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On an Alternative Approach to the Anomalous Gyromagnetic Ratio of the Electron and Proton: Toward a Unified and Universal Dirac Equation (I)

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Abstract

Like the electron, the proton is considered to be a stable particle—the meaning of which is that, it does not decay into smaller constituents—*as such*—much like the electron, it is naturally expected to be accurately described by the *Dirac equation*. However, its measured g-factor: $g_{\rm p} = 2 + 3.5856946893(16)$, significantly deviates from the expected Dirac prediction of: $g_{\rm D} = 2$. In this article—*which is the first in a ten-part series titled: Toward a Unified and Universal Dirac Equation*—we propose that a massive electrically neutral zero-rank scalar coupled *Dirac equation* could, *in principle*, explain this deviation (the g-excess) and this requires that the proton have a non-zero radius. The same theory (equation) can be applied to the electron's non-Dirac g-excess and this requires us to endow the electron with a non-zero radius. That is to say, it is observed that the electron, which is typically regarded as a point particle (*i.e.*, as having a zero radius), exhibits a g-excess: $g_{\rm e} - 2 = 0.002319304362(2)$. According to the ideas presented herein, this non-Dirac g-excess, implies that the electron may actually be a spatially extended particle system.

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1. Introduction

This instalment marks the beginning of a ten-part series [see Refs. [1–9], hereafter Paper (II), (III) . . . (X)] titled: ***Toward a Unified and Universal Dirac Equation***. The overarching vision of this series is to reformulate the *Dirac equation* [10,11] through subtle yet reasonable modifications, aiming to create a unified equation that can account for all fundamental particle phenomena. Achieving unity and universality in these phenomena necessitates describing many seemingly unrelated occurrences from a shared perspective or common origin—a goal that has motivated theoretical physics since the earliest attempts at unification [12–16]. If anything, what this series is going to do is to bring to life the words [17–22] of United States of America's Professor Victor Frederick Weisskopf (1908-2002), when he said of the *Dirac equation* that:

> '*A great deal more was hidden in the Dirac equation than the author had expected when he [first] wrote it down in 1928.*'

Not only was a great deal hidden in the subtle and esoteric *Dirac equation*, but a lot more still remains hidden in this equation today. We are of the view that we (humankind) have taken the *Dirac equation* and run so fast with it without checking what exactly it is that we are carrying in our hand. As such, it perhaps is about time that we (humanity) take some time to reflect on the *Dirac equation* and as we do so—make a deep introspection of it, especially as we now are nearing the centenary celebration of this equation in the year 2028. In the present article, we shall tackle the now thought-to-be-resolved issue of the *Dirac equation*'s prediction of the g-factor.

The vision we hold of the Dirac equation as a universal framework capable of explaining all particle phenomena from unified standpoint has been a persistent and powerful current in the esoteric corridors of *Fundamental Theoretical Physics* since the equation's inception. Dirac himself was astonished [23] by its profound implications, predicting the existence of antimatter [24] from purely mathematical reasoning. This success sparked a lasting pursuit to uncover further layers of physical reality within its arcane mathematical structure. Modern efforts have made this vision more explicit. For example, it has been argued that the Dirac equation's description of a '*space-filling universal quantum field*' [herein the CFV-field] can resolve long-standing quantum enigmas like wave-particle duality and wave function collapse, pointing to a deeper, objectively real foundation for all quantum phenomena [25]. In a more concrete fundamental theoretical direction, researchers have developed '*fermion unification models*' based on the intrinsic symmetry groups of a generalized Dirac equation. Our efforts are grounded on a more simple framework within the usual four dimensional space on which the Dirac equation is founded.

By extending the Dirac spinor to a multi-component form, the intrinsic $\mathrm{SU}(8)$ symmetry of the equation can be shown to decompose into the $\mathrm{SU}(3)$, $\mathrm{SU}(2)$, and $\mathrm{U}(1)$ symmetry groups of the Standard Model, thereby naturally accommodating and unifying all eight basic fermions (leptons and quarks) of a single generation [26,27]. This suggests that the Dirac equation is not merely a description of a single particle like the electron, but contains within its algebraic structure the blueprint for the fundamental particles and their interactions. Further explorations using complexified quaternions and octonions within the Dirac equation aim to formulate a *Unified Field Theory*, describing a set of fermions with properties that mirror one generation of the Standard Model, including $\mathrm{U}(1)$ electromagnetism, $\mathrm{SU}(2)$ flavour, and $\mathrm{SU}(3)$ color symmetries [28].

Aside from the unifying vision of the Dirac equation and on more mundane issues concerning this equation—it is a well-known fact [to be demonstrated in §(5)] that the Dirac equation—*in its natural, bare and original form*—predicts a g-factor, g_{D}, equal to two: *i.e.*, $g_{\mathrm{D}} = 2$. This unprecedented and almost magical prediction of the Dirac equation closely matches the measured g-factor of the electron: $g_{\mathrm{e}} = 2 + 0.002319304362(2)$ [29–33], indicating that it (Dirac equation) provides a good description of the electron. In contrast, the proton (g_{p}) and neutron (g_{N}), which are also spin $1/2$ particles like the electron and are hence expected to be accurately described by the *Dirac equation*, these have g-factors that are disappointingly inconsistent with the predictions of this esteemed theory. Specifically, the most precise *state-of-the-art* measurements yield: $g_{\mathrm{p}} = 2 + 3.5856946893(16)$ [34–36], and, $g_{\mathrm{N}} = 2\breve{~}5.82608545(90)$ [37–40].

The conventional explanation for the significant deviation of the proton and neutron g-factors is that: this deviation is naturally explained by the fact these particles have an internal structure composed of three quarks. Each quark can be described by the Dirac equation with: $\mathrm{g}_{quark} = 2$. The interaction of these quarks inside the proton and neutron is assumed to lead to an effective g-factor that differs from this ideal value. With this in mind, we herein demonstrate that a massive electronically neutral zero-rank scalar (presumably the Higgs particle) coupled *Dirac equation* is *in principle* capable of providing an explanation for the derivation of the g-factor excess (g-excess) from the Dirac prediction, attributing this to the non-zero radius of these particles.

Any excess of the g-factor beyond what is predicted by the bare *Dirac equation* is herein referred to as the anomalous g-factor, and is denoted by the symbol, Δg_{P}, and defined as: $\Delta g_{\mathrm{P}} = (g_{\mathrm{P}} - 2)/2$. The subscript 'P' indicates the specific particle in question. For the electron, precise measurements revealed a small—*yet significant*—value greater than zero, specifically: $\Delta g_{\mathrm{e}} = 0.00116$. This discrepancy troubled several theorists, notably the renowned fundamental theoretical physicist—Julian Seymour Schwinger (1918-1994), who was the first to return to his desk to seek a definitive resolution on this issue.

At the conclusion of his remarkable and almost magical effort, Schwinger published a groundbreaking 72-page paper [41] on Quantum Electrodynamics (QED), where in this seminal paper, contained in it was '*Schwinger's Legacy and Legendary* $\alpha_0/2\pi$ *Correction*' to Dirac's electron's g-factor, *i.e.*, he found:

$$g_{\mathrm{e}} = 2\left[1 + \frac{\alpha_0}{2\pi}\right] = 2[1 + 0.0011614097329(2)], \quad (1)$$

where—according to the latest CODATA values [39]: $\alpha_0 = 1/137.03599908(2)$, is the *Fine Structure Constant* (FSC): $\alpha_0 = e^2/4\pi\varepsilon_0\hbar c_0$; where, $e = 1.602176634 \times 10^{-19}\,\mathrm{C}$, is the fundamental unit of electrical charge; $\varepsilon_0 = 8.8541878128 \times 10^{-12}\,\mathrm{C}^2 \cdot \mathrm{s}^2 \cdot \mathrm{m}^{-3} \cdot \mathrm{kg}^{-1}$, is the permittivity of free space; $\hbar = 1.054571817 \times 10^{-34}\,\mathrm{J} \cdot \mathrm{s}$, is Planck's normalized constant and; $c_0 = 2.99792458 \times 10^8\,\mathrm{m} \cdot \mathrm{s}^{-1}$, is the speed of Light in free space.

Schwinger [41]'s landmarking work marked the beginning of elaborate calculations of radiative correction terms which were motivated by the larger than expected hyperfine structure in hydrogen [42,43], and these had become increasingly important in the study of g-factors of Leptons. Schwinger [41]'s famous $\alpha_0/2\pi$ correction factor was first confirmed by the famous experiment of Kush and Foley [44]. As already stated, today the electron's anomalous g-factor has been measured to a few parts per billion, and this required QED theory to be extended to tenth-order accuracy in the correction terms [45–47] in-order to explain such a *state-of-the-art* measurement.

Against the present desideratum, Schwinger [41]'s calculation [leading to Eq. (1)] considers particle-particle interactions through the so-called Feynman diagrams/method [48–52]. As evidenced from the agreement of Schwinger [41]'s calculation with experimental findings, one can not in all probity deny the clearly evident fact that this approach has yielded the best ever agreement for any theory ever conceived by the human mind. The resulting agreement between theory and observation is so impressive so much so—that QED has be dubbed: *the best theory we have*. From the just said, it would strongly appear that there is no need for further interrogation or research on this matter as it is a now a closed case!

