

On the nature of the photon and the electron

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ABSTRACT

A new theory, describing both light and material particles, is proposed. An extension and sharpening of relativity is adopted which brings the underlying properties of space and time into the theory at the most fundamental level. An equation encompassing the usual free-space Maxwell equations but similar in form to the Dirac equation is proposed. This equation has new kinds of solutions. Propagating, pure-field solutions may have any energy, but the energy transferred must be proportional to the frequency. These are identified with the physical photon. Solutions with a rest-mass term allow any incoming propagating field to merge into re-circulating vortex-like solutions. The minimum energy configuration “rectifies” the oscillating electric field of light into a uni-directional, radial (inward or outward directed) configuration. The resulting apparent external charge may be readily estimated and is found to be of the order of the elementary charge. The spin may, likewise, be calculated, and is found to be half integral, exhibiting a double-covering internal symmetry. Charge is then not a fundamental quantity in the theory - but is a result of the way field folds from a bosonic to a fermionic configuration. The simplest such charged, fermionic particles are identified with the electron and positron.

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1. INTRODUCTION

A companion paper has outlined many aspects of the theoretical basis to be used here.¹ In the preparation of that paper and in a discussion with many physicists all over the world, primarily in the context of the 2015 SPIE conference on the nature of light for which both are submissions, it became clear that the understanding of many terms in common usage in physics carried almost as many different detailed interpretations as there were physicists. These were not esoteric terms (which tend, in fact, to be better defined), but common concepts such as “energy”, “rest-mass” and “electromagnetic field”. This led to many enjoyable discussions as to just what these terms really meant. Such discussions generally tended to generate more heat than light. Accordingly here, for the avoidance of doubt, a new nomenclature has been made-up to allow the precise and rigorous local definition of terms within the limited context of this paper - without bringing in too many pre-conceptions of what these terms may or may not mean. The theory is then developed on its own terms. The reader may judge to what extent it then describes the particles we call the electron and the photon.

Space-time, at its simplest, is described by four and only four “linear” degrees of freedom. It has been fashionable in science, for the past half-century or so, to take complicated starting positions involving an extensive a-priori mathematical and conceptual structure. Complex groups have been taken as the starting points of many theories too numerous to mention. Further, there has been a tendency to wish to “quantise” everything from the beginning. It should seem self-evident that, in doing that, one loses the possibility of finding out why such things may be quantised at all. Putting in a quantisation or a symmetry observed experimentally as a starting axiom has some merit of course, but is a poor starting choice if one wants to understand the origins of that quantisation or symmetry. In this paper an attempt will be made to avoid any superfluous complexity, keep everything possible continuous and linear and keep the a-priori basis as simple as possible. Accordingly, all that will be introduced are four vector basis “directions” in space and time, their properties under multiplication and division, and a rest mass-energy term (introduced as a square-root energy density and denoted here “vot”). The paper will develop dynamical equations as to how this vot flows between fundamental space-time forms. A striking similarity in form between these equations, Newton’s equations, Maxwell’s equations and Dirac’s

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equation then justifies making an association between vot as manifested in various space-time forms and physical quantities such as rest-mass, current, angular momentum and electromagnetic field. If, on top of this, certain quantised values derived from experiment are then introduced such as the elementary angular momentum \hbar for example, it will be shown how certain others may be related to them, such as the elementary charge q .

2. OUTLINE OF THE STARTING BASIS

Four unit vector components $\alpha_0, \alpha_1, \alpha_2, \alpha_3$ representing one temporal and three spatial unit lines respectively are introduced. These are labelled α_0 for time, and α_1, α_2 and α_3 for three perpendicular directions in space. These latter three may conveniently be thought of as being the unit “ x ”, “ y ” and “ z ” of Cartesian space. The Maxwell equations (and any other linear equations) are, however, equally valid in any proper, conformal, orthonormal system of co-ordinates. Here we will use the right-handed ordered triple $(1, 2, 3)$ for the general case, (x, y, z) for Cartesian, (r, ϕ, z) for cylindrical, (r, θ, ϕ) for spherical and (ρ, θ, ϕ) for toroidal co-ordinates.

Under strict definitions^{1,2} of “multiplication” and “division” these lead to self-consistent relativistic properties of further unit elements derived from them at any level of expansion and to any differential order. These further elements represent elementary points, planes, volumes and a 4-volume derived from their products and quotients. Because the space-time basis has four linearly-independent base unit elements, under multiplication twelve further such unit geometrical objects are generated. Provided that “division” maps to the same set, this leads to sixteen linearly independent units elements in all. This may seem at first complicated, even larger than the 11 dimensions in some string theories, but these unit objects are quite simple, most of them being quite familiar to a child of three. They are just such things as unit planes and volumes, with only the unit scalar (point), quadrivector (4-volume) and spatio-temporal planes requiring much more thought and mathematical explanation.

It is neither desirable nor necessary to introduce a-priori any group on these other than that implicit in the algebra of points, lines, planes, volumes and a 4-volume. In the usual parlance of the field one might talk of introducing the Lorentz group at this point (but perhaps not the Poincaré group - since general translations lie outside the allowed light-cone of the restrictions of absolute relativity). The closest match would be to introduce the Clifford group corresponding to the space-time algebra $\text{Cl}(1,3)$, but that is not a division algebra, which is widely thought to cause problems.³ Imposing any of these a-priori, however, reasonable they may appear, may introduce deep-held convictions of how a well-behaved mathematics should behave. Such convictions may or may not be paralleled in nature. Mathematics is a powerful language which allows one to think things that could otherwise not be thought at all. Its misuse, however, may render one blind to aspects of experimental reality which should be blindingly obvious.

An algebra may be designed such that it is strictly simpler than it would be if the general consensus of the meaning of a “group” were to be imposed. It is intended that the theory to be developed should be simultaneously local, causal, linear and unitary in each and every proper Lorentz frame, right up to the limit of the speed of light. It would be desirable if the theory could be made both unitary and relativistic - a prize which has proven elusive in standard representations even of just the Lorentz group. It is the view of the author that the technical problems inherent in this lie in the imposition of a mathematics which differs from the minimal observed physically. In particular, there is a tendency to allow definitions of base-vectors and of addition, multiplication and division into the popular definition of such groups which may not have a proper underlying parallel in reality. This is well-meaning, in that it is thought to increase their generality, but is misconceived if it introduces properties, particles or fields simply not observed in experiment. Just what is the proper meaning, for example, of the “division” of one spatial component of a 4-vector by another (temporal) component of the *same* 4-vector? For example, by dividing space (in S.I. base units of metres) by time (measured in different S.I. base units- seconds). This is a velocity, of course, but a consensus on the meaning of “velocity” itself provokes strong discussion, even within a narrow group of professional scientists, on such things as the proper meaning of the velocity of light. Further, what is the physical meaning of the complex (imaginary) dimension popular in the solutions of elementary quantum mechanics? Just which “space” are such solutions oscillating in?

