The Nature of the Electron and Proton as Viewed in the Planck Vacuum Theory

William C. Daywitt

National Institute for Standards and Technology (retired), Boulder, Colorado. E-mail: wcdaywitt@me.com

There is a long-standing question whether or not the proton obeys the Dirac equation. The following calculations answer that question in the affirmative. The paper argues that, even though the proton has an internal structure, unlike the electron, it is still a Dirac particle in the sense that it obeys the same Dirac equation

$$\pm\left[ie_*^2\gamma^\mu\frac{\partial}{\partial x^\mu}-mc^2\right]\psi=0$$

as the electron, where the upper and lower signs refer to the electron and proton respectively with their masses m_e and m_p. Calculations readily show why the proton mass is orders-of-magnitude greater than the electron mass, and suggest that the constant 1836 can be thought of as the 'proton structure constant'.

1 Introduction

The electron is assumed to be a structureless particle [1, p.82] that obeys the Dirac equation; so it is somewhat surprising that the structured proton also obeys that same equation. The reason for this apparent conundrum is tied to the nature of the Planck vacuum (PV) state itself [2].

The manifestly covariant form of the Dirac equation [1, p.90] is

$$\left[i\hbar\gamma^\mu\frac{\partial}{\partial x^\mu}-mc\right]\psi=0 \tag{1}$$

which, using $c\hbar=e_*^2$, can be expressed as

$$\left[ie_*^2\gamma^\mu\frac{\partial}{\partial x^\mu}-mc^2\right]\psi=0 \tag{2}$$

with

$$\frac{\partial}{\partial x^\mu}\equiv\left(\frac{\partial}{c\partial t},\,\nabla\right) \tag{3}$$

where ψ is the 4x1 Dirac spinor, [$\mu=0,1,2,3$], and ∇ is the normal 3-dimensional gradient operator. See Appendix A for the definition of the γ^μ matrices. The summation convention over the two μs in the first terms of (1) and (2) is understood.

The two particle/PV coupling forces [3]

$$F_e(r)=\frac{e_*^2}{r^2}-\frac{m_ec^2}{r}\quad\text{and}\quad F_p(r)=\frac{e_*^2}{r^2}-\frac{m_pc^2}{r} \tag{4}$$

the electron and proton cores $(-e_*,m_e)$ and $(+e_*,m_p)$ exert on the PV state, along with their coupling constants

$$F_e(r_e)=0\quad\text{and}\quad F_p(r_p)=0 \tag{5}$$

and the resulting Compton radii

$$r_e=\frac{e_*^2}{m_ec^2}\quad\text{and}\quad r_p=\frac{e_*^2}{m_pc^2} \tag{6}$$

lead to the important string of Compton relations

$$r_em_ec^2=r_pm_pc^2=e_*^2=r_*m_*c^2\quad(=c\hbar) \tag{7}$$

where $\hbar$ is the reduced Planck constant. The electron and proton masses are m_e and m_p respectively. The vanishing of $F_e(r_e)$ and $F_p(r_p)$ in (5) frees the electron and proton from being tethered by their coupling forces to the vacuum state, insuring that both particles propagate in free space as free particles. The Planck particle mass and Compton radius are m_* and r_*.

2 Electron and positron

The Dirac electron equation from (2) with the positive sign from the abstract leads to [3]

$$\left[i(-e_*)(-e_*)\gamma^\mu\frac{\partial}{\partial x^\mu}-m_ec^2\right]\psi=0 \tag{8}$$

where the first charge $(-e_*)$ comes from the electron core, and the second charge $(-e_*)$ from any one of the Planck-particle cores in the negative branch of the PV state (Appendix B).

Charge conjugation of (8) then leads to the positron equation

$$\left[i(+e_*)(+e_*)\gamma^\mu\frac{\partial}{\partial x^\mu}-m_ec^2\right]\psi=0\,. \tag{9}$$

where the first charge $(+e_*)$ comes from the positron core $(+e_*,m_e)$, and the second charge $(+e_*)$ from any one of the Planck-particle cores in the positive branch of the PV state.

3 Proton and antiproton

The proton equation from the preceding abstract

$$-\left[ie_*^2\gamma^\mu\frac{\partial}{\partial x^\mu}-m_pc^2\right]\psi=0 \tag{10}$$

can be expressed as

$$\left[i(+e_*)(-e_*)\gamma^\mu\frac{\partial}{\partial x^\mu}+m_pc^2\right]\psi=0 \tag{11}$$

where the first charge ($+e_*$) comes from the proton core, and the second charge ($-e_*$) from any one of the Planck-particle cores in the negative branch of the PV state.

