Electromagnetic Self-Field Theory and Its Application to the Hydrogen Atom

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Abstract

Despite nearly a century of considered opinion to the contrary, an electromagnetic self-field theory has been developed for atomic systems consisting of charged particles. An azimuthal modal spinor is used as a trial solution for the motions of each particle and tested using Maxwell's equations for particle-field interactions. Both the particles and the field are seen in terms of coupled spinors associated with electric and magnetic fields. Unconventionally, the particle electric and magnetic fields are measured between centers of motion and not between charge points. Maxwell's curl equations are seen as a balance of the electric and magnetic kinetic energies with a particle's total energy and a balance of its electric and magnetic potential energies. The theory results in a system of inhomogeneous equations, the unknowns being the coupled spinors of each particle: four equations for the electron and also for the proton in the hydrogen atom and two conjugate pairs of equations for each particle. The modal equations for the electron yield analytic solutions for the resonant frequencies, the radii, the Rydberg constant, and the Balmer series. The modal equations for the proton give an estimate for the size of the proton.

Key words: electromagnetic self-field theory, Maxwell's equations, Bohr quantum theory, quantum electrodynamics, quantum chromodynamics, quantum field theory, dynamic motion of electron and proton in hydrogen atom, Rydberg constant, Balmer formula, atomic physics, Planck's constant, nuclear physics, spectroscopy, strong and weak forces

1. INTRODUCTION

Present-day understanding of the hydrogen atom is linked to the quantum theory that evolved during several decades of effort from the late 19th century until the late 1920s.[1,2] Bohr put forward a quantum theory of spectroscopy in which angular momentum is whole-number multiples of Planck's quantum[1] $\hbar = h/(2\pi)$. Using Bohr's theory we can express spectral lines as a quantum series, for example, the Balmer series, $\nu_{mn} = R(1/m^2 - 1/n^2)$, where $m^2 = 4$, $n = 3, 4, 5, \ldots$, and Rydberg's number is $R = q_e^4 m_e/(8\varepsilon_0^2 h^3 c)$. With this theory the ground state energy of the hydrogen atom, Bohr's energy, $E_B = Rhc$, and the electron's position, the Bohr radius, $r_B = \varepsilon_0 h^2/(\pi m_e q^2)$, can be estimated. Spectroscopic experiments led to an understanding of how the hydrogen atom was excited by electric (E) and magnetic (H) fields. By 1926, four quantum numbers, n, l, m, and s, had been revealed to be associated with the electron.

Despite intensive investigation, this same period saw a complete failure to find any way to base atomic physics on electromagnetic (EM) theory. Maxwell had previously reached the conclusion that gravitation could not be based on EM theory despite the similarity between the inverse square forms of Coulomb's electrostatic force and Newton's gravitational force.[3,4] Concepts of planetary motion led only to unstable spiraling of the electron in atoms. The conviction against EM as a basis for atomic physics grew as methods termed quantum mechanics (QM) evolved. Developed from the late 1920s to the mid-1940s, quantum electrodynamics (QED) is a generalized hybrid of EM, quantum theory, and special relativity (SR).[5] Due to the uncertainty principle, quantum field theories including QED cannot be solved deterministically.[6] At their core are discrete quadratic functionals based on quantized EM potential solutions to Maxwell's equations requiring

numerical solution methods. As well as the second-order partial differential equations, boundary conditions at infinity and near singularities need formulating. Applications require evaluation of significant terms among infinite numbers of integrals (Feynman diagrams) and also renormalization. Quantum chromodynamics (QCD) in turn is a generalization of QED, devised to handle the added particles falling within the standard model of particle physics observed in the last half of the 20th century.[7] Quantum numbers such as "flavor" and "color" exist in addition to those due to electronic interactions with the nucleus. Despite the numerical difficulties, the standard model of the hydrogen atom resulting from the Schrödinger equation has until recently been the only option.[8,9] Certainly no EM solution based on the dynamics of charged particles has been useful in modeling the hydrogen atom apart from Bohr's early model. Yet EM theory has been and remains at the heart of all quantum field theories.

In this paper an EM self-field theory (EMSFT) yields analytic solutions for the electron's motion in the hydrogen atom including Rydberg's number and the Balmer formula. The fields are unconventionally measured relative to centers of motion (COMs)[2] rather than directly between charge points as in the Liénard–Wiechert potentials.[10] Although there are several, this is perhaps *the* essential difference between the present and previous attempts to solve for the atomic motions using electromagnetics. After testing spinor solution forms for the fields via Maxwell's equations, EMSFT results in a system of equations. For the hydrogen atom this induces no new physics; the only change is in the mathematical apparatus used to obtain the physics. Unlike QM's potentials yielding probabilistic solutions, the field variables of EMSFT allow deterministic solutions; thus a clear picture of the physics emerges. Based on Lorentz-compatible field solutions to Maxwell's equations, neither SR nor gauge is problematic. Its field variables being *a priori* relativistically correct, no correction terms are required, its solutions being analytic rather than numerical. In the formulation of quantum field theories, the EM fields are ubiquitous. In EMSFT a concept emerges of photon streams — two "pencil-beams" mutually coupling electron and proton. The EM field is not spherically symmetric or continuous; photon streams mediate energy between particles, it being a discrete, discontinuous form of field. QED and QCD concern collision dynamics, seeking cross sections, momenta, and energies of the particles. EMSFT concerns dynamic equilibria seeking the frequencies and velocities of all particles deterministically. It is pointed out that in EMSFT no constraint on the speed of light other than the experimentally observed speed in free space is assumed. Therefore, perhaps not surprisingly, Planck's "constant" is found *not* to be a constant but a *variable* associated with the EMSFT theory of the hydrogen atom.

2. SELF-FIELD THEORY

A mathematical description for the self-fields of charged particles was first derived by Abraham in 1903 and Lorentz in 1904 (Ref. 10, pp. 750–755). This is the effect upon a moving charge of any back-reaction due to its own radiating field. In this report two charged particles and their fields form a closed atomic system; the particles and their mutual fields form a balanced atomic self-system. This is not an infinite but a spatially finite closed system where the photons are contained inside the atom. The standing waves surrounding a loop cross-dipole representing the hydrogen atom can be shown to have no far-field radiation at certain frequencies and dimensions of the loop dimensions.[11] A condition of balance is found that is associated with the radiation fields of the cross-dipole such that no Bessel functions of kind 2 are involved; the internal standing waves are self-fields of finite extent rather than far fields of infinite extent. These fields have the same spinorial form as the EMSFT COM fields (Appendix B).

In general, both the particles and the EM fields that control the motions of charged particles satisfy the Maxwell–Lorentz equations.[10] For application to atomic physics, regions where particle-field interactions occur are assumed isotropic and homogeneous and thus the constitutive parameters, ε_0 and μ_0, the permittivity and permeability of free-space, are scalars. Where discrete particles carrying units of elementary charge q of opposite polarity are studied, in the absence of nebular regions of charge and current density, the Maxwell–Lorentz equations can be written

$$\nabla \cdot \vec{E} = \frac{q}{v_q}, \tag{1a}$$

$$\nabla \cdot \vec{H} = 0, \tag{1b}$$

$$\nabla \times \vec{E} + \mu_0 \frac{\partial \vec{H}}{dt} = 0, \tag{1c}$$

$$\nabla\times\vec{H}-\varepsilon_0\frac{\partial\vec{E}}{dt}=\frac{\pi}{s_q}q\vec{v}, \qquad (1d)$$

where the Lorentz equation for the field forces acting on the particles is written

$$\vec{F}=q\vec{E}+q\vec{v}\times\vec{B} \qquad (1e)$$

along with the constitutive equations $\vec{B}=\mu_0\vec{H}$ and $\vec{D}=\varepsilon_0\vec{E}$. There is a relationship between the speed of light[3] and the ratio of the fields $c = (\varepsilon_0\mu_0)^{-1/2}$. Also the atomic energy density $dU_A = \rho_A dV(1/2)(\varepsilon_0\tilde{E}\cdot\tilde{E} + \mu_0\tilde{H}\cdot\tilde{H})dV$ depends upon the fields in the atomic region. Equations (1a)–(1d) are termed the EM field equations.[4] In these equations v is the particle's velocity and m is its mass. It is assumed that the volume of integration v_q over which the charge density is evaluated, and the area the charge circulates normal to its motion s_q, are calculated during successive periods over which the internal motions of the atom take place (Fig. 1). At this stage the periodic motions are not assumed circular, regular, or constant.[5] The area parameters need retrospective examination to check any solutions that are uncovered for a particle's motion. Distinct from quantum theory, charge and mass points are nonsingular, as a particle does not reside at the origin due to the mathematical form of its motions.

As well as the motions of the atomic particles, Maxwell's equations specify the spatial distribution of photons that make up the E and H fields due to the presence of charged particles. The concept of the field and the charged particles within it is that of a collection of smaller particles (photons) that transit between larger particles (electrons and protons). We may think of the visual capability of computers to "zoom" in to a displayed region. From afar, the field looks like a nebulous cloud. As we zoom in, the cloud making up the field becomes a series of discrete point-like particles, the photons. At the same time, the particles, the electron and the proton, may change their visual character from point-charges to objects with internal dynamic structure.[6] The E and H fields acting on the electron for instance are a photon exchange process between proton and electron. The rotating motions are related to this photon exchange. In QM terminology spinors represent the orbits of electrons that possess spin. In EMSFT the electron's spinorial motion results from the mathematics. The orbital/cyclotron motion is visualized as many discrete photon/electron interactions that change the electron's direction and vice versa. The fields are stream-like and exist only between particles.

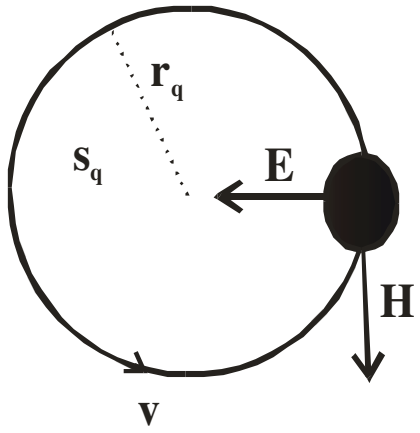


Figure 1. A charged atomic particle moving due to E and H fields. Two geometric parameters are associated with the motion: the radius of motion r_q and the surface area of intersection s_q.

2.1 Solving Maxwell's Equations for Atomic Self-Fields

Maxwell's equations (1) can be solved to yield analytically cyclic solutions where atomic particles and their E and H fields perform rotations in two orthogonal but coupled directions (Fig. 3). Because this field pair induces another pair of fields this second pair can, depending on its speed and frequency, in turn produce the original fields. These field pairs are produced by atomic particles each performing two orthogonal motions. The overall result is a "self-perpetuating" field. This approach is general in its application; recently it was used as the basis of a predicted photon chemistry where the photon, assumed to be massive, may have an analytic "Balmer-like" spectroscopic nature that is continuous rather than discrete.[12,13] We turn now to the details of this analytic self-field solution for the hydrogen atom.