The intention here is to keep the basis of the mathematics as minimal as possible. This will mean that, for example “multiplication” and “division” will be defined for the individual unit elements but “addition” and “subtraction” will not. That this is necessary should be self-evident: there is no such thing as a double-sized unit

element. This is not to say that addition is not important. It is crucially and fundamentally important. Indeed it is so important that it will be forced here to apply simultaneously to more than one kind of quantity: both the total integral energy and the local square-root energy density manifesting in many different space-time forms. The reason for forcing this on the mathematics is simply experimental: energies must add linearly but other quantities such as fields, for example, (corresponding to a square-root density of energy) are also observed to add linearly. The property of addition must also be ascribed to a further degree of freedom, related to but more fundamental than the energy in that it is more properly a square-root energy density. This degree of freedom is common to each of the geometrical space-time forms to be derived and will be represented by (positive definite) real number quantities. It turns out that, to achieve this dual linearity of energy and field, it is space and time themselves which must transform from frame to frame and locality to locality. The transformation required is just that of special relativity, as was shown in the companion paper to this one.¹ To aid readability in the following a shortcut will sometimes be used, with square-root energy density, being replaced with “root-energy” where the square and the density should be understood.

It should be taken here that, if a particular process is not allowed in the mathematical system, then it must be taken to be forbidden. That this is true of any logical system may be attributed to Wittgenstein.⁴ If the reader finds keeping in mind this kind of separation of the areas to which addition, multiplication and division should be applied too uncomfortable, read no further. The judgement of whether this kind of distinction has had any value must be considered in retrospect.

To introduce the proper (Lorentz-like) properties of space and time, multiplication of the temporal component α_0 by itself is defined such that its square yields a fundamental positive (Lorentz) invariant scalar unity $\alpha_0^2 = \alpha_P$. For this to be consistent with relativity (and experiment: the square of 4-vectors are Lorentz invariants) the three spatial components α_1, α_2 and α_3 must then square to the negative scalar unity $\alpha_i^2 = -\alpha_P$. Here and in the sequel, Greek indices run from 0 to 3 and Roman from 1 to 3, with 0 representing the time “direction”. That is, it is taken that the square (or quotient) of the base line elements with themselves yields a unit “point” element. This is a point as opposed to a line or a plane, not in the common meaning of an infinitesimal place. In English the word “point” is often used to denote a place with zero extent - sometimes, perhaps incorrectly, called a mathematical point. Such points are (usually) frame dependent. In any event, trying to imagine a place which is as close as you like to not there at all is likely to lead to woolly thinking at best and to total confusion at worst. Here, it is considered that a place, for any given observer, is better defined by a relative position vector with respect to that observer. This is a line vector. Vectors are not invariant under a general Lorentz rotation. For example, a simple, positive 90-degree planar rotation in the 1-2 plane will convert a vector in the 1 direction wholly to one in the 2 direction and one in the 2 direction to the negative 1 direction. A Lorentz boost will convert elements of time into elements of space and vice-versa. The unit point α_P is invariant under both transformations. It is the author’s view that a physical point, especially the point corresponding to the point of view of an observer, is better defined with respect to its property of invariance under (general) Lorentz rotations than as the limit of a line (or volume) tending to zero length (or capacity). Here, the unit scalar point α_P is not taken to be a place or an event, it is simply that frame-independent unit sized element invariant under a general Lorentz rotation or boost (and also under several other transformations such as an order inversion).

In previous work the root rest-mass component, which takes the geometrical form α_P in the new theory, has been called the pivot.^{2,5} To make a connection with the earlier work, a new word has been invented to express square-root energy density in any space-time form. Many particles end with the suffix -on, this new concept is designed to express an underlying nature (of energy) even more elementary than that of particles - square-root energy density as conditioned by the space-time nature of elementary forms. This root-energy form will be argued here, indeed to give rise to the inner physical properties of the photon and the electron and is hence considered here to be more “fundamental” than either. The new word (and suffix) to be used here is “vot” and the nomenclature for the scalar, rest-mass density, point element here will be the p-vot. The closest existing conceptual description to an element of p-vot is to think of it as a square-root mass-energy density. The p-vot is then similar in some ways to the probability density (wave-function) term in non-relativistic quantum mechanics often denoted Ψ . To derive the energy, such forms must be squared and integrated over a relevant volume. Anything taking the same geometrical form as the p-vot form is strictly always invariant under a Lorentz transformation; the symbol “ Ψ ” and the concept of a wave-function are often used in the literature (perhaps

confusingly) to describe things which are not. The p-vot may take, just as is the case for any field or density component, any magnitude. This is then a “point” quantity that can have any size. Given that it has similar properties with respect to energy to those of the electromagnetic field, where the energy inherent in the field is derived by squaring it and integrating over an appropriate volume, it may be conveniently thought of as a (rest) mass field.

The algebra is defined such that anything with the geometrical form of a vector, in the directions of $\alpha_0, \alpha_1, \alpha_2$ and α_3 , transforms as a 4-vector. Root-energy of this form is denoted here v-vot. Six unit “areas”, properly denoted bi-vectors, are derived from the base lines by multiplying mutually perpendicular pairs such that unit plane element is, for example, $\alpha_1 \alpha_2 = \alpha_{12}$. Because there are four unit directions, there are six such planes: $\alpha_{23}, \alpha_{31}, \alpha_{12}, \alpha_{10}, \alpha_{20}, \alpha_{30}$. Root-energy here is then b-vot. The algebra forces these to transform relativistically as do the (1,2,3,) components of the magnetic (B) and electric (E) field respectively.¹¹ Because of this, the six components of field with this form may also be denoted f-vot. If desired the three components of the electric field could be denoted E-vot and those of the magnetic field B-vot, but this is a frame-dependent choice as under a Lorentz transformation elements of the electric field transform to the magnetic and vice-versa. Note that, if one allows, conceptually, one and only one bi-vector quantity in the mathematics, b-vot=f-vot. This would mean that, for extensions to the theory, the electric field term may mix in with the momentum density term as both are space-time bi-vectors. This possibility will be explored in the section on new electron-like solutions below. Alternatively, one could distinguish the momentum-like quantities as m-vot, but this would enlarge the algebra and will not be followed here, but reserved for future work. In any event, the base form of the fields is of a square-root mass-energy density, as is anyway conventional for fields. Again, this may seem unnecessarily complicated at this point but it will transpire that, in the new formalism, all four Maxwell equations are simply the vector differential of the field - properly with vector and tri-vector components as will be discussed below. To get the total energy in the field, one must (and always did), translate to the right units, square the basic field quantities (f-vot) and integrate over the relevant volume. The 4 tri-vectors (the dual of the vectors) represent unit “volume” elements ($\alpha_{123}, \alpha_{023}, \alpha_{031}, \alpha_{012}$). The latter three are a momentum density multiplied by a perpendicular unit vector, and therefore transform as the components of an angular momentum density. These are denoted t-vot. Finally, there is a single quadri-vector, (α_{0123}) which, just as the scalar, is invariant under a Lorentz transformation but, similarly to the unit imaginary i , squares to the negative unity $\alpha_{0123}^2 = -\alpha_P$. Square-root energy with this form would be denoted q-vot. In total there are then sixteen linearly independent space-time forms. Six square to the positive scalar unity α_P : $\alpha_0, \alpha_{10}, \alpha_{20}, \alpha_{30}, \alpha_{123}$ and α_P itself. The remaining ten square to the negative scalar unity $-\alpha_P$: $\alpha_1, \alpha_2, \alpha_3, \alpha_{23}, \alpha_{31}, \alpha_{12}, \alpha_{023}, \alpha_{031}, \alpha_{012}$ and α_{0123} .

