The Trouble with the Equations of Modern Fundamental Physics

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The equations of modern fundamental physics are difficult, if not impossible, to understand because they are expressed in terms of the secondary constants G (Newton), $\hbar$ (Planck), and α (fine structure). The emerging Planck vacuum theory derives the primary (fundamental) constants associated with these secondary constants, enabling the equations of modern particle physics to be intuitively understood in terms of the free particle and its coupling to the vacuum state. What follows is a review of some aspects of this new theory, including inelastic electron-proton scattering and the antiparticle aspects of these two particles.

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1 Introduction

The two observations: "investigations point towards a compelling idea, that all nature is ultimately controlled by the activities of a single superforce", and "[a living vacuum] holds the key to a full understanding of the forces of nature" ; come from Paul Davies' popular 1984 book [1, pp.5,104], Superforce: The Search for a Grand Unified Theory of Nature. This modern vacuum state, as opposed to the classical void, is often referred to as the quantum vacuum (QV) [2].

Among other things, the following text will argue that the source of the QV is the Planck vacuum (PV) [3] which is roughly modeled as an omnipresent degenerate state of negative-energy PPs characterized by the triad $(-e_*, m_*, r_*)$, where e_*, m_*, and r_* are the Planck particle (PP) charge, mass, and Compton radius respectively. The charge e_* is the massless bare charge common to all charged elementary particles and is related to the observed electronic charge e through the fine structure constant $\alpha = e^2/e_*^2$, which is one manifestation of the PV polarizability. The PP mass and Compton radius are equal to the Planck mass and length respectively [4, p.1234]. The zero-point (ZP) random motion of the PP charges e_* about their equilibrium positions within the degenerate PV, and the PV dynamics, are the source of the QV. The non-propagating virtual fields of the QV are assumed to be real fields appearing in free space which are analogous to induction fields with the PV as their source. In addition to the fine structure constant, the PV is the source of the gravitational and Planck constants.

Section 2 traces the concept of the PV from the first observation of the initial paragraph above to the derivation of the fine structure, gravitational, and Planck constants; to the PP Compton relation and to the free-space permittivities. A rough heuristic argument shows the binding force of the vacuum state to be van-der-Waals in nature.

The ultimate PV curvature force is also derived in Section 2 from Newton's gravitational equation. This ultimate force is shown in Section 3 to be tied to the spacetime of General relativity (GR) which, therefore, is related to the real physical curvature of the PV state. As a consequence, the GR theory describes the Minkowski spacetime curvature of the PV.

Using the Coulomb field of the bare charge, the polarizability of the PV, and an internal feedback mechanism intrinsic to the PV; Section 4 derives the relativistic electric and magnetic fields associated with the charge, and infers the Lorentz transformation and constancy of the speed of light from the results.

The electromagnetic vacuum (EV) [3] consists of the virtual photons of the QV, which lead collectively to the ZP electromagnetic field which Section 5 argues has its origin in the PV.

A free charged particle distorts the PV in two ways. Its bare Coulomb field polarizes the vacuum, and its mass exerts a van-der-Waals attractive force on the PPs within the PV. Section 6 shows how these two vacuum-distorting forces lead to the quantum theory.

Sections 7 and 8 discuss the inelastic electron-proton scattering and the electron and proton antiparticles. A bifurcated PV state $(\mp e_*, m_*, r_*)$ is introduced in Section 8.

Most of the thirty-nine-plus papers describing the PV theory can be found in the Progress in Physics journal from circa 2009 onward. Temporarily, they can also be found on the web site www:planckvacuum.com.

2 Planck Particle and Vacuum

The idea from Davies' first observation that a single superforce controls all of nature is interpreted here to mean that the ultimate strengths of nature's fundamental forces are identical. The static Coulomb and gravitational forces between two like, charged elementary particles are used in this section to derive the fine structure constant, the ultimate Coulomb force, the ultimate gravitational force, the gravitational constant, and the ultimate PV curvature force. Using these results, the Compton relation of the PP and the free-space permittivities (the dielectric constant and magnetic permeability) are derived. These derivations utilize three normalization constants to isolate the ultimate forces. The three constants correspond to charge normalization (e_*), mass normalization (m_*), and length normalization (r_*). These constants start out as normalization constants, but end up defining a new particle (the PP) and a fundamental vacuum state (the PV).

The static Coulomb force between two like, charged particles can be expressed in the following two forms:

$$F_{\text{el}} = \frac{e^2}{r^2} = \alpha \left(\frac{r_*}{r}\right)^2 F'_* \tag{1}$$

where r is the distance between particles, $\alpha \equiv e^2/e_*^2$, and $F'_* \equiv e_*^2/r_*^2$. If e_* is assumed to be the maximum particle charge (the electronic charge unscreened by a polarizable vacuum state), and r_* is assumed to be some minimum length; then F'_* is the ultimate Coulomb force.

The static gravitational force of Newton acting between two particles of mass m separated by a distance r can be expressed in the following forms:

$$-F_{\text{gr}} = \frac{m^2 G}{r^2} = \frac{m^2}{m_*^2}\left(\frac{r_*}{r}\right)^2 F_* \tag{2}$$

where G is Newton's gravitational constant and $F_* \equiv m_*^2 G/r_*^2$. If m_* is the maximum elementary particle mass, and r_* is the minimum length, then F_* is the ultimate gravitational force as m_*/r_* is the ultimate mass-to-length ratio.

Adhering to the idea of a single superforce implies that the force magnitudes F'_* and F_* should be equal. This equality leads to the definition of the gravitational constant

$$G = \frac{e_*^2}{m_*^2} \tag{3}$$

in terms of the squared normalization constants e_*^2 and m_*^2.