Separation of pairs of E and H fields or potential variable pairs into azimuthal modes is well known to EM theory using isolated[10,14] or coupled modes.[15,16] In the following only the principal azimuthal mode (m = 1) is investigated, and also we retain the complete spatial information (Figs. 3–4) rather than substituting any parametrically related rotation times. Following Von Hippel (Ref. 17, p. 45) we assume a separated form for the electron's E field as a radial spinor rotating in the azimuthal angle ϕ:

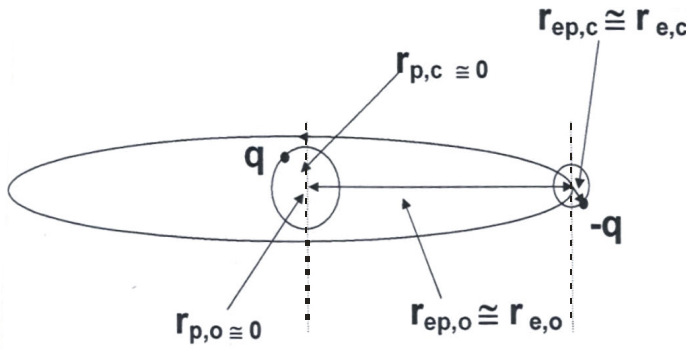


Figure 2. Hydrogen atom modeled with "infinite-mass" proton.

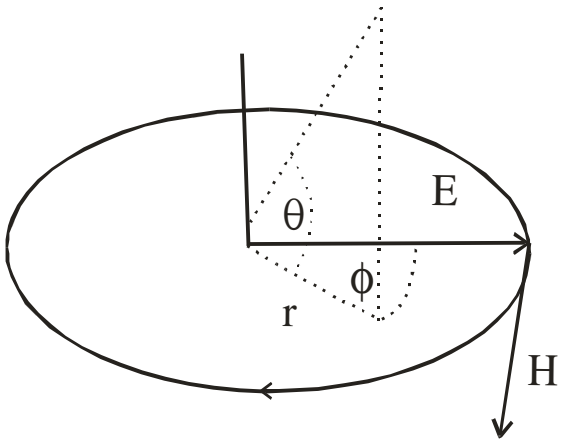


Figure 3. A rotating pair of orthogonal E and H fields.

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}e^{j\phi}\hat{r}. \tag{2}$$

The E field is actually a stream of individual photons all following each other, forming an expanding spiral as it moves from proton to electron. A coupled stream forms a diminishing spiral as the photons move from electron back to proton.[7] Each photon in the stream emanating from the proton tracks the electron as it moves in a double-spinor movement; thus the photon motion is similar to that of the electron. Equation (2) is a dynamic field in contrast to the well-known static Coulomb field. Equation (2) is a solution to Maxwell's first divergence equation (1a).[8]

The time derivative of the H field can be formed from the curl of the E field (1c). Assuming a linear relationship between time and angular rotation, $\phi = \omega t$, integration with respect to time yields an H field rotating with the E field:

$$H = \frac{1}{4\pi\varepsilon_0\mu_0}\frac{q}{\sin\theta\omega r^3}e^{j\phi}\hat{\phi}, \tag{3}$$

where this form is a solution to Maxwell's second divergence equation (1b),[9] where the constant of integration has been assumed zero[10] and where the imaginary part of any motion or field is a coupled orthogonal motion or field (see Appendix B). To here the solution is consistent — the E and H fields can both be represented as spinors related by a similar radial dependence that solve the divergence equations and the first curl equation (1a)–(1c). We continue with the time derivative of the H field. The cycle of differentiation implicit in Maxwell's equations is now completed to see if the form is consistent with the original trial form (2). In order to see if the resulting analytic form is the same as when we started our theoretical cycle, we take the curl of the time derivative of the H field (1d) and substitute $c^2 = 1/(\mu_0\varepsilon_0)$ to obtain

$$\nabla\times\frac{\partial H}{\partial t} = \frac{-1}{4\pi}\frac{c^2 q}{\sin^2\theta r^4}e^{j\phi}\hat{r} + \frac{c^2}{2\pi}\frac{q}{\sin\theta r^4}e^{j\phi}\hat{\theta}. \tag{4}$$

Differentiating (2) twice with respect to time, where the dependence $\phi = \omega t$ is again assumed, reveals its similarity in form to the first term on the right-hand side of (4):

$$\frac{\partial^2 E}{\partial t^2} = \frac{-1}{4\pi\varepsilon_0}\frac{\omega^2 q}{r^2}e^{j\phi}\hat{r}. \tag{5}$$

Equation (4) gives the two scalar components of current density in (1d) differentiated with respect to time. Starting with the E field in (2) its second derivative is given by (5) and has a similar form to the first term on the right-hand side of (4). Notice that by starting with negative exponential forms for the spinors a similar negative solution can be formed.

At this stage Maxwell's two divergence equations have supplied our initial spinorial forms while Maxwell's two curl equations have been cycled through and returned with a consistent E-field solution. For the hydrogen atom to be stable as detailed in Appendix B we require the H fields to rotate in the negative direction to the E fields; then the electric and magnetic potential energies act against each other. In the above analysis there was no spatial phase shift

assumed. The only phase shift, $\pi/2$, was due to differences between the E field and the H field and the differentials involved in Maxwell's equations. These phase shifts by themselves do not allow us to have positive and negative exponentials for our spinors. The presence of *both* signs allows internal standing waves, as is known from the study of waveguides.[10] We can achieve a mixed exponential form for the spinors if there are spatial phase shifts to provide an overall phase change of $2m\pi$, where m is the azimuthal mode. In the case where the orbital and cyclotron separations both provide phase shifts of $\pi/2$, we end up with a phase shift 2π across the analytic cycle. The overall self-field system starts with the E field of the first particle; this provides the E field to the second with a spatial phase shift of $\pi/2$ between the E fields; the two H fields are similarly shifted in phase. The shift is over the analytic field cycle (length 4). ($\tilde{E}_1$, $\tilde{H}_1$, $\tilde{H}_2$, $\tilde{E}_2$, $\tilde{E}_3$, $\tilde{H}_3$) is seen as (0, $-\pi/2$, $-\pi$, $-3\pi/2$, -2π, $-5\pi/2$, …).

In the case of the atomic self-fields the E and H fields form two streams that occur in orthogonal planes. The fields can be separated into two coupled spatial coordinate systems (Fig. 4). In terms of these coordinates a radial E-field spinor rotates in ϕ_o; this spinor and its time derivatives form a discrete cyclic set (period 4 as with the phase shifts) in the $r_o - \phi_o$ plane (Fig. 5). An H-field spinor derivative also rotates in ϕ_o; the H-field spinor and its derivatives also form a discrete cyclic set in the $r_o - \phi_o$ plane causing the electron to perform a cyclotron motion in the $r_o - \phi_o$ plane. The H-field cyclotron force rotates in θ_c.

Given certain conditions, the coupled spinor motion between two particles is a self-field solution for the hydrogen atom. The two spinors move at all times relative to their respective COMs. The motions depend on Maxwell's equations and are orthogonal. In general, for systems where there may be many particles in an atomic structure, Maxwell's two curl equations provide three scalar equations per particle. For the Lorentz forces to be counterbalanced (1e) resolves into E- and H-field components, providing two coupled scalar equations per pair of particles. Hence there are eight equations per pair of particles and our system of self-field equations is solvable there being four unknowns, the orbital and cyclotron radii and frequencies, and four equations per particle. This corresponds with the quantum numbers observed spectrographically in the hydrogen atom, the 4-vectors of relativity, and quantum field theory in general.

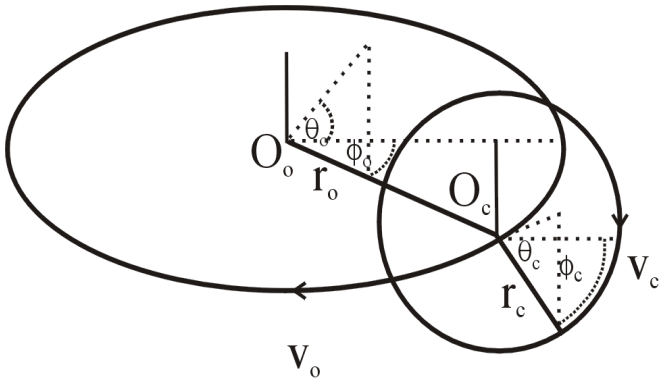


Figure 4. Orbital and cyclotron radii and velocities of electron showing spherical coordinate system oriented at the electron's electrical COM (center of mass). The coordinate systems of the orbital and cyclotron motions are coupled via the EM field equations. Only four of the six spatial coordinates are independent, as in space-time coordinate systems.

Examining (4), a condition for the EM self-field solution to cycle theoretically is $v^2/\sin^2\theta = c^2$, where $v = \omega r$ rad. Where $v = c$, a precondition is $\sin\theta = 1$ or $\theta = \pi/2$. Thus the rotations occur in the equatorial elevation. To this point the EM equations (1)–(5) describe the fields regardless of their application and involve the speed of light. Certain systems of charged particles are indeed self-sustaining and involve a rotation speed equal to the speed of light (Ref. 5, p. 324).[12,13] We assume our equations are quite general, describing atomic systems, or the internal structure of the photon,[12,13] in fact anywhere self-fields occur (see Section 4). Our focus here is to see if these equations yield motions for the electron in the hydrogen atom. The electron's rotational speed is known to be around 1/137 that of light, $v_e = \alpha c$, where α is the fine-structure constant. The condition for an equatorial elevation angle in the hydrogen atom is assumed as $\sin\theta = v_e/(\alpha c)$, so $\theta = \pi/2$ when $v_e = \alpha c$.

2.2 The Hydrogen Atom: Periodic Solutions for the Electron's Principal Mode

EMSFT proposes a spinorial solution to Maxwell's equations capable of modeling atomic systems composed of charged particles. In this report the theory is specialized to an electron moving dynamically inside the hydrogen atom in its various modes. As detailed in Appendix B, the proton is assumed to have an infinite mass that complements the electron's motion electrically and magnetically (Fig. 2). Equatorial spinors ($\theta = \pi/2$) represent the two rotational

motions of the electron: an orbital spinor $\sigma_o(r_o, \omega_o) = r_o e^{j\omega_o t}$ associated with the E field and a cyclotron spinor $\sigma_c(r_c, \omega_c) = r_c e^{j\omega_c t}$ associated with the H field. Closely related to the motions of the electron, the fields too are spinors, as shown in Fig. 3. Maxwell's equations yield equations for the electron representing a balance of its kinetic and potential energies.

