A Periodic Structural Model for the Electron Can Calculate its Intrinsic Properties to an Accuracy of Second or Third Order

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In two previous papers, the electron was described in terms of a periodic structural model, namely a four-dimensional "helix" or "stationary wave" of spin ½ symmetry. That specific model generates most first-order properties of the electron as observed, and is stable in a Casimir sense where inward vacuum pressure balances outward inertial motion. It predicts a large electrical self-repulsion equal to 1/137 of mc^2 across the helical diameter $2r$, or a small electrical self-repulsion equal to $1/(137\times 2p)$ of mc^2 along the curved helical path $4pr$.

Here it will be shown how those two finite electrical self-repulsions, when used together, can explain the magnetic moments of an electron or muon to second or third order in powers of $1/(137\times p)$. The small self-repulsion of $1/(137\times 2p)$ represents a stable part of the electron mass, and accounts for a first-order Lamb shift in atoms. By contrast, the large self-repulsion of 1/137 contributes only temporarily to electron mass, and accounts for the probability of any electron to emit or absorb light.

A periodic structural model may also explain the quantized nature of magnetism in atoms, on the hypothesis that a bound electron can only join to itself using an integral number of spin ½ double-turns. The electron paths can then be considered as resonant, non-radiating rings whose net angular momenta explain the magnetic energies s, p, d, f of atomic fine-structure spectra.

Keywords: finite models for electron and muon magnetism, finite model for the Lamb shift, closed electron paths in atoms

1. Review of Past Work

> *"An integer spin particle is unchanged by* 2p *rotation, whereas a half-odd-integer spin particle requires* 4p *rotation to return to itself. Since* $s = ½$ *particles actually occur in nature, this result cannot be dismissed as a mathematical curiosity." L. Schiff, Quantum Mechanics* (1968)

In two previous papers, we described the electron in terms of a periodic structural model, namely a four-dimensional "helix" or "stationary wave" of spin ½ symmetry, when studied over very brief intervals of time near 10^{-20} seconds (1,2). This contrasts with the conventional view of an electron as some kind of randomly-moving point that fills a probabilistic cloud, of mean radius $r = 2 \times 10^{-13}$ meters when calculated from vacuum QED theory (3).

The conventional view has been explained in many places, for example Section 11.5 of ref. 3 where it is stated: "the electron in some respects behaves as though it were spread out over a distance on the order of its Compton wavelength or $2r = 4 \times 10^{-13}$ meters. It is nevertheless regarded in QED as a point-particle, that jiggles around as a consequence of vacuum fluctuations."

On the contrary, our four-dimensional model asserts that periodic rather than random motion may generate that same finite radius of $r = 2 \times 10^{-13}$ meters. Also, our model asserts that two turns of rotation rather than one may represent the internal symmetry of this spin ½ helix.

The series of logical steps by which we arrived at a four-dimensional periodic model cannot be restated here in complete detail. But to summarize briefly, we argued first that Lorentz-covariant special relativity is a theory of "perception" rather than a theory of "dynamics". Hence it may be applied usefully to experimental phenomena which involve reciprocal light-signals; yet it cannot be applied beyond the realm of its original derivation to experimental phenomena which involve particle dynamics, without causing a series of paradoxes and incorrect predictions: for example paradoxes concerning time, length or spin; and an incorrect prediction concerning the measurability of Thomas precession (2,4).

For experimental phenomena concerning particle dynamics, therefore, one should consider other theoretical formulations that are not "covariant" but rather "invariant," with respect to dynamic changes of the particle due to its motion through a surrounding medium (1). Authors such as T. Phipps and G. Galeczki have commented similarly (4-6).

Next in order to choose the best model for electron structure and dynamics, we argued that most or all intrinsic properties of the electron (*e.g.*, spin ½ symmetry, spin angular momentum $h/4p$, fine-structure constant 1/137 for electricity, $1/(137 \times 2p)$ for anomalous magnetism, $g = 2$ for total magnetism, de Broglie diffraction, righthand rule for magnetism) can be explained through the use of fewest independent postulates, by starting from a doubly-rotating periodic structure in four dimensions.

The point-like size of an electron near 10^{-17} meters as measured by high-energy scattering would be interpreted in this framework as the diameter of some underlying electron filament, which extends locally through space and time; whereas the finite size of an electron near 10^{-13} meters as inferred from de Broglie waves in diffraction or vacuum QED theory would be interpreted as the diameter of some higher-level coiling of that tiny filament, which extends globally through space and time (1).

Our use of the word "helix" to describe such a strange, periodic four-dimensional structure may not be entirely appropriate, since the model which we favour does not actually exist in commonsense reality as perceived with our senses. For example, one could call the atomic electron instead a four-dimensional "stationary electromagnetic scalar wave" as in the paper of Simulik and Krivsky (7) or work cited therein. Its key feature in any case would be a double rotation within two mutually orthogonal planes, where the radii for rotation about its major *versus* minor planes would *differ by a factor of two*.

2. General Versus Specific Advantages of the New Model

From a general point of view, this new model seems attractive for two reasons: (i) it remains *continuous* through both space and time, thereby removing a source of false infinities from the point-like model; and (ii) it seems to account for many *experimental properties* of the electron in a natural and unforced way, whereas the jiggling point-like model does not.