The gravitational force in (2) can also be expressed as

$$-F_{\text{gr}} = \frac{m^2 G}{r^2} = \frac{(mc^2/r)^2}{c^4/G} \tag{4}$$

by a simple manipulation, where c is the speed of light. The ratio mc^2/r has the units of force, as does the ratio c^4/G. It can be argued [5] that c^4/G is a superforce, i.e. some type of ultimate force. The nature of the two forces, mc^2/r and c^4/G, is gravitational as they emerge from Newton's gravitational equation; but their meaning at this point in the text is unknown. As an ultimate force, c^4/G can be equated to the ultimate gravitational force F_* because of the single-superforce assumption. Equating c^4/G and F_*, and taking a square root, then leads to

$$\frac{c^4}{G} = \frac{m_*\, c^2}{r_*} \tag{5}$$

for the ultimate force c^4/G. It is noteworthy that the form $m_* c^2/r_*$ of this force is the same as that ratio in the parenthesis of (4), which must be if c^4/G is to represent an ultimate force of the form mc^2/r. That (5) is an ultimate force is clear from the fact that m_* is the ultimate particle mass and r_* is the minimum length (roughly the nearest-neighbor distance between the PPs constituting the degenerate PV state).

Invoking the single-superforce requirement for the ultimate force c^4/G from (5) and the ultimate Coulomb force F'_* leads to

$$\frac{m_* c^2}{r_*} = \frac{e_*^2}{r_*^2} \tag{6}$$

or

$$r_* m_* c = \frac{e_*^2}{c} = \hbar \tag{7}$$

where e_*^2/c defines the (reduced) Planck constant. Furthermore, if the reasonable assumption is made that the minimum length r_* is the Planck length, then m_* turns out to be the Planck mass. Noting also that (7) has the classic form of a Compton relation, where r_* is the Compton radius, it is reasonable to assume that the triad $(-e_*, m_*, r_*)$ characterizes a new particle (the PP). Thus the Compton radius r_* of the PP is $r_* = e_*^2/m_* c^2$.

The units employed so far are Gaussian. Changing the units of the first equation in (7) from Gaussian to mks units [6] and solving for ϵ_0 leads to

$$\epsilon_0 = \frac{e_*^2}{4\pi r_* m_* c^2} \qquad \text{[mks]} \tag{8}$$

where ϵ_0 is the electric permittivity of free space in mks units. Then, utilizing $\epsilon_0 \mu_0 = 1/c^2$ leads to

$$\mu_0 = 4\pi \frac{r_* m_*}{e_*^2} \qquad \text{[mks]} \tag{9}$$

for the magnetic permittivity. The magnitude of μ_0 is easy to remember—it is $4\pi \times 10^{-7}$ in mks units. Thus $r_* m_*/e_*^2$ in (9) had better equal 10^{-7} in mks units, and it does (e_* in Gaussian units is obtained from (3) and

G, or from (7) and $\hbar$; and then changed into mks units for the calculation).

Shifting (8) and (9) out of mks units back into Gaussian units leads to

$$\epsilon = \frac{1}{\mu} = \frac{e_*^2}{r_* m_* c^2} = 1 \tag{10}$$

for the free-space permittivities in Gaussian units. Considering the fact that the free-space permittivities are expressed exclusively in terms of the parameters defining the PP, and the speed of light, it is reasonable to assume that the free-space vacuum (the PV) is made up of PPs. Furthermore, the negative-energy solutions to the Klein-Gordon equation or the Dirac equation [7] suggest that a reasonable starting point for modeling the PV may be an omnipresent degenerate state of negative energy PPs.

At this point, the PV is assumed to be a degenerate state of charged PPs. Thus the PPs within the vacuum repel each other with strong Coulombic forces, nearest neighbors exerting a force roughly equal to

$$\frac{e_*^2}{r_*^2} = \left(\frac{5.62 \times 10^{-9}}{1.62 \times 10^{-33}}\right)^2 \sim 10^{49} \quad [\text{dyne}] \tag{11}$$

where r_* is roughly the nearest-neighbor distance. The question of what binds these particles into a degenerate state naturally arises. The following heuristic argument provides an answer. Using the definition of the gravitational constant ($G = e_*^2/m_*^2$), the unscreened gravitational force between two free PPs separated by a distance r can be written in the form

$$\frac{m_*^2 G}{r^2} = \frac{e_*^2}{r^2} \tag{12}$$

leading to a total gravitational-plus-Coulomb force between the particles equal to

$$-\frac{m_*^2 G}{r^2} + \frac{e^2}{r^2} = (-1 + \alpha)\,\frac{e_*^2}{r^2} \tag{13}$$

where the screened Coulomb force ($\alpha e_*^2/r^2$) comes from (1). This total force is attractive since the fine structure constant $\alpha \approx 1/137 < 1$. The total force between two PPs within the PV should be roughly similar to (13). Thus it is reasonable to conclude that the vacuum binding force is gravitational in nature.

3 General Relativity

Newton's gravitational force acting between two particles of mass m_1 and m_2 separated by a distance r can be expressed as

$$F_{\text{gr}} = -\frac{m_1 m_2 G}{r^2} = -\frac{(m_1 c^2/r)(m_2 c^2/r)}{c^4/G}$$

$$= \frac{(-m_1 c^2/r)(-m_2 c^2/r)}{-m_* c^2/r_*} \tag{14}$$

where (5) has been used to obtain the final expression. Although the three forces in the final expression must be gravitational by nature as they come from the gravitational equation, their meaning is unclear from (14) alone.

Their meaning can be understood by examining two equations from the GR theory, the Einstein field equations [8] [9]

$$G_{\mu\nu} = \frac{8\pi T_{\mu\nu}}{c^4/G} = \frac{8\pi T_{\mu\nu}}{m_* c^2/r_*} \tag{15}$$

and the Schwarzschild metric equation

$$ds^2 = -\left[1 - 2n_r\right] c^2 dt^2 + \frac{dr^2}{\left[1 - 2n_r\right]} + r^2\, d\Omega^2 \tag{16}$$

where the n-ratio is

$$n_r \equiv \frac{mc^2/r}{c^4/G} = \frac{mc^2/r}{m_* c^2/r_*} \tag{17}$$

$G_{\mu\nu}$ is the Einstein curvature tensor, $T_{\mu\nu}$ is the energy-momentum density tensor, ds is the Schwarzschild line element, and dt and dr are the time and radius differentials. The final term in (16) is defined in [8] and is independent of n_r. The line element ds in (16) is associated with the curvature of spacetime outside a static spherical mass—thus in the particle case the equation is only valid outside the particle's core radius [10] (see Sections 7 and 8). For a vanishing mass ($m = 0$), the n-ratio vanishes and the metric bracket $[1-2n_r]$ reduces to unity; in which case (16) describes a "flat" (zero curvature or Lorentzian) spacetime.