It is now assumed that the spinor forms (A15)–(A16) yield the fields, forces, and motions required for dynamic equilibrium. These spinors provide COM E and H fields consistent with Maxwell's equations. The coupled fields balance the forces of the proton and electron. The orbital and cyclotron fields control the motions of the proton and electron and vice versa — the particle motions cause the fields. Where we use a substitution for the speed of light, $\varepsilon_0\mu_0 = 1/c^2 = 1/(r_c^2\omega_c^2)$, (2)–(3) become

$$E(\omega_o, r_o) = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_o^2}e^{j\omega_o t}\hat{r}, \tag{6}$$

$$H(\omega_c, r_c) = \frac{\omega_c}{4\pi}\frac{q}{r_c}e^{j\omega_c t}\hat{\phi}, \tag{7}$$

where ω_o and ω_c are orbital and cyclotron angular velocities and r_o and r_c are orbital and cyclotron radii. The spinorial field forms are consistent with the COM forces discussed in Appendix B. The motion of the electron forms an EM self-field solution; its position is a sum of two spinors $\sigma_o(r_o, \omega_o)$ and $\sigma_c(r_c, \omega_c)$:

$$r(r_o, \omega_o, r_c, \omega_c) = r_o e^{j\omega_o t} + r_c e^{j\omega_c t}. \tag{8}$$

In (8) each spinor refers to a COM; the orbital (E field) COM is stationary and the cyclotron (H field) rotates. This results from the coupled nature of the two spherical coordinate systems shown in Fig 3. Figures 2–5 illustrate the spinor dynamics while Fig. 6 shows an actual motion. In terms of mathematical forms that lead to discrete or decoupled azimuthal modes, the complex exponential form of (8) is one such form. Solutions that return to their starting point, in other words are periodic, can maintain dynamic motions without net efflux or influx of energy. In general, the various azimuthal modal forms that are written $e^{jm\phi}$, where m = 1, 2, 3, …, are a possible prerequisite to a discrete or quantum physics.

For the simplified case of the principal mode a system of equations based on Maxwell's curl equations (1c)–(1d) can be written where the orbital and

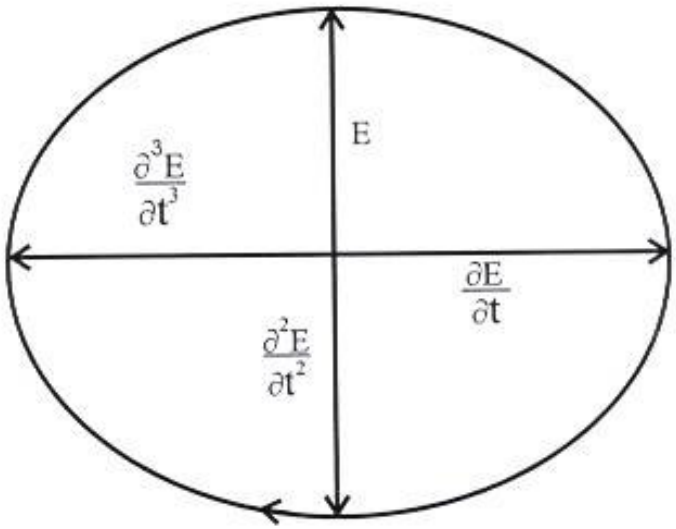


Figure 5. The time derivatives of the EM field form a series, n = 0, 1, 2, 3, that returns to the initial direction after a complete cycle. Shown is the E-field series that lies in the r-ϕ plane.

cyclotron frequencies are assumed equal: $|\omega| = |\omega_o| = |\omega_c|$. The $e^{j\omega t}$ factor also simplifies out, and the system reduces to three equations in three unknowns (ω, r_o, r_c):

$$\frac{q}{4\pi\varepsilon_0 r_o^3} + \frac{\mu_0\omega^2 q}{4\pi r_c} = 0, \tag{9}$$

$$\frac{c^2}{2\pi}\frac{q}{\omega r_c^4} = \frac{q}{2\pi r_c^2}\omega, \tag{10}$$

$$\frac{1}{4\pi}\frac{c^2 q}{\omega r_o^4} + \frac{1}{4\pi}\frac{\omega q}{r_o^2} = \frac{-q}{2\pi r_o^2}\omega. \tag{11}$$

Equations (9)–(11) follow substitution of the field spinors (6)–(7) into (1c)–(1d). Equation (9) follows (1c) while (10)–(11) are the two components of current performed by the electron; a negative sign in the source terms of (11) indicates anticlockwise current. Equations (9)–(11) are satisfied if as well as the radii and angular frequencies having equal magnitude, a phase difference of $\pi/2$ exists between ω_o and ω_c or, equivalently, $\pm j$. The potentials oppose each other in (9).

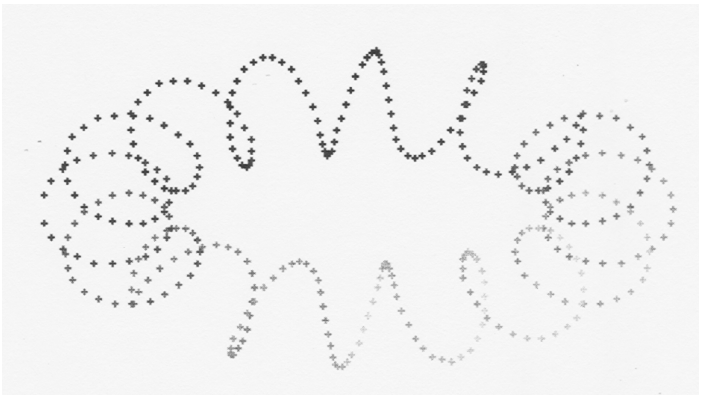


Figure 6. Coupled spinor solution; the motion spinors are rotating in the $r_o - \phi_o$ and $r_c - \theta_c$ planes, where $r_o = 4r_c$ and $\omega_c = 16\omega_o$. Such a plot provides comparison with the probability densities of quantum theory.

By substitution of $\varepsilon_0\mu_0 = 1/(r_o^2\omega_o^2)$ and cyclotron area constants $s_o = \pi r_o^2$ and $s_c = \pi r_c^2$, (9)–(11) yield three equations in three unknowns (ω, r_o, r_c):

$$\frac{1}{4\pi}\frac{\omega^2 q}{\varepsilon_0 r_o} - \frac{1}{4\pi}\frac{\omega^2 q}{\varepsilon_0 r_c} = 0, \tag{12}$$

$$\frac{c^2}{2\pi}\frac{q}{r_c^4} = \frac{1}{2s_c} q\omega^2 r_o, \tag{13}$$

$$\frac{c^2}{4\pi}\frac{q}{r_o^4} + \frac{c^2}{4\pi}\frac{q}{r_o^4} = -\frac{1}{2s_o} q\omega^2 r_o. \tag{14}$$

What are normally called the field terms are on the left-hand side and the particle or source terms are on the right-hand side of (12)–(14) as in (1c)–(1d). As will be seen, quanta of Planck's number, photons, are found theoretically on the right-hand side and the electron parameters on the left-hand side, vice versa to the normal particle-field system.

3. FORCES AND ENERGIES OF THE PRINCIPAL MODE OF THE HYDROGEN ATOM

Equations (12)–(14) can be written in terms of the forces and energies associated with them. As known from studies of electrostatic and gravitational orbits, centripetal and centrifugal forces can establish balance while performing circular or elliptic motions. Where an electron and a proton are in dynamic equilibrium, pairs of electrical and magnetic forces each balance the mass of the particle in orthogonal directions of motion. Equation (15) below can be written for the electron's orbital motion. Substitution of the E-field spinor (6) and the orbital position spinor $\sigma_o(r_o, \omega_o)$, (8), yields an electric form of the virial theorem:

$$m_e \frac{d^2\sigma_o}{dt^2} = qE, \tag{15}$$

$$m_e \frac{d^2\sigma_o}{dt^2} = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r_o^2} e^{j\phi}, \tag{16}$$

$$m_e\omega_o^2 r_o e^{j\omega_o t} = -\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r_o^2} e^{j\omega_o t}, \tag{17}$$

$$m_e\omega_o^2 r_o^2 = -\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r_o}, \tag{18}$$

where m_e is the mass of the electron. The charges being equal and opposite, the E field is attractive and the magnitude of the orbital centripetal force is $m_e\omega^2 r_o$. The virial theorem given by (18) links the kinetic and potential energies due to the E field.[18] How can the electron and proton maintain a constant E-field spinor? The two rotate around a common stationary COM. A constant orbital separation is achieved if the two maintain a certain prescribed angular velocity in ϕ and if the phases of their ϕ rotations differ by 0 or π, where the larger separation is the lower energy state. On its own such an orbital system would be unstable.[17]

Equation (19) below can be written for the electron's cyclotron motion. Substitution of the H-field spinor (7) and the cyclotron position spinor $\sigma_c(r_c, \omega_c)$, (8), yields a magnetic form of the virial theorem:

$$m_e \frac{d^2\sigma_c}{dt^2} = qv_c \times B, \tag{19}$$

$$m_e \frac{d^2\sigma_c}{dt^2} = \frac{-\omega^2\mu_0 q^2}{4\pi} e^{j\omega_c t} = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r_c^2} e^{j\omega_c t}, \tag{20}$$

$$m_e\omega_c^2 r_c e^{j\omega_c t} = \frac{-1}{4\pi\varepsilon_0}\frac{q^2}{r_c} e^{j\omega_c t}, \tag{21}$$

$$m_e\omega_c^2 r_c^2 = \frac{-1}{4\pi\varepsilon_0}\frac{q^2}{r_c}, \tag{22}$$

where $\hat{r}_c = j\hat{r}_o$ and the charges due to the electron and proton rotate in the same direction and hence the cyclotron force $m_e\omega^2 r_c$ is repulsive (centrifugal). Again, a constant cyclotron radial separation can be maintained provided both particles maintain a certain angular velocity in θ and their θ rotations differ in phase by π (for the lower state). On its own such a cyclotron system would be impossible as well as unstable, requiring the E field for its existence, which in turn requires the H field; together the E and H fields form an "entrapped" EM self-field inside the atom.

Using the virial relationships (18) and (22), (12)–(14) can now be recast in terms of electric and magnetic forms of kinetic and potential energies:

$$\frac{1}{4\pi\varepsilon_0}\frac{\omega^2 q^2}{r_o} - \frac{1}{4\pi\varepsilon_0}\frac{\omega^2 q^2}{r_c} = 0, \tag{23}$$

$$m_e v_c^2 = \hbar\omega, \tag{24}$$

$$m_e v_o^2 = \hbar\omega. \tag{25}$$

Note that the right-hand sides of (24)–(25) are known in terms of Planck's constant and at this stage the system of equations has been transformed into an eigenvalue problem. Hence discrete quanta of Planck's energy are found on the right-hand sides of (24)–(25). These are source terms that can be traced back from the right-hand side of (1d). The connection to quantum theory is obtained from (18) and (22) by dividing (18) by ω_o and (22) by ω_c so $\hbar = q^2/(4\pi\varepsilon_o v_o) = q^2/(4\pi\varepsilon_0 v_c)$. In this form Planck's "constant" is a variable of motion, dependent on the solution of the equations. The quantum nature of the electron's motion has long been observed.[19] The system of three equations in the unknowns ω and r_o and r_c are based on classical energy forms. Eliminating (24), the system may be recast in terms of the energies in diagonal matrix form:

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} V \\ T \end{bmatrix} = \begin{bmatrix} \hbar\omega \\ \hbar\omega \end{bmatrix}. \tag{26}$$

In (26) $V = V_o = [1/(4\pi\varepsilon_0)](q/r_o) = V_c = [1/(4\pi\varepsilon_0)](q/r_c)$ and $T = T_o = m_e v_o^2 = T_c = m_e v_c^2$ are the orbital or cyclotron components of the potential and kinetic energies. In this form $\omega = |\omega_o| = |\omega_c|$ and $r = |r_o| = |r_c|$. From inspection (26) agrees with the virial theorem.