Using this kind of algebra proves to provide a better parallel of the physical way energy flows through space and time than do alternatives. It should be noted that the concept of “volume” is not frame-independent. This concept is taken care of by the proper transformations of space within the algebra. In any given frame and locality it is well-defined, however, and hence vot is conserved locally. To keep track of this, the principle of absolute relativity is that no quantity may appear without its proper geometrical form, as defined by one of the sixteen distinct unit elements outlined above. This ensures the proper local values of all values transform correctly to each and every Lorentz frame. For those wishing to gain further insight into the properties of the sub-algebra than that expressed in the companion paper, the sub-algebra of the space-time unit elements amongst themselves parallels the Clifford algebra $Cl(1, 3)$ ⁷ championed by Hestenes as the space-time algebra in internal models of the electron structure⁸ and is a simplification, in some ways, of certain Dirac algebras.⁶ The closest algebra discussed in the literature is sometimes called the Clifford-Dirac algebra and has been well-described in recent popular books³ or more extensively in recent textbooks.⁷ As mentioned before, the precise algebra used here, however, has certain extra restrictions not usual in standard approaches with either. The reader is referred elsewhere for details.^{1, 2, 11} In this paper, the consequence of adding a seventh (and eventually eighth) term to the six components of the electromagnetic field in this formalism, corresponding to a dynamical scalar (or pseudo-scalar) rest-mass, will be discussed. The resultant effect on the electromagnetic field is to cause it to deviate in the direction of the electric (or magnetic) field. A solution with radial electric field then allows a solution with a re-circulation of electromagnetic energy. An electromagnetic vortex in momentum space. The re-configuration of the field forces the electric field - oscillating in the photon, to become rectified in the sense that it becomes either radially inward-directed (electron-like) or outward directed (positron-like). Similarly, the fundamental spin, if taken to be integral for the photon, becomes half-integral for the simplest such charged

particle. The method and topology of the confinement, allows pure-field to re-configure in the process of the creation of particle-antiparticle pairs of opposite charge and half-integral spin from uncharged photons with integral spin. Conversely, the annihilation of particle-antiparticle systems to photons cancels the topological vortex-anti-vortex pair in the recirculating system - allowing the particle-antiparticle system to decay to two free photons, the process conserving both charge and angular momentum. It will be claimed that the new insight and the new solutions parallel more closely that which is observed in experiment than do alternative approaches.

3. EXTENSION OF THE MAXWELL THEORY

The unit elements give the proper form and the relativistic transformation properties of the vector and hence the scalar and the bi- tri- and quadri- vectors, but to represent an actual quantity these must also have a magnitude. For this real numbers are used - keeping an explicit separation between the amount (of a scalar energy for example) or magnitude (of a vector force for example) and its proper form. This is not merely a question of style, it is this rigour that allows the imposition of absolute relativity at all levels and that gives rise to the new results of light quantisation and the formation of charged fermions from uncharged bosons in the following.

A four vector is written ($\mathbf{v} = a_0\alpha_0 + a_1\alpha_1 + a_2\alpha_2 + a_3\alpha_3$). The a_μ are (positive definite) real number quantities expressing a magnitude and the α_μ are fundamental, invariant unit lines which may take at most the two values $\pm\alpha_\mu$. Here and in the sequel, Greek indices run from 0 to 3 and Roman from 1 to 3, with 0 representing the time “direction”.

For Cartesian co-ordinates a 4-vector 4-differential is defined as:

$$\begin{aligned}\mathcal{D}_4 &= \frac{\partial}{\alpha_\mu \partial x_\mu} = \partial_\mu / \alpha_\mu \\ &= \alpha_0 \partial_0 - \alpha_1 \partial_1 - \alpha_2 \partial_2 - \alpha_3 \partial_3 = \alpha_0 \partial_0 - \alpha_i \vec{\nabla}\end{aligned}\tag{1}$$

Where the subscript on the left denotes the number of distinct unit elements in the expression and in this case, denotes that it is a 4-vector derivative. The over-arrow denotes a conventional three-vector, as in the original formulation of (the Helmholtz form of) the Maxwell equations. Note the change of sign of the space components due to the implicit quotient of the unit vectors and the fact that the three spatial vectors α_1, α_2 and α_3 square to the negative scalar unity $\alpha_i^2 = -\alpha_P$. The x_μ are taken here to have the same physical units. Expressing all quantities in metres, for example means that $x_0 = ct$.

The 4-differential of a 4-vector (v-vot identified as 4-vector potential) conventionally yields field components. Writing v-vot as:

$$A_4 = \alpha_\mu A_\mu = \alpha_0 A_0 + \alpha_1 A_1 + \alpha_2 A_2 + \alpha_3 A_3 = \alpha_0 A_0 + \alpha_i \vec{A}\tag{2}$$

It should be noted that there is a possibility, in the full theory to be developed below, that the 4-trivector may also yield field components. Although it is always possible to find a 4-vector whose derivative gives all the physical field components, it is also possible to find a tri-vector term which does so.

The 16 ($= 1 + 3 + 3 \cdot 2 + 3 \cdot 2$) terms of the 4-derivative of the v-vot $\mathcal{D}_4 A_4$ may then be gathered together and written as:

$$\mathcal{D}_4 A_4 = \alpha_P (\partial_0 A_0 + \vec{\nabla} \cdot \vec{A}) - \alpha_{i0} (\partial_0 \vec{A} + \vec{\nabla} A_0) - \alpha_{ij} \vec{\nabla} \times \vec{A} = P\alpha_P + F\alpha_{\mu\nu}\tag{3}$$

which is the sum of a scalar (pivot) part $P\alpha_P$ and a bivector (field) part $F\alpha_{\mu\nu}$. The corresponding 4-derivative of the 4-trivector potential, $\mathcal{D}_4 T_4$, would yield additional field components as well as a quadri-vector term $Q\alpha_{0123}$.

Before proceeding further a discussion on the fundamental quantities to appear and on the units in which they are expressed is required. Firstly, it has already been noted that the magnitudes referred to here have the properties of a sort of square-root energy density, similar to the properties of the electromagnetic field or the “probability density” in normal quantum mechanics. Given the widespread currency of the concept, it seems strange to the author that there is no good English word expressing such a concept succinctly. It is partly for this reason that the word “vot” has been introduced here. All that has been introduced so far is space and time, forms

derived from space and time such as areas, and an root-energy within those forms denoted vot. The question remaining is, what are appropriate units for vot? If one thinks in terms of the p-vot, a square-root mass density invariant under a Lorentz transformation, the natural units would be $\sqrt{(kg\ m^{-3})}$, for the electric field they would be Vm^{-1} , for the electric displacement Cm^{-2} , Tesla for the magnetic flux, Am^{-1} for the magnetic field. More generally, in terms of energy, one could use the units $\sqrt{(J\ m^{-3})}$. The plethora of units reflects, amongst other things, the desire to understand the interaction of light with material systems. This is, in itself, a worthy aim. Here, one is seeking to describe how the elementary particles, which themselves make up material systems, might come into being. To keep the initial step for this simple enough to have any hope of understanding, the system and the mathematics are being kept as simple as possible - partly by allowing only one kind of “field”. One can always re-introduce the distinctions, complexity and beauty of the usual electric displacement \mathcal{D} , the electric field \mathcal{E} , the magnetic flux \mathcal{B} and the magnetic field \mathcal{H} by using the constitutive relations in the usual way.