As mc^2/r in (16) and (17) is a spacetime-curvature force, (14) implies that $m_1 c^2/r$ and $m_2 c^2/r$ are PV curvature forces. The ultimate curvature force $m_* c^2/r_*$ appears in the denominators of (14), (15), and (17). Thus it is reasonable to conclude that the theory of GR refers to the spacetime-curvature aspects of the PV. The forces $m_1 c^2/r$ and $m_2 c^2/r$ are attractive forces the masses m_1 and m_2 exert on the PPs of the PV at a distance r from m_1 and m_2 respectively. This latter conclusion is further supported by the following calculation:

$$\frac{mc^2}{r} = \frac{mc^2 \cdot G}{r \cdot G} = \frac{mc^2 G}{r \cdot e_*^2/m_*^2} = \frac{mc^2 G m_*^2}{r \cdot r_* m_* c^2}$$

$$= \frac{m m_* G}{r r_*} \tag{18}$$

where (3) is used to arrive at the third ratio and (7) is used to arrive at the fourth. The final ratio represents the m-m_* attractive force.

According to Newton's third law, if a free mass m exerts a force mc^2/r on a PP within the PV at a radius $\mathbf{r}$ from m, then that PP must exert an equal and opposite force on m. However, the PP at $-\mathbf{r}$ exerts an opposing force on m; so the net average force the two PPs exert on the free mass is zero. By extrapolation, the entire PV exerts a vanishing average force on the mass. As the PPs are in a perpetual state of ZP agitation about their average $\mathbf{r}$ positions, however, there is a residual, random van der Waals force that the two PPs, and hence the PV as a whole, exert on the free mass.

Puthoff [11] has shown the gravitational force to be a long-range retarded van der Waals force, so forces of the form mc^2/r are essentially van der Waals forces. The ZP electromagnetic fields of the EV are the mechanism that provides the free bare-charge agitation necessary to produce the particle mass m [3] and the van der Waals force. But since the source of the EV is the PV (Section 5), the PV is the ultimate source of the ZP agitation responsible for the van-der-Waals-gravitational force between free particles, and the free-particle/PV force mc^2/r.

4 Maxwell and Lorentz

The previous two sections argue that curvature distortions (mass distortions) of the PV are responsible for the curvature force mc^2/r and the equations of GR. This section argues that polarization distortions of the PV by the free charge are responsible for the Maxwell equations and, by inference, the Lorentz transformation. These ends are accomplished by using the bare Coulomb field of a free charge in uniform motion, a feedback mechanism intrinsic to the PV [12] [13], and the Galilean transformation; to derive the relativistic electric and magnetic fields of a uniformly moving charge.

The bare Coulomb field $e_*\mathbf{r}/r^3$ intrinsic to a free bare charge e_* polarizes the PV, producing the free-space Coulomb field

$$\mathbf{E}_0 = \frac{e\mathbf{r}}{r^3} = \frac{e}{e_*}\frac{e_*\mathbf{r}}{r^3} = \alpha^{1/2}\frac{e_*\mathbf{r}}{r^3} = \frac{e_*\mathbf{r}}{\epsilon' \, r^3} \qquad (19)$$

observed in the laboratory, and creating the effective dielectric constant ϵ' ($\equiv e_*/e = 1/\sqrt{\alpha}$) viewed from the perspective of the bare charge, where α is the fine structure constant. In terms of the fixed field point (x,y,z) and a charge traveling in the positive z-direction at a uniform velocity v, the observed field can be expressed as

$$\mathbf{E}_0 = \frac{e\,[x\widehat{\mathbf{x}} + y\widehat{\mathbf{y}} + (z-vt)\widehat{\mathbf{z}}]}{[x^2+y^2+(z-vt)^2]^{3/2}} \qquad (20)$$

where, at $t=0$, the charge crosses the laboratory frame origin $(0,0,0)$. This expression assumes that the space-time transformation between the charge- and laboratory-coordinate frames is Galilean — i.e., (x,y,z) and t are assumed to be independent variables.

The observed field produces an electric dipole at each field point. As the charge moves along the z-axis, the dipole rotates about the field point and creates an effective current circulating about that point. The circulating current, in turn, produces the magnetic induction field

$$\mathbf{B}_1 = \boldsymbol{\beta}\times\mathbf{E}_0 = \frac{e\beta(z-vt)}{r^3}\,\boldsymbol{\phi} \qquad (21)$$

where $\beta = v/c$, $\boldsymbol{\beta} = \beta\,\widehat{\mathbf{z}}$, $\boldsymbol{\phi}$ is the azimuthal unit vector, and $r^2 = x^2+y^2+(z-vt)^2$ is the squared radius vector $\mathbf{r}\cdot\mathbf{r}$ from the charge to the field point. The field $\mathbf{B}_1$ is the first-step magnetic field caused by the bare charge distortion of the PV.

An iterative feedback process is assumed to take place within the PV that enhances the original electric field $\mathbf{E}_0$. This process is mathematically described by the following two equations [12]:

$$\nabla\times\mathbf{E}_n = -\frac{1}{c}\frac{\partial\mathbf{B}_n}{\partial t} \qquad (22)$$

and

$$\mathbf{B}_{n+1} = \boldsymbol{\beta}\times\mathbf{E}_n \qquad (23)$$

where n $(= 1,2,3\ldots)$ indicates the successive partial electric fields $\mathbf{E}_n$ generated by the PV and added to the original field $\mathbf{E}_0$. The successive magnetic induction fields are given by (23). Equation (22) is recognized as the Faraday equation.

The calculation of the final electric field $\mathbf{E}$, which is the infinite sum of $\mathbf{E}_0$ and the remaining particle fields $\mathbf{E}_n$, is conducted in spherical polar coordinates and leads to [13]

$$\mathbf{E} = \frac{(1-\lambda)\,\mathbf{E}_0}{\left(1-\beta^2\sin^2\theta\right)^{3/2}} \qquad (24)$$

where λ is the infinite sum of integration constants that comes from the infinity of integrations of (22) to obtain the $\mathbf{E}_n$, and θ is the polar angle between the positive z-direction and the radius vector from the charge to the field point. The field $\mathbf{E}_0$ in (24) is the nonrelativistic ($\beta \approx 0$) electric field (20). The final magnetic field is obtained from $\mathbf{B} = \boldsymbol{\beta}\times\mathbf{E}$.

