Particles and Antiparticles in the Planck Vacuum Theory

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This short note sheds some light on the negative energy vacuum state by expanding the Planck vacuum (PV) model and taking a closer look at the particle-antiparticle nature of the Dirac equation. Results of the development are briefly discussed with regard to the complexity of the PV interaction with the massless free charge, the Dirac electron, and the proton; an exercise that may lead to a better proton model.

The negative energy PV model [1] can be expanded to include negative energy particle states in the following manner: the structure of the PV is related to the string of Compton relations

$$r_e m_e c^2 = \cdots = r_p m_p c^2 = \cdots = r_* m_* c^2 = e_*^2 = c\hbar \qquad (1)$$

where the subscripts represent respectively the electron, proton, Planck particle, and their antiparticles; and where the dots represent any number of intermediate particle-antiparticle states. The r_e and m_e, etc., are the Compton radii and masses of the various particles, c is the speed of light, and $\hbar$ is Planck's constant. The bare charge e_* is assumed to be massless and is related to the elementary charge e observed in the laboratory via $e^2 = \alpha e_*^2$, where α is he fine structure constant. The particle-antiparticle masses are the result of their bare charges being driven by ultra-high-frequency zero-point fields that exist in free space [2, 3]. The charge on the Planck particles within the PV is negative. It is assumed that positive charges are holes that exist within the negative energy PV, an assumption that is supported by the Dirac equation and its negative energy solution [4].

The relation of positive and negative particles and antiparticles to the Compton relations in (1) is easily explained. In the above scheme, negatively charged particles or antiparticles exist in free space and exert a perturbing force [1]

$$\frac{(-e_*)(-e_*)}{r^2} - \frac{mc^2}{r} \qquad (2)$$

on the PV, where m is the particle-antiparticle mass. The first charge on the left is due to the free particle or antiparticle and the second to the Planck particles within the PV. The hole exerts a corresponding force within the PV equal to

$$\frac{(+e_*)(-e_*)}{r^2} - \frac{(-mc^2)}{r} \qquad (3)$$

where the effective positive charge on the left is due to the missing negative charge (the hole) in the PV sea and the negative mass energy $(-mc^2)$ is due to the hole belonging to a negative energy state. The radius r at which (2) and (3) vanish is the particle or antiparticle Compton radius $r_c\ (= e_*^2/mc^2)$. The more complete form for (1) can then be expressed as

$$r_e(\pm\, m_e c^2) = \cdots = r_p(\pm\, m_p c^2) = \cdots = r_*(\pm\, m_* c^2) = \pm\ e_*^2 \qquad (4)$$

which renders its application to both particles and antiparticles more explicit and transparent. The positive mass energies belong to the negatively charged free-space particles or antiparticles, while the negative mass energies belong to the PV holes which are responsible for the ficticious positively charged particles or antiparticles imagined to exist in free space. Both equations in (4) lead back to the single equation (1) which defines $\hbar$.

The preceding ideas are illustrated using the Dirac equation and provide a clearer view of that equation as it is related to the concept of Dirac holes. The Dirac equation for the electron can be expressed as [4, 5]

$$\left(c\,\vec{\alpha}\cdot\widehat{p}_e + \beta m_e c^2\right)\psi_e = E_e\psi_e \qquad (5)$$

where the momentum operator and energy are given by

$$\widehat{p}_e = \frac{\hbar\nabla}{i} = \frac{(-e_*)(-e_*)\nabla}{ic} \text{ and } E_e = +\sqrt{m_e^2c^4 + c^2p_e^2} \qquad (6)$$

and where $\vec{\alpha}$ and β are defined in [5]. The relativistic momentum is $p_e\ (= m_e v/\sqrt{1-v^2/c^2}\,)$. The shift from the positive-energy electron solution to the negative-energy hole (positron) solution proceeds as follows:

$$E_e \longrightarrow E_h = -E_e \qquad (7)$$

$$m_e c^2 \longrightarrow m_h c^2 = -m_e c^2 \qquad (8)$$

$$p_e = \frac{m_e v}{\sqrt{1-v^2/c^2}} \to p_h = \frac{-m_h v}{\sqrt{1-v^2/c^2}} = -p_e, \qquad (9)$$

$$\widehat{p}_e = \frac{(-e_*)(-e_*)\nabla}{ic} \to \widehat{p}_h = \frac{(+e_*)(-e_*)\nabla}{ic} = -\widehat{p}_e. \qquad (10)$$

Substituting equations (7) through (10) into (5) yields

$$\left(c\,\vec{\alpha}\cdot\widehat{p}_h + \beta m_h c^2\right)\psi_h = E_h\psi_h \qquad (11)$$

for the hole solution, where $E_h = -(m_h^2c^4 + c^2p_h^2)^{1/2}$. From (5) and (11) and $m_h = m_e$ it follows that the electron and hole satisfy the same Dirac equation of motion with $E_h = -E_e$. Although the hole exists in the PV, it appears experimentally in free space as a positron due to the hole's field permeating that space. In turn, the positron's deflection in a free-space magnetic field is due to that field permeating the PV and affecting the hole.

From the development of the PV theory so far, the Dirac equation appears to be part of a succession of equations involving an increasingly more complicated interaction between the free-space particle and the PV. For example, the interaction of a massless point charge traveling at a constant velocity results in the relativistic electric and magnetic fields (and by inference the Lorentz transformation) that can be easily calculated directly from the charge's Coulomb field (the first term in (2)) and its interaction with the PV [1, Section 4]. The Dirac electron (a massive point charge) is next in complexity to the point charge and perturbs the PV with the total force in (2), leading to the Dirac equation (and the quantum fields associated with it) which represents the PV reaction to the moving Dirac electron [4].

The proton is the next more complex and stable particle whose properties are shaped by its interaction with the PV. Being in essence a more complicated PV hole than the positron, the proton exhibits some structure as witnessed by its three-quark nature associated (it seems correct to assume) with the hole. The calculational difficulties besetting quantum chromodynamics [6, p.70] attest to the idea expressed above that things are getting more complex in the progression from leptons to hadrons and their PV interactions. Perhaps these difficulties can be resolved by a better model for the heavy particles based on the PV theory.

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