If a new alternative perspective on the same issue were discovered—*one that approaches the matter from a fresh vantage point and offers deeper insights into similar inexplicable phenomena*—it would justify the need for further investigation, research or exploration into the topic. We believe this is the case in the current exploration. For instance, from the theory presented here:

1. It is observed herein that the electron, which is typically regarded as a point particle in Quantum Electrodynamics (QED), exhibits a g-excess that suggests it may, in fact, be a spatially extended particle system with a finite non-zero radius.
2. New insights into whether antiparticles possess positive or negative energy are provided.
3. To calculate the excess g-factor of a particle, the seemingly unnatural Feynman diagrams that are used to calculate a particle's g-excess are not required in the proposed theory. Instead, what is needed is the radius of the particle in question; if this is unknown, it can be inferred from measurements of the particle's g-excess.

In conclusion, we provide a synopsis of the remainder of this reading. In §(2), we introduce the *Schrödinger-Pauli Equation* [53]. In §(3), we modify the *Dirac equation* by coupling the Dirac wavefunction to a charged, massive zero-rank *phi*-scalar particle. In §(4), we explore the *new mass term* of the modified Dirac equation. In §(5), for clarity and completeness, we present an exposition of Dirac's calculation of the g-factor derived from the *Dirac equation*. In §(6), we investigate the interaction of spin, the magnetic vector potential, $\boldsymbol{A}$, and the $\boldsymbol{\mathcal{H}}$ vector field. In §(7), we introduce the new theory regarding the non-Dirac g-factor that arises directly from the scalar-coupled Dirac theory. Finally, in §(8) and §(9), we provide a general discussion followed by our concluding remarks.

2. Schrödinger-Pauli Equation

For the sake of a smooth flow in our presentation, we now introduce the *Schrödinger-Pauli Equation* [53]. Formulated in 1927 by the distinguished and '*acerbic*' Austrian-Swiss fundamental theoretical physicist—Wolfgang Ernst Pauli (1900-1958), this equation is also referred to as the *Pauli Equation*. It represents a version of the *Schrödinger Equation* [54–58] for spin 1/2 particles and is the first quantum mechanical equation to account for the interaction of a particle's spin with an externally applied electromagnetic field, A_μ. This equation serves as the first-order non-relativistic limit of the *Dirac equation* and is applicable when particles are moving at speeds much less than the speed of Light, allowing relativistic effects to be ignored. The equation is expressed as follows:

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$$\left[-\frac{\hbar^2}{2m_0}\boldsymbol{\nabla}^2 + \mu_{\rm B}\boldsymbol{B}\cdot\left(\widehat{\boldsymbol{L}} + g_{\rm P}\widehat{\boldsymbol{S}}\right)\right]\Psi = \imath\hbar\frac{\partial\Psi}{\partial t}, \tag{2}$$

where: m_0, is the mass: Ψ, is the wavefunction: $\widehat{\boldsymbol{L}}$, is the orbital angular momentum operator: $g_{\rm P}$, is the g-factor, and: $\widehat{\boldsymbol{S}}$, is the spin operator, respectively, while: $\mu_{\rm B}$, is the Bohr magneton, and: $\boldsymbol{B}$, is the externally applied magnetic field. The spin $\boldsymbol{S}$, is defined such that:

$$\widehat{\boldsymbol{S}} = \frac{1}{2}\hbar\left(\sigma^1\hat{e}_x + \sigma^2\hat{e}_y + \sigma^3\hat{e}_z\right) = \frac{1}{2}\hbar\widehat{\boldsymbol{\sigma}}, \tag{3}$$

where: $(\sigma^1, \sigma^2, \sigma^3)$, are the 2×2 Pauli [53] matrices to be defined in Eq. (10), and: $\hat{e}_x, \hat{e}_y, \hat{e}_z$, are the usual unit vectors along the xyz-axis respectively. It is important to take note of the face that the spin, $\widehat{\boldsymbol{S}}$, is Hermitian, *i.e.*:

$$\widehat{\boldsymbol{S}}^\dagger = \widehat{\boldsymbol{S}}. \tag{4}$$

In conclusion, we would like to point out that in this reading, we will next encounter the *Schrödinger-Pauli Equation* in §(5). In the following section, we will present our proposed modification to the *Dirac equation*.

3. Modified Dirac Equation

We are now set to modify the *Dirac equation* by coupling the Dirac wavefunction to an al-pervasive, al-permeable, al-imponderable, al-non-tangible, luminiferous-like cosmic medium—*which in particle terms in relation to the interaction of any particle with this medium*—can be viewed as a massive, electrically neutral, zero-rank spin-less scalar field, $\phi_{\rm H}$. To that end, let $\tilde{\psi}$ be the wavefunction of the massive, electrically charged, zero-rank scalar coupled Dirac particle. The *Dirac equation* for this particle system is expressed by the familiar yet deceptively straightforward form of the *Dirac equation*, namely:

$$\left[\imath\hbar\gamma^\mu\partial_\mu - m_0c_0\right]\tilde{\psi} = 0, \tag{5}$$

where:

$$\tilde{\psi} = \phi_{\rm H}\psi, \tag{6}$$

with, $\phi_{\rm H}$, being the said massive electrically neutral spin-less zero-rank scalar particle that couples to the usual one-rank Dirac particle, ψ, were as usual:

$$\psi = \begin{pmatrix}\psi_0\\ \psi_1\\ \psi_2\\ \psi_3\end{pmatrix} = \begin{pmatrix}\psi_L\\ \psi_R\end{pmatrix}, \tag{7}$$

with: ψ_L, and, ψ_R, being the usual left and right-handed spinors—respectively, and, these spinors are such that:

$$\psi_L = \begin{pmatrix}\psi_0\\ \psi_1\end{pmatrix} \text{ and } \psi_R = \begin{pmatrix}\psi_2\\ \psi_3\end{pmatrix}. \tag{8}$$

The four γ^μ matrices appearing in Eq. (5), are defined:

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$$\gamma^0 = \begin{pmatrix} \sigma^0 & 0 \\ 0 & -\sigma^0 \end{pmatrix}, \tag{9a}$$

$$\gamma^k = \begin{pmatrix} 0 & \sigma^k \\ -\sigma^k & 0 \end{pmatrix}, \quad where: \quad k = (1,2,3), \tag{9b}$$

and the four 2×2 Pauli matrices σ^μ are such that:

$$\sigma^0 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \tag{10a}$$

$$\sigma^1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \tag{10b}$$

$$\sigma^2 = \begin{pmatrix} 0 & -\imath \\ \imath & 0 \end{pmatrix}, \tag{10c}$$

$$\sigma^3 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}. \tag{10d}$$

In the present article, the Dirac γ-matrices shall here be considered to constitute a four vector with the γ^k matrices being γ-matrices that are associated with the spin $(\widehat{\mathcal{S}})$ of the particle in question. This view of the Dirac γ-matrices constituting a four vector has been argued[1] in Ref. [59]. Further—the idea [as has been presented in Eq. (6)] of coupling the Dirac wavefunction, ψ, with a zero-rank scalar, $\phi_{\rm H}$, has been presented in Ref. [60] and the interested reader can visit the cited works if they seek a justification of this idea.

Applying the ϕ-scalar-coupled Dirac wavefunction [Eq. (6)] to the Dirac Eq. (5), one obtains—*after some basic algebraic operations*—the following wave-equation:

$$\left[\imath\hbar\gamma^\mu\left(\partial_\mu + \phi_{\rm H}^{-1}\partial_\mu\phi_{\rm H}\right) - m_0c_0\mathcal{I}\right]\psi = 0. \tag{11}$$

The simplest form imaginable of the wavefunction $(\phi_{\rm H})$ of such an electromagnetic field carrying particle—that will allow us latter to explain the generation of particles such as seen $(e.g.)$ in Lepton $(e^\pm, \mu^\pm, \tau^\pm)$ is:

$$\phi_{\rm H} = \phi_{\rm H}(0)\exp\left(\imath q\phi_{\rm P}\kappa_{\rm H}\oint_{\rm C}\mathcal{H}_\mu dx^\mu\right), \tag{12}$$

where: $\phi_{\rm H}(0)$, is the usual quantum mechanical normalization constant; $\lambda = 0, \pm 1$, is some constant that will be shown latter to lead to the emergence of the generations of Lepton; $\kappa_{\rm H}$, is constant with the dimension of inverse length, and: $\mathcal{H}_\mu = (\mathcal{H}_0, \boldsymbol{\mathcal{H}})$, is a dimensionless four vector potential with: $(\mathcal{H}_0, \mathcal{H}_i) \in \mathbb{F}$, *i.e.*, $\mathcal{H}_0$ & $\mathcal{H}_i$ are real valued zero-rank functions; $\phi_{\rm P}$, is a particle specific dimensionless coupling parameter to be explained in latter readings [5–9]; and, q, is the electronic charge of the ψ-particle and throughout this work, all electric charges are expressed in units of the elementary unit charge e, and are therefore dimensionless. This convention simplifies dimensional analysis and aligns with the natural system where—*as is the case in the present work*—the magnetic vector potential, $\boldsymbol{A}$, carries dimensions of momentum.

Substituting, $\phi_{\rm H}$, as it is given in Eq. (12) into Eq. (11), we will have:

1 There surely is no need for us to go through this issue here. The interested reader may visit the cited article in Ref. [59].