Finally, the constant λ can be evaluated from the conservation of electric flux [12] (the second of the following equations) which follows from Gauss' law and the conservation of bare charge e_* (the first equation):

$$\int \mathbf{D}\cdot d\mathbf{S} = 4\pi e_* \longrightarrow \int \mathbf{E}\cdot d\mathbf{S} = 4\pi e \qquad (25)$$

where $d\mathbf{S}$ is taken over any closed Gaussian surface surrounding the bare charge, and where $\mathbf{D} = \epsilon'\,\mathbf{E} = (e_*/e)\mathbf{E}$

is used to bridge the arrow. Inserting (24) into the second equation of (25) and integrating yields

$$\lambda = \beta^2 \tag{26}$$

which, inserted back into (24), leads to the relativistic electric field of a uniformly moving charge [6]. The relativistic magnetic field is $\mathbf{B} = \boldsymbol{\beta} \times \mathbf{E}$. The conservation of electric flux expressed by the second equation of (25) is assumed as a postulate in [12]. The first equation shows that the postulate follows from Gauss' law and the conservation of bare charge.

The relativistic fields $\mathbf{E}$ and $\mathbf{B}$ for a uniformly moving charge are derived above from the Coulomb field $e_*\mathbf{r}/r^3$ of the bare charge in (19), an assumed PV feedback dynamic given by (22) and (23), and the Galilean transformation. Of course, the relativistic equations can also be derived from the Coulomb field $e\mathbf{r}/r^3$ [6] (where $r^2 = x^2 + y^2 + z^2$) of the observed electronic charge e at rest in its own coordinate system, and the Lorentz transformation. It follows, then, that the Lorentz transformation is a mathematical shortcut for calculating the relativistic fields from the observed charge e $(= e_* \sqrt{\alpha})$ without having to account directly for the polarizable PV and its internal feedback dynamic. Furthermore, it can be argued that the constancy of the speed of light c from Lorentz frame to Lorentz frame, which can be deduced from the resulting Lorentz transformation, is due to the presence of the PV in the charge's line of travel.

If there were no polarizable vacuum, there would be no rotating dipole moments at the field points (x, y, z); and hence, there would be no magnetic field. A cursory examination of the free-space Maxwell equations [6] in the case where the magnetic field $\mathbf{B}$ vanishes shows that the equations reduce to $\nabla \cdot \mathbf{E} = 4\pi\rho_*$, and to the equation of continuity between e_* and its current density. Thus it can be argued that the Maxwell equations owe their existence to the polarizable PV state.

5 Electromagnetic Vacuum

The EV is the photon part of the QV [3], i.e. the virtual photons that quickly appear and disappear in free space according to the Heisenberg uncertainty principle. This section argues that the EV has its origin in the PV.

The virtual photons of the EV lead collectively to the free-space ZP electric field [11]

$$\mathbf{E}_{zp}(\mathbf{r}, t) = \mathrm{Re} \sum_{\sigma=1}^{2} \int d\Omega_k \int_0^{k_{c*}} dk\, k^2\, \widehat{\mathbf{e}}_\sigma \{A_k\} \cdot \exp\left[i\left(\mathbf{k} \cdot \mathbf{r} - \omega t + \Theta\right)\right] \tag{27}$$

the spectrum of which Sakharov [14] has argued must have an upper cutoff wavenumber k_{c*} that is related to the "heaviest particles existing in nature". In the present context, the heaviest particles existing in nature are clearly PPs. Puthoff has calculated the wavenumber to be $k_{c*} = \sqrt{\pi c^3/\hbar G}$, which can be expressed as $k_{c*} = \sqrt{\pi}/r_*$ by substituting the constants $\hbar = e_*^2/c$ and $G = e_*^2/m_*^2$ and using the PP Compton relation (7). The cutoff wave number is characteristic of the minimum length r_* , the Compton radius of the PPs associated with the PV. Θ is a random phase.

The amplitude factor in (27) is [11]

$$A_k = \left(\frac{\hbar\omega}{2\pi^2}\right)^{1/2} = \pm e_* \left(\frac{k}{2\pi^2}\right)^{1/2} \tag{28}$$

where $\hbar = e_*^2/c$ and $k = \omega/c$ are used to obtain the second expression. This result implies that bare charges are the source of the ZP field, for if e_* were zero, the amplitude factor would vanish and there would be no field. It is reasonable, then, to assume that these bare charges reside within the PV.

Equation (27) can be expressed in the more revealing form

$$\mathbf{E}_{zp}(\mathbf{r}, t) = \left(\frac{\pi}{2}\right)^{1/2} \frac{e_*}{r_*^2}\, \mathbf{I}_{\mathrm{zp}}(\mathbf{r}, t) \tag{29}$$

where $\mathbf{I}_{\mathrm{zp}}$ is a random variable of zero mean and unity mean square; so the factor multiplying $\mathbf{I}_{\mathrm{zp}}$ in (29) is the root-mean-square ZP field. Since m_*c^2/r_*^3 is roughly the energy density of the PV, the ZP field can be related to the PV energy density through the following sequence of equations:

$$\frac{m_*c^2}{r_*^3} = \frac{e_*^2/r_*}{r_*^3} = \left(\frac{e_*}{r_*^2}\right)^2 \approx \langle \mathbf{E}_{\mathrm{zp}}^2 \rangle \tag{30}$$

where the PP Compton relation is used to derive the second ratio, and the final approximation comes from the mean square of (29). The energy density of the PV, then, appears to be intimately related to the ZP field. So, along with the k_{c*} and the A_k from above, it is reasonable to conclude that the PV is the source of the EV.

6 Quantum Theory

A massive charged particle exerts two distortion forces on the collection of PPs constituting the PV, the curvature force mc^2/r and the polarization force e_*^2/r^2 . Sections 2 and 3 examine the PV response to the curvature force, and Section 4 the response to the polarization force. This section examines the PV response to both forces acting simultaneously, and shows that the combination of forces leads to the quantum (wave) theory.