Considering further these field forms, Maxwell⁹ identified three pairs of quantities whose product had the dimensions of an energy density, the “electrostatic pair” (the electric field \mathcal{E} and the electric displacement \mathcal{D}), the magnetic pair (the magnetic flux \mathcal{B} and the magnetic field \mathcal{H}) and the “electrokinetic pair” (the vector potential \mathcal{A} and the current density \mathcal{J}). It is worth noting that, for Maxwell, the relationship between vector potential and current was similar to that between field and flux or displacement in that they represent the same underlying physical quantity in free-space, differing only by their units. The energy density for the electric field in S.I. units is: $\frac{1}{2}\mathcal{E}\mathcal{D} = \frac{1}{2}\epsilon_0\mathcal{E}^2$ and for the magnetic field it is $\frac{1}{2}\mathcal{B}\mathcal{H} = \frac{1}{2}\epsilon_0c^2\mathcal{B}^2$, where ϵ_0 is the electric constant and c is the speed of light respectively. Similarly, for the 4-potential (units $V.s.m^{-1}$) and the 4-current (units $A.m^{-2}$) the product represents an energy density in $J\ m^{-3}$. The theory here will investigate simply the properties of the transformation of vot between different space-time forms. It will not allow two different quantities to represent the same physical field or current, in particular it will allow one and only one bi-vector quantity, the electromagnetic field, denoted F and split into electric ($E \equiv \sqrt{\mathcal{E}\mathcal{D}}$) and magnetic ($B \equiv \sqrt{\mathcal{B}\mathcal{H}}$) parts. Similarly, the theory will allow one and only one vector quantity, which may be visualised as either the 4-current density or the 4-vector potential, denoted here $A \equiv \sqrt{\mathcal{J}\mathcal{A}}$. This is a significant departure from the conventional approach, and has consequences in fixing the gauge for example, which many may find uncomfortably restricting. The main advantage of this is that it will allow the derivation of the elementary charge, rather than having to insert it a-priori. It must be judged whether the loss of some gauge freedom is worth an understanding of the underlying nature of charge, quantum spin, and an understanding of the underlying nature of both the photon and the electron. The approach here will be to develop this strongly-constrained theory, compare it with the Maxwell and Dirac theories, and investigate its consequences in terms of new solutions. The reader must then judge whether or not the resultant benefits outweigh the costs.

If one defines the four elements of the 4-vector derivative to have the same units as each other (as above), then all elements of vot within a single equation - square-root current and mass densities and the field, should also share a common unit. The equations to be derived then hold for any choice of the units discussed above, as different choices merely scale all terms by a constant. It is probably better, then to think of the units as one of the general forms ($\sqrt{(J\ m^{-3})}$ or $\sqrt{(kg\ m^{-3})}$) rather than one of the field forms, to avoid confusing oneself. My choice here has been to think of vot in terms of $\sqrt{(J\ m^{-3})}$ and space and time in terms of metres. Any other choices of units from the lists above (such as seconds and Teslas, for example) is equally valid and obeys the same equations as they then differ merely by a constant.

Over each of the sixteen multivector-quantities defined above, a general dynamical multi-vector field G_{16} is defined over a scalar term P , a vector term A_4 , a field term $F_6 = F_{\alpha\mu\nu} = E_i\alpha_{i0} - B_i\alpha_{jk}$, a trivector term $T_4 = \alpha_{123}T_0 + \alpha_{023}T_1 + \alpha_{031}T_2 + \alpha_{012}T_3$ and an eventual quadri-vector potential Q such that: $G_{16} = P\alpha_P + A_0\alpha_0 + A_i\alpha_i + E_i\alpha_{i0} - B_i\alpha_{jk} + T_k\alpha_{0ij} + T_0\alpha_{123} + Q\alpha_{0123}$.

Writing, by analogy with the form of the free-space Maxwell equation $\mathcal{D}_4F_6 = 0$, $\mathcal{D}_4G_{16} = 0$, and again using the conventional 3-space patterns for reference, one obtains a more general equation:

$$\begin{aligned} \mathcal{D}_4G_{16} = & \alpha_0(\vec{\nabla} \cdot \vec{E} + \partial_0P) + \alpha_{123}(\vec{\nabla} \cdot \vec{B} + \partial_0Q) + \alpha_i(\vec{\nabla} \times \vec{B} - \partial_0\vec{E} - \vec{\nabla}P) + \alpha_{0ij}(\vec{\nabla} \times \vec{E} + \partial_0\vec{B} + \vec{\nabla}Q) + \\ & \alpha_P(\vec{\nabla} \cdot \vec{A} + \partial_0A_0) + \alpha_{0123}(\vec{\nabla} \cdot \vec{T} + \partial_0T_0) + \alpha_{i0}(\partial_0\vec{A} + \vec{\nabla}A_0 + \vec{\nabla} \times \vec{T}) + \alpha_{jk}(\partial_0\vec{T} + \vec{\nabla}T_0 - \vec{\nabla} \times \vec{A}) = 0 \end{aligned} \quad (4)$$

Since all unit elements are linearly independent, the meaning of the zero on the right is that each expression on the left is zero separately. With P and Q zero the first four terms then correspond exactly to the free-space Maxwell equations. The Maxwell equations, in the present context, may be expressed as four coupled differential equations over the 24 terms of the expression $\mathcal{D}_4 F_6 = 0$. The second four terms express a similar set of constraints between current-like and angular momentum-like quantities. The full set may be viewed as eight coupled differential equations over the 64 terms of the expression $\mathcal{D}_4 G_{16} = 0$.

Within the extended equations, the physical effect of the new scalar invariant mass term P , for example, will prove to be to allow a curvature of the momentum transport direction in the direction of the electric field. If both are non-zero, this leads to the possibilities of a pivoting of the field flow around the resultant mass leading to new kinds of self-confined circulating solutions with rest-mass.^{2,14}

4. NEW SOLUTIONS: THE PHOTON

In the companion paper a left circularly polarised electromagnetic wave, travelling in the the $+z$ -direction and transmitting a quantum of energy \mathcal{E} in the centre of mass frame has been written:

$$F_L = H_0 U_F R \mathcal{E} (\alpha_{10} + \alpha_{31}) e^{\frac{\mathcal{E}}{\hbar} R (\alpha_3 \frac{z}{c} - \alpha_0 t) \alpha_{012}} = F_0 R (\alpha_{10} + \alpha_{31}) e^{R(k\alpha_3 z - \omega\alpha_0 t) \alpha_{012}} = \mathcal{F} \mathcal{W} \quad (5)$$

This has a pre-factor part representing the initial (or final) field configuration \mathcal{F} , and a hypercomplex exponential wave-function \mathcal{W} . The wave-part \mathcal{W} has 4 parts p-vot field, electric and magnetic fields (E-vot and B-vot parts) and a q-vot part. The whole expression is a pure field.

This wave-function $\mathcal{W} = e^{R(k\alpha_3 z - \omega\alpha_0 t) \alpha_{012}}$ is not a solution itself of the free-space Maxwell equations but is a solution of the more general set of equations above such that $\mathcal{D}_4 \mathcal{W} = 0$. In the product $F_L = \mathcal{F} \mathcal{W}$, the (rest-massive) p-vot and q-vot terms cancel if and only if the field components conform to that which is observed physically (as written above), so that the whole expression is then a solution of the free-space Maxwell equations alone $\mathcal{D}_4 F_L = 0$. What this means, physically, is that, if \mathcal{W} is an element of the proper relativistic wave-function of the emitter and absorber, such functions propagate field configurations of arbitrary total energy. Such fields are propagated at lightspeed only if the initial (emitter) and final (absorber) fields have equal and perpendicular magnetic field components and are such that the total energy in their frames (note carefully that these are usually different) is proportional to the local wave-function frequency ν such that $\mathcal{E} = h\nu$. This is exactly what is observed in experiment.