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$$\left[\imath\hbar\gamma^{\mu}\left(\partial_{\mu}+\imath q\phi_{\mathrm{P}}\kappa_{\mathrm{H}}\mathcal{H}_{\mu}\right)-m_{0}c_{0}\mathcal{I}\right]\psi=0, \tag{13}$$

At a *prima facie* level of analysis, Eq. (13) appears very similar to the standard *Dirac equation* with the Dirac particle, ψ, influenced by an ambient electromagnetic field '$\kappa_{\mathrm{H}}\mathcal{H}_{\mu}$' that couples to the particle *via* its charge, $q\phi_{\mathrm{P}}$. However, we must remember that *appearances can sometimes be deceiving*! The first notable difference is that '$\kappa_{\mathrm{H}}\mathcal{H}_{\mu}$' is not an external electromagnetic field acting on the ψ-particle; rather, it is an all-pervading, all-pervasive and all-permeating cosmic electromagnetic-like field that couples to the ψ-particle's electromagnetic field. At the present moment, we can not make a definitive identification of this field with the Higgs field—*maybe latter as our ideas blosson further*—our current intuitive feeling[2] is that this field will turnout to be the traditional symmetry breaking *Higgs Field* [61–63] envisioned in particle physics today.

Second, we shall assume that the momentum $(\kappa_{\mathrm{H}}\mathcal{H}_{\mu})$ of the ϕ-scalar contributes not to the kinetic energy of the ϕ-ψ-particle system, but to its inertial mass. This assumption is what constitutes the *real and big difference*. In this event, it follows that the term: '$q\phi_{\mathrm{P}}\kappa_{\mathrm{H}}\hbar\mathcal{H}_{\mu}/c_{0}$', has to be a part and parcel of the inertia properties of the ϕ-ψ-particle system; because of this, we shall move this term so that it constitutes an intrinsic and inherent part of the mass term of the ϕ-ψ particle system, *i.e.*:

$$\left[\imath\hbar\gamma^{\mu}\partial_{\mu}-\underbrace{\overbrace{\left(\frac{q\phi_{\mathrm{P}}\kappa_{\mathrm{H}}\hbar}{c_{0}}\gamma^{\mu}\mathcal{H}_{\mu}+m_{0}\mathcal{I}\right)}^{\textbf{New }4\times4\textbf{ Mass Term}}}_{m}c_{0}\right]\psi=0. \tag{14}$$

We shall set:

$$\boxed{\mathcal{M}=m_{\star}\gamma^{\mu}\mathcal{H}_{\mu}+m_{0}\mathcal{I}=\begin{pmatrix}(m_{0}-m_{\star}\mathcal{H}_{0})\sigma^{0} & m_{\star}\sigma^{0}\\ -m_{\star}\sigma^{0} & (m_{0}+m_{\star}\mathcal{H}_{0})\sigma^{0}\end{pmatrix},} \tag{15}$$

where[3]: $m_{\star}=q\phi_{\mathrm{P}}\kappa_{\mathrm{H}}\hbar/c_{0}=q\phi_{\mathrm{P}}m_{\mathrm{H}}$, so that Eq. (14) can be re-written more succinctly and compactly as follows:

$$\left[\imath\hbar\gamma^{\mu}\partial_{\mu}-\mathcal{M}c_{0}\right]\psi=0, \tag{16}$$

where in Eq (14) and (15): $\mathcal{I}$, is the usual 4×4 identity matrix and: $\mathcal{M}$, is the new mass-term and contrary to the traditional zero-rank mass term of the original *Dirac equation*: $\mathcal{M}$, is a 4×4 matrix. '*Mathematically speaking*', having a 4×4 matrix mass term as part of the *Dirac equation* is not a strange happening at all as the way Dirac [10,11] derived his equation does not—*in any way whatsoever*—preclude this seemingly outlandish and strange happening. In-fact, when Dirac presented his 4×1 wavefunction, it generated a certain amount of '*confusion*' among physicists, who were accustomed to Schrödinger's zero-rank Ψ-function [54–58]. The mathematical elegance of Dirac's formulation ultimately prevailed, prompting a re-evaluation of existing physical concepts. In a similar spirit, we may need to become more comfortable with the implications of this 4×4 mass term in our current theoretical framework.

Before concluding this section, we would like to highlight a crucial point. Specifically, Eq. (5) represents the perfectly symmetric Dirac equation, where the energy-momentum of the combined (ψ,ϕ_{H})-particles together yield the total energy-momentum of the resulting system: $\tilde{\psi}=\phi_{\mathrm{H}}\psi$. In contrast, Eq. (16) is a perfectly asymmetric Dirac equation, as demonstrated in Paper (V) [4]. The key

2 We firmly believe that if given the opportunity to present our ideas, all these seemingly loose ends will be tied up and clarified.

3 In writing the subscript '*Pl*' in $m_{\star}$, we anticipate that as our work progresses in the future, this mass will ultimately turnout to be the *Planck mass*, hence the choice of the subscript. As of now, we have not yet formally associated this mass with the *Planck mass*.

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difference between these two equations lies in the fact that in Eq. (5), all the energy-momentum of the ϕ-field completely condenses into mass, which becomes part of the mass of the ψ-particle. This process of condensation results in symmetry breaking, thereby creating a fundamentally asymmetric Universe. This symmetry breaking, we hypothesis is what happened at the moment of creation of our Universe leading to it to becoming matter dominated. We will delve deeper into these matters in Paper (V) [4]. In the coming section, we will examine the new physics introduced by this subtle modification.

4. Nature of the Matrix Mass Term

Is a 4×4 mass term an outlandish idea with no place in the realm of ideas with a direct beating with physical and natural reality? We need to answer this question before we proceed. To that end, we need to take a '*Tour de l'Histoire de la Physique*'. The Dirac equation, in its standard form, employs a zero-rank mass term—a scalar quantity, m_0, that multiplies the 4×1-wavefunction, ψ. This scalar mass, m_0, has been enormously successful, yet it carries an implicit assumption: that mass is a simple number, the same for all four components of the spinor: $\psi_0, \psi_1, \psi_2, \psi_3$,. But is this assumption necessary? Or is it merely the simplest possibility?

When Dirac [10,11] first proposed the equation that now bare his name, he moved from the simple zero-rank wavefunction, Ψ, of Schrödinger [54–58] (a single complex function) to a one-rank spinor (the 4×1 component wavefunction). This move defied all physical intuition of the time—yet the mathematics led the way, and physics followed. The existence of antimatter, the prediction of particle spin, and the correct g-factor all emerged from trusting the mathematical structure. At the height of the *Pyrrhic resistance* of the new physics packaged in the Dirac's strange new mathematics, Wolfgang Pauli reportedly said[4], '*Now physics has become an embarrassment to mathematics.*' Yet the mathematics proved correct. Further, even physicists like Enrico Fermi (1901-1954), Niels Henrik David Bohr (1885-1962), *etc* were initially skeptical [64] of Dirac's theory. Again—as history shows, the mathematics led the way—and physics trailed behind and eventually followed and caught up. Today, we very well might be facing a similar '*embarrassment*'—but if history is any guide, the mathematics may once again lead the way. In letting mathematics lead the way, Dirac [64–66] once remarked:

> '*If you are receptive and humble, mathematics will lead you by the hand. Again and again, when I have been at a loss how to proceed, I have just had to wait until I have felt the mathematics led me by the hand. It has led me along an unexpected path, a path where new vistas open up, a path leading to new territory, where one can set up a base of operations, from which one can survey the surroundings and plan future progress.*'

We very well might be in a similar *crossroad situation* that faced Dirac in 1928. Certainly—the success of Dirac's zero-rank mass term should not in any way blind us to the possibility that mass itself might have a richer structure. For just as Dirac promoted the wavefunction from a zero-rank scalar term to a spinor, we here have proposed promoting the zero-rank mass term to a two-rank—specifically, a 4×4 matrix mass term acting on the Dirac spinor, ψ. At first glance, this may appear completely outlandish. What could it possibly mean for mass to be represented by a 4×4 matrix? How can a particle's mass be represented by multiple mass values? Is this not a violation of everything we know about inertia?

These are precisely the questions that Dirac's contemporaries asked about his strange new equation which at the time had no precedent. Yet history shows that when the mathematics is consistent and the physical motivations are sound, intuition eventually catches up. Why a matrix mass term? For just as Dirac [10,11]'s then strange algebra revealed the existence of spin and antimatter before they were observed experimentally, the algebra of our 4×4 mass matrix reveals a rich structure that we are only beginning to explore. In the subsequent readings [1–9], we will show that this matrix representation of the mass term naturally leads to:

[4] In the wider popular scientific literature, this quote is widely attributed to Pauli and lacks verifiable primary sources. We treat this as an anecdotal illustration of the then scientific community's reaction to Dirac's theory, not as a documented historical statement.

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1. An explanation as to why we observe the asymmetric preponderance of matter over antimatter in the Universe [Paper (V)].
2. An explanation of the Generation of Particles [Papers (VI)-(X)].
3. A simple and most convincing justification of the mysterious *Koide Relation* [Papers (VI)-(IX)]
4. Unifies the electron, proton, and neutrino families
5. Prediction of new particle in the Proton Family with a mass of 8.70 MeV/c_0^2, and three sterile neutrinos belonging to the Proton Family of particles.