The equality of the two force magnitudes

$$\frac{mc^2}{r} = \frac{e_*^2}{r^2} \qquad \longrightarrow \qquad r_c = \frac{e_*^2}{mc^2} \tag{31}$$

at the Compton radius r_c of the particle is a Lorentz invariant property of the particle/PV interaction, where m is the derived particle mass [3]. This equality shows the radius to be a particle/PV property, not a property solely of the particle.

The vanishing of the force difference $e_*^2/r_c^2 - mc^2/r_c = 0$ at the Compton radius can be expressed as a vanishing tensor 4-force [6] difference. In the primed rest frame ($\mathbf{k}' = \mathbf{0}$) of the particle, where these static forces apply, this force difference $\Delta F'_\mu$ is ($\mu = 1, 2, 3, 4$)

$$\Delta F'_\mu = \left[\mathbf{0}, i\left(\frac{e_*^2}{r_c^2} - \frac{mc^2}{r_c}\right)\right] = [0, 0, 0, i\,0] \tag{32}$$

where $i = \sqrt{-1}$. Thus the vanishing of the 4-force component $\Delta F'_4 = 0$ in (32) is the source of the Compton radius in (31) which can be expressed in the form $mc^2 = e_*^2/r_c = (e_*^2/c)(c/r_c) = \hbar\omega_c$, where $\omega_c \equiv c/r_c = mc^2/\hbar$ is the Compton frequency associated with the Compton radius r_c.

In what follows it is convenient to define the 4-vector wavenumber tensor

$$k_\mu = (\mathbf{k}, k_4) = (\mathbf{k}, i\,\omega/c) \tag{33}$$

where $\mathbf{k}$ is the ordinary vector wavenumber, and $i\omega/c$ is the frequency component of k_μ. This tensor will be used to derive the particle/PV state function, known traditionally as the particle wavefunction.

The vanishing of the 4-force component $\Delta F'_4$ from (32) in the rest frame of the particle leads to the Compton frequency ω_c. Thus from (33) applied to the prime frame, and $\mathbf{k}' = \mathbf{0}$, the equivalent rest-frame wavenumber is $k'_\mu = (\mathbf{0}, i\,\omega_c/c)$.

The laboratory-frame wavenumber, where the particle is traveling uniformly along the positive z-axis, can be found from the Lorentz transformation $k_\mu = a_{\mu\nu}k'_\nu$ [6] which leads to

$$k_z = \gamma k'_z - i\beta\gamma k'_4 \qquad \text{and} \qquad k_4 = i\beta\gamma k'_z + \gamma k'_4 \tag{34}$$

where

$$a_{\mu\nu} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \gamma & -i\beta\gamma \\ 0 & 0 & i\beta\gamma & \gamma \end{pmatrix} \tag{35}$$

is used, $\beta = v/c$ and $\gamma^2 = 1/(1-\beta^2)$, and where the x- and y-components of the wavenumbers vanish in both frames. With $k'_z = 0$ and $k'_4 = i\omega_c/c$, the laboratory-frame wavenumber from (33) and (34) becomes

$$k_\mu = (0, 0, \beta\gamma\omega_c/c, i\,\gamma\omega_c/c) = (0, 0, p/\hbar, iE/c\hbar) \tag{36}$$

where $p = m\gamma v$ and $E = m\gamma c^2$ are the relativistic momentum and energy of the particle. The second parenthesis in (36) is derived from the first parenthesis and $\omega_c = mc^2/\hbar$, from which $k_z = p/\hbar$ and $k_4 = iE/c\hbar = i\omega_z/c$ emerge.

The relativistic momentum p and energy E in $k_z = p/\hbar$ and $\omega_z = E/\hbar$ characterize the classical free-particle motion, and suggest the simple plane-wave

$$\psi = \mathrm{A}\exp\left[i(k_z z - \omega_z t)\right] = \mathrm{A}\exp\left[i(pz - Et)/\hbar\right] \tag{37}$$

as a suitable state function to characterize the wave behavior of the particle/PV system. This laboratory-frame state function reduces to the state function $\psi = \mathrm{A}\exp\left(-imc^2t/\hbar\right)$ in the particle rest frame where $v = 0$. The $S(z,t) \equiv pz - Et$ in the exponent of (37) are particular solutions (for various non-vanishing m) of the free-particle, relativistic, Hamiltonian-Jacobi equation [10, p.30], although this fact is not used here in deriving the state function.

Since $-i\hbar\nabla\psi = \mathbf{p}\psi$ and $i\hbar(\partial/\partial t)\psi = E\psi$ from (37), it is clear that the momentum ($\widehat{\mathbf{p}} \equiv -i\hbar\nabla$) and energy ($\widehat{E} \equiv i\hbar(\partial/\partial t)$) operators have their origin in the vacuum perturbation caused by the two forces mc^2/r and e_*^2/r^2, as these two forces are responsible for the particle/PV state function (37). Once the operators $\widehat{\mathbf{p}}$ and $\widehat{E}$ are thus defined, the quantum theory follows from the various non-quantum, energy-momentum equations of classical particle dynamics.

7 Inelastic e-p Scattering

This section describes the scattering of an incident electron from a proton initially at rest, under the assumptions: that the structureless electron interacts directly with the proton and its structure; that the energy and "size" of the electron are determined by its de Broglie radii; and that the shape of the inelastic scattering curve depends upon how deeply the electron core penetrates the proton structure. The deep inelastic scattering ends when the electron is small enough (energetic enough) to penetrate and destroy the proton core and its derived mass [15].

The current theory describing electron-proton (e-p) scattering is the Standard Model theory, where the incident electron interacts with the proton via the exchange of a single virtual photon [16, p.160]. The present section offers an alternative theory that is based on the emerging PV theory, where the electron core interacts directly with the proton and its structure [17] [18].

In the PV theory both the electron and proton particles are assumed to possess an invisible (vacuum) substructure, while in addition the proton possess a visible free-space structure due to its positive charge acting on the degenerate PV quasi-continuum (Appendix A). The particle/PV forces and potentials, and their corresponding Compton and de Broglie radii, are associated with this vacuum substructure. The term “structure” by itself refers in what follows exclusively to the free-space proton structure.