The real-number constants c are the (scalar) speed of light and $\mathcal{E} (= \hbar ck = \hbar \omega)$ the (scalar) quantum of energy transmitted in the centre-of-momentum frame respectively. U_F is a universal constant, converting to field units but dependent on the nature of the emitter and absorber. It takes the same value for all photons emitted and absorbed from systems quantised under the usual rules. The “usual rules” here includes most atoms, molecules and plasmas at anything much above a few Kelvin. The possibility that this may take other values under certain circumstances will be discussed in the section on “experimental tests”. H_0 is a distribution function over the number of cycles in phase representing the spread of field over phase, whose square integrates to unity. This is an invariant and is the same in all frames, right up to the limit of light-speed where the integrated energy goes to zero. The single parameter R is that factor which determines the scales of energy, frequency, length and time. This function, though a major result in itself, has been discussed in more detail in the companion paper and is used, here, merely as the starting point for the development of solutions to charged, material particles.

Equation (5) may be readily be expanded in any particular frame. For the conditions corresponding to experimentally observed photons, the non field (scalar and quadri-vector) terms in the exponential part cancel. Setting $F_1 = H_0 U_F R \mathcal{E}$ and $ck = \omega = \frac{\mathcal{E}}{\hbar}$ one obtains:

$$F_L = F_1 [(\alpha_{10} + \alpha_{31}) \cos(kz - \omega t) + (\alpha_{23} - \alpha_{20}) \sin(kz - \omega t)] \quad (6)$$

This describes electric (α_{i0}) and magnetic (α_{ij}) fields rotating in time in a plane perpendicular to the direction of momentum transport and transforming in space from magnetic field to electric field and vice-versa. The

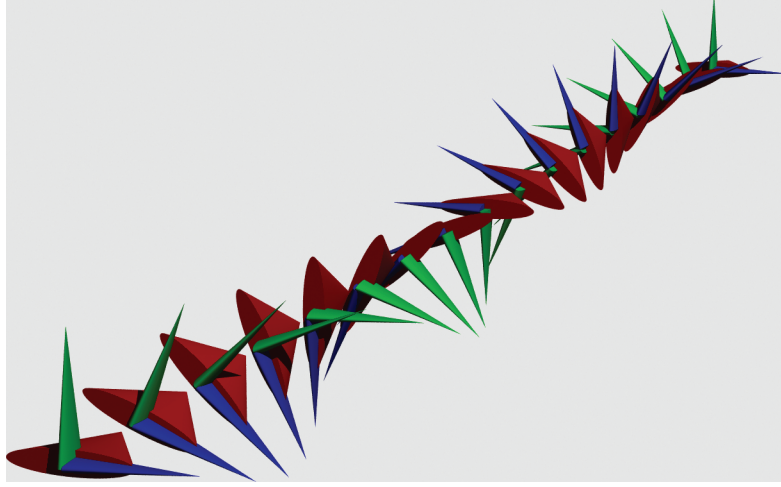


Figure 1. Representation of a single wavelength of a circularly polarised photon of equation (5). The electric field direction is represented using green arrowheads, the magnetic field blue and the momentum density (just $E \times B$ here) red.

resultant field configuration is that shown in figure 1. It appears identical to that found in any elementary textbook on electromagnetism for a left-handed circularly polarised wave.

The wave-function in equation (5) describes a temporal rotation. This means the lateral extent of any elements of it in the photon frame should not exceed a rotation horizon imposed by the speed of light. Note that this does not imply that the photon should rotate about a single axis. Such an axis is not defined by the equations. The only places where a photon is constrained spatially remain those of the emitter and absorber. The physical limitation of the rotation horizon, nonetheless, imposes conditions on the angular momentum of allowed solutions. The concept was used in previous work to lay bare the physical origin of the anomalous magnetic moment of the electron as a localised photon.¹⁶ For a given frequency, the limit imposed by the speed of light on rotation, the rotation horizon, is just $r_h = c\omega$. Introducing the photon momentum observed in experiment, $\vec{p} = \hbar\omega/c$, gives a limit on the integral allowed angular momentum of the solutions of $r_h \times \vec{p} = \hbar$. This sets the intrinsic scale of unit angular momentum for all solutions such as that described by equation (5). In conclusion, demanding the principle of absolute relativity, manifested in the form of equation (5), places strong restrictions on allowed solutions, over and above those required by the Maxwell equations alone. Though the underlying theory remains continuous, travelling wave solutions have energy proportional to frequency and a quantised angular momentum.

The discussion of the essential rotation of solutions and the resultant angular momentum may raise questions about the forces in electromagnetism constraining that rotation. This misunderstands that the Maxwell equations are, and always were, a sufficient condition for force-free motion of the constituent elements. To see this, consider a generalisation of the Lorentz force equation, the product of field and 4-current $F_6 J_4$, long-considered by Einstein.¹⁵ Using the Maxwell equations to substitute for the 4-current $\mathcal{D}_4 F_6 = J_4$ and considering displacement currents alone in the pure-field case, one may generalise the Lorentz force equation to $F_6(\mathcal{D}_4 F_6) = 0$. Following the extended Maxwell equation (4), setting mass terms P and Q to zero (so considering field alone) and writing the electric and magnetic displacement currents as $\vec{J} = \alpha_i(\vec{\nabla} \times \vec{B} - \partial_0 \vec{E})$ and $\vec{J}^m = \alpha_{0ij}(\vec{\nabla} \times \vec{E} + \partial_0 \vec{B})$ and, further, setting charge and magnetic monopole charge to zero one obtains for the generalised forces:

$$\begin{aligned}
 F_6(\mathcal{D}_4 F_6) = & \alpha_0(\vec{E} \cdot \vec{J} + \vec{B} \cdot \vec{J}^m) + \alpha_{123}(-\vec{B} \cdot \vec{J} + \vec{E} \cdot \vec{J}^m) \\
 & + \alpha_i(-\vec{B} \times \vec{J} + \vec{E} \nabla \cdot \vec{E} + \vec{E} \times \vec{J}^m + \vec{B} \nabla \cdot \vec{B}) \\
 & + \alpha_{0jk}(-\vec{E} \times \vec{J} - \vec{B} \nabla \cdot \vec{E} - \vec{B} \times \vec{J}^m + \vec{E} \nabla \cdot \vec{B})
 \end{aligned} \tag{7}$$

Note that, for the magnetic field divergence and magnetic monopole current zero (as is usual), the vector term (α_i) is just the usual Lorentz force term. There are, however, other terms corresponding to “forces” without the vector form of a force. These act internally on the field. In this simple context force-free motion corresponds to $F_6(\mathcal{D}_4 F_6) = 0$. Note, however, for this to be zero it is sufficient that the free-space Maxwell equations are zero such that $\mathcal{D}_4 F_6 = 0$. Anything satisfying the Maxwell equations, such as equation (5), is then a force-free motion of the electromagnetic field. Although there are (balanced) forces here, these are not sufficient by themselves to confine pure field to a localised solution such as that considered in earlier work.¹⁶ For that one must consider the further “forces” described by the 144 terms in the eight coupled non-linear equations derived from the product of the extend field and its derivatives such that $G_{16}(\mathcal{D}_4 G_{16}) = 0$.