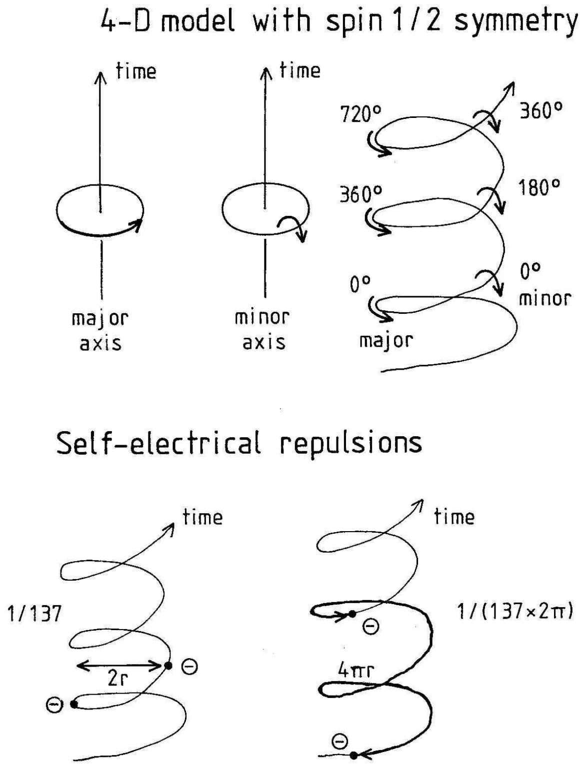

Figure 1. A four-dimensional periodic electron shows two separate planes of rotation called "major" and "minor" in accord with spin ½ symmetry. It also shows two discrete energies of electrical self-repulsion equal to 1/137 of mc^2 across the helical diameter $2r$, or $1/(137 \times 2\pi)$ of mc^2 along the curved helical path $4pr$.

From a specific point of view, the new model seems to possess several distinct advantages over other schemes which have been proposed previously. First, if we consider the electron spin symmetry of ½ to be a real and not just a mathematical attribute (as in the Pauli spin matrices, which say simply that two turns of rotation provide for identity), then such symmetry can be generated only by simultaneous rotation within two separate planes given four dimensions or more. For example, it could be generated by rotation in the planes *xy* or *zt* for a four-dimensional space *x,y,z,t* (Fig. 1, upper left).

Two independent planes of rotation are not possible in three dimensions alone, or for a randomly-moving point. Yet they represent the most fundamental symmetry in four dimensions (8) known as 22. In other words, once 22 symmetry is postulated as the simplest symmetry which is unique to four dimensions or higher, then many other attributes of the electron, such as spin ½, a non-classical $g = 2$ for total magnetism, and squaring of the wave function, can be deduced without further postulate (1). It does not seem plausible that those two orthogonal planes could be physically linked, say for overlapping planes *xy* and *yz* in a three-dimensional space *xyz*, because the electron remains isotropic in space with regard to properties such as mass and charge which would depend on rotation by a finite model.

As just mentioned, the total magnetism ($g = 2$) of an electron would follow from that same symmetry of ½, if charge *e* were to rotate half as frequently in one plane *versus* the other, say by 180° *versus* 360° over some small interval of time. Two separate frequencies of rotation would then generate twice the radius *r* at constant speed *c*, for 180° motion in a minor magnetic plane *versus* 360° motion in a major electrical plane (Fig. 1, upper right).

Similarly, the tendency of any electron to diffract can be explained by our model in terms of its periodic and particulate structure on a very small scale. Does not the very nature of diffraction have to do with the re-assembly of many small constituent precursors to the electron, after any interference event? And would not such re-assembly proceed as the *square* of the wave function, if the underlying structure to be re-assembled is *dimeric* in nature (1)?

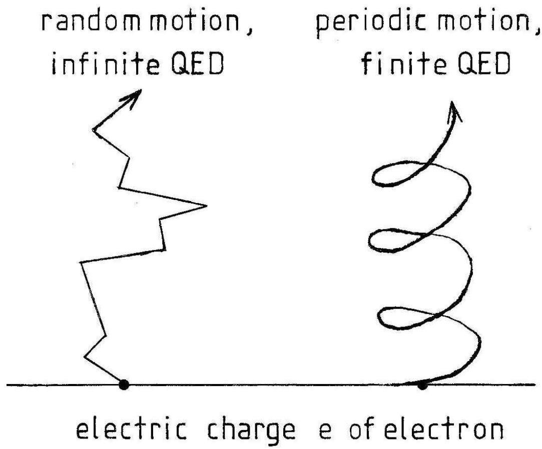

Figure 2. Local motion of the point-like charge *e* that is associated with any electron may describe: (a) a random path through space and time, in which case infinite QED theory follows; or (b) a periodic path through space and time, in which case some finite theory follows. Any point-like charge *e* may prefer to adopt a periodic structure due to Casimir vacuum pressure, if there exist fewer modes of electrical self-energy inside of the structure than in the zero-point vacuum outside.

Lastly, the finite size of an electron in our scheme generates two finite energies of electrical self-repulsion, which may be calculated as either 1/137 of mc^2 through space across the helical diameter $2r$, or $1/(137 \times 2p)$ of mc^2 through time along the curved helical path $4p\,r$ (Fig. 1, lower). Those two well-defined self-energies would seem to account for the electricity and anomalous magnetism of an electron to first order, as either 1/137 or $1/(137 \times 2p)$ respectively in the same units, even though those values did not form part of the original assumptions. In the case of total magnetism, a relative value of 1 in a classical sense (given $g = 2$) increases slightly to $1 + 1/(137 \times 2p)$ upon the inclusion of a small self-repulsion through time.

3. Two Possible Models for Motion of Electric Charge e

Here we will try to extend the predictions of our new model to an accuracy of second or third order, when compared with well-tested experimental attributes of the electron such as anomalous magnetic moment or Lamb shift. Also, we will try to show how an electron of finite size may interact with external light waves in a well-defined fashion, without generating any false infinities of energy as in QED (3,9,10). On what conceptual basis might this new scheme be based?

As shown in Fig. 2, the local motion of electric charge *e* over any brief interval of time near 10^{-20} seconds allows for two logical possibilities. First, if the point-like charge *e* describes purely random motion through space and time, as shown in Fig. 2 (left), then its electric self-repulsion e^2/r becomes infinite and undefined since $r = 0$. Also, it will interact with an infinity of external photons of all possible frequencies in an equally undefined fashion. Only if we assign a small and precise value of 1/137.036 to each charge-light interaction, as taken *empirically from experiment*, will those interactions become amenable to mathematical calculation.