3.1 Rydberg's Number

The complete matrix equation forms two conjugate parts, for the orbital and cyclotron motions, each a submatrix of two equations. The principal mode case has simplified the analysis. Equation (26) solves analytically and can be compared with the Bohr theory expressions for the Bohr radius, resonant frequency, and Rydberg's number:

$$r_o = r_c = \frac{4\pi\varepsilon_0 h^2}{m_e q^2} = r_B, \tag{27}$$

$$\omega_o = \omega_c = \frac{q^4 m_e}{16\pi^2\varepsilon_0^2 h^3}, \tag{28}$$

$$R_o = R_c = \frac{q^4 m_e}{4\varepsilon_0^2 h^3 c} = 2R. \tag{29}$$

From (27) the orbital and cyclotron radii are both r_B, where, as in Appendix A, $r_B = 0.529\,177\,1 \times 10^{-10}$ m. From (28) the orbital and cyclotron angular frequencies are both $\omega = 4.134\,129 \times 10^{16}$ rad/s. If the two components of energy from the electron's motion are combined with two equal components of energy from the proton's motion, we obtain the frequency $f_e = 6.579\,671 \times 10^{15}$ s^{-1}, or a wave-number 10 973 710. In this way the total system energy is linked to the motions of both the electron and the proton; as the electron changes state, the motion of the proton complements any such change.

3.2 Complete Azimuthal Mode Solution — Balmer Formula

At this stage the study has revealed that there are two spinors associated with the electron's motion in the principal mode that have equal magnitude and are separated in phase by $\pi/2$. The complete eigensolutions will involve two radial modes and two frequency modes. The radial modes are required to be periodic; an equation based on (25) where $v_m = \omega mr$ and $v_n = j\omega nr$ can be written as

$$m_e v_m^2 - m_e v_n^2 = 2h\omega. \quad (30)$$

Algebraic manipulation of (30) gives the analytic Balmer formula (Ref. 17, p. 106) (as distinct from the Balmer series), which is based on the energy emitted if an atom shifts between two radial modes:

$$v_{mn} = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right), \quad (31)$$

where $m^2 = 1, 2, 3, \ldots$ and $n = 2, 3, 4, \ldots$.

There are other possible radial modes whereby a "fine structure" is revealed. A complete series analysis reveals angular modes that are much closer to each other than the radial modes. If the principal mode analysis is repeated using higher-order separated azimuthal modal series for both E-field ($e^{jm\phi}$) and H-field ($e^{jn\phi}$) spinors, a complete azimuthal series is easily obtained from (4)–(5):

$$\nabla \times \frac{\partial H}{\partial t} = \frac{-1}{4\pi}\frac{m^2\omega^2 q}{r^2} e^{jl\phi}\hat{r} + \frac{m^2\omega^2}{2\pi}\frac{jq}{r^2} e^{jl\phi}\hat{\phi}, \quad (32)$$

$$\frac{\partial^2 E}{\partial t^2} = \frac{-1}{4\pi\varepsilon_0}\frac{n^2\omega^2 q}{r^2} e^{jk\phi}\hat{r}, \quad (33)$$

where it is assumed that $\sin\theta = 1$ at equatorial elevations and once again the speed of light is not proscribed. The energy levels associated with the azimuthal modes are separated by a quantum factor $\alpha\hbar\nu$ involving the fine-structure constant α. Overall there are four modes arising from the two spinors. These modes correspond to the experimental data provided by spectroscopy and theory provided by quantum theory.

3.3 Stability

An important question concerns the stability of the EM spinor solution given the well-known instability of electrostatic theory.[17] The total energy exhibits nontrivial stability points in phase space and may be written so as to emphasize the nature of the energy forms present:

$$\langle E_{Tot} \rangle = m_e \left| v_o^2 \right| + m_e \left| v_c^2 \right| + \frac{1}{4\pi\varepsilon_0}\frac{\omega_o^2 q}{r_o} - \frac{1}{4\pi\varepsilon_0}\frac{\omega_c^2 q}{r_c}. \quad (34)$$

The total energy for the electron includes the photon field energy and is balanced when $V_o = V_c$ and $T_o = T_c$. The sign associated with the magnetic energy shows that EMSFT is consistent with the negative magnetic moment associated empirically and theoretically via QED with the electron (Landé g-factor[17]). In terms of Maxwell's equations, (1c) is seen as a balance of electric and magnetic potential energies and (1d) a balance between electric and magnetic kinetic energies and the total energy of the photonic field.

3.4 The Proton's Motion in the Hydrogen Atom

If the proton has "infinite mass" (Fig. 2), it is assumed not to move from the COM and the electron moves with the entire orbital and cyclotron radius. If a finite-mass proton is used (Fig. 7), the EMSFT equations involve both the electron and the proton. In this case the electric and magnetic potentials become functions of the orbital and cyclotron radial distances of both electron and proton. There are six equations where, as in (23)–(25), the cyclotron and orbital frequencies are assumed equal. From these equations Rydberg's number can be adjusted, giving $R_H = q^4 m_e/(8\varepsilon_0^2\hbar^3 c)[(m_p m_e)/(m_p + m_e)] = 10\,967\,757.78$ m^{-1}, which is in excellent agreement with spectroscopic data 10 967 757.6 m^{-1}. The proton orbital and cyclotron radii can be estimated as $r_B m_e/(m_p + m_e) = 2.924\,085 \times 10^{-15}$ m, while the electron's orbital and cyclotron radii become $r_B m_p/(m_p + m_e) = 5.288\,89 \times 10^{-11}$ m. These results are similar to the concept of *reduced mass*, $\mu = m_p m_e/(m_p + m_e)$, well known in Bohr's early work. This estimate of the size of the proton is somewhat larger than current estimates from scattering experiments of ~ 1.2 fm[20] and is due to the fact that there are no strong nuclear forces in our model. The proton's motion can be better estimated if the strong nuclear forces are explicitly included using a more refined three-quark model (Figs. 8–9). In this case both EM (photons) and strong (gluons) fields are present. Further discussion and results are left to a separate report.

4. DISCUSSION

4.1 Comparison of EMSFT with Conventional Field Theories

Compared to classical and quantum fields, EMSFT fields inside the hydrogen atom are very different and physically realistic. They do not exist in all space, only inside the atom; they are not radiating fields. They are assumed to consist of discrete photons. The fields are like "tiny beads on a spiral string." Even inside the atom, photons do not make up the whole interior of the atom; photon streams exist only between the proton and electron, whose motions are

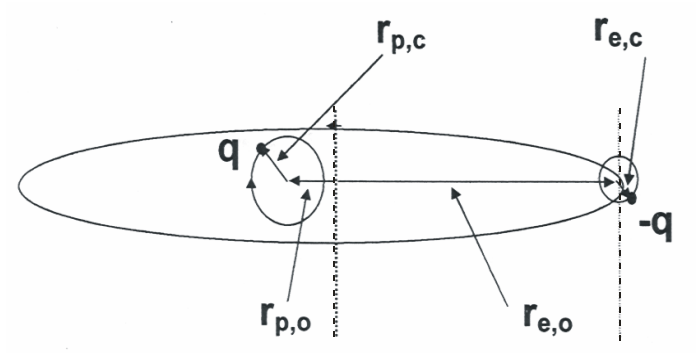


Figure 7. Hydrogen atom modeled with finite-mass proton.

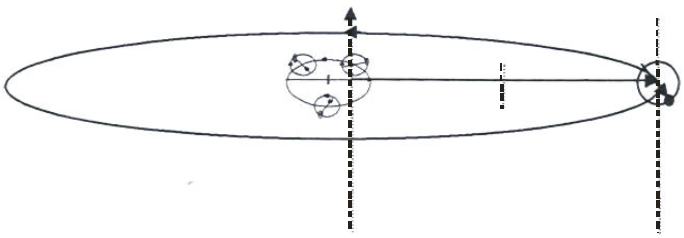


Figure 8. Hydrogen atom modeled with both strong and EM fields with a finite-mass proton consisting of three quarks coupled via gluon fields.

also spinorial. In EMSFT there is no difference in classification between field and particle; both electron and photon yield spinorial solutions to Maxwell's equations.

The classical field vectors are measured macroscopically with dipoles and coils and therefore are the fields of the everyday world we live in, but these are *not* the COM fields that are used in this report. They are not measurable, although they *do exist* in the real world and can be modeled as spinors. There are many possible pairs of Lorentz-compatible E and H fields,[11] but only the COM fields are invariant in form as velocity is varied. As the rotation speed varies, no relativistic correction terms are needed. The COM E field is *not* a point-to-point field as in Coulomb's law, but is taken between the COMs of *both* the electron and proton, two points in vacant space (Figs. B1–B2). These fields cannot be measured directly in the real world but can be calculated.

Detailed comparison of EMSFT and quantum theory is left to a separate report. Briefly, there is an intimate relationship between these theoretical field models, both capable of modeling the hydrogen atom. The spinor equations, (12)–(14), and energy equations, (23)–(25), in particular the relationship between their right-hand sides and Planck's energy quanta, are reminiscent of the theoretical basis of QED and QCD. Quantum field theory relies on a mixed formulation of two conjugate potentials, enabling observables such as energy shifts between allowed states to be determined. Compared to this, the spinors of EMSFT provide distance and frequency as separated entities. Therefore, unlike QM, which cannot provide deterministic motions but must provide probabilistic solutions, there is no uncertainty in EMSFT.[9,21] In EMSFT motions and frequencies are defined, allowing comparison with data such as the probability densities provided by QM by choosing a suitable time-sample interval (see Fig. 6). In stark contrast to the edicts of the uncertainty principle, the actual time evolution of the motions can be obtained from EMSFT.

4.2 Planck's "Constant"

Empirically the value of $\hbar$ comes from (24)–(25), where $\hbar\omega = q^2/(4\pi\varepsilon_0 r_o) = q^2/(4\pi\varepsilon_0 r_c)$, so $\hbar = q^2/(4\pi\varepsilon_0 v_o) = q^2/(4\pi\varepsilon_0 v_c)$ can be calculated from the solution of the Bohr radius and the resonant frequency (27)–(28). To see the relationship between Planck's constant and velocity, let $\hbar = T_0/\nu_0 = [q^2/(4\pi\varepsilon_0 r_o)](1/\nu_0) = q^2/(4\pi\varepsilon_0 v_o)$, where ν_0 is the frequency and T_0 is seen as E-field potential energy. Hence since $v_o = r_o\omega_o = v_c = r_c\omega_c = 2.187\,689 \times 10^6$ m/s we can compare the known value of Planck's constant (Appendix A) with our estimate to an accuracy of seven significant figures.

