the new electron model can be summarized in the following manner. The zero point agitation of the Planck particles within the degenerate negative-energy PV create zero-point electromagnetic fields that exist in free space [5], the evidence being the e_* and k_{c*} in (7), the rms Coulomb field e_*/r_*^2 in (16), and the fact that $\mathbf{E}_{\text{zp}}$ drives the free-space charge e_*. When the charge is injected into free space (presumably from the PV), the driving force $e_*\mathbf{E}_{\text{zp}}$ generates the electron mass in (9), thereby creating the point electron characterized by its bare point charge e_*, its derived mass m, and its Compton radius r_c. Concerning the point-charge aspect of the model, it should be recalled that, experimentally, the electron appears to have no structure at least down to a radius around 10^{-20} [cm], nine orders of magnitude smaller than the electron's Compton radius in (12).

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References

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