Even after adding 1/137.036 to our point-like scheme, such charge-light interactions may still proceed to infinity for other reasons: for example, if we include photons of infinitely high or low frequency, or if we include infinitely small separations in space down to $r = 0$ between charge *e* and an external photon. That is the scenario found today for QED: the 1/137 is added by arbitrary postulate, and many different false infinities arise from the various causes listed above. Those infinities must then be removed by renormalization (*i.e.*, the division of one infinite quantity by another) or by cut-offs (*i.e.*, the arbitrary termination of divergent infinite series).

As a second possibility, the point-like electric charge e may describe some sort of periodic motion through space and time, as shown in Fig. 2 (right). In that case, its electric self-repulsions e^2/r will remain finite and well-defined, for example as shown in Fig. 1 (lower). Thus, since radius r remains finite, and since the entire structure is rotating in a periodic fashion, only certain small parts of the structure will repel with an integral difference of phase near 360° (about either the major or minor axes), to create a virtual light particle for self-repulsion. It can be shown (1) that those small parts yield just two significant self-repulsions of 360° phase-difference to first order, as either 1/137 or $1/(137 \times 2p)$ in units of mc^2.

The interaction of a periodically-revolving charge e with external photons may also remain finite and well-defined, if it occurs mainly by means of two-way exchange between virtual light which is present already within an electron, and light from the outside world. One can deduce from the spectrum of hydrogen, for example, that a large self-energy of 1/137 or integral undertones thereof (such as $1/137n$) may be exchanged through space between a proton and an electron, to yield discrete electrical energies equal to $1/137^2$ for $n = 1$ (or $1/137^2 n^2$ in the general case).

A value of 1/137.036 for the charge-light interaction therefore follows naturally from our model, and is not an *ad hoc* postulate as in the random point-like scheme. Such a number may even be calculated plausibly from first principles (not shown). Nor will external photons of infinitely high or low frequency create infinities of energy, because the periodic electron shown in Fig. 2 (right) cannot interact with them, unless it already contains a self-energy of similar size. Nor will small distances of separation near $r = 0$ cause infinities, because the electron diameter of $2r$ sets a maximum energy of $1/137^2$ to any typical electrical exchange.

4. Why a Helix? The Casimir Model of 1953

But why might charge *e* prefer to follow a periodic path as shown in Fig. 2 (right), rather than a random path as shown in Fig. 2 (left)? One relevant observation here, is that any closed periodic structure will contain far fewer modes of electrical self-energy than for an exposed, randomly-moving point. This well-known reduction of internal energy for any microscopic closed system (*e.g.*, between two nearby plates) leads to an observable effect known as the Casimir force (11,12). Thus, if many more modes of vibration exist outside of a closed system than inside, due to a vacuum zero-point energy of $E = hf/2$, that difference will generate an inward vacuum pressure which could conceivably cause a finite electron to fold back on itself. By analogy, consider the van der Waals force in chemistry which causes polypeptides in water to fold as periodic coils.

In fact, the original Casimir model seems relevant here (11). For simplicity, let us consider a four-dimensional periodic electron when projected into three-dimensional space as a neutral shell of radius *r*, whose electrical self-repulsion $e^2/2r$ equals just 1/137 of mc^2, rather than a full mc^2 as suggested by Casimir in 1953. Then the inward vacuum pressure due to an external zero-point wave of frequency $f = c/2\mathbf{p}\, r$, which is equivalent to one turn around the helix or shell at speed *c*, yields $E(in) = hf/2 = hc/4\mathbf{p}\, r$. Meanwhile, the outward inertial motion of mc^2 yields $E(out) = 137 \times (e^2/2r)$. Next, using the familiar relation $hc/2\mathbf{p} = 137 \times e^2$, we find that those two terms are essentially equal as $E(in) = E(out)$.

Hence our new model with electrical self-repulsion 1/137 seems stable in a dynamic sense, unlike the earlier Casimir model, which was unstable due to its very-high electrical self-repulsion of mc^2; and unlike the point model, which is unstable due to its electrical self-repulsion of infinity. Since the probability for any electron to emit or absorb light equals 1/137, it would seem that our new model provides both for Casimir stability and also simple electrodynamics. Interestingly enough, the electron diameter in our scheme of $2r = 3.8 \times 10^{-13}$ meters is the smallest distance over which a screened charge of 1/137 still applies. For any distance less than $2r$, one sees a bare charge of 1/129. In other models, the electron dynamics have been presumed to be purely electromagnetic without invoking mass or inertia (13).

Having explained the underlying conceptual basis for our periodic electron, in terms of its double rotation, Casimir stability and finite self-energies, we will next: (a) repeat a few of the infinite QED calculations using a finite model, namely for electron magnetic moment, muon magnetic moment and Lamb shift; (b) show how an electron which is periodic and continuous through space and time may form closed paths which can potentially explain the magnetic fine-structure energies *s*, *p*, *d*, *f* seen in atomic spectra.

5. Two Possible Models for Anomalous Magnetic Moment

Now we will proceed to the first novel part of our paper, where we calculate anomalous magnetic moments and the Lamb shift from a periodic model. The magnetic moments of an electron or muon are known experimentally (3) to very high accuracies of 1.001159652188(4) or 1.00116592(1) respectively in units of $eh/4pmc$. Can our finite scheme calculate both values as observed? Yes, but first we need to understand more about the mechanisms of anomalous magnetism before embarking onto lengthy mathematics.