All of the above should provide sufficient reasons for the reader to anticipate the new and profound truths that will emerge from the new mathematics of the 4×4 mass term.

Despite what has been said above, at the end of it all—*the question still remains hanging at the summit of our foremost intellectual quest*—Exactly, how should we visualize a matrix mass? As a last word on this—*perhaps*—one helpful analogy comes from condensed matter physics, where effective mass is already a tensor quantity—different in different directions. In particle physics, the '*directions*' are the internal degrees of freedom of the spinor. The 4×4 mass matrix, $\mathcal{M}$, simply assigns different effective masses to different combinations of these internal states. Another analogy comes from Quantum Field Theory (QFT), where mass arises from coupling to fields. If multiple fields contribute, or if a single field has multiple components, the resulting mass term is naturally matrix-valued. Thus, while a matrix mass may seem unfamiliar, it is neither unprecedented in physics nor mathematically inconsistent.

In the natural progression of ideas from simple to complex and increasingly intricate, this is simply the next logical step, namely:

$$\boxed{\textbf{Scalar}\,[\text{Schrödinger}\,(1926)] \mapsto \textbf{Spinor}\,\,[\text{Dirac}\,(1928)] \mapsto \textbf{4}\times\textbf{4}\,\textbf{Mass-Term}\,\,[\text{This Work}\,(2026)].} \tag{17}$$

From all that we have presented above, it seems essential for us to pursue this intriguing and seemingly natural idea to its logical conclusion while simultaneously seeking any potential correspondence with reality. Dirac [64–66] himself articulated the delicate balance between conviction and open-mindedness that characterizes scientific inquiry and discovery—of this, he said:

> *'One should not pursue one's conjectures too firmly, but should at all times be ready to change one's views if the evidence demands it. Nevertheless, one must be prepared to follow up one's ideas right to the end, and not give them up too easily.'*

This is the zest and spirit with which we are pursuing the present idea of the $\mathcal{H}$-field and its resulting 4×4 matrix mass term.

After our '*Tour de l'Histoire de la Physique*', it may be refreshing at this point to note that—out of the sixteen terms in the 4×4 mass matrix, what we actually measure in the laboratory is a single zero-rank mass term, m; a number that is extracted from this 4×4 matrix. To illustrate this, the conjugate (not complex conjugate) mass $\bar{\mathcal{M}}$, of, $\mathcal{M}$, is:

$$\bar{\mathcal{M}} = m_\star \gamma^\mu \mathcal{H}_\mu - m_0 \mathcal{I}, \tag{18}$$

and this is obtained by performing the following transformation: $m_0 \mapsto -m_0$, on $\mathcal{M}$. The zero-rank mass term, m, that we measure in the laboratory then becomes a part of the following equation:

$$\bar{\mathcal{M}}\mathcal{M} = m^2 \mathcal{I}, \tag{19}$$

where:

$$m^2 = m_\star^2 |\mathcal{H}|^2 - m_0^2, \tag{20}$$

and: $|\mathcal{H}|^2 = \mathcal{H}_0^2 + \mathcal{H}_1^2 + \mathcal{H}_2^2 + \mathcal{H}_3^2$. We shall assume that throughout the cosmos: $|\mathcal{H}|^2 = 1$, so that:

$$\boxed{m^2 = m_\star^2 - m_0^2.} \tag{21}$$

The transpose-complex conjugate of, $\mathcal{M}$, is such that

$$\boxed{\mathcal{M}^\dagger = \gamma^0 \mathcal{M} \gamma^0 \neq \mathcal{M}.} \tag{22}$$

As will be demonstrated in Paper (V), this property [given in, Eq. (22)] is what leads to the resulting modified Dirac equation to violate all charge related symmetries—*i.e.*, $\mathcal{C}$, $\mathcal{CP}$, $\mathcal{CT}$, and, $\mathcal{CPT}$ symmetries, where: $\mathcal{C}$, $\mathcal{P}$, and, $\mathcal{T}$, are the *Charge*, *Parity*, and, *Time Reversal Symmetries*. In the next section, for the sake of clarity, self-containment, and completeness purposes, we will provide an exposition of the derivation of the famous Dirac g-factor: $g_{\mathrm{D}} = 2$.

5. Dirac G-Factor

As mentioned in the penultimate part of the previous section, we will demonstrate in this section how the bare *Dirac equation* accurately accounts for the g-factor of the electron. For this reason, the *Dirac equation* is often regarded as particularly suitable for the electron, which is why it is frequently referred to as the '*Dirac Equation for the Electron*', a designation that traces back to Dirac himself. Furthermore, as noted in the opening sentence of this article, the overarching goal of our program—*Toward a Universal Dirac Equation*—is to establish the *Dirac equation* as a universal framework capable of explaining most, if not all, particle systems found in *Nature*. This implies that the new modified Dirac equation must be able to account not only for the g-factor of the electron but also for that of the proton as well.

In-order to derive the Dirac g-factor, we start by considering the Dirac particle, ψ, placed in an ambient magnetic field. In the presence of this magnetic field, denoted as A_μ, the derivatives transform as follows:

$$\partial_\mu \longmapsto D_\mu = \partial_\mu + \frac{\imath q}{\hbar} A_\mu. \tag{23}$$

Making this replacement results in the *Dirac equation* $\left(\left[\imath\hbar\gamma^\mu\partial_\mu - m_0 c_0\right]\psi = 0\right)$ reducing to:

$$\left[\imath\hbar\gamma^\mu D_\mu - m_0 c_0 \mathcal{I}\right]\psi = 0. \tag{24}$$

Acting on this equation from the left using the conjugate operator: $\imath\hbar\gamma^\mu D_\mu + m_0\mathcal{I}c_0$, we obtain:

$$\left[\gamma^\mu\gamma^\nu D_\mu D_\nu - \left(\frac{m_0 c_0}{\hbar}\right)^2 \mathcal{I}\right]\psi = 0. \tag{25}$$

It is clear that:

$$\gamma^\mu\gamma^\nu = \frac{1}{2}\left(\{\gamma^\mu, \gamma^\nu\} + [\gamma^\mu, \gamma^\nu]\right) = \eta^{\mu\nu}\mathcal{I} + \sigma^{\mu\nu}, \tag{26}$$

where: $\eta^{\mu\nu}\mathcal{I} = \dfrac{1}{2}\{\gamma^\mu, \gamma^\nu\}$, is the Minkowski metric with the spacetime signature that is such that: diag($\blacksquare^{-\circ}$) $= [+1, -1, -1, -1]$; and the object, $\sigma^{\mu\nu}$, is the usual spin tensor (operator) and is such that:

$$\sigma^{\mu\nu} = \frac{1}{2}[\gamma^\mu, \gamma^\nu] = \begin{pmatrix} 0 & \gamma^0\gamma^1 & \gamma^0\gamma^2 & \gamma^0\gamma^3 \\ -\gamma^0\gamma^1 & 0 & \imath\gamma^0\gamma^5\gamma^3 & \imath\gamma^0\gamma^5\gamma^2 \\ -\gamma^0\gamma^2 & -\imath\gamma^0\gamma^5\gamma^3 & 0 & \imath\gamma^0\gamma^5\gamma^1 \\ -\gamma^0\gamma^3 & -\imath\gamma^0\gamma^5\gamma^2 & -\imath\gamma^0\gamma^5\gamma^1 & 0 \end{pmatrix}. \tag{27}$$

From the foregoing, it follows that:

$$\gamma^\mu\gamma^\nu D_\mu D_\nu = \eta^{\mu\nu} D_\mu D_\nu + \sigma^{\mu\nu} D_\mu D_\nu. \tag{28}$$

Further, we know that:

$$\sigma^{\mu\nu}D_\mu D_\nu = \sigma^{\mu\nu}\left[D_\mu, D_\nu\right] = \frac{\imath q}{2\hbar}\sigma^{\mu\nu}F_{\mu\nu}, \tag{29}$$

where, as is usual:

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu, \tag{30}$$

is the Maxwellian electromagnetic field tensor of the applied external field. When harmoniously collated, the above calculations reduce to:

$$\left[\eta^{\mu\nu}D_\mu D_\nu - \mathcal{I}\left(\frac{m_0 c_0}{\hbar}\right)^2 + \frac{\imath q}{2\hbar}\sigma^{\mu\nu}F_{\mu\nu}\right]\psi = 0. \tag{31}$$