5. NEW SOLUTIONS: THE ELECTRON AND POSITRON

A purely electromagnetic theory of the electron requires forces capable of confining the electron charge, the so called Poincaré stresses. Within the new theory there is more than one way to look at the forces and at force-like terms. One may consider the generalisation of the Lorentz force in $G_{16}(\mathcal{D}_4 G_{16})$. Alternatively, one may generalise the expression for the 4-momentum density of the electromagnetic field $FF^\dagger = \frac{1}{2}\alpha_P(\vec{E}^2 + \vec{B}^2) + \alpha_{i0}(\vec{E} \times \vec{B})$ to the 4-momentum flow of a more general field GG^\dagger and develop an equation of motion for this (corresponding to Hamiltonian description or Newtons laws) by considering its vector differential $\mathcal{D}_4(GG^\dagger)$. Both are sets of 144 coupled non-linear differential equations and both turn out to give similar, though not quite identical, results. They differ in that the change of signs engendered by changing the order of differentiation is slightly different to that in implementing the “Hermitian” conjugate within the sub-Clifford algebra, generating a generalisation of the energy-momentum density and looking at the four differential of this quantity. In particular, both lead to the conventional expression for the Lorentz force, as outlined above, and both lead to internal “forces” with forms corresponding to space-space-space (volume) pressures and space-space-time “pressures”. Both possible force equations have been considered in passing in earlier work.^{5,14} Which, if either (or both!), corresponds with that observed in nature must be determined from experiment.

It is beyond the scope of this paper to investigate the full implications of the extended linear equations $\mathcal{D}_4 G_{16} = 0$, let alone the non-linear generalised balanced force equations $G_{16}(\mathcal{D}_4 G_{16}) = 0$ or $\mathcal{D}_4(GG^\dagger) = 0$. Here, only the smallest possible extension to the theory of the six field components F_6 described by the free-space Maxwell equations to include a seventh component giving rise to an invariant (rest) mass, the p-vot P will be investigated. That is the equation $\mathcal{D}_4(F_6 + P) = 0$ will be considered. It is not claimed here that this is necessarily the complete new equation governing the existence of and the full internal motion of the electron, that should involve more terms in the general equation as discussed above. It does, however, introduce a new, essential feature into the theory of electromagnetism: a term allowing electro-pivot-magnetism to confine itself. Denoting the 7-component field and pivot as $G = F + P$ and the conjugate set as $G^\dagger = F^\dagger + P^\dagger$. The generalised energy-momentum density may then be written as:

$$\frac{1}{2}GG^\dagger = \frac{1}{2}(F + P)(F^\dagger + P^\dagger) = \frac{1}{2}\alpha_P(\vec{E}^2 + \vec{B}^2 + P^2) + \alpha_{i0}(\vec{E} \times \vec{B} + P\vec{E}) \quad (8)$$

It is apparent that, for the case $P = 0$, one obtains the usual expression for the electromagnetic energy density $\frac{1}{2}(\vec{E}^2 + \vec{B}^2)$ and for the momentum density (the Poynting vector) $\vec{E} \times \vec{B}$ as expected. The new feature for $P \neq 0$ is the emergence of an extra term in the rest mass-energy density ($\frac{1}{2}P^2$) and an extra term in the momentum density ($P\vec{E}$). The $P\vec{E}$ term turns the direction of momentum propagation in the direction of the electric field. Force-free motion (the equation of motion) in this simple extension corresponds to the four differential of this being zero such that $\mathcal{D}_4(GG^\dagger) = 0$. For a radial electric field this is a radial force allowing for spherically symmetric solutions. This allows the possibility of a closed vorticial flow in momentum space corresponding to elements of the field of a physical particle.

Electromagnetic flow in such a topology has been proposed in earlier work.¹⁶ It corresponds to an electromagnetic momentum flow around a toroidal topology in momentum space. It is possible to model this in terms of the twisting of the electromagnetic field about its propagation axis, as in equation (5) combined with a

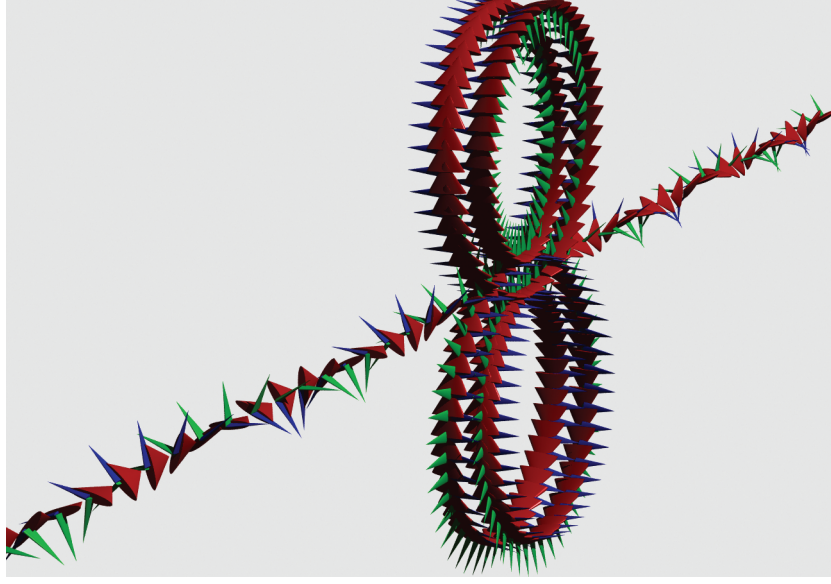


Figure 2. Diagram of the process of electron-positron pair creation or annihilation in phase (momentum) space at the point of separation. The incoming photons are shown on a different scale to the electron and positron vortices. The vortex radius is a factor of 4π smaller than the photon wavelength. The electron (above) encloses a pool of positive p-vot, the positron (below) a pool of negative p-vot.

turning of the momentum direction in the direction of the electric field, as in equation (8). The process of electron-positron decay into two photons (where the p-vot rest-mass term annihilates), or the photo-production of an electron positron pair (where the p-vot term is created) may then be understood as a continuous process described by the new general linear equation equation (4). The electromagnetic field patterns in the process of the photo-production of an electron-positron vortex pair (or electron-positron annihilation) in momentum space is illustrated in figure 2. The figure is drawn at the point where the electron and positron just separate (or where annihilation just begins). For a complete separation to a free particle-antiparticle pair the initial photon energies must be sufficient to impart enough momentum to overcome the Coulomb attraction.

A single such particle, illustrating the essentially toroidal topology, is shown in figure 3. The particle illustrated is the positron rather than the electron, since the outward-directed field shows the radial nature of the electric field more clearly. The smoke disks in the toroidal loop denote the pivot. The curvature illustrated is, however, not a curvature in ordinary space, but in momentum-space. This is because equation (8) is an equation in energy-momentum space not in space-space. It is a particular projection of the much more complicated “motion” of the (potentially) sixteen linearly independent elements onto the bi-vector subset (and not the vector subset) of that space. The main subtlety to be taken on board in understanding the diagrams is that they are not drawn in ordinary space but in bi-vector space. This has, as described above, six degrees of freedom (six dimensions if you like). The form is toroidal in bi-vector space, but the projection to (the linearly independent three dimensions of) normal space is spherical. The curvature is the ratio between the $P\vec{E}$ term and the $\vec{E} \times \vec{B}$ term in equation (8). Though this has a physical value of $\frac{4\pi}{\lambda_C} m^{-1}$, it is properly also a bi-vector and not a vector term. In order to project on to a spatial distribution, it should be noted that, properly, each smoke disk represents a slice through a spherically symmetric p-vot sphere at the particle core. Since an isolated particle has nothing to rotate about but itself, all of these disks (representing spheres) should be drawn at the same point in space-time. Also the figure should rotate about a vertical axis such that the magnetic field is cancelled to some extent, leading to a minimal total energy. Experimentally, isolated electrons do not have a magnetic moment. Such a moment is induced only in an external field. This means that the field distribution shown should rotate, resonantly at the Compton frequency, about a vertical axis - leading to an electric field radial in space - as is observed. Taking these together one arrives at a projection onto space like that illustrated in the core of the figure. A spherical ball of p-vot with a spherically symmetric, radial electric field. A charged particle.