To a low accuracy of first order, both the electron and muon show similar magnetic moments near $1.00116 = 1 + 1/(137 \times 2p)$, where 1 is the classical part (for $g = 2$) and $1/(137 \times 2p)$ the extra anomalous

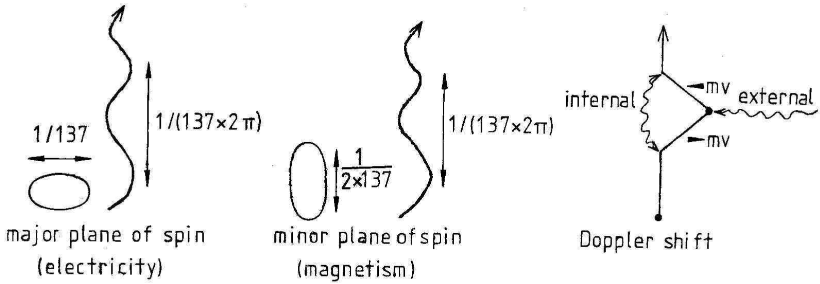

Figure 3. By our model, the self-energy of 1/137 for electricity lies perpendicular to $1/(137 \times 2\pi)$, while the self-energy of $1/(2 \times 137)$ for magnetism lies parallel to $1/(137 \times 2\pi)$. Hence that self-energy for magnetism should increase by $1 + 1/(137 \times 2\pi)$ if it repels itself slightly along the curved helical path. Yet according to infinite QED, some internally-bound photon may produce altered momentum of a point-like charge *e*, so as to change its frequency of interaction with external light by $1 + 1/(137 \times 2\pi)$ as for a Doppler shift.

part. Obviously there will be no trouble in calculating 1, but how might we calculate $1/(137 \times 2p)$?

This can be understood in the context of a four-dimensional helix, and its two mutually orthogonal planes of rotation, which were shown in Fig. 1. As shown in Fig. 3 (left), the major plane lies "horizontally" in space across a helical diameter of $2r$, and is responsible for electricity by means of its exchangeable self-repulsion of 1/137. Alternatively as shown in Fig. 3 (centre), the minor plane lies "vertically" in time across a twofold-larger diameter of $4r$, and is responsible for magnetism by means of its exchangeable self-repulsion of $1/(2 \times 137)$.

Now that exchangeable self-repulsion of $1/(2 \times 137)$ for magnetism evidently lies *parallel* to the curved helical path $4p\ r$, and hence may self-repel along that path by an extra $1/(137 \times 2p)$, so as to generate a slightly larger total of $1/(2 \times 137) \times (1 + 1/(137 \times 2p))$. Yet the analogous self-repulsion of 1/137 for electricity lies *perpendicular* to the curved helical path, and hence should not self-repel along it at all. The total magnetic moment therefore increases in our scheme from a relative 1 to $1 + 1/(137 \times 2p)$, on account of a cross-interaction between two different self-energies within a periodic electron. (Total electricity as 1/137 may be influenced by cross-interactions of another kind, as noted in Fig. 8a below.)

Meanwhile according to infinite QED, the extra anomalous factor of $1/(137 \times 2p)$ comes about due to a microscopic Doppler shift as shown in Fig. 3 (right). There the emission and absorption of some internal photon changes the electron momentum mv in a temporary sense, and thereby causes a point-like electric charge e to interact differently with an external photon by $f'/f = (1 + mv/mc) = 1 + 1/(137 \times 2p)$.

But why should a change of electron momentum be directed in the same sense as that of an external photon? Secondly, how might that change become well-defined as $1/(137 \times 2p)$ if the electron has no periodic structure? Thirdly, how can a Doppler shift remain linear in $(1 + mv/mc)$ without any relativistic gain of mass by $v^2/(2 \times c^2)$? A historical review (3,9,10) reveals that QED was only meant as a provisional, and not a final answer to these difficult questions.

6. Anomalous Electron and Muon Magnetisms by Infinite QED

Having described two possible mechanisms for anomalous magnetism, let us ask next: how do modern theorists calculate the magnetism of an electron or muon to second or third-order accuracy by infinite QED? First, they represent any magnetic moment as a linear series in powers of $1/(137 \times p)^n$, namely $1 + C_1/(137 \times p) + C_2/(137 \times p)^2 + C_3/(137 \times p)^3 + \ldots$ Each term in this series represents a

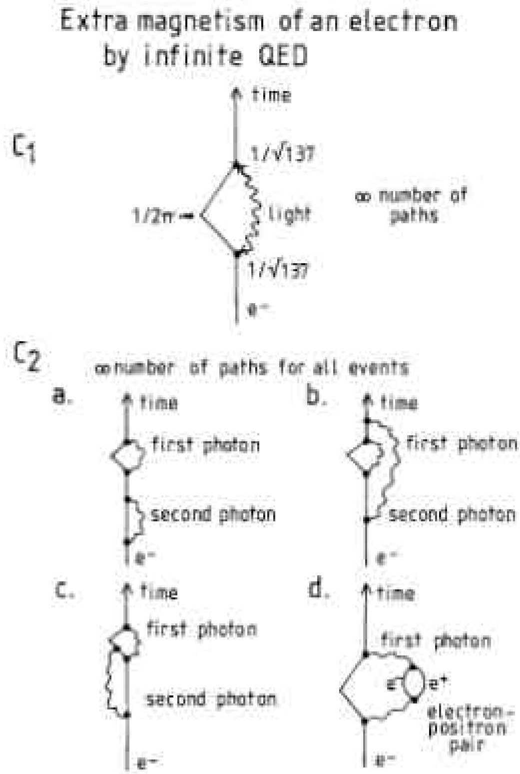

Figure 4. Model for anomalous electron magnetism by infinite QED. To first order in C_1, a single internally-bound photon alters the magnetic moment by $1/(137 \times 2\pi)$ as for a Doppler shift. To second order in C_2, a second photon may interact with the first in various ways, while the first photon may split temporarily into an electron-positron pair.

Doppler shift of order *n* by infinite QED, or a self-repulsion of order *n* by finite methods. Next, they assign different values to the constants C_1, C_2, C_3, *etc.*, by adding up over all space and time, the many ways by which an electron or muon can exchange light so as to alter its magnetism slightly (14,15).

For example, the first constant C_1 describes all possible influences on the magnetic moment due to one-photon events (Fig. 4, upper). Essentially, it is first assumed that the electron will exchange light with itself at two different points in time, to obtain a probability of $(1/\sqrt{137})^2 = 1/137$ for the product of two charge-light junctions. Next, it is argued that the electron will move with altered momentum, essentially $1/(137 \times 2p)$, once it has emitted or absorbed internal light. Yet both of the QED probabilities for propagation of an electron: (*i*) with or (*ii*) without internal light, become infinite on a small scale, since infinitely many paths are allowed. Hence the entire calculation must be renormalized to reduce C_1 to a small 0.50000, and first-order magnetism to $1 + 0.50000/(137 \times p) = 1.0011614$. For any order n in powers of $1/(137 \times p)$, all of mass, charge and a quantum wave function become infinite and must be renormalized to yield a finite answer.