Obviously this raises an issue at the heart of quantum theory. Condon and Odabasi[2] discuss the acceptance of Planck's constant in the prequantum era, 1900, as a fundamental concept, in that quantities associated with the description of atomic phenomena assumed only a discrete set of allowed values that incorporate Planck's constant. After failing to find a classical framework for the thermodynamic equilibrium of matter, otherwise known as *black-body radiation*, Planck in an "act of desperation" solved the problem by assuming only certain analytic frequencies could exist for the radiation. At that time Planck and his contemporaries thought of the solution as a mathematical artifice and not a defining point in the evolution of quantum physics. He numerically solved a two-variable problem in h, Planck's constant, and k, Boltzmann's constant, using empirical data, and thus established the groundwork for the photoelectric relationship $E = \hbar\nu$ that Einstein verified in 1905.

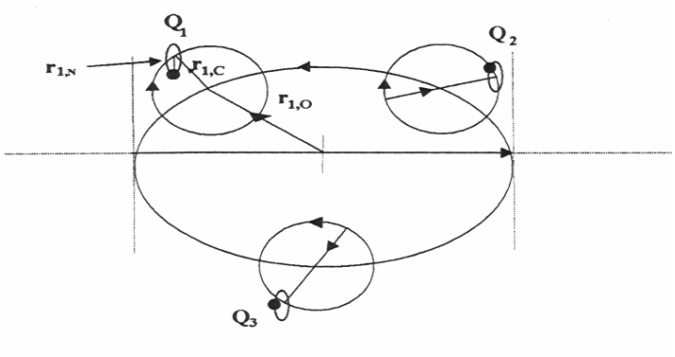


Figure 9. Proton modeled as three quarks coupled via gluon fields.

EMSFT does appear to be the theoretical framework that Planck and many others including Einstein sought. That Planck's "constant" represents a variable in EMSFT demonstrates the fundamental nature of EMSFT. This finding follows from the assumption that the speed of light is not proscribed from being variable in EMSFT. Empirical measurements, no matter how widespread their physical reach, cannot determine whether any quantity, no matter how cherished, is a constant or variable until a theoretical framework has been established. EMSFT is an eigenvalue problem and its solution consists of four eigenvalues. The constitutive parameters of free space — ε_0, the permittivity, and μ_0, the permeability — are also called "constants" where deep space is being considered. These parameters are constants where the universe is considered homogeneous and isotropic. In reality, there are variations, for example the outer boundary of the universe or inside the nuclei of atoms. This means that there are six degrees of freedom in total in EMSFT, where the fields are EM fields, leaving aside nuclear forces and weak gravitational forces. This corresponds with the six degrees of freedom indicated by the equipartition theorem $3kT$.[22]

Where does the self-energy of the system come from? The theory suggests that photons supply the energy to the electron and the proton and vice versa. That discrete quanta of Planck's energy are involved in the particle-field interactions strongly implicates the photon as the energy provider/mediator for the atomic system. The dynamics of the atomic system can be written as (23)–(25), an inhomogeneous system where the right-hand side contains the photon energy. In addition to representing Planck's quanta, these are derived directly from the current densities of Maxwell's equations (1c). This suggests two interfacing systems of motion at differing scales, each supplying the other's energy — two interfacing inhomogeneous systems of equations. The stability of the field/particle system (34) may also be reflected in a similar equation as seen from the perspective of the photon; hence a state of balance between the motions and interactions of the proton, electron, and photons may exist.

That Planck's constant exists on the right-hand side of (24)–(25) demonstrates empirically that the source terms of the E and H fields of the electron are indeed photons, as is the case for quantum field theory.[5] Looking at the matrix structure of EMSFT, the fields (photons) represent the source terms on the right-hand side for the electron's motion. Conversely, the motions of the electron (and proton) can be written as source terms for the photons if they are written as the particles. The "fields" and "particles" are thus interchangeable in the mathematics of EMSFT. The source term variable $\hbar = q^2/(4\pi\varepsilon_0 v_o) = q^2/(4\pi\varepsilon_0 v_c)$ on the right-hand sides in this case will be identical, in both cases yielding Planck's energy. This is a most fundamental finding indeed and an insight into self-fields and their balance inside atoms. Not only are the particles, in this case the proton and electron, locked in a dynamic balance but the photons are demonstrably part of this balance. As well as the electron, an EMSFT application concerning the internal dynamics of the photon can be examined.

The E and H fields of classical physics are continuously differentiable "objects" in space-time, as waves moving through a ubiquitous *ether*. In EMSFT the fields are represented as photon *streams*. Thus EMSFT is not a classical field theory, but like quantum field theories, Maxwell's equations and a *quantization* are incorporated.[5] In EMSFT quantization is not heuristic but an outcome of the solution. There are two photon streams, from proton to electron and electron to proton, flowing at a constant rate (photons per second). Each photon's motion is similar to that of the electron and proton but of different magnitude and overall shape. Whereas the electron or proton circles along its orbital path, each photon either moves out from the proton to the electron or vice versa, spiral in overall orbital form.

4.3 EMSFT and Its Applications to Other Physical Phenomena

In contrast to the use of unit spinors within classical and quantum field theory, EMSFT uses the physical basis of spinors and as such can be applied as a variable across physics. Particle motions inside high-energy accelerators, orbital and cyclotron spin mo-

tions in solar systems and galaxies, and the double-helix structure of DNA exemplify the existence of spinors in the real world. We may think here of numerical modeling and the use of approximation functions. EMSFT can be applied to the fields and particles within the nucleus and to the motions of solar systems and supergalaxies. There appears to be a hierarchical system of physical spinors that can be modeled by EMSFT. Spinor fields undergo a form of "differentiation" on scales larger than the atom and an "integration" on smaller scales (see discussion on quarks below), while the spinor particles appear to operate in the opposite direction of scale.

For dynamic balances where elliptic solutions occur the spinors vary over each rotation and a numerical approach may be needed to obtain the motions. Further, atoms are not stable in only the one state, as given by EMSFT in this report, since the equilibrium points in state space are saddle points, allowing for small perturbations around a central equilibrium state without becoming unstable. In the sense that there are many possible motions involved in the overall spinorial motion, the motions may average out to the simple circular solutions given in this report. In EMSFT the fields, forces, and motions can all be modeled as spinors. EMSFT also applies to nonequilibrium applications where the spinors can again vary with time.

The photon's orbital motion in the hydrogen atom is not unlike spiral forms seen in galaxies and elsewhere.[10] These spiral shapes have half-integer "spins" associated with them, 180°, 540°, 810°, etc., reminiscent of the angular spin of quantum theory, whereby dynamic balances as in atoms can be achieved. One particular series of dynamic balances relates to the successive radial gradients of the gravitational force and other presently observed but theoretically unknown gravitation-like forces acting at the galactic and supergalactic levels.[12] In the hydrogen atom there are two spiral streams of photons, one flowing from proton to electron, and another from electron to proton. The two streams associated with each particle are orthogonal to each other and hence so too are the E and H forces, while the photons from each particle are antiparallel to those of the other particle. The concept of a photon beam or stream is an accepted physical description (Ref. 10, pp. 671–673). Instead of a straight-line stream where all particles have the same velocity, the stream is a helix where the photon velocities have a circular variation. These streams support/create the spinor motions of the electron. The two mutual photon streams also form coupled spinor motions. The spinors formed by the motions of charged particles and the photons are valid solutions to Maxwell's equations; fields and the motions of particles are very similar. Barut[23] discussed the duality of particle and field in classical and quantum field theory.

The EM field studied by Einstein in the early 20th century consisted of discrete photons. In classical field theory these photons are assumed to radiate equally in all directions, over all solid angles to infinite radius. In EMSFT photon streams do not radiate in all directions but only between masses; also, they do *not* radiate to infinity since they are not massless. These distinctions are crucial in solving current cosmological problems seen to require a quantized form of gravitation.[24]

The fact is that by direct substitution Maxwell's equations turn out to be useful for the electron in the hydrogen atom *and*, as was known *a priori*, they can be used to determine E and H fields or, equivalently, photon densities. Hence Maxwell's equations can be used for analyzing both particles *and* fields. As Barut pointed out, we already knew this.[23] In EMSFT the particles and the fields are both discrete, the field having a quantum nature as well as the atom, albeit of a different kind.

The coupled spinors come from the motions of the electron *and* the proton, a mutual motion. Quantum theory involves mathematical entities such as matrix or tensor elements. In EMSFT the spinors are physical entities such as motions and can be used as the variables in the mathematical formulation. The spinors form elements of a closed, self-sustaining system composed of two particles whose motions are mutual and complementary. Each spinor can be written mathematically as column vectors that are coupled via 2×2 interaction submatrices of the overall interaction matrix. One of the coupled spinors is associated with the E field as seen by the electron, and the other with its H field. Conversely, the proton sees these two spinors as an H field and an E field, respectively. It is worth noting in the hydrogen atom that both streams traverse the same path, as both particles appear symmetrically to each other at all times. Since the spinors are 90° out of phase with each other, the two spiraling streams do not collide with each other even though they follow opposite paths toward and past each other. This is not the case where equilibrium is not maintained. There are other complex situations that can occur where there are other forces at play, including any weak and strong nuclear forces.

4.4 Strong Nuclear Fields

One fascinating aspect of EMSFT and the spinors that represent the motions of the electron, the proton, and the photon is the relationship of the spinors to the strong forces inside the nucleus and the ability of the quarks inside the proton to balance each other in triplets. As is well known, there are three quarks inside the proton. In this case there is a self-field interaction submatrix of size 3 × 6 per particle, as distinct from the EM-field submatrix that is of size 2 × 4. Now each particle has *three* spinors that mutually link the three quarks together. Each spinor operates in a plane and the three planes form an orthogonal set in 3D space. This means that there exists a system of equations similar to Maxwell's equations but having additional differential components such as to form four scalar equations instead of the three associated with Maxwell's equations.