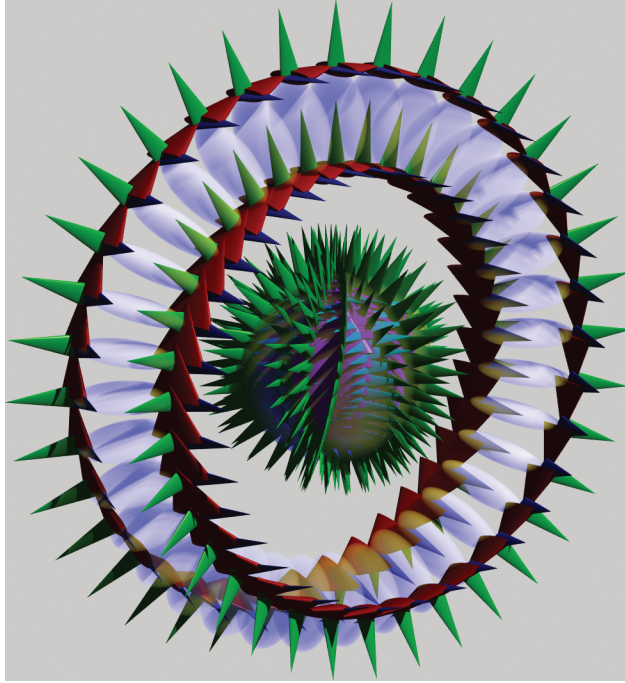


Figure 3. The toroidal field distribution in momentum space and the projection to the rest-massive sphere in normal space. This makes manifest both the internal double-loop and its relationship to the toroidal topology. The smoke disks representing p -vot in the momentum representation and correspond to slices through the hypersphere in space-time. These each project to the same sphere of p -vot. An artist's impression of what this would look like if one rotated at the same rate as the vortex is given in the core of the figure. Externally, one should observe a radial electric field and zero (on average) magnetic field.

6. DISCUSSION

The first question is: how can the initial state, with uncharged photons give rise to a final state with charged particles, an electron and a positron? Firstly, it should be noted that this is a process which occurs in nature, that is manifest in experiment. Particle-antiparticle pairs are created all over the place if there is sufficient energy. The author was lucky enough to work for many years at CERN - and there this kind of thing happens all the time. The primary process, if a high-energy photon or electron hits a material, is a shower of electrons, positrons and photons. If one's current favourite theory does not provide a satisfactory description of this kind of process, then that theory is simply not good enough. It should, by the scientific method, be either refined or replaced with something that does.

The process illustrated in figure 2 is one where the field in the initial photon pair transforms, at least partially, into two equal and opposite pools of p-vot. These p-vot pools then deflect any incoming field into two counter-rotating vortices which curl up more and more tightly as more and more of the initial photon energy is incorporated into them. Charge is conserved in that the two final state particles (as well as the intermediate state vortices) have equal and opposite charge. Vorticity (spin) is conserved in that the vortices have equal and opposite vorticity.

The field curls up into a rotating double loop, as illustrated, because that is a minimum energy configuration. To minimise the energy as much field as possible should cancel. Any field which cannot cancel should, as far as possible, align. Any internal rotational component should align to facilitate this. In the figure the initial axis of the twist of the photon about its propagation direction as described by equation (5) is aligned perpendicular to that of the momentum flow, with the result that the electric field is everywhere aligned radially. This configuration, with a harmonic rotation about the vertical axis, has maximum magnetic field cancellation as illustrated in figure 3. The radial electric field is required for photon confinement with p-vot, since the new forces act on the electric field component alone. There is also a possibility to produce a dual, magnetic monopole solution if one introduces a q-vot (which acts only on the magnetic field). Such a configuration, which differs in the confined field configuration only by a 90 degree twist around the propagation direction will, presumably, have much higher mass and may, as suggested in earlier work,¹⁶ be unstable to decay into an electric monopole. That the magnetic monopole is excluded in favour of the electric monopole is also due to the magnetic forces taking priority in the "heirarchy of forces" as discussed by M.B. van der Mark.¹⁷ It is speculated, however, that this configuration may be the "source" of the weak force within the new theoretical framework.

It is blindingly obvious from figure 3 that, for an outside observer, such vortices exhibit a charge. The oscillating electric field in the incident photons has been re-configured (rectified) so that it is everywhere inwards directed (for the electron) or outward-directed (for the positron). Such solutions are essentially charged. The stability is ensured in that, once it exists, trying to unravel the vortex leads, rapidly, to much higher energy configurations. The only simple way to take an electron to pieces once created it to present it with an anti-vortex, anti-spin, anti p-vot particle - a positron.

This position now enables one to address one of the central mysteries of 20th century physics: just what is charge anyway? Depending on the theoretical basis, charge has two aspects. Within classical field theory it is the source of the electric field. As viewed from the standpoint of quantum electrodynamics it is that thing which may emit or absorb photons, the "carrier" of the electromagnetic force. Clearly, charge should not be one or the other, but both. The object depicted in figure 3 contains both dynamical p-vot and f-vot. A rest-mass component and a field component. Within the theory, the field is confined by the mass, and the mass by the field. One can view the field component as being like a rapidly rotating light-speed sheepdog, corralling the rest-mass component which is its attractor. Once such objects exist, what is their interaction with field (in the form of light) and p-vot? Free p-vot, on encountering such an object, would simply be absorbed, increasing its energy. If there ever was any such stuff in the locality of the solar system, observations suggest that most of it has long ago been incorporated into existing particles. Light, is another matter. It has been argued above that light is confined into the vortex in the process of pair creation. It follows that such existing vortices may absorb more light. Equally, the time reversed process, where the vortex sheds light, is allowed provided certain conditions (corresponding to those observed for the physical photon - as argued above) are met. The new solutions then, fulfil both aspects of light discussed above. They are simultaneously a source of radial electric field, and that object which may emit or absorb photons. Charge is not a fluid which an electron possesses. Charge is a process.