Next in order to calculate the constant C_2, one has to take into account all possible ways by which an electron can emit and absorb two photons at once. There are three general geometries (*a, b, c*) by which this can happen (Fig. 4, lower). Also there is a small probability (*d*) for the first photon to fall apart temporarily into an electron-positron pair. By adding up amplitudes and probabilities for all four events and renormalizing as before, one calculates $C_2 =$ -0.328479 for the electron or +0.765858 for the muon. The value of C_2 for an electron is negative, because any second photon may interfere destructively with the first; while C_2 for a muon is positive, because light within a muon may fall apart not only to muon-antimuon pairs of low magnetism, but also to electron-positron pairs of high magnetism.

Using those constants C_2, one can calculate magnetic moments of $1 + 0.50000/(137 \times p) - 0.328479/(137 \times p)^2 = 1.0011596375$ for an electron, or $1 + 0.50000/(137 \times p) + 0.765858/(137 \times p)^2 = 1.00116554$ for a muon. Such second-order values compare well with experiment as 1.0011596522 for the electron or 1.00116592 for the muon.

In order to get a constant C_3, which describes the simultaneous exchange of three photons, and various two-photon events which create a matter-antimatter pair, one must analyze 72 kinds of event. Then to get a constant C_4, one has to analyze 891 kinds of event. The final calculated values are $C_3 = +1.18$ for an electron, so as to raise the last three digits of its theoretical magnetism from 375 to 522 (*versus* 522 by data); or $C_3 = +24.1$ for a muon, so as to raise the last three digits of its theoretical magnetism from 554 to 584 (*versus* 592 by data). Such values are the best that can be achieved today, since the fine-structure constant is known to an accuracy of only 137.035989(6).

Might there exist another way to calculate anomalous magnetic moments for an electron or a muon? Let us now try to carry out such calculations, based on our periodic model and its finite electrical self-repulsions (1,2). The final values of C_1, C_2, C_3 and C_4 as derived from our model are listed in Table I along with analogous values from QED.

Table I. Calculated Values of Magnetic Constant C_n for the Electron or Muon

Constant	Electron model		Muon model	
	finite periodic	infinite QED	finite periodic	infinite QED
C_1	+0.50000	+0.50000	+0.50000	+0.50000
C_2	-0.32836	-0.32848	+0.773	+0.766
C_3	+1.12	+1.18	+19.4	+24.1
C_4	-0.8	-0.8	—	—

7. Anomalous Electron Magnetism from a Model of Finite Size

The electron by our finite scheme contains a small self-energy of $1/(137\times 2p)$ which, as an internally exchanged light through time, increases both the total mass and also the exchangeable magnetic self-repulsion from a relative 1 to $1 + 1/(137\times 2p)$.

So far we have treated $1/(137\times 2p)$ as a single kind of electrical self-repulsion e^2/r, where $r = 4pR$ after two turns along a curved helical path (Fig. 5, upper left). But now for greater accuracy, we will treat it as the sum over many different electrical self-repulsions through time: as $e^2/r = 1/(137\times 2p)$ after two turns (360° minor), or $1/(137\times 4p)$ after four turns, or $1/(137\times 8p)$ after eight turns, *etc.* (Fig. 5, upper right).

Each successive term in this series $4p$, $8p$, $16p$, *etc.* shows half the frequency and twice the wavelength of its predecessor $2p$, $4p$, $8p$, *etc.*, just as for the same note played at successively lower octaves on a musical instrument. Hence those frequencies $2p$, $4p$, $8p$, $16p$, *etc.* would seem to represent the natural vibrations of a periodic electron along its curved helical path. Other possible values of $n\times 360^\circ$ such as

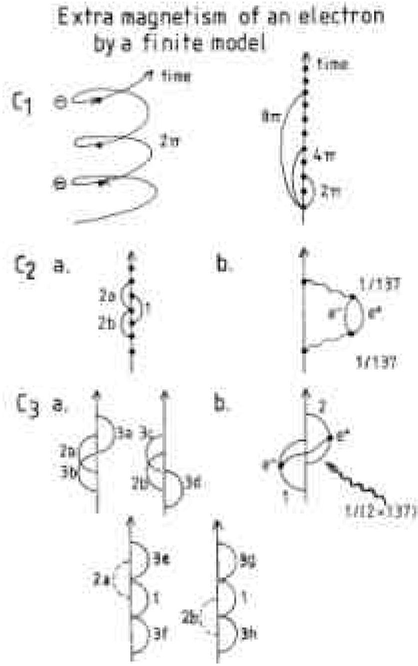

Figure 5. Finite model for anomalous electron magnetism. To first order in C_1, the extra anomalous part of magnetic self-energy represents an infinite series which includes self-repulsions (or vibrations) over many different frequencies: namely $1/(137 \times 2\pi)$, $1/(137 \times 4\pi)$, $1/(137 \times 8\pi)$ *etc.* To second order in C_2, a second self-repulsion (or vibration) may cancel the first 1 in either of two locations 2*a,* 2*b*, while the first photon 1 may split temporarily into an electron-positron pair. To third order in C_3, a third self-repulsion may cancel the second or else reinforce the first in any of eight locations 3*a* to 3*h*; while the first two photons may share an electron-positron pair with an external magnetic field by photon-photon scattering.

6*p* or 10*p* will not enter into this series, because their predecessors 3*p* or 5*p* show an odd phase of $n \times 180^{\circ}$.

The anomalous self-repulsion of an electron, in excess over its classical amount of 1, may therefore be calculated as a convergent infinite series of the kind $e^2/r = (½ + 1/4 + 1/8 + ...) \times (1/137p) = 1/(137 \times p)$. When total energy e^2/r is converted into net energy $e^2/2r$ as for any dynamic system in equilibrium, the same series produces just $e^2/2r = (½) \times 1/(137 \times p)$. That yields $C_1 = +½ = +0.50000$ to first order, and (using 137.03599) a magnetic moment of 1.0011614098 which is the same as for QED.