7.1 Electron Energy and Size

The electron core $(-e_*, m_e)$ exerts the two-term coupling force

$$\frac{(-e_*)(-e_*)}{r^2} - \frac{m_e c^2}{r} \tag{38}$$

on the PV state, where the first $(-e_*)$ belongs to the electron and the second $(-e_*)$ to the separate Planck particles making up the PV continuum. This force difference vanishes

$$\frac{e_*^2}{r_e^2} - \frac{m_e c^2}{r_e} = 0 \tag{39}$$

at the electron Compton radius r_e $(= e_*^2/m_e c^2)$. Treating this vanishing force as a Lorentz invariant constant then leads to the important Compton-(de Broglie) relations for the electron [19]

$$r_e \cdot m_e c^2 = r_d \cdot cp = r_L \cdot E = e_*^2 \qquad (= c\hbar) \tag{40}$$

where p $(= m_e \gamma v)$ and E $(= m_e \gamma c^2)$ are the relativistic momentum and energy of the electron, and e_* is the massless bare charge. The radii r_d $(= r_e/\beta\gamma)$ and r_L $(= r_e/\gamma)$ are the electron de Broglie radii in the space and time directions on the Minkowski space-time diagram, where $\beta = v/c < 1$ and $\gamma = 1/\sqrt{1-\beta^2}$.

From (40) the size of the electron is taken to be the de Broglie radii

$$r_d = \frac{r_e}{\beta\gamma} \approx \frac{r_e}{\gamma} = r_L \tag{41}$$

where the approximation applies to the high energy ($\beta \approx 1$) calculations of the present section. With (41) inserted into (40),

$$cp = \frac{e_*^2}{r_d} \approx \frac{e_*^2}{r_L} = E \tag{42}$$

leading to

$$E = cp = \frac{e_*^2}{r_d} \, . \tag{43}$$

Thus to reduce the electron size (a substructure concept) to the proton Compton radius ($r_d = r_p$) requires an electron energy equal to $E = e_*^2/r_p$.

The comparisons to follow utilize

$$E = \frac{e_*^2}{r_d} = \frac{e_*^2}{r_p}\frac{r_p}{r_d} = m_p c^2 \frac{r_p}{r_d} \tag{44}$$

to convert electron energies to r_d/r_p ratios. The Lorentz invariance of (39) insures that equations (40) and (44) apply in any inertial reference frame.

7.2 Proton Structure

The proton substructure arises from the two-term coupling force [20]

$$\frac{(e_*)(-e_*)}{r^2} + \frac{m_p c^2}{r} \tag{45}$$

the proton core (e_*, m_p) exerts on the PV state, where the force vanishes at the proton Compton radius r_p $(= e_*^2/m_p c^2)$.

The proton also possesses a free-space structure (in contradistinction to the electron) in the form of a spherical rest-frame “collar” surrounding the proton core (Appendix A). This collar may affect the formation of the proton de Broglie radii; if, indeed, these radii even exist for the proton. Either way, the following scattering calculations employ only the proton Compton radius from the vanishing of (45).

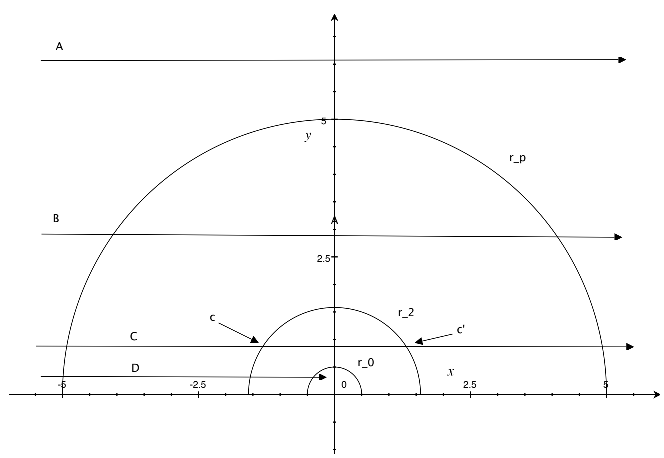

Fig. 1. A highly schematic cross section of the proton structure and four electron-core “trajectories”. The radii r_p and r_2 $(= r_p/3.15)$ represent respectively the proton Compton radius of the substructure and the outer radius of the free-space proton structure.

7.3 Scattering

A highly schematic diagram of the proton cross section is presented in Fig. 1, where r_p is the substructure Compton radius for reference, r_2 $(= r_p/3.15)$ is the outer radius of the proton structure on whose surface resides the apparent charge e of the proton, and r_0 is the radius of the proton core. The latter radius is assumed to be no larger than $r_p/39000$ [20]. Also shown are four electron-core “trajectories” A, B, C, and D, where A and B are propagating in free space and thus represent two elastic e-p scatterings.

Trajectory C ($r_0 < r_d < r_2$) goes through the proton structure, where the electron continuously looses energy (due to excitations of that structure) between its entry and exit points c and c'. Furthermore, since the electron possesses a de Broglie radius (with a corresponding de Broglie wavelength $2\pi r_d$), it exhibits a wave-like nature throughout the trajectory. This wave-like nature, and the finite length (c-c') of the traversed structure, produce a resonance within the measured scattering data.

Finally, when the electron energy is great enough ($r_d \ll r_0$) to allow the electron core to penetrate the proton core, this highly energized electron destroys the proton core, leading to the destruction of the proton mass and Compton radius, with a resulting hadron debris field (see Fig. 8.13 in [16, p.199]).

Fig. 2 shows the experimental scattering data for a beam of 4.879 GeV electrons ($r_d = r_p/5.2$ in (44)) from a proton at rest. The elastic peak at the far right of the figure is represented by B in Fig. 1 with $r_d = r_2$. (This elastic peak is shifted down from the incident electron energy 4.879 GeV to approximately 4.55 GeV ($r_d = r_p/4.9$) by recoil effects.) From the far right to approximately 2.9 GeV on the left the scattering is represented by C in Fig. 1, where the destruction of the proton core has not yet taken place. The three inelastic resonance peaks from left to right in the figure correspond to $r_d \approx r_p/(3.8, 4.1, 4.5)$ from (44).