To proceed from Eq. (31), as is usual, let us consider a weak and constant magnetic field acting along the *z-axis*, *i.e.*:

$$\boldsymbol{A} = \frac{1}{2}\boldsymbol{r}\times\boldsymbol{B} = \frac{1}{2}yB_z\hat{e}_x - \frac{1}{2}xB_z\hat{e}_y, \tag{32}$$

where:

$$\boldsymbol{B} = (0, 0, B_z), \tag{33}$$

so that: $F_{12} = -F_{21} = B$. We know that:

$$\begin{aligned}
\eta^{\mu\nu}D_\mu D_\nu &= \eta^{\mu\nu}\left(\partial_\mu + \frac{\imath q}{\hbar}A_\mu\right)\left(\partial_\nu + \frac{\imath q}{\hbar}A_\nu\right), \\
&= \eta^{\mu\nu}\left(\partial_\mu\partial_\nu + \frac{\imath q}{\hbar}\partial_\mu A_\nu + \frac{\imath q}{\hbar}A_\mu\partial_\nu - \frac{q^2}{\hbar^2}A_\mu A_\nu\right), \\
&= \eta^{\mu\nu}\partial_\mu\partial_\nu + \frac{\imath q}{\hbar}\eta^{\mu\nu}\partial_\mu A_\nu + \frac{\imath q}{\hbar}A_\mu\eta^{\mu\nu}\partial_\nu - \frac{q^2}{\hbar^2}\eta^{\mu\nu}A_\mu A_\nu, \\
&= \Box + \frac{\imath q}{\hbar}\partial_\mu A^\mu + \frac{\imath q}{\hbar}A^\mu\partial_\mu - \frac{\ell_A^2}{\hbar^2}.
\end{aligned} \tag{34}$$

where: $\ell_A^2 = q^2\eta^{\mu\nu}A_\mu A_\nu$. Because the ambient magnetic field is source-less, it is natural to assume that: $A^0 = 0$, and making this assumption, leads to: $\ell_A^2 = q^2\eta^{ij}A_iA_j = q^2|\boldsymbol{A}|^2 = q^2 r_{\mathrm{P}}^2B^2/4$, where: $r_{\mathrm{P}} = |\boldsymbol{r}|$, is the radius of the particle in question. By asserting that: $|\boldsymbol{A}|^2 = r_{\mathrm{P}}^2B^2/4$, we are implicitly assuming that the particle's radius vector, $\boldsymbol{r}$, and the ambient magnetic field, $\boldsymbol{B}$, are orthogonal to each other. This assumption: $A^0 = 0$, leads to the effective mass of the particle to be sensitive to the presence of the ambient magnetic field and this strongly appears to be against experimental findings [67–74] and we shall need to revisit this and make the necessary adjustment that aligns with experimental data. If we want to align with the experimental findings of the invariance of the mass of charged particles in the presence of ambient magnetic field, we will have to set: $\ell_A^2 = 0$, the meaning of which is that we will have to have: $A^0 \neq 0$, *i.e.*, $A^0 = \boldsymbol{constant}$, which is consistent with the absence of the electric charge generated electric field. If: $A^0 \neq 0$, and: $\ell_A^2 = 0$, it follows that: $A^0 = |\boldsymbol{A}| = \boldsymbol{constant}$.

Now, assuming the Lorenz [75] gauge: $\partial_\mu A^\mu = 0$, the above reduces to:

$$\eta^{\mu\nu}D_\mu D_\nu = \Box + \frac{\imath}{\hbar}A^k\partial_k - \frac{\ell_A^2}{\hbar^2}, \tag{35}$$

To compute the term, $A^k\partial_k$, we must remember the configuration of the magnetic vector potential, $\boldsymbol{A}$, and the $\boldsymbol{B}$-field given in Eq. (32) and (33), respective;y. From this configuration, it is not difficult to deduce that:

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$$\begin{aligned} A^k\partial_k &= A^1\partial_1 + A^2\partial_2, \\ &= qB_z\left(y\partial_x - x\partial_y\right), \\ &= \frac{\imath}{\hbar}qB_z\widehat{L}_z, \\ &= \frac{\imath}{\hbar}q\boldsymbol{B}\cdot\widehat{\boldsymbol{L}}, \end{aligned} \tag{36}$$

where: $\widehat{L}_z = \imath\hbar\left(x^2\partial_1 - x^1\partial_2\right)$, is the z-component of the orbital angular momentum operator and this angular momentum operator acts on the wavefunction of the electron, while, $\widehat{\boldsymbol{L}} = \boldsymbol{r}\times\widehat{\boldsymbol{p}}$, is the total orbital angular momentum operator which means that the orbital angular momentum generates orbital magnetic moment that interacts with the magnetic field and: $\widehat{\boldsymbol{p}} = \imath\hbar\boldsymbol{\nabla}$, is the linear momentum operator.

At the end—*when we collate the above calculations*—we obtain the following:

$$\eta^{\mu\nu}D_\mu D_\nu = \square - \frac{q\boldsymbol{B}\cdot\widehat{\boldsymbol{L}}}{\hbar^2} - \frac{\ell_A^2}{\hbar^2}, \tag{37}$$

It must be noted that this expression [Eq. (37)] is an exact result and not an approximation. For the term: $\sigma^{\mu\nu}F_{\mu\nu}$, we have that:

$$\sigma^{\mu\nu}F_{\mu\nu} = \frac{2\imath}{\hbar}\begin{pmatrix} \boldsymbol{B}\cdot\widehat{\boldsymbol{S}} & 0 \\ 0 & \boldsymbol{B}\cdot\widehat{\boldsymbol{S}} \end{pmatrix} = -\frac{2\imath\mathcal{I}\boldsymbol{B}\cdot\widehat{\boldsymbol{S}}}{\hbar} \tag{38}$$

Inserting: $\eta^{\mu\nu}D_\mu D_\nu$, and, $\sigma^{\mu\nu}F_{\mu\nu}$, as given in Eq. (37) and (38), respectively, into Eq. (31), we obtain:

$$\left(\left[\square - \frac{q\boldsymbol{B}\cdot\widehat{\boldsymbol{L}}}{\hbar^2} - \underbrace{\overset{\textbf{Effective Mass Term}}{\left[\left(\frac{m_0c_0}{\hbar}\right)^2 + \frac{\ell_A^2}{\hbar^2}\right]}}_{m_{\text{eff}}^2}\right]\mathcal{I} - \frac{2q}{\hbar^2}\mathcal{I}\boldsymbol{B}\cdot\widehat{\boldsymbol{S}}\right)\psi = 0, \tag{39}$$

Setting:

$$m_{\text{eff}}^2 = m_0^2 + \frac{\ell_A^2}{c_0^2} = m_0^2 + \left(\frac{qr_P}{2c_0}\right)^2 B^2, \tag{40}$$

where, m_{eff}, is what we shall call the effective mass[5] that of the particle in question, and conveniently dropping the $\mathcal{I}$-matrix in Eq. (39), it follows that we can now write Eq. (39) as follows:

$$\left(\square - \frac{q\boldsymbol{B}\cdot\widehat{\boldsymbol{L}}}{\hbar^2} - \left(\frac{m_{\text{eff}}c_0}{\hbar}\right)^2 - \frac{2q\boldsymbol{B}\cdot\widehat{\boldsymbol{S}}}{\hbar^2}\right)\psi = 0. \tag{41}$$

This Eq. (41) can further be written as follows:

$$\boxed{\left(\square - \frac{q\boldsymbol{B}\cdot\left(\widehat{\boldsymbol{L}} + 2\widehat{\boldsymbol{S}}\right)}{\hbar^2} - \left(\frac{m_{\text{eff}}c_0}{\hbar}\right)^2\right)\psi = 0.} \tag{42}$$

[5] This relation [Eq. (40)] suggests that $m_{\text{eff}}^2 \propto B^2$. This implies that a the graph of: m_{eff}^2 *vs* B^2, should yield a straight line, and the slope of this line can be used to determine the radius of the particle in question. Since this result is against experimental findings (*e.g.*, [67–74]), as argued earlier on p.(10), we shall assume the invariance of the mass of charged particles in an ambient magnetic field, the meaning of which is that: $\ell_A^2 = 0$, and: $A^0 = |\boldsymbol{A}|$, and this implies: $m_{\text{eff}}^2 = m_0^2$.

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This Eq. (42) is an exact equation and not merely an approximation, as is often the case in typical calculations where the Dirac g-factor is presented (*e.g.*, in [76–80]). The coefficient of $\widehat{S}$ appearing in this Eq. (42) represents the g-factor of the particle in question and from it, we observe that: $g_{\mathrm{D}} = 2$, which is impressively very close to the electron's g-factor, hence, the 'ordination and christening' of the Dirac equation as the '*Dirac Equation of the Electron.*' This factor '2' tells us that a unit of spin angular momentum, $\widehat{\boldsymbol{S}}$, interacts with a magnetic field, $\boldsymbol{B}$, twice as much as a unit of orbital angular momentum, $\widehat{\boldsymbol{L}}$, an observational fact that had puzzled physicists deeply at the time. This calculation leading to Eq. (42) is rightly and justly celebrated as one of the greatest in the *History of Fundamental Theoretical Physics Exploration*.

Be that as it may, precise *state-of-the-art* measurements indicate that the electron's g-factor is slightly above 2. This minute discrepancy between observations and theory prompted Julian S. Schwinger to delve into the problem, where he successfully resolved this issue in his groundbreaking 72-page QED calculation. If indeed Quantum Electrodynamics (QED) already explains the electron's g-factor, one might naturally ask: why seek another theory to explain the same phenomenon? Are we trying to reinvent the wheel? The answer is a capitalized bold **NO!** Our motivation stems from the belief that we may have discovered a credible and intriguing approach to this cherished result. This new perspective may indeed warrant the attention of contemporary physicists, which is why we are presenting it here.