To second order, the constant C_2 must take into account two processes: (a) the probability that a second photon will bind (or self-repel) near the first, but with a phase difference of 180° so as to cancel any effect of the first on magnetism; and (b) the probability that any first photon will dissociate temporarily into an electron-positron pair, so as to create an extra pair of charges e^+ and e^- at the same radius r (Fig. 5, centre).

The probability (a) that some second photon will bind near the first may be calculated from a sum of the squares in that previous series as: $1/(2 \times 2) + 1/(4 \times 4) + 1/(8 \times 8) + ... \times 1/(137 \times p)^2 = (1/4 + 1/16 + 1/64 + ...) \times 1/(137 \times p)^2 = ? \times 1/(137 \times p)^2$. Here many different second-order self-repulsions of frequency $1/(137 \times 2p)$ or $1/(137 \times 4p)$ or $1/(137 \times 8p)$ lie close to a first-order self-repulsion of the same kind; but they will be located one turn away or 180° out of phase, so as to cancel any effect of the first on magnetism. Now that second-order self-repulsion may occupy either of two locations $2a$, $2b$ relative to the first 1, as one turn ahead of it ($+180^\circ$) or else behind it (-180°) along the curved path (Fig. 5, centre left). Our preliminary value of $e^2/r = -?$ must therefore be doubled to $-2/3$, in order to account for those two possible locations. Finally, when converted from e^2/r to $e^2/2r$, this model predicts for part (a) of C_2 a value of $(½) \times (-2/3) = -0.33333$.

A slight correction must still be made for the extra self-repulsion of $e' = 1 + 1/(137 \times 2p)$, which was added by the first series of photons. That will increase $e^2/4\pi R$ for any second photon to cancel the first by $1+1/(137\times\pi) = 1.002324$. Thus part (a) will increase slightly from -0.33333 to -0.334108, or from -17984.9×10^{-10} to -18026.8×10^{-10}.

The probability (b) that some first-order photon will fall apart temporarily into an electron-positron pair may be calculated, from the net electrical energy of all first-order photons as $(½)\times1/(137\times\pi)$, when that series is multiplied by a net probability of $1/(2\times137^2)$ to yield $+309.23\times10^{-10}$. Here two virtual charges as electron e^- and positron e^+ exchange light across a helical diameter of $2r$, with a probability of 1/137 at one end of a closed loop through time, then again with a probability of 1/137 at the other end, by a schematic process $L—e^-,e^+—L$ (Fig. 5, centre right). For the loop as a whole, we find a combined probability of $1/137^2$ for e^2/r, or $1/(2\times137^2)$ for $e^2/2r$. That increases the magnetism by $+309.23\times10^{-10}$, since two new charges are formed which were not present earlier, while half as much first-order light is lost.

A slight correction for e' will increase $e^2/2r$ by 1.002324 to $+309.95\times10^{-10}$. Part (b) as $+309.95\times10^{-10}$ then adds to C_2 a fraction of +0.005745, once it is converted into units of $1/(137\times\pi)^2 = 53954.9\times10^{-10}$. The total value for C_2 as (a) plus (b) equals $(-0.334108+0.005745) = -0.328363$, or equivalently, -17716.9×10^{-10}. This may be used to calculate an overall electron magnetism to second order of $1.0011614098 - 0.0000017717 = 1.0011596381$, *versus* 522 by experiment in the last three digits. The analogous value for C_2 by QED (15) is a very similar -0.32848 or -17723×10^{-10}, which our finite calculation matches to within 0.03%.

Now to third order, the constant C_3 for an electron must take into account two major processes: (a) the probability that some third photon will bind (or self-repel) so as to cancel the second, or reinforce the first in phase; and (b) the probability that two photons as already bound, will share a single electron-positron pair with an external magnetic field (Fig. 5, lower).

Part (a) may be calculated from the same series used to obtain C_2 as $(1/4 + 1/16 + 1/64 + ...) \times 1/(137 \times p)^2$, once each term is multiplied by $1/(137 \times 2p)$ or $1/(137 \times 4p)$ or $1/(137 \times 8p)$, *etc.* for an additional photon of third order, which can cancel a photon of second order, or reinforce a photon of first order. That yields $(1/8 + 1/64 + 1/512 + ...) \times 1/(137 \times p)^3$ for any single photon to third order, but how many will there be?

Each photon $2a$ or $2b$ may be cancelled by two different photons $3a$, $3b$ or $3c$, $3d$ respectively, which are shifted in phase by $+180^\circ$ or -180° (Fig. 5, lower left). In addition, photon 1 when cancelled by either $2a$ or $2b$ may be reinforced by two different photons $3e$, $3f$ or $3g$, $3h$ respectively, which are shifted in phase by $+360^\circ$ or -360° (Fig. 5, lowermost). Hence we find eight photons which may increase magnetism to third order, in accord with a general formula $C_{n\text{-}1} \times (n - 1) \times 2 = 2 \times 2 \times 2 = 8$.

Also, if both photons to first and second order are of frequency $1/(137 \times 2p)$, then an additional photon to third order may be of the same frequency $1/(137 \times 2p)$, or else of half the frequency $1/(137 \times 4p)$. For C_1 and C_2 the half-frequency $1/(137 \times 4p)$ constitutes an independent term, yet for C_3 it overlaps with the C_1-C_2 pair to create a new cross-term. Each $1/(137 \times 4p)$ cross-term will increase magnetism by one-half; and since there are eight photons of that kind, we find in total $8 + (8 \times ½) = 12$.