Charge conjugation of (11) then leads to the antiproton equation

$$\left[i(-e_*)(+e_*)\gamma^\mu \frac{\partial}{\partial x^\mu} + m_p c^2\right]\psi = 0 \qquad (12)$$

where the first charge ($-e_*$) comes from the antiproton core ($-e_*, m_p$), and the second charge ($+e_*$) from any one of the Planck-particle cores in the positive branch of the PV state.

4 Proton structure

The reason for the proton structure is easily seen from the nature of the charge products in equations (8) and (9), as opposed to those in equations (11) and (12). In (8) and (9) both products yield a positive e_*^2, signifying that the electron and positron charges repel their corresponding degenerate collection of PV charges (Appendix B); isolating the characteristics of the electron/positron from the PV state.

In (11) and (12), however, things are reversed. Both products yield a negative e_*^2, signifying that the proton and antiproton charges are attracting their corresponding degenerate collection of PV charges; converting a small portion of the PV energy into the proton and antiproton states, elevating the proton/antiproton masses orders-of-magnitude over those of the electron/positron masses.

5 Conclusions and comments

From (7) the mass energies of the electron and proton are [2]

$$m_e c^2 = \frac{e_*^2}{r_e} \qquad \text{and} \qquad m_p c^2 = \frac{e_*^2}{r_p} \qquad (13)$$

which lead to

$$m_p = \frac{r_e}{r_p} \cdot m_e \qquad (14)$$

where the ratio $r_e/r_p \approx 1836$. Thus, since m_e is assumed to be structureless, (14) suggests that the constant 1836 can be thought of as the 'proton structure constant'.

Finally, in the PV theory the so-called structure appears in the proton rest frame as a small spherical 'collar' surrounding the proton core [5].

Appendix A: The γ and β matrices

The 4x4 γ, β, and α_i matrices used in the Dirac theory are defined here: where [1, p.91]

$$\gamma^0 \equiv \beta = \begin{pmatrix} I & 0 \\ 0 & -I \end{pmatrix} \qquad (A1)$$

and ($i = 1, 2, 3$)

$$\gamma^i \equiv \beta\alpha_i = \begin{pmatrix} 0 & \sigma_i \\ -\sigma_i & 0 \end{pmatrix} \qquad (A2)$$

and where I is the 2x2 unit matrix and

$$\alpha_i = \begin{pmatrix} 0 & \sigma_i \\ \sigma_i & 0 \end{pmatrix} \qquad (A3)$$

where the σ_i are the 2x2 Pauli spin matrices

$$\sigma_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \sigma_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \sigma_3 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \qquad (A4)$$

and $\boldsymbol{\alpha} = (\alpha_1, \alpha_2, \alpha_3)$.

Appendix B: Charge conjugation

Charge conjugation [4] in the PV theory implies that the invisible vacuum state must be a bifurcated state—bifurcation meaning that at each point in free space there exists a vacuum subspace consisting of the charge doublet $(\pm e_*)^2$ that leads to two vacuum branches

$$e_*^2 = (-e_*)(-e_*) \qquad \text{and} \qquad e_*^2 = (+e_*)(+e_*) \qquad (B1)$$

where, by definition, the second charge in each product defines the branch. The first charge in each branch belongs to the electron or positron. For example, if the first charge ($-e_*$) in the negative branch on the left belongs to the electron, then the first charge ($+e_*$) in the positive branch at the right belongs to the positron. In the PV theory charge conjugation simply switches back and forth between the two PV branches, which amounts to changing the signs in the four products $(\pm e_*)(\pm e_*)$. For example, if C is the charge conjugation operator, then

$$C(\pm e_*)(\pm e_*) = (\mp e_*)(\mp e_*)\,. \qquad (B2)$$

In the proton case (the negative sign in the abstract)

$$-e_*^2 = (+e_*)(-e_*) \quad \text{and} \quad -e_*^2 = (-e_*)(+e_*) \qquad (B3)$$

where the first charge on the left belongs to the proton and the first charge on the right belongs to the antiproton. Again, the second charge in each product defines the branch.

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