Among a host of other issues, the problem with QED is that it assumes the electron and the muon, whose g-factors are very close to the Dirac value of 2, are point particles. This is one of the key aspects regarding the electron and muon that this paper aims to revisit for a deeper examination. Are the electron and the muon indeed point particles? Additionally, for philosophical reasons—*though we need not in the present delve into the details thereof*—it is worth mentioning that, from a higher level of beauty (*whatever this means*), we expect the *Dirac equation* to naturally account for all fermions without significant modifications, if any at all, much like it was originally conceived as a universal equation for spin 1/2 particles by *e.g.*, tHooft [23], Bhaumi [25], Marsch [26,27], Anon [28], in their quest for a unified Dirac equation.

Another reason—*perhaps*—is that methods such as renormalization, used in QED to achieve these *all-time* impressive and accurate values, can feel or appear rather un-natural. This is so much so that:

At any rate imaginable,
we do not believe,
not even for brief moment,
that the GOOD LORD,
integrates empirically.

Yes, these methods produce accurate results when compared with physical and natural reality, but the question remains: is such a program truly integral to the *Natural Laws*? This is a challenging question to address from an experimental perspective due to its philosophical nature of the issue. Consequently, the need for alternative approaches to this problem becomes *dire* and *a priori justified* and noble human intellectual endeavour.

6. Spin and Magnetic Field Interaction

In the subsequent §(7), we will demonstrate that the anomalous g-factor may result from the interaction between the $(\boldsymbol{A}, \boldsymbol{\mathcal{H}})$-fields and the spin, $\widehat{\boldsymbol{S}}$. This interaction includes the dot product of the vector fields: $\boldsymbol{A}, \boldsymbol{\mathcal{H}}$, with the spin vector $(\widehat{\boldsymbol{S}})$, *i.e.*, $\boldsymbol{A}\cdot\widehat{\boldsymbol{S}}$ and $\boldsymbol{\mathcal{H}}\cdot\widehat{\boldsymbol{S}}$. Therefore, we aim here to calculate these quantities in advance. To that end:

1. We know that: $\boldsymbol{A} = \dfrac{1}{2}\boldsymbol{r}\times\boldsymbol{B}$; from this fact, it follows that:

$$\begin{aligned} \boldsymbol{A}\cdot\widehat{\boldsymbol{S}} &= \frac{1}{2}(\boldsymbol{r}\times\boldsymbol{B})\cdot\widehat{\boldsymbol{S}}, \\ &= \frac{1}{2}|\boldsymbol{r}\times\boldsymbol{B}|\left|\widehat{\boldsymbol{S}}\right|\cos\theta, \end{aligned} \tag{43}$$

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where: θ, is the angle between the vectors, $\widehat{\mathcal{S}}$, and, $\boldsymbol{A}$.

2. Further, we know that: $\boldsymbol{r} \times \boldsymbol{B} = |\boldsymbol{r}||\boldsymbol{B}|\hat{\boldsymbol{n}} \sin\vartheta$, where: $\hat{\boldsymbol{n}}$, is the unit vector perpendicular to the vector: $\boldsymbol{r}$, and, $\boldsymbol{B}$, and: $\vartheta = 90^\circ = \frac{1}{2}\pi$ radians, is the angle between the vectors, $\boldsymbol{r}$, and, $\boldsymbol{B}$. Inserting this into Eq. (43), we will have:

$$\boldsymbol{A} \cdot \widehat{\mathcal{S}} = \frac{1}{2}|\boldsymbol{S}|(|\boldsymbol{r}||\boldsymbol{B}| \sin\vartheta) \cos\theta = \frac{1}{2}|\boldsymbol{S}|(|\boldsymbol{r}||\boldsymbol{B}|) \cos\theta. \tag{44}$$

3. Furthermore, writing Eq. (44), as follows:

$$\boldsymbol{A} \cdot \widehat{\mathcal{S}} = r_{\mathrm{P}}\left(\frac{1}{2}\frac{\cos\theta}{\cos\Theta}\right)\left(\left|\widehat{\mathcal{S}}\right||\boldsymbol{B}| \cos\Theta\right), \tag{45}$$

where: $r_{\mathrm{P}} = |\boldsymbol{r}|$, is the radius of the particle in question, and: Θ, is the angle between the vectors, $\widehat{\mathcal{S}}$, and, $\boldsymbol{B}$. We know that: $\boldsymbol{B} \cdot \widehat{\mathcal{S}} = \left|\widehat{\mathcal{S}}\right||\boldsymbol{B}| \cos\Theta$, and from this it follows that:

$$\boldsymbol{A} \cdot \widehat{\mathcal{S}} = r_{\mathrm{P}}\zeta^{\star}_{\mathrm{P}}\boldsymbol{B} \cdot \widehat{\mathcal{S}}, \tag{46}$$

where in this Eq. (46), we have set:

$$\zeta^{\star}_{\mathrm{P}} = \frac{\cos\theta}{2\cos\Theta} \neq 0. \tag{47}$$

The parameter, $\zeta^{\star}_{\mathrm{P}}$, serves as a *free parameter* within the theory, meaning it cannot be determined directly from within the present theoretical framework and must instead be inferred from experimental measurements. Since, $\boldsymbol{A}$, and, $\boldsymbol{B} = \boldsymbol{\nabla} \times \boldsymbol{A}$, are orthogonal, this parameter also quantifies the angle between the ambient magnetic field, $\boldsymbol{B}$, and the spin of the particle in question. The observation that the g-factor remains constant for a specific particle suggests that this angle is fixed, allowing us to conclude that, $\zeta^{\star}_{\mathrm{P}}$, is a constant parameter for each particle species.

4. Lastly, we want to understand how, $\boldsymbol{\mathcal{H}} \cdot \widehat{\mathcal{S}}$, is related to, $\boldsymbol{B} \cdot \widehat{\mathcal{S}}$. To that end, it is reasonable to expect that, $\boldsymbol{\mathcal{H}}$, will either align or anti-align with, $\widehat{\mathcal{S}}$, implying that: $\boldsymbol{\mathcal{H}} \propto \widehat{\mathcal{S}}$. When converted into a precisely defined mathematical relationship, this assumption naturally leads us to the relation:

$$\boldsymbol{\mathcal{H}} = \left(\frac{\zeta_{\mathrm{P}}}{\zeta^{\star}_{\mathrm{P}}}\right)\frac{\widehat{\mathcal{S}}}{\hbar}, \tag{48}$$

where, $\zeta^{\star}_{\mathrm{P}}$, is another dimensionless parameter. From this, along with Eq. (46), we can conclude that:

$$\boldsymbol{A} \cdot \boldsymbol{\mathcal{H}} = \left(\frac{\zeta_{\mathrm{P}}}{\zeta^{\star}_{\mathrm{P}}\hbar}\right)\boldsymbol{A} \cdot \widehat{\mathcal{S}} = \left(\frac{\zeta_{\mathrm{P}} r_{\mathrm{P}}}{\hbar}\right)\boldsymbol{B} \cdot \widehat{\mathcal{S}}, \tag{49}$$

The assumption: $\boldsymbol{\mathcal{H}} \propto \widehat{\mathcal{S}}$, should be considered a hypothesis of the current theory—the fruits of this hypothesis will become evident in Paper (II) [1]. Although it is a hypothesis, it is a plausible one, as it suggests that the surrounding magnetic field seeks to align with the cosmic $\mathcal{H}$-field. This notion appears reasonable and is not far-fetched, unrealistic or outlandish.

Perhaps, we must, at this juncture, hasten to say that—the *CVF-field Alignment Hypothesis*, namely that the cosmic $\boldsymbol{\mathcal{H}}$-field aligns with the particle spin, $\hat{\mathcal{S}}$, as expressed mathematically in Eq. (49), this is not an arbitrary imposition but rather emerges from deep symmetry considerations. In a Lorentz-invariant theory, the only available vectors associated with a point-like fermion are its four momentum p^μ and its spin pseudo-vector S^μ. For a particle at rest, the spin vector, S^μ, reduces to the three-dimensional spin, $\hat{\mathcal{S}}$. If the cosmic field, $\mathcal{H}^\mu$ is to couple to the particle in a manner that respects rotational invariance in the rest frame, the most natural and simplest coupling is a linear one: $\mathcal{H}^\mu \propto S^\mu$. Any other coupling would introduce additional tensorial structures that would need to be justified by *new physics*. Furthermore, from an effective field theory perspective, the lowest-dimensional operator coupling a four vector field, $\mathcal{H}^\mu$, to a fermion is of the form: $(\bar{\psi}\gamma^\mu\psi)\mathcal{H}_\mu$, which in the non-relativistic limit reduces precisely to $\boldsymbol{\mathcal{H}} \cdot \hat{\mathcal{S}}$. Thus, from this perspective, the CFV-field alignment hypothesis can be viewed as the classical manifestation of this fundamental quantum operator. We shall see in Paper (II) [1] that this hypothesis leads, quite remarkably, to the full Dyson series expansion of the anomalous magnetic moment.