Our single-photon series for C_3 can therefore be multiplied plausibly by a factor of 12, to yield $(3/2 + 3/16 + 3/128 + ...) \times 1/(137 \times p)^3 = (12/7) \times 1/(137 \times p)^3$. That suggests a value of $+12/7$ for e^2/r, or $+6/7$ for $e^2/2r$. When multiplied further by

$1/(137\times p)^3 = 125.33\times 10^{-10}$, it adds $+107.43\times 10^{-10}$ to the electron magnetism of third order *versus* $+115\times 10^{-10}$ by QED (14). Finally, a slight correction for *e'* as added by both C_1 and C_2 series of photons gives $e^2/4pR = 1.004651$, and increases part (a) to $+107.93\times 10^{-10}$.

Part (b) of C_3 may be calculated from a net energy of 18026.8×10^{-10} for the first two photons as already bound, once that term is multiplied by another probability of $1/(4\times 137)$ to yield $+32.89\times 10^{-10}$. Here a single electron-positron pair is shared between two internal photons with a probability of $e^2/r = 1/(2\times 137)$, before it exchanges light with an external magnetic field, by a process *L,L*(*internal*)—e^-,e^+—*L*(*external*) which is called photon–photon scattering (Fig. 5, lower right).

The probability for two internal photons to share an electron-positron pair remains large as 1/137 instead of $1/137^2$, since the second exchange is to external light which is in excess and hence not counted. Still, we have to take into account that only one electron-positron pair is shared rather than two, giving $e^2/r = 1/(2\times 137)$. Finally, when we convert to a net energy of $e^2/2r = 1/(4\times 137)$, we find $(18026.8\times 10^{-10})\times 1/(4\times 137) = +32.89\times 10^{-10}$ *versus* $+46\times 10^{-10}$ by QED (14). A slight *e*' will increase part (b) by 1.004651 to $+33.04\times 10^{-10}$.

Two minor processes include: (c) forming an electron-positron pair within either photon of the C_1-C_2 pair, with probability $2/(2\times 137^2)\times(18027\times 10^{-10}) = +0.96\times 10^{-10}$; or (d) closing an electron-positron pair to light within the first photon, with probability $1/(2\times 137)\times(309.9\times 10^{-10}) = -1.13\times 10^{-10}$.

A total value for C_3 as $(+107.93 + 33.04 + 0.96 - 1.13) = +140.8\times 10^{-10}$ may be used to calculate an electron magnetism to third order of $1.0011596381 + 0.0000000141 = 1.0011596522$, which matches experiment 522 precisely in the last three digits (or 5219 precisely). Note that $C_3 = +1.12$ by our model matches $C_3 = +1.18$ by QED (15) to within 5%.

To fourth order, the constant C_4 will include six terms, but only three (a), (b) and (c) are significant. Term (a) describes the probability that some fourth-order photon will cancel a photon of third order, or reinforce a photon of second order, or cancel a photon of first order (there are $48 + 24 = 72$ fourth-order photons in total, or $C_{n-1} \times (n - 1) \times 2 = 8 \times 3 \times 2 = 48$ for any frequency); while term (b) describes the probability that three internal photons 1, 2, 3 will exchange a single electron-positron pair with an external magnetic field; and term (c) describes the probability that two internal photons 1, 2 will exchange a single electron-positron pair with an external magnetic field, that later closes to light.

It can be shown that the sum of (a), (b) and (c) equals $(-0.70 + 0.59 - 0.12) = -0.23 \times 10^{-10}$, which leaves the electron magnetism almost unchanged. The constant C_4 by our model equals –0.8, which is identical to QED (15). See Table I for a detailed comparison between our model and QED. Our C_1 and C_2 terms should be fairly reliable, yet our C_3 and C_4 terms may be only approximate, owing to the lengthy calculations involved. This calculation in any case demonstrates the feasibility of calculating 10-digit QED quantities from a finite model.

8. Anomalous Muon Magnetism from a Model of Finite Size

The anomalous magnetic moments of an electron or muon remain the same to first order, where $C_1 = +0.50000$. Yet the anomalous magnetism of a muon differs greatly from that of an electron to second or third order (16,17), because any internal light of self-repulsion may convert not only to muon-antimuon pairs of low

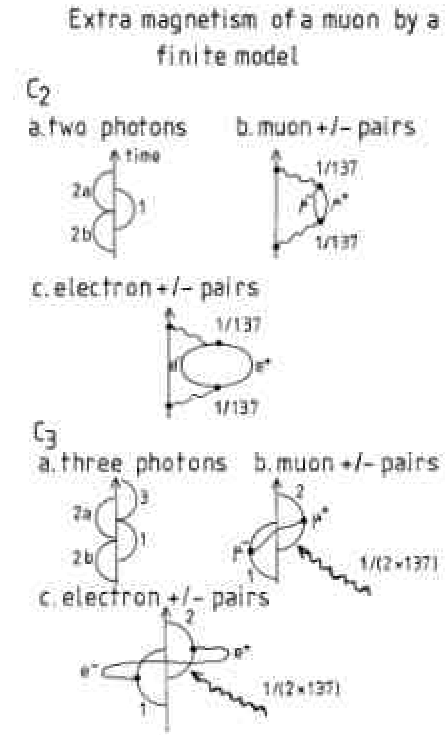

Figure 6. Finite model for anomalous muon magnetism. To second order in C_2, a second photon may cancel the first in either of two locations 2*a*, 2*b*, while the first photon may split temporarily into either a muon-antimuon or an electron-positron pair. To third order in C_3, a third photon may cancel the second or else reinforce the first in any of eight locations; while the first two photons may share either a muon-antimuon or an electron-positron pair with an external magnetic field by photon-photon scattering.

magnetism, but also with equal probability to electron-positron pairs of high magnetism.

Let us see how the overall magnetism of a muon will be affected by these processes, to second order in the constant C_2. Recall that the probability for cancellation of a first internal photon by some second internal photon equals ? $\times 1/(137 \times p)^2 = 180.3 \times 10^{-8}$ (including *e'*). That two-photon term remains the same within a muon as within an electron, and reduces magnetism to $(1.00116141 - 0.00000180) = 1.00115961$ (Fig. 6, upper left).