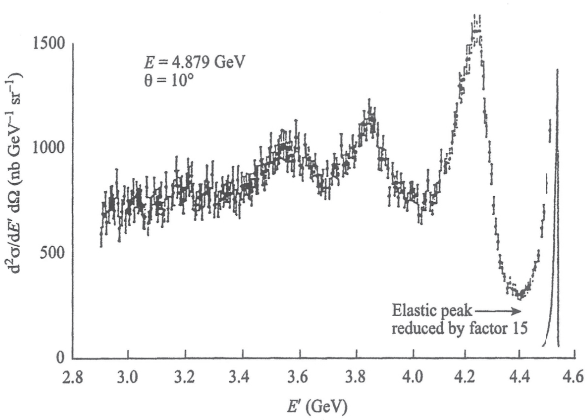

Fig. 2. Elastic and inelastic electron scattering from protons, where E' represents the energy of the scattered electron [21, p.14] [22]. The scattering angle is 10°. Electron loss increases from right to left.

Fig. 3 shows a repetition of Fig. 2 in a different format, for various scattering angles of the electron. Once more, the destruction of the proton core has not taken place, but the idea of the resonance scattering in the second and fourth paragraphs above is reinforced by the set of five three-peaked curves in the figure. The curves become monotonic when the trajectory between c and c' is deep enough to prevent constructive and destructive interference between reflections at c and c'. Furthermore, when the trajectory is deeper still, D ($r_d \approx r_0$), the electron core will scatter off the proton core.

Again, the proton core is destroyed when $E \gg m_p c^2$ ($r_d \ll r_0$). In this case the incident electron energy is sufficient to overcome the loss sustained in crossing the structure barrier ($r_2 - r_0 \approx r_2$) to penetrate and destroy the proton core.

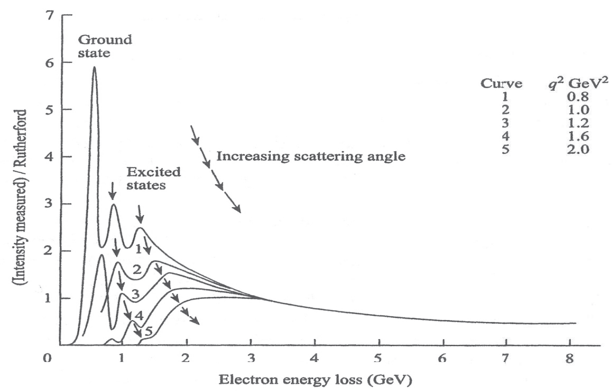

Fig. 3. Inelastic e-p scattering as a function of electron scattering angle [21, p.17] [23]. Electron loss increases from left to right.

8 e-p Antiparticles

This section defines charge conjugation in terms of the Planck vacuum substructure rather than the equation of motion of the particle. As such, the corresponding operator applies to the proton as well as the electron. Results show that, like their electron and proton counterparts, the positron is structureless while the antiproton possesses a structure consisting of a small vacuum "collar" surrounding its negatively charged core [24].

Before circa 2015, the PV theory only included a model for the electron and proton and the PV state $(-e_*, m_*, r_*)$ to which these two particles are coupled [15]. But there is a problem: while the theory suggests a source for the negative bare charge ($-e_*$) of the electron, it is mute when it comes to the positive bare charge (e_*) of the proton. What follows assumes a bifurcated vacuum state that includes both negative and positive bare charges ($\mp e_*$). This bifurcated state is understood to mean that at each point in free space there exists a PV subspace consisting of a charge doublet ($\mp e_*$), to either branch of which a free particle charge can be coupled.

The charge conjugation operator C from the quantum theory is an operator that changes particles into antiparticles, and visa versa [7, p.118]. An analogous operator is defined below to expand the the earlier PV model $(-e_*, m_*, r_*)$ to a model $(\mp e_*, m_*, r_*)$ that includes the particle-antiparticle symmetries and a source for the proton charge (e_*).

8.1 Charge Conjugation

The electron and proton cores, $(-e_*, m_e)$ and (e_*, m_p), exert the two particle/PV coupling forces

$$\pm\left(\frac{e_*^2}{r^2} - \frac{mc^2}{r}\right) \tag{46}$$

on the PV state, where the plus and minus signs in (46) refer to the electron and proton respectively. At their respective Compton radii these forces reduce to

$$F_e = \frac{(-e_*)(-e_*)}{r_e^2} - \frac{m_e c^2}{r_e} = \frac{e_*^2}{r_e^2} - \frac{m_e c^2}{r_e} = 0 \tag{47}$$

and

$$F_p = \frac{(e_*)(-e_*)}{r_p^2} + \frac{m_p c^2}{r_p} = -\left(\frac{e_*^2}{r_p^2} - \frac{m_p c^2}{r_p}\right) = 0 \tag{48}$$

where $r_e\,(= e_*^2/m_e c^2)$ and $r_p\,(= e_*^2/m_p c^2)$ are the electron and proton Compton radii. The first $(-e_*)$ and second $(-e_*)$ in (47) belong to the electron core and PV charges respectively. The charge (e_*) in (48) belongs to the proton core. The vanishing forces F_e and F_p are Lorentz invariant constants; and the two forces on the right side of (47) are the "weak" forces, while the two on the right side of (48) are the "strong" forces [18].

If it is assumed that the charge conjugation operator C' applies only to free-particle charges, then from (47) and (48)

$$C'F_e = \frac{(e_*)(-e_*)}{r_e^2} - \frac{m_e c^2}{r_e} = -\left(\frac{e_*^2}{r_e^2} + \frac{m_e c^2}{r_e}\right) \neq 0 \tag{49}$$

and

$$C'F_p = \frac{(-e_*)(-e_*)}{r_p^2} + \frac{m_p c^2}{r_p} = \frac{e_*^2}{r_p^2} + \frac{m_p c^2}{r_p} \neq 0 \tag{50}$$

both of which destroy the electron and proton Compton radii because the equations are nonvanishing. Since the corresponding antiparticles should possess a Compton radius like their particle counterparts, the C' operator is not a valid charge conjugation operator.