Fleming and Colorio[12,13] have recently suggested that the strong nuclear fields controlling the motions of charged particles satisfy the following adaptation of the Maxwell–Lorentz equations (35). In general, the region is assumed isotropic and homogeneous and ε_n, μ_n, and ν_n are invariant scalars. Where nuclear subparticles — quarks — carrying units of elementary charge q_q are studied, the modified Maxwell–Lorentz equations can be written

$$\nabla \cdot \vec{E} = \frac{q_q}{v_q}, \tag{35a}$$

$$\nabla \cdot \vec{H} = 0, \tag{35b}$$

$$\nabla \cdot \vec{N} = 0, \tag{35c}$$

$$\nabla \times \vec{E} + \mu_n \frac{\partial \vec{H}}{dt} = 0, \tag{35d}$$

$$\nabla \times \vec{H} - \varepsilon_n \frac{\partial \vec{E}}{dt} = \frac{\pi}{s_q} q_q \vec{v}, \tag{35e}$$

$$\nabla \times \vec{N} + \nu_n \frac{\partial \vec{E}}{dt} = 0, \tag{35f}$$

where the modified Lorentz equation for the forces acting on the quarks is written

$$\vec{F} = q_q \vec{E} + q_q \vec{v} \times \vec{B} + q_q \vec{v} \times \vec{M} \tag{35g}$$

and the constitutive equations $\vec{B} = \mu_n \vec{H}$, $\vec{D} = \varepsilon_n \vec{E}$, and $\vec{M} = \nu_n \vec{N}$, where ε_n, μ_n, and ν_n are invariant scalars, the nuclear constitutive parameters being similar to those of free space, ε_0 and μ_0, except the energy density within the nucleus now depends upon the three gluon fields $dU_N = \rho_N dV = (1/2)(\varepsilon_0 \tilde{E} \cdot \tilde{E} + \mu_0 \tilde{H} \cdot \tilde{H} + \nu_0 \tilde{N} \cdot \tilde{N}) dV$, where $\tilde{N}$ is termed the nuclear field and $\tilde{M}$ is the nuclear flux density. As with $c = (\varepsilon_0 \mu_0)^{-1/2}$, there are corresponding relationships between the gluon speed and the ratios of the three fields. These modified equations provide three orthogonal motions per quark. There are six unknowns per particle, eighteen in the nuclear system. The curl equations (35d)–(35f) provide four scalar equations, and there are two virial equations to give six equations in six unknowns. As with the photon, the resulting analytic parametric solutions may be compared to the experimental results given by particle physics.

In this strong nuclear force case there are 3 × 4 scalar curl equations plus 3 × 2 force balance equations, making 18 equations in 3 particles altogether that can be solved to yield 6 quantum numbers per particle in nuclear structures. This compares with the 2 × 3 scalar equations from Maxwell's curl equations plus two force balance equations totaling eight equations per two particles, giving four quantum numbers per particle for atomic structures. The two extra quantum numbers agree with the experimental observations of high-energy physics.[7] The three quarks have three-way streams so that each particle performs spinor motions in three planes and not two as in the case of EM-related particles such as the proton and the electron. Now of course the only way that the quarks can perform these additional spinor motions is if the photons themselves have formed into compounds *beyond* "ordinary" or low-energy photons. When photons are inside high-energy regions they may exist in higher-energy states and compounds. Like atomic structures, then, photons may *also* form into structured compounds. In the case of quarks the photon particles may have a third spinor motion when they form into triplets. The forces these photonic compounds carry yield the third component of spatial direction and they *only* carry this extra force component *inside* the nucleus.

4.5 Photonic States and Compounds

The ongoing search for an upper limit of the photon's rest mass has continued over many dec-

ades.[10,25] The aim of the search is to quantify the cutoff between classical and quantum electrodynamics and to establish the accuracy of Coulomb's electrostatic square law. Different experiments have tightened the limit downward. Due to Earth's geomagnetic field, fluctuations in the torque of a Cavendish balance are observed. The Jovian geomagnetic effect has similarly been measured. In addition, magnetic fields have been found to permeate the cosmos, arising if photons possessed mass during the big bang. The current best estimate is $m_{ph} < 4 \times 10^{-51}$ kg. If photons are indeed massive, EMSFT may reveal an internal dynamics.

EMSFT provides a spinorial solution for the electron in the hydrogen atom *and*, if its mass were known, the photon. It is suspected from known physical data that photons may have similar states and compound structures to atoms.[12,13] The "ordinary" photon of free space may have two particles, similar to the hydrogen atom, rotating around each other to achieve a balance of their dynamic energies. Since the energy response of the photon is continuous, the two particles have equal mass. The difference between quantum and continuous physics is seen as the ability of continuous systems to solve the underlying equations at any frequency due to the mass equality of their subparticles (Fig. 10).

While the photon's mass is not known beyond a lower limit,[10] photons are seen to obey EMSFT as do atoms. Inside atoms there are central nuclear regions of enhanced energy densities where photonic states and compounds might exist due to the slower-moving nucleus sweeping out smaller volumes relative to the faster electron. Photon states and compounds may help explain some important ecological and biological phenomena. Schumann resonances occur at extremely low frequencies (8, 14, 20, 26, 32 Hz, etc.) — the result of the Earth-ionosphere region having a discrete geometry — a series of spherical layers that forms a large resonant cavity wave-guide whose resonances are sensitive to variations in temperature. These layers may be due to the increase in energy density as Earth is approached or departed by photons.

The energy states of individual cells and tissues composed of many cells acting in cooperation may depend on photonic mechanisms and on the dynamic balances given by EMSFT. First, H_2O in the cell may take liquid or crystallized multilayered forms inside and around chromosomes and other macromolecules.[26] Such structures may depend on *slow* changes induced by shifts between photonic states driven by changes in energy. Second, cell division may depend on *sudden* changes induced by similar photonic shifts. The E and H fields in and around DNA and other structures such as the extracellular matrix may change abruptly over the cell cycle

Dramatic cellular changes are observed: the chromosome first aligns at the cell equator in equilibrium between the spindle poles, and then it cleaves into halves; each chromatid replicates into a complete chromosome that moves to its spindle pole; the membrane walls cleave at the equator into two complete cells.[27] The energy distribution inside cells and tissues may reflect the type of dynamic balance seen within the hydrogen atom. Such applications to computational cell biology[28] will require numerical versions of EMSFT to be tested against known data.[29]

5. CONCLUSION

In this report it has been demonstrated that despite a century of suggestions to the contrary, it is possible to successfully use EM theory as a basis for the physics of the hydrogen atom. Assumed spinor forms consistent with Maxwell's divergence equations for the E and H fields were shown to also be consistent with Maxwell's curl equations. These spinor fields were unconventional, defined between centers of rotation rather than between charge points. They are *a priori* correct relativistically. Using Maxwell's equations they provide a system of two spinors, or four equations in four unknowns — the radial distances and frequencies of the coupled spinors of each particle. Applying these forms of analytic solution to the hydrogen atom, the dynamics of the electron was determined. These solutions were consistent with spectroscopic data and quantum theory. Analytic expressions obtained for the resonant frequencies and radii agreed with Rydberg's number and Balmer's formula. In terms of present knowledge of the electron in the hydrogen atom EMSFT introduces no new physics, only a simpler, clearer version of existing knowledge.

The EMSFT model of the hydrogen atom used a simplified dynamics involving only EM dynamics using two spinors per particle. The internal structure of the neutron and proton each having three spinorial motions to model the strong nuclear forces may allow a more general treatment of atomic and nuclear systems. Other applications await the broad theoretical approach of EMSFT. The next stage of the development of EMSFT is to develop a numerical version of the theory and to compare these numerical results with quantum theory

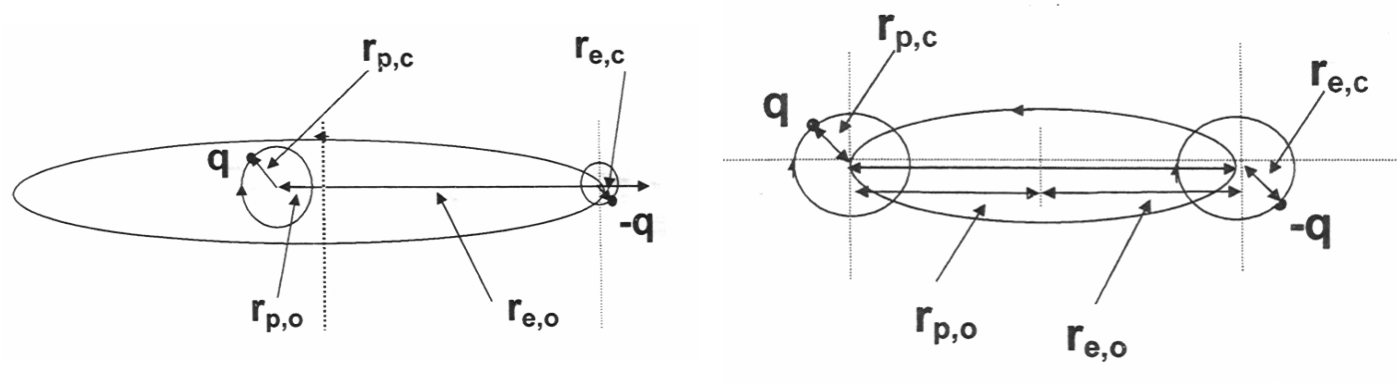


Figure 10. EMSFT provides a rationale for the differences between (a) quantum physics (e.g., the hydrogen atom) having a discrete energy spectrum as its subparticle masses are unequal — only certain radii and velocities are valid solutions to the EMSFT equations — and (b) continuous physics (e.g., the photon) having a continuous energy spectrum as its subparticle masses are equal; all radii and associated velocities are valid solutions to the EMSFT equations.

APPENDIX A

Table I: Physical Constants

Physical Constant	Symbol	Known Value[20]
Planck's quantum	$\hbar$	$1.054\,589 \times 10^{-34}$ J × s
Speed of light	$c = (\varepsilon_0\mu_0)^{-1/2}$	$2.997\,924\,58 \times 10^{8}$ m/s
Fundamental unit of charge	q	$1.602\,189 \times 10^{-19}$ C
Permittivity of free space	ε_0	$10^7/(4\pi c^2)$
Rest mass of electron	m_e	$5.485\,803 \times 10^{-4} \times u$
Rest mass of proton	m_p	$1.007\,276\,47 \times u$
Mass scale factor relative to C_{12}	u	$1.660\,566 \times 10^{-27}$ kg
Bohr radius	r_B	$0.529\,177\,1 \times 10^{-10}$ m

APPENDIX B: MATHEMATICAL PRELIMINARIES

B.1 EM Particle and Field Motions Described via Variable 2D Spinors

The mathematics of classical and contemporary quantum field theories goes back to the mid-19th century.[22,29,30] Fields are seen in relativistic dynamics as auxiliary quantities behind particles and in relativistic field theory as real "objects" able to fill the whole space like a "fluid." Scalar, vector, tensor, and spinor fields are defined as mathematical entities.[30]

Spinors are conventionally defined as having constant magnitude, similar to unit vectors. Such spinors are used as bases for Lorentz fields, continuously differentiable objects in 4D Hilbert space, or pairs of spinors each in 2D Hilbert space. In particle physics spinors are two-component complex column vectors of constant magnitude used to represent motions of particles with intrinsic half-integral spin (fermions have spin $\hbar/2$, $3\hbar/2$, $5\hbar/2$, …). In general, such unit spinors are used as a basis for Hermitian matrices whose determinants are positive definite and whose eigenvalues are all real.[23] The EM field equations and the stress-energy tensor can both be expressed in terms of unit spinors.

In this report variable spinors are used to model the COM fields. The term represents space-time vectors whose magnitude may vary and rotate extrinsically according to Maxwell's equations. Space-time vectors that rotate (spin) in a single 2D plane can be expressed in terms of a complex C_2 basis, e.g., $\tilde{r}_0 e^{jm\phi}$. The motions of charged particles that perform EM rotations may be termed spinorial. For example, the motion of the electron in the hydrogen atom is described via two spinors (see (8) and Fig. 7). At the same time, the photons that make up the EM self-field also perform spinorial motions as they move between electron and proton. In this case the fields perform inward spirals toward the proton and outward spirals toward the electron while performing these spinorial motions.