Although it may now be obvious that the new solutions are charged, calculating that charge from first principles is less straightforward. Assuming that the electron was purely electromagnetic, a lower limit for the electric charge presuming the electromagnetic field was maximally distributed within a rotation horizon defined by the speed of light, remained half and half electric and magnetic and was effectively radial at the characteristic size of the double loop ($\lambda_C/4\pi$) gave a value of 0.91 q .¹⁶ This is (surprisingly) close to the charge observed. As stated, this assumed the electromagnetic energy to be uniformly distributed within a volume of radius $\lambda_C/2$. Imagining that only a quarter of the initial energy manifest as electric field (rather than a half) reduces the lower limit on the charge by a factor of $\frac{1}{\sqrt{2}}$. An upper limit on the electron charge is more difficult to estimate. The average field manifesting radially at the other appropriate length scale in the model, the rotation horizon $\lambda_C/2$ would give a charge π^2 larger. Taking another value of the region over which the field is averaged - that of a loop deformed to a single covering disk with radius $\lambda_C/2\pi$ increases the effective charge by a factor of $\sqrt{\pi^3}$. Concentrating the field down to a smaller and smaller radius, of course, raises the effective charge to infinity, as in standard quantum electro-dynamics and will then require re-normalisation to give sensible results. That the object must be charged is manifest. Calculating that charge depends on the percentage of the initial energy manifesting as electric field, and the precise distribution of that field within the double-covering flow. That distribution should minimise the total energy of the complete solution as well as satisfying the generalised Maxwell equations. Such a particular solution is unlikely to be analytic, but may be subject to finite element modelling. The important thing for the present work is that such solutions are charged, and that the charge estimated from reasonable models is of the order of the elementary charge.

Now let us consider the spin of the resultant object. Given the spin of the constituent photon, it is straightforward to calculate the spin of the photon momentum in the double looped object¹⁶ and this is found to be half-integral. The total spin is then that of the initial photon minus that of the orbital spin ($\hbar - \frac{1}{2}\hbar = \frac{1}{2}\hbar$). By the spin-statistics theorem, therefore, the proposed object is a fermion. More fundamentally, as is clear from Fig. 3, the object is double-covering over the torus in momentum space and returns to its starting configuration after a 720-degree rotation in the space of an outside observer. That is, the object has the intrinsic symmetry of a fermion. A consideration of the internal interference of the fields on overlap leads to a possible physical origin for the exclusion principle itself, as discussed in earlier work.¹⁴

One further important feature of the earlier model was that it gave a physical explanation of the anomalous magnetic moment of the electron, which could be obtained from a proper consideration of the matching of rotating and non-rotating parts across the rotation horizon.¹⁶ The value obtained, to first order, was the same as in quantum electrodynamics. That consideration carries over in the present model, as it has the same rotation horizon.

Given that the charge, spin and anomalous magnetic moment of the double-looped object are close to those of the electron, it is considered self-evident that, in the theory of vot over 4-dimensional space time forms, it should be identified with the electron (or positron).

The body of physics, as it stands, is pretty good. Any new theory should either encompass aspects of the old, improve on it, or provide a proper basis for its starting points. Like its sister model, the Dirac model, the new theory has four and only four rest-massive solutions. The spin up and spin down electron and positron. The differences are twofold - the new model has a (slightly) simpler mathematics and a (slightly) more sophisticated substance. The new mathematics is simpler in that it does not allow the complex imaginary. The substance is more sophisticated in that, in the Dirac model the mass is not brought in as a dynamical term and the fields are brought in through minimal coupling and the vector potential. The substance of the solutions are then a set of "spinor" quantities. In the present theory the substance is just the dynamical root-mass and the physical fields. The four solutions, one of which is illustrated in Fig. 3, are physical spinors constructed of underlying root-mass and fields. Quantum electrodynamics is a theory of photon exchange between charged particles. The new theory provides the physical basis both for the charges and for the exchange particles. This underpins the starting point of the theory and will (hopefully) help removing some of the re-normalisation infinities present. The present theory encompasses the Maxwell equations, but provides the physical basis for charge rather than inserting it a-priori.

7. EXPERIMENTAL TESTS

Experimental tests of the new theory depend to a certain extent on which aspects of it are expressed. For example, it is perfectly possible that the tri-vector term is, as in conventional electromagnetism, precisely zero. This would, however, remove the possibility of describing an underlying angular momentum density, a feature expressed in the experimental properties of particles and markedly absent in conventional electromagnetic theory. Likewise, p-vot (and q-vot) could be absent - the theory then reduces simply to conventional electromagnetism and nothing new will be detected at all.

If the tri-vector term is non-zero, field could be generated from changes in angular momentum, as described by the α_{i0} term in equation (4). One should then observe electromagnetic radiation from a rapidly stopped neutral, spun, spinning object. This may sound a straightforward enough experiment, but the experimental challenge will lie in finding uniformly uncharged material (even the neutron has a very large magnetic moment for such a small particle), finding a suitable means of stopping it spinning (note that hitting it with photons or electrons may impart angular momentum as well), and removing the possibility of the object simply absorbing its own radiation as low-energy heat. Even so, it may be possible to devise experiments to measure this effect.

As mentioned above, free p-vot (if it exists) is strongly scavenged by existing material particles. Such a process should manifest at low densities as an increase in low energy heat. If there are yet regions of the universe where free p-vot exists, it will manifest itself in particular properties. Firstly, even at very low densities, it will interact gravitationally, making it a candidate for dark matter. Secondly, it will heat matter impinging on it - which may be detectable. Thirdly, if there were to exist regions of very high p-vot density, matter incident on it would heat very rapidly, perhaps yielding x or gamma ray radiation. A re-analysis of existing cosmological data may then be sufficient to confirm or deny the existence of free p-vot.

It may be possible to generate free p-vot in the lab, for example by cancelling electromagnetic fields in the vacuum, where the p-vot is then formed to conserve energy. One could then attempt to probe this region with particle beams or low-energy photons. Plane polarised photons with a (half) wavelength similar to the region of p-vot, for example, should then be deflected in the electric-field plane, depending on the phase of the field. In designing experiment it should be noted that free p-vot will fall in a gravitational field. This effect is then best-measured on a wall-mounted light table.

It is quite possible that pivot exists only as a transient dynamical effect in existing rest-massive particles. The most direct tests of the new theory, then, lie in high energy polarised particle scattering. Polarised electrons, for example, incident on electrons within a strong magnetic field, should show asymmetric, non-point-like scattering. Again, a re-analysis of existing experimental data through the prism of the new theory may confirm or deny this possibility.

8. CONCLUSIONS

A theory has been developed of root-energy transforming within sixteen linearly independent relativistic space time forms. The base forms are the lines of a relativistic four dimensional space-time. From these are derived twelve additional, relativistic linearly independent elements representing six planes, four volumes, a 4-volume and a scalar "point". Root-energy is allowed to transform between these forms in a manner similar to that represented by a conventional 4-vector derivative. Root-energy in each of these forms is then identified with physically observed phenomena. Integration over the p-vot squared is an element of rest mass-energy. The vector part is identified with the (root) charge and current density. The six bi-vector components with the electromagnetic field. The tri-vector with a root angular momentum density and the quadri-vector with an inward or outward directed four-volume root-energy, whose derivative yields angular momentum components. The interaction between the various forms is then argued to be responsible for generating the forces required for the system as a whole to confine itself into particles. Possible further developments of the theory to describe these forces explicitly have been proposed. Within the new theory a new kind of solution to the (field only) Maxwell equations and conforming to the principle of absolute relativity has been found. This is expressed by equation (5). This equation satisfies the Maxwell equation, has energy proportional to frequency, a fixed angular momentum limit and is identified with the physical photon. Extending the Maxwell equations by introducing a further rest-mass component allows qualitatively new kinds of solutions. These contain, as well as the rest-mass

component, re-circulating field components. Such solutions are necessarily charged, have half-integral spin and have the proper 720 degree symmetry of fermions. These solutions are identified with the electron and positron.

8.1 Acknowledgments

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