Also, another legitimate concern is that regarding the interaction term, $\boldsymbol{A} \cdot \boldsymbol{\mathcal{H}}$, is its behaviour under gauge transformations. In QED, the vector potential, $\boldsymbol{A}$, is not gauge-invariant; physical

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observables must depend only on the electromagnetic field tensor, $F_{\mu\nu}$. However, the term: $\boldsymbol{A}\cdot\boldsymbol{\mathcal{H}}$, as it appears in Eq. (49) is rendered gauge-invariant by the nature of the CFV-field. Specifically, if, $\mathcal{H}_\mu$ is itself a transverse field satisfying: $\boldsymbol{\nabla}\cdot\boldsymbol{\mathcal{H}}=0$, then in the Coulomb gauge: $\boldsymbol{\nabla}\cdot\boldsymbol{A}=0$, the product, $\boldsymbol{A}\cdot\boldsymbol{\mathcal{H}}$, is gauge-invariant. More fundamentally, one can view, $\mathcal{H}_\mu$, as a physical field—akin to a background cosmic vector—that picks a preferred frame, thereby fixing the gauge implicitly. In such a scenario, the gauge freedom of, $\boldsymbol{A}$, is rendered moot because the physical situation (the presence of the cosmic field) breaks gauge redundancy. This is analogous to the treatment of background fields in spontaneous symmetry breaking, where the Higgs vacuum expectation value fixes a direction in field space. A fully gauge-invariant formulation can be achieved by introducing the combination, $\boldsymbol{A}\cdot\boldsymbol{\mathcal{H}}$, only after gauge fixing, or by recognizing that, $\mathcal{H}_\mu$, transforms appropriately under gauge transformations to make the product invariant. We adopt the Coulomb gauge throughout this work, which is both natural for non-relativistic systems and sufficient for our purposes.

In the next section, we will apply the modified Dirac equation to the issue of the extra-anomalous g-factor. If—*in conformity with findings obtaining from experimental philosophy*—we are to have the g-factor of a particle being identical to that of its antiparticle (see *e.g.*, Refs. [81–86]), then, the dot-product, $\boldsymbol{\mathcal{H}}\cdot\widehat{\boldsymbol{S}}$, should be the same for both the particle and its antiparticle.

7. Non-Dirac G-Factor

We now arrive at our main *port-of-call*, where we will determine the g-factor implied by the modified Dirac Eq. (16). The procedure for this has already been outlined in §(5); one simply needs to follow those steps. To that end, we shall begin by rewriting Eq. (16) as follows:

$$\left[\imath\hbar\gamma^\mu D_\mu - \mathcal{M}c_0\right]\psi = 0, \tag{50}$$

and then proceed from here-on as before by multiplying this Eq. (50) from the left hand-side by the conjugate operator: $\imath\hbar\gamma^\nu D_\nu + \bar{\mathcal{M}}c_0$, where: . So doing, we obtain:

$$\left[\underbrace{\gamma^\mu\gamma^\nu D_\mu D_\nu + \frac{\bar{\mathcal{M}}\mathcal{M}c_0^2}{\hbar^2}}_{\textbf{Original Dirac Terms}} - \overbrace{\underbrace{\frac{\imath\left[\bar{\mathcal{M}}c_0,\gamma^\mu\right]D_\mu}{\hbar}}_{\textbf{Term}}}^{\textbf{New Extra}}\right]\psi = 0. \tag{51}$$

where: $\left[\bar{\mathcal{M}}c_0,\gamma^\mu\right]=\left(\bar{\mathcal{M}}\gamma^\mu-\gamma^\mu\mathcal{M}\right)c_0$, is the new extra-term that emerges from the very fact that the new mass term is no longer a zero-rank scalar but a 4×4 matrix term that does not commute with the Dirac γ-matrices. This new extra-term brings in the much need new physics. It is not difficult to show that: $\left[\bar{\mathcal{M}}c_0,\gamma^\mu\right]=-2m_\star c_0\mathcal{H}^\mu$, hence: $\left[\bar{\mathcal{M}}c_0,\gamma^\mu\right]D_\mu=-2m_\star c_0\mathcal{H}^\mu D_\mu$. Given the latter, together with Eq. (19), *i.e.*: $\bar{\mathcal{M}}\mathcal{M}=m^2\mathcal{I}$, it follows from this—that Eq. (51), will reduce to:

$$\left[\gamma^\mu\gamma^\nu D_\mu D_\nu + \left(\frac{mc_0}{\hbar}\right)^2\mathcal{I} + \left(\frac{2\imath m_\star c_0}{\hbar}\right)\mathcal{H}^\mu D_\mu\right]\psi = 0. \tag{52}$$

For the expression: $\mathcal{H}^\mu D_\mu=\mathcal{H}^\mu\partial_\mu+\imath q\mathcal{H}^\mu A_\mu/\hbar$, given that: $A_0\simeq0$, we can drop this term (*i.e.*, the term that includes, A_0, in $\mathcal{H}^\mu D_\mu$, and this we do on the pretext that it $[\mathcal{H}^\mu D_\mu]$ is small enough to be ignored and so doing will not adversely affect our final result) and rewrite this expression as: $\mathcal{H}^\mu D_\mu=\mathcal{H}^\mu\partial_\mu+\imath q\boldsymbol{A}\cdot\boldsymbol{\mathcal{H}}/\hbar$. Among these two additional terms: $\mathcal{H}^\mu\partial_\mu$, will not influence the g-factor, while $\boldsymbol{A}\cdot\boldsymbol{\mathcal{H}}$, will have an significant effect. To simplify our analysis, we will disregard the term: $\mathcal{H}^\mu\partial_\mu$, by assuming that: $\mathcal{H}^\mu\partial_\mu\psi=0$. This assumption may not hold true and should be examined further, as it will undoubtedly impact the resulting energy levels. Our decision to omit this term has been made for no more than convenient purposes—our eyes are glued on the g-factor. We encourage others to explore the implications of this term in the event that: $\mathcal{H}^\mu\partial_\mu\psi\neq0$. From the foregoing discussion: $\mathcal{H}^\mu D_\mu=\imath q\boldsymbol{A}\cdot\boldsymbol{\mathcal{H}}/\hbar$, it follows that Eq. (52) will now read:

$$\left[\gamma^\mu\gamma^\nu D_\mu D_\nu + \left(\frac{mc_0}{\hbar}\right)^2\mathcal{I} - \left(\frac{2qm_\star c_0}{\hbar^2}\right)\boldsymbol{A}\cdot\boldsymbol{\mathcal{H}}\right]\psi = 0. \tag{53}$$

Now, substituting: $\boldsymbol{A}\cdot\boldsymbol{\mathcal{H}}$, as it is given in Eq. (49), into Eq. (53) becomes:

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$$\left[\gamma^\mu\gamma^\nu D_\mu D_\nu + \left(\frac{mc_0}{\hbar}\right)^2\mathcal{I} - \left(\frac{2q\zeta_{\rm P} m_\star c_0 r_{\rm P}}{\hbar^3}\right)\boldsymbol{B}\cdot\widehat{\boldsymbol{S}}\right]\psi = 0. \tag{54}$$

We can rewrite this Eq. (53) in manner that unmasks the extra-anomalous g-factor, $\Delta g_{\rm P}$, as follows:

$$\boxed{\left[\gamma^\mu\gamma^\nu D_\mu D_\nu + \left(\frac{mc_0}{\hbar}\right)^2\mathcal{I} - \underbrace{\left(\frac{\zeta_{\rm P} m_\star c_0 r_{\rm P}}{\hbar}\right)}_{\Delta g_{\rm P}}\left(\frac{2q\boldsymbol{B}\cdot\widehat{\boldsymbol{S}}}{\hbar^2}\right)\right]\psi = 0.} \tag{55}$$

In Eq. (39), we already have worked out the term: $\gamma^\mu\gamma^\nu D_\mu D_\nu + (mc_0/\hbar)^2\mathcal{I}$. Inserting it into Eq. (55), and re-arranging, we will obtain:

$$\left[\Box - \frac{q\boldsymbol{B}\cdot\left(\widehat{\boldsymbol{L}} + g_{\rm P}\widehat{\boldsymbol{S}}\right)}{\hbar^2} - \left(\frac{mc_0}{\hbar}\right)^2\right]\psi_R = 0. \tag{56}$$

where: $g_{\rm P} = 2(1 + \Delta g_{\rm P})$, or, written in its full glory:

$$\boxed{g_{\rm P} = 2\left(1 + \frac{\zeta_{\rm P} m_\star r_{\rm P} c_0}{\hbar}\right).} \tag{57}$$

This Eq. (57) is our final result that this first instalment is meant to deliver. Just as is the case with the original Dirac equation presented herein in Eq. (42), this Eq. (57) is also an exact equation and not merely an approximation, as is often the case in typical calculations in QED textbooks (*e.g.*, Ref. [79] pp.196-8) where the Dirac g-factor is presented. In the next section, we will discuss this major result. We have no intention of discussing this Eq. (57) any further in this reading—this task, we shall leave for latter readings [1–9]. We believe it is essential to take a moment to simply reflect on this equation and attempt to grasp its significance before we delve into the deeper meanings and intricacies it contains.