B.2 COM E and H Fields

The spatially continuous nature of the fields currently used within quantum field theory is fundamentally different from the discrete nature of the COM fields used in this report. The differences are reminiscent of Planck's initial explanation of black-body radiation in 1900 assuming only certain frequencies were present in the EM oscillators.[32] These COM fields have a particulate or quantum nature imbedded in them *a priori*. As a tool for mathematically modeling various situations they can be used widely across physics since there is no difference between particle and field; what is perceived as a particle at one level can be a field at a larger scale from within nuclei to the domain of the universe, as with a fractal. The mathematics of EMSFT applies to different domains with either a quantum or a continuous, classical-like physics applying to each domain depending on the masses of the subparticles involved (see Fig. 10). In general, various forms of potential and kinetic energies can be linked together using Maxwell's equations and/or modified systems of equations inside nuclei where additional spinorial motions and their associated energies are possible (see Fig. 9, where inside the proton a third spinorial motion is possible for both quarks and gluons at high energy densities).

Jackson discussed the assumptions in basing electromagnetics on Coulomb's law of electrostatics and the Biot–Savart law of magnetic induction.[10] Both laws are based on macroscopic experiments conducted in the late 18th to early 19th centuries. The EM field forms that ensued are assumed to carry over to atomic,[8,10] nuclear,[7] and cosmological[4,9,33] domains. It was natural in the macroscopic domain to assume all actions occurred directly between charges. The fields were assumed to extend from charged particles over all solid angles to infinity. How the fields imparted forces to charges was unclear; the fields somehow "mediated" the forces. Bohr applied these field forms to the hydrogen atom with some success but the problem remained until quantum mechanics showed the way forward.[1] One major assumption in applying these fields to atoms is that in Coulomb's law they should be stationary. Yet atomic charged particles move. Perhaps these classical field forms that have been incorporated within quantum field theory may not be correct at the subatomic level and over other domains as well. It is a matter of trial and error to theoretically test other field forms against a wealth of known empirical data.

In this report the E and H fields are taken relative to COMs of atomic particles in dynamic equilibrium and relative to the coordinate system of an isolated stationary hydrogen atom (see Figs. 2–3). The finding that these COM forms *can* provide an EM theory consistent with known empirical data for the hydrogen atom is proof of their accuracy at the atomic level. That the E-field forms are inverse square functions of the orbital and cyclotron separations, as in Coulomb's law, and similarly for the H fields as in the Biot–Savart law, is also confirmed by the analytic solutions derived via EMSFT. The fields are assumed to consist of photon streams and the process of force mediation is similar to kinetic models of gases where numbers of collisions occur over the walls of a container, thus imparting pressure to the area of the wall. Similarly, photons are considered to "collide" in some coherent way with the charged particles, thus imparting impulses that, averaged over time, become the fields and forces at the atomic level given by Maxwell's equation. Spatial and temporal averaging processes are important in the mathematics of EMSFT.

In the hydrogen atom the essential physics is the spinorial motion of the photons that move between the charged particles, which also perform spinorial motions in concert with the photons. These photonic motions yield both an axially directed force and an axisymmetric or rotational force on the particles when averaged over statistical mechanics numbers of impulses — in other words the E and H fields at atomic levels of interaction.

To mathematically describe the physics we choose the four independent coordinates to form the two spinors (r_o, ω_o, r_c, ω_c) shown in Fig. B1 that are related to the four coupled spherical coordinates (r_o, ϕ_o, r_c, ϕ_c) shown in Fig. 3. There is a simple mathematical relationship between these orbital and cyclotron spinors since the E fields rotate clockwise while the H fields rotate anticlockwise. Also, since the mathematics turns out to be an eigenvalue problem, the rotation speeds of the modes are related by integer multiples of the principal mode. We choose to describe the coupling between the rotations via imaginary numbers, where the phase shift (also shown in Fig. 4) is $\pi/2$. This can be thought of as a phase shift between the spinors that in imaginary numbers becomes simply j (see Section B.3 below).

Figures B1–B2 illustrate the COMs of the fields acting between two particles, q_e and q_p, of equal mass $m_e = m_p$ and opposite charge $q_e = -q_p$. In this symmetric case the motions for the orbital and cyclotron radii of both particles are assumed to be circular. In general, the relative time-varying orbital radial distance

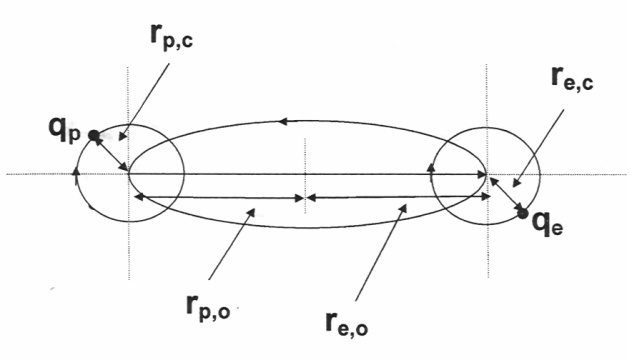


Figure B1. Geometry for determining the COM E and H fields. In this diagram both particles have equal magnitudes of mass and charge.

of q_e is given by the spinor $\tilde{r}_{e,o}e^{j\omega_{e,o}t}$ and the cyclotron radial distance by $\tilde{r}_{e,c}e^{-j\omega_{e,c}t}$, while the relative time-varying orbital radial distance of q_p is given by the spinor $\tilde{r}_{p,o}e^{j\omega_{p,o}t}$ and the cyclotron radial distance by $\tilde{r}_{p,c}e^{-j\omega_{p,c}t}$. The overall orbital and cyclotron separations can be written

$$\tilde{r}_{ep,o} = \tilde{r}_{e,o}e^{j\omega_{e,o}t} + \tilde{r}_{p,o}e^{j\omega_{p,o}t}, \tag{B1}$$

$$\tilde{r}_{ep,c} = \tilde{r}_{e,c}e^{-j\omega_{e,c}t} + \tilde{r}_{p,c}e^{-j\omega_{p,c}t}. \tag{B2}$$

Generally, the orbital and cyclotron spinors may be fixed or varying in frequency, in keeping with the need that the total system self-energy remain constant at all times unless external factors intervene. Where the particles are in dynamic balance the electron and proton orbital and cyclotron frequencies are equal, $\omega_{e,o} = \omega_{p,o} = \omega_o$ and $\omega_{e,c} = \omega_{p,c} = \omega_c$:

$$\tilde{r}_{ep,o} = (\tilde{r}_{e,o} + \tilde{r}_{p,o})e^{j\omega_o t}, \tag{B3}$$

$$\tilde{r}_{ep,c} = (\tilde{r}_{e,c} + \tilde{r}_{p,c})e^{-j\omega_c t}. \tag{B4}$$

If needed there is a swapping between the electric and magnetic energies of the particles; for example, when a particle slows down in an elliptic orbital path, its cyclotron motion speeds up, so the particle energy is fixed.[13] Figure 4 shows the two coupled spherical coordinate systems that define the orbital and cyclotron distances.

The energy density of the region is controlled by the constitutive parameters ε_0 and μ_0 as given by (B5a)–(B5b). In generalized media the permittivity and permeability are related to the relative permittivity ε_r, where $\varepsilon = \varepsilon_r\varepsilon_0$, and relative permeability μ_r, where $\mu = \mu_r\mu_0$. In various media such as metals, dielectrics, and biological tissue relative permittivities and permeabilities can vary by several orders of magnitude and hence the kinetic and potential energies, forces, fields, and energy densities also vary. Mathematically EM applications have six degrees of freedom per subatomic particle: the orbital and cyclotron velocities $\tilde{v}_{e,o} = j\omega_e\tilde{r}_{e,o}e^{j\omega_o t}$, $\tilde{v}_{e,c} = -j\omega_c\tilde{r}_{e,c}e^{-j\omega_c t}$, and the constitutive parameters. In regions of high energy density such as the nucleus the motions of particles and fields consist of three orthogonal spinors and hence each particle possesses extra kinetic and potential energies over EM interactions; overall in such regions of high energy density there are eight degrees of freedom: three spinors and the constitutive parameters.

In the case for the proton and electron in the hydrogen atom, where $m_p >> m_e$, $q_e = -q$, and $q_p = q$, the principal orbital motions are at balance again circular and that is the case of interest in this report. The relative positions of the proton and electron define their E fields, while their relative positions and velocities define their H fields. These relative motions also define the proton and electron COMs (Fig. 7). The forces acting on the electron $\tilde{F}_{E,e}$ and proton $\tilde{F}_{E,p}$ due to the mutual E field acting between the two orbiting particles are attractive and are written

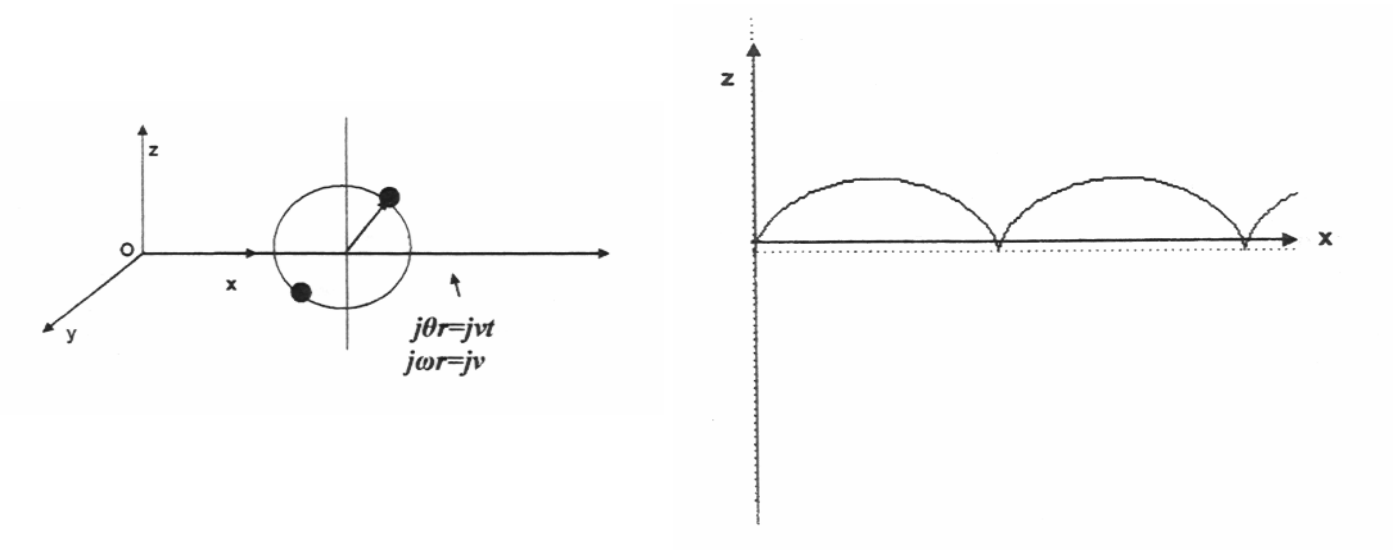
$$m_e \frac{d^2(\tilde{r}_{e,o})}{dt^2} = -q\tilde{E}, \tag{B5}$$

$$m_p \frac{d^2(\tilde{r}_{p,o})}{dt^2} = q\tilde{E}, \tag{B6}$$

$$\tilde{F}_{E,e} = \frac{-q^2}{4\pi\varepsilon_0}\frac{\hat{r}_{ep,o}}{\left|r_{ep,o}^2\right|}e^{j\omega_o t}, \tag{B7}$$

$$\tilde{F}_{E,p} = \frac{-q^2}{4\pi\varepsilon_0}\frac{\hat{r}_{pe,o}}{\left|r_{pe,o}^2\right|}e^{j\omega_o t}, \tag{B8}$$

where $\tilde{r}_{ep,o} = -\tilde{r}_{pe,o}$ are the orbital separation vectors and $\hat{r}_{ep,o} = \hat{r}_{pe,o}$ the unit orbital separation vectors. The forces acting on the electron $\tilde{F}_{H,e}$ and proton $\tilde{F}_{H,p}$ due to the mutual H field acting between the two rotating particles are repulsive. Where the constitutive