If it is assumed, however, that the charge conjugation operator C applies to both the free-space particle charge and the PV charge doublet, then (47) and (48) yield

$$CF_e = \frac{(e_*)(e_*)}{r_e^2} - \frac{m_e c^2}{r_e} = \frac{e_*^2}{r_e^2} - \frac{m_e c^2}{r_e} = 0 \tag{51}$$

and

$$CF_p = \frac{(-e_*)(e_*)}{r_p^2} + \frac{m_p c^2}{r_p} = -\left(\frac{e_*^2}{r_p^2} - \frac{m_p c^2}{r_p}\right) = 0 \tag{52}$$

where both the electron and proton Compton radii are preserved in their antiparticles. Equations (51) and (52) imply that the equations in (46) are also the antiparticle/PV coupling forces. It is clear from the first charges in (51) and (52), (e_*) and $(-e_*)$, that the positron is positively charged and that the antiproton carries a negative charge.

8.2 Comments

The second charges $(-e_*)$ in the first ratios of (47) and (48), and the second charges (e_*) in the first ratios of (51) and (52), suggest that free particles and their antiparticles exist in two separate spaces, corresponding respectively to the negative and positive branches of the PV charge doublet.

In addition to the C operator preserving electron and proton Compton radii, the form of the first ratios in (51) and (52) imply that the positron is structureless and that the antiproton has structure (Appendix A). This mirrors those same qualities in the electron and proton, the first ratios in (47) and (48).

As an aside, it is interesting to apply C to the free electron equation of motion. The Dirac equation for the electron can be expressed as [7, p.74]

$$ic\hbar\left(\frac{\partial}{c\partial t} + \boldsymbol{\alpha}\cdot\nabla\right)\psi = m_e c^2 \beta\psi \tag{53}$$

or, using $c\hbar = e_*^2$, as

$$\left[i(-e_*)(-e_*)\left(\frac{\partial}{c\partial t} + \boldsymbol{\alpha}\cdot\nabla\right) - m_e c^2\beta\right]\psi = 0 \tag{54}$$

where the first $(-e_*)$ belongs to the electron and the second to the negative branch of the PV charge doublet. The corresponding positron equation of motion is then obtained from the charge conjugation of (54)

$$C\left[i(-e_*)(-e_*)\left(\frac{\partial}{c\partial t} + \boldsymbol{\alpha}\cdot\nabla\right) - m_e c^2\beta\right]\psi$$

$$= \left[i(e_*)(e_*)\left(\frac{\partial}{c\partial t} + \boldsymbol{\alpha}\cdot\nabla\right) - m_e c^2\beta\right]\psi_c = 0 \tag{55}$$

where ψ_c is the positron spinor that obeys the same equation (54) as the electron spinor ψ. Due to the second (e_*) in (55), however, it is clear that the positron belongs to the positive branch of the PV doublet.

The same calculations in (53)-(55) are not applicable to the proton particle because, due to the vacuum "collar" (of radius $r_p/3.15$) surrounding the proton core (e_*, m_p), the proton does not obey a Dirac equation of motion. In effect, the proton cannot be modeled as a massive point charge because of this large vacuum "collar", even though the proton core radius r_0 is orders-of-magnitude smaller than its Compton radius r_p.

Appendix A: e-p Structure

This appendix is a brief review of why the proton is structured and the electron is not [20].

The electron and proton are assumed to exert the two coupling forces

$$F(r) = \pm \left(\frac{e_*^2}{r^2} - \frac{mc^2}{r} \right) \qquad \text{(A1)}$$

on the PV state, where the plus and minus signs refer to the electron and proton respectively. In effect the negative charge of the electron core $(-e_*, m_e)$ in (38) repels the negative PV charges $(-e_*)$ away from this core; while the positive charge of the proton core (e_*, m_p) in (45) attracts the PV charges. These oppositely charged Coulomb forces (the first terms in (A1)), close to their respective cores, are the fundamental cause of the structureless electron and the structured proton.

The potential energies associated with (A1) are defined by [20]

$$V(r) - V_0 = \int_{0^+}^{r} F(r')\, dr' \quad \text{with} \quad V(r_c) = 0 \qquad \text{(A2)}$$

where $r_c\,(= e_*^2/mc^2)$ is the Compton radius of either particle and the 0^+ accounts for the finite (but small) size of the cores. This definition leads to

$$V_p(r) \geq 0 \quad \text{and} \quad V_e(r) \leq 0 \qquad \text{(A3)}$$

where V_p and V_e are the proton/ and electron/PV coupling potentials.

It is shown in the Klein paradox [7, p.127] that a sufficiently strong positive potential acting on the vacuum state can force a portion of that state into free space, where that part of the vacuum can then be attacked by free-space particles. Thus the positive and negative potentials in (A3) imply that the proton core, but not the electron core, forces a small spherical (in the core's rest frame) portion of the vacuum into the free space around the proton core. This free-space vacuum "collar" is identified in the PV theory as the proton structure. Furthermore, this structure leads to an apparent spread in the charge e_* of the proton core (Appendix B).

Appendix B: Charge Spread

The polarization of the proton structure by the proton core leads to an apparent spread of the proton charge that is roughly expressed in the proton electric field as

$$E_p(r) = \frac{e(r)}{r^2} \qquad \text{(B1)}$$

where the spread is

$$e(r) = \begin{cases} e_* & , r < r_0 \\ < e_* & , r_0 < r < r_2 \\ e = \alpha^{1/2} e_* & , r_2 \leq r \end{cases} \qquad \text{(B2)}$$

$r_2 = r_p/3.15$, and $\alpha\,(\approx 1/137)$ is the fine structure constant. The radius r_2 defines the outer extent of the proton structure. An important characteristic of this result is the large charge gradient

$$\frac{\Delta e}{\Delta r} = \frac{e - e_*}{r_2 - r_0} \approx -\frac{e_*(1-\sqrt{\alpha})}{r_2} \approx -\frac{0.92 e_*}{r_2} \approx -\frac{11e}{r_2} \qquad \text{(B3)}$$

between the core charge e_* and the observed proton charge e at r_2. This result explains a similar gradient in the QED spread depicted in Fig. 11.6 of [21, p.319].

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