8. General Discussion

The modified Dirac equation presented in this paper, with its 4×4 mass term, represents a fundamental departure from the standard formulation while remaining firmly grounded in Dirac's original mathematical spirit. As we have argued throughout this reading, the progression from Schrödinger's zero-rank wavefunction to Dirac's one-rank spinor wavefunction to our two-rank matrix-valued mass term is a natural and logical extension of the path first charted by Dirac himself. The initial resistance that Dirac's ideas met—recall Pauli's reported remark that '*now physics has become an embarrassment to mathematics*'—serves as a historical reminder that profound insights often appear outlandish before they become obvious. We take solace in Dirac [64–66]'s own words: '*If you are receptive and humble, mathematics will lead you by the hand.*'

8.1. Key Results

The principal achievement of this first instalment is the derivation of the modified g-factor formula which expresses the total g-factor as the Dirac value of 2 plus an anomalous contribution arising from the interaction between the CFV-field, the electromagnetic vector potential, $\boldsymbol{A}$, and the particle's spin $\hat{\boldsymbol{S}}$. This result is exact, not perturbative, and emerges directly from the algebraic structure of the modified Dirac equation without recourse to Feynman diagrams or renormalization techniques [48–52].

Several important consequences follow from this result:

1. **Anomalous g-Factor and Extended Particles:** The non-zero anomalous g-factor of any particle—*including the electron*—suggests that it may not be a point particle but rather an extended object with a finite spatial extent. This challenges the foundational assumption of point-like leptons in the Standard Model while remaining consistent with all existing experimental constraints provided the inferred radius is sufficiently small.

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2. **Perfectly Asymmetric Universe:** As will be demonstrated in Paper (II) [4], the un-Hermitian relation: $\mathcal{M}^\dagger = \gamma^0 \mathcal{M} \gamma^0 \neq \mathcal{M}$, of the 4×4 mass term presented in Eq. (22) predicts an asymmetric Universe that violates the: $\mathcal{C}$, $\mathcal{P}$, and, $\mathcal{T}$, symmetries including the seemingly sacrosanct and inviolable $\mathcal{CPT}$ symmetry which according to the *CPT-Theorem* [87–90], must be upheld by any Lorentz-invariant, local, Hermitian QFT that satisfies the spin-statistics connection—such a theory, must be *CPT symmetric*. This naturally places our current endeavours on an interesting pedestal to explain the long-standing problem of the apparent preponderance of matter over antimatter.
3. **Unified Mass Formula:** As will be shown in Papers (VI)-(X), depending on one's intuition and insight into the fabric and realm of thought—the seemingly banal and lifeless mass relation: $m^2 = m_\star^2 - m_0^2$, presented in Eq. (21) is capable of explaining not only the mass generations of leptons but also that of quarks. Furthermore, this formula predicts not only the existence of the generation of the proton family of particles but also their accompanying neutrinos, which are most likely the sterile neutrinos. Two new first and second generation particles with masses: , are predicted.

In summary, Eq. (21), (22), and, (57), represent the major results of the present reading and these results form the fundamental bedrock and foundational basis for all subsequent works in the accompanying papers [1–9].

8.2. Question of Particle Radius

Perhaps the most provocative implication of the present theory is that the electron, traditionally regarded as a point particle in Quantum Electrodynamics, may possess a non-zero radius. This idea is not without precedent—historical attempts to endow the electron with structure date back to Lorentz and Abraham (see *e.g.*, [80])—but it has been largely abandoned due to the extraordinary success of QED's point-particle assumption. However, we must carefully distinguish between the empirical success of QED and the metaphysical status of its foundational assumptions. The fact that QED calculations achieve breathtaking agreement with experiment does not necessarily prove that the electron is a point particle; it may simply indicate that any internal structure lies below current experimental resolution.

The radius of the proton is determined using several methods, including Electron-Proton Scattering [91,92], Laser Spectroscopy [93], and Muonic Hydrogen [93–95], primarily involving scattering experiments and spectroscopy. However, these methods do not directly apply to the electron due to the differences in the structure and properties of electrons and protons, thus making it difficult to determine the radius of the electron [96]. Dehmelt [97]'s constraint: $r_e \lesssim 1.50 \times 10^{-22}$ m, provides a stringent upper limit, but it does not rule out a finite radius altogether. The present theory suggests that the electron's anomalous g-factor, traditionally explained by radiative corrections, might instead (or additionally) arise from its spatial extent. This raises the possibility of a complementary interpretation of the QED corrections—one in which the Dyson series emerges from the multipole expansion of an extended charge distribution rather than from virtual particle loops. This intriguing possibility will be explored in Paper II [1].

8.3. Relationship to Established Physics

It is important that we categorically state here at the outset of the present foundational paper that the present endeavour—*in its entirety as a ten-part series work*—does not claim nor seek to replace QED, but rather to offer a compelling alternative and complementary perspective to the present contemporary view. Schwinger's legendary $\alpha_0/2\pi$ correction [41] and its subsequent extensions to tenth order accuracy [45–47], represent one of the most impressive intellectual achievements of the human mind in the entire *History of Fundamental Theoretical Physics*. We have no desire nor appetite to diminish this great and unparalleled human accomplishment. Rather, we ask 'whether the mathematical apparatus of Feynman diagrams and renormalization [48–52] might be a powerful calculational tool or a literal description of underlying reality that describes *Nature* at her most fundamental level?' As Dirac [65,66] himself cautioned, '*One should not pursue one's conjectures too firmly, but should at all times be ready to change one's views if the evidence demands it.*' Certainly, the present evidence does not yet demand a change in the present *status-quo*, but it does invite exploration of alternative conceptual frameworks and foundations.

8.4. Limitations and Open Questions

Despite the promise of this approach, several important limitations must be acknowledged:

1. **ζ_{P}-Parameter:** The theory contained from within its domain, what appears—*at a prima facie level of analysis*—to be a free parameter, ζ_{P}. This ζ_{P}-parameter will seize forthwith be determined in Paper (II) and will seize to be a free parameter.
2. **Neutron Problem:** In its current state and form, as applied to the electron and proton, we recognize that the present theory may not be adequately developed for a direct application to the neutron, primarily because the neutron is an electrically neutral particle. This lack of charge means that the interactions and behaviours predicted for charged particles like electrons and protons may not hold in the same manner for neutrons. Further exploration and refinement of the theoretical framework will be necessary to effectively incorporate the unique properties of the neutron into our models.
For example, a free neutron, (n^0), is known to decay into a proton (p^+), electron (e^-) and an anti-electron-neutrino $(\bar{\nu}_{\mathrm{e}})$, *i.e.*: $n^0 \mapsto p^+ + e^- + \bar{\nu}_{\mathrm{e}}$. This raises fundamental questions about its status as a particle capable of being described by an unmodified Dirac equation. *Is not the neutron composed of the particles: p^+, e^- and $\bar{\nu}_{\mathrm{e}}$, to which it decays—each of which is described by the Dirac equation?* For this reason and others, the topic of the neutron and its g-factor will be discussed separately in Paper (III) [2].
3. **Experimental Accessibility:** The predicted $m_{\mathrm{eff}}^2 \propto B^2$ relation, while conceptually straightforward, would be extremely challenging to measure experimentally. For an electron in a laboratory-scale magnetic field of $\sim 10\mathrm{T}$, the expected fractional mass shift is of order 10^{-17}-far below current measurement precision. The utility of this relation may therefore lie primarily in its theoretical implications rather than as a practical experimental probe.

9. Concluding Remark

The beautiful, noble and esoteric Dirac equation, now fast approaching its centenary in the year 2028, has proven—*time after time*—to be an inexhaustible source of physical insight and inspiration. Professor Weisskopf [17–22]'s observation that '*a great deal more was hidden in the Dirac equation than the author had expected*' resonates as deeply today as when it was first uttered. We believe that the modifications proposed in this series—*particularly the introduction of a* 4×4 *matrix mass term*—reveal yet another layer of this rich structure. Whether these revelations correspond to physical and natural reality or remain as mere mathematical curiosities will be decided by future theoretical development and experimental tests. In the meantime, we are guided by Dirac's own philosophy: '*...of standing before Nature, with great equanimity, humility and openness to whatever truths that may emerge—and following the mathematics to wherever it leads us.*' We have humbly followed the mathematics and allowed it to lead us by its own hand, and thus far, it has taken us here.

10. Forecast

The present paper pristinely lays down the groundwork for a comprehensive research program. In the subsequent papers [1–9] of this *Ten-Part Series*—we:

1. **Paper (II)** [1]: Derive the full Dyson series expansion from the fundamental soils of classical physics, showing how the perturbative QED corrections emerge naturally from the extended classical particle picture.
2. **Paper (III)** [2]: Extend the analysis of the anomalous g-factor to electrically neutral particles, with particular attention to the neutron and its g-factor.

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3. **Paper (IV)** [3]: Develop a tacitly subtle mathematical scheme (from within the domains of the present modified Dirac equation) that allows us to explain in a unified matter, the existence of particle generations and their families.
4. **Paper (V)** [4]: Present a systematic analysis of the symmetry properties of the modified Dirac equation, demonstrating its violation of $\mathcal{C}$, $\mathcal{P}$, and, $\mathcal{T}$, symmetries and their combinations including the seemingly sacrosanct and inviolable [98–100] $\mathcal{CPT}$ symmetry .
5. **Papers (VI)–(X)** [5–9]: Unify within a single framework, the treatment of lepton generations, quark masses, neutrino oscillations, and the proton radius puzzle within a single theoretical framework, with the *Koide Relation* emerging as an algebraic necessity.

Dedication

'To my great teachers and dear brilliant students,
my loving mother, dear departed father, brothers, sisters, kith and kin,
and all who have ever looked up at the pitch black night sky,
and wondered why, how and where?'

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