(a) (b)

Figure B2. (a) Particle in Fig. B1 moves along the +*X* axis performing internal rotations in the *XZ* plane; (b) each subparticle performs a cycloid motion. Where time is related to the internal rotations of the particle, its motion can be shown to be relativistic. As the velocity in *X* increases there will be a time and length dilation as given by the Lorentz transform.

parameters are assumed to be dependent on the speed of the particle $\varepsilon_0\mu_0 = 1/(\omega_o^2 r_o^2) = 1/(\omega_c^2 r_c^2)$, the forces can be written

$$m_e \frac{d^2(\tilde{r}_{e,c})}{dt^2} = -qv_{e,c} \times B, \tag{B9}$$

$$m_p \frac{d^2(\tilde{r}_{p,c})}{dt^2} = qv_{p,c} \times B, \tag{B10}$$

$$\tilde{F}_{H,e} = \frac{q^2 \omega_c r_{e,c} \mu_0}{4\pi} \frac{\hat{r}_{ep,c}}{|r_{ep,c}|} e^{-j\omega_c t} = \frac{q^2}{4\pi\varepsilon_0} \frac{\hat{r}_{ep,c}}{|r_{e,c} r_{ep,c}|}, \tag{B11}$$

$$\begin{aligned} \tilde{F}_{H,p} &= \frac{q^2 \omega_c r_{p,c} \mu_0}{4\pi} \frac{\hat{r}_{pe,c}}{|r_{pe,c}|} e^{-j\omega_c t} \\ &= \frac{q^2}{4\pi\varepsilon_0} \frac{\hat{r}_{pe,c}}{|r_{p,c} r_{pe,c}|} e^{-j\omega_c t}, \end{aligned} \tag{B12}$$

where $\tilde{r}_{ep,c} = -\tilde{r}_{pe,c}$ are the radial cyclotron separation vectors and $\hat{r}_{ep,c} = -\hat{r}_{pe,c}$ the unit radial cyclotron separation vectors between the charges.

Where the "infinite-mass" proton approximation is assumed (Fig. 2), the E- and H-field vectors for the electron can be written in terms of orbital and cyclotron spinors

$$\tilde{F}_{E,e} = \frac{-q^2}{4\pi\varepsilon_0} \frac{\hat{r}_{ep,o}}{|r_{ep,o}^3|} \sigma_o, \tag{B13}$$

where $\sigma_o(r_{ep,o}, \omega_o) = r_{ep,o} e^{j\phi_o}$, and

$$\tilde{F}_{H,e} \cong \frac{q^2}{4\pi\varepsilon_0} \frac{\hat{r}_{ep,c}}{|r_{ep,c}^3|} \sigma_c, \tag{B14}$$

where $\sigma_c(r_{ep,c}, \omega_c) = r_{ep,c} e^{-j\phi_c}$, where the parametric functions of time and speed $\phi_o = \omega_o t$ and $\phi_c = \omega_c t$ are written explicitly as orbital and cyclotron phase angles. The radial separation of the charges in this approximate case can be obtained: $\tilde{r}_{ep} = \tilde{r}_{ep,o} + \tilde{r}_{ep,c}$. The two components are not generally orthogonal to each other; thus the separation varies with time and is a function of both orbital and cyclotron angular frequencies. The forces can be seen to be center seeking (centripetal) and center repelling (centrifugal) and as such form a balanced system in dynamic equilibrium. The overall motion of the hydrogen atom is a combination of all the electric and magnetic forces, a time-varying function of the orbital and cyclotron spinors. By representing the cyclotron phase angle as $\phi_c = -\omega_c t$ and the separations as $r_o =$

$r_{ep,o}$ and $r_c = r_{ep,c}$, the spinors and fields can be written in terms of positive exponentials as

$$\sigma_o(r_o, \omega_o) = r_o e^{e^{j\omega_o t}}, \tag{B15}$$

$$\sigma_c(r_c, \omega_c) = r_c e^{j\omega_c t}. \tag{B16}$$

In the case of the principal mode, where one period occurs within both the orbital and cyclotron motions, the phase angles are the negative of each other: $\phi_c = -\phi_o$. Within this coordinate transformation, each time we differentiate in either time or space we must be careful to ensure that the signs of our magnitudes are correct.

While the fields on the electron $\tilde{E}_e$ and $\tilde{H}_e$ are orthogonal at all times, the forces $\vec{F}_{E,e}$ and $\vec{F}_{H,e}$ are not, although they are orthogonal to the velocity of each particle, and similarly for the proton.

B.3 Imaginary Numbers in 4D Coordinate Systems

Oftentimes in EM formulations complex numbers are used from the start, a theoretical procedure is followed, and at the end the real and imaginary parts are collected and the imaginary parts are discarded. In this report a physical significance is meant for both real and imaginary parts of the formulation at all times. This said, imaginary numbers are treated no differently within this report from their common usage except that the concept is generalized to the 4D coordinate system involving the two coupled spinors as illustrated in Fig. 3. They are "real" in the sense that they are orthogonal entities to mathematically real numbers. Wherever the symbol *j* appears in 3D coordinate systems it can be substituted by a real component in an orthogonal direction. We may thus think of it as an "orthogonality operator." Defined in terms of imaginary numbers, 2D spinors are rotations moving in planes that include axes orthogonal to a stated direction, e.g., (B3)–(B4), where time is a parameter of rotation. The interpretation is consistent with the conventional cyclic ordering of coordinate systems, e.g., Cartesian (*x*, *y*, *z*), spherical (r, θ, ϕ) and cylindrical (ρ, ϕ, *z*). Thus $j\hat{x} = \hat{y}$. A positive imaginary number is a distance in a positive orthogonal direction, and similarly for a negative imaginary number; thus $-j\hat{\theta} = -\hat{\phi}$. It should be noted that an alternative but more complicated notation for imaginary numbers (*j*, *k*, *l*) in 3D might have been used in this report, whereas the sole symbol *j* is used to denote orthogonality to any direction as is its common usage in mathematics. The interpretation of orthogonality also holds for the parametric time operator and its differentials, as shown in Fig. 4. There is implicit in electromagnetics a cycle of four phase shifts of $\pi/2$ involved in the physical directions of differentials, whether spatial or temporal. For the strong nuclear forces where three spinors are involved the cycle is longer, being six phase shifts of $\pi/3$, which complicates the mathematics to some degree.

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Résumé

En dépit du fait qu'il y a eu des opinions contraires pour près d'un centenaire, une théorie du champ électromagnétique induit (EMSFT) a été développée pour les systèmes atomiques consistant de particules chargées. Un spineur modal azimutal choisi comme solution d'essai pour les mouvements de chaque particule a été testé en utilisant les équations de Maxwell relatives aux interactions particules-champs. Les particules et le champ sont considérés comme spineurs couplés associés aux champs électrique et magnétique. Les champs électrique et magnétique de la particule sont mesurés peu conventionnellement entre les centres de

mouvement et non pas entre les points de charge. Les équations rotationnelles de Maxwell sont considérées comme un point d'équilibre entre les énergies électrique et magnétique de l'énergie totale de la particule et un équilibre de ses énergies potentielles électrique et magnétique. La théorie résulte en un système d'équations inhomogènes dont les inconnues sont les rotateurs couplés de chaque particule, quatre équations pour l'électron et aussi pour le proton de l'atome d'hydrogène, et deux paires d'équations conjuguées pour chaque particule. Les équations modales pour l'électron rendent les solutions analytiques pour les fréquences de résonance, les rayons, la constante de Rydberg et les séries de Balmer. Les équations modales pour le proton donnent une évaluation pour la taille du proton.

Endnotes

[1] Appendix A lists all relevant physical constants and their known values.

[2] Appendix B details the mathematical preliminaries including spinors, the center-of-motion (COM) E and H fields, and the usage of so-called imaginary numbers within 3D and 4D coordinate systems.

[3] In EMSFT the speed of light is not proscribed from being variable. Depending on the energy density of the region under investigation, and the photon state, c can vary inside nuclei. Recently, Fleming and Colorio assumed that the photon is massive and hence has a spectroscopy similar to the hydrogen atom, having Balmer-like states; these photonic states are continuous due to the photon's subparticles having equal mass.[12,13]

[4] Where a nebular current density is used in (1d), the factor 4π comes about from an application of Green's theorem leading to a surface over the volume enclosed by the charge density. For the case of discrete charges the factor π represents the area enclosed by the moving charge point.

[5] For nonperiodic motions any imbalance may perhaps be formulated in terms of the weak forces found in radioactive reactions and atomic/nuclear radiation/absorption reactions in general.

[6] Photons cluster in regions of enhanced energy and can partake in the formation of high-energy nuclear particles.

[7] Thus the energy volume density due to photon density is much higher near the proton.

[8] The scalar potential φ is related to the E field ($\varphi = -[1/(4\pi\varepsilon_0)](q/r)e^{j\phi}$).

[9] Demonstrating its similarity to potential theory, this H-field form can also be derived from the vector and scalar potentials $\vec{H} = (1/\mu_0)\nabla\times\vec{A}$ and $\partial A/\partial t = (-1/\varepsilon_0)(E + \nabla\varphi)$.

[10] This constant cancels out in applications to periodic equilibria, but not for radiation reactions.

[11] All such Lorentz-compatible vector pairs form a set of triangles lying on the circumference of a semicircle whose diameter squared is proportional to the energy density.

[12] These forces and their relationship to EMSFT will be discussed in a future report on the unification of the physical forces.

[13] It is possible to study planets with large eccentricities as a check of energy conservation to see if EMSFT applies to solar systems where dipole moments may apply instead of charges.

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