But within a muon, the other term for C_2 could become much larger than before, as $(½) \times 1/(137 \times p) \times 1/(2 \times 137^2) = +3.0995 \times 10^{-8}$ within an electron (including *e'*), but potentially $(3.0995 \times 10^{-8}) \times (206.77 + 1.00) = +644.0 \times 10^{-8}$ within a muon. Here it has been assumed that each electron-positron pair will contribute to magnetism 206.77 times more strongly than each muon-antimuon pair, for an electron of mass 1.00 and a muon of mass 206.77 (Fig. 6, upper right and centre). Now that extra term of $+644.0 \times 10^{-8}$ enables us to estimate the magnetism of a muon as $(1.00115961 + 0.00000644) = 1.00116605$, which turns out to be a little larger than observed or 1.00116592.

Yet we have neglected to account so far for the increased mass of our electron-positron pair (16,17), when it is bound to an internal photon rather than free in space. One can calculate this increased mass when the pair is bound to a first-order, muon-like photon as $2m' = 2 + 206.77/(137 \times 2p) = 2.24014$ for the $2p$ term, or 2.12007 for the $4p$ term, or 2.06004 for the $8p$ term, *etc.* A magnetism-weighted sum of $(½) \times (2.24014) + (1/4) \times (2.12007) + (1/8) \times (2.06004)$, *etc.* gives 2.1534. Thus any electron-positron pair in C_2 should generate less magnetism than expected, due to its increased mass as $2m' = 2.1534$ instead of 2.0000. The correction to either particle separately equals $m' = 1.0767$.

The mass-corrected magnetism of electron-positron and muon-antimuon pairs in C_2 therefore equals $(3.0995 \times 10^{-8}) \times [(206.77/1.0767) + 1.00] = +598.3 \times 10^{-8}$, which is slightly less than before. An expansion using individual frequencies gives $+597.4 \times 10^{-8}$.

The overall second-order contribution to muon magnetism may therefore be calculated as $(+597.4 \times 10^{-8} - 180.3 \times 10^{-8}) = +417.1 \times 10^{-8}$. When divided by $1/(137 \times \pi)^2 = 539.55 \times 10^{-8}$, it yields C_2 for the muon as +0.773, which matches +0.766 by QED to within 1% (17). Finally, the total muon magnetism to second order equals $(1.00116141 + 0.00000417) = 1.00116558$, *versus* 592 by data in the last three digits.

To third order, the constant C_3 for a muon will be affected by three major processes: (a) any cancellation of a second-order photon by a third-order photon, or reinforcement of a first-order photon by a third-order photon, which will increase magnetism by $+1.08 \times 10^{-8}$ (including *e'*); and (b, c) any sharing of a muon-antimuon or electron-positron pair between two internal photons and an external magnetic field (Fig. 6, lower). The latter processes (b, c) might increase magnetism by a large $(33.04 \times 10^{-10} \times 207.77) = +68.6 \times 10^{-8}$ (including *e'*) for an assumed electron mass of 1.00.

But still we have to take into account the increased mass of our electron or positron, when it is bound to three photons rather than free in space. Such increased mass equals in this case $m' = 1 + 2 \times (206.77)/(137 \times 2p) + (206.77/137) = 2.99$ for the $2p$ term, or 2.75 for the $4p$ term, or 2.63 for the $8p$ term, *etc.* Here each electron or positron is bound to two internal muon-like photons of the kind $1/(137 \times 2p)$, and to a single external muon-like photon of the kind 1/137. A magnetism-weighted sum of $2p$, $4p$, $8p$, *etc.* yields $m' = 2.92$. After making that mass-correction, we find a revised contribution to magnetism by (b, c) of just $(33.04 \times 10^{-10}) \times [(206.77/2.92) + 1.00] = +23.7 \times 10^{-8}$, which now matches well the $+23 \times 10^{-8}$ of QED (18).

As a minor process (d), formation of an electron-positron pair within either photon of the C_1-C_2 pair gives a probability of $(180.3 \times 10^{-8}) \times 2/(2 \times 137^2) \times (206.77/1.16 + 1.00) = +1.7 \times 10^{-8}$. As a minor process (e), some of the electron-positron pairs formed in C_2 may close to light with a probability of $(597.4 \times 10^{-8}) \times 1/(2 \times 137) = -2.2 \times 10^{-8}$.

All five terms (a, b, c, d, e) yield in total $(+1.1 + 23.7 + 1.7 - 2.2) = +24.3 \times 10^{-8}$ for C_3. Hence the muon magnetism may be calculated to third order as $(1.001165581 + 0.000000243) = 1.00116582$, *versus* 592 by data in the last three digits. The value of C_3 by our model equals +19.4, which is slightly less than +24.1 for QED (17-19). See Table I for a summary: our values for C_1 and C_2 should be more reliable than for C_3, owing to lengthy calculations in the latter case.

To fourth order, the constant C_4 for a muon will be influenced by: (a) sharing of a single electron-positron pair between three internal photons 1, 2, 3 and an external magnetic field; and (b) sharing of a single electron-positron pair between two internal photons 1, 2 and an external magnetic field, that later closes to light. It can be shown that a fourth-order term of $(0.42 - 0.09) = +0.33 \times 10^{-8}$ leaves the magnetism almost unchanged at 1.00116583.

Finally, other kinds of matter-antimatter pair will show a moderate influence on muon magnetism in C_4. For example, a pion-antipion pair might increase the magnetism by $(3.0995 \times 10^{-8}) \times (206.77/273.14) = +2.3 \times 10^{-8}$, while a kaon-antikaon pair might contribute $+0.8 \times 10^{-8}$. The QED estimate (14,15) for all such pairs is $+7 \times 10^{-8}$. This last term (c) increases our calculated muon magnetism to 1.00116590, which lies fairly close to data as 592 in the last three digits; or 5916(1) by latest measurements, which emphasize that "real observable muons are surrounded by many different virtual particles, that briefly pop in and out of existence in the quantum vacuum" (20).

9. The First-Order Lamb Shift of Electrons in Atoms

We have seen above how the anomalous magnetic moments of an electron or muon may be calculated plausibly in a finite fashion, using a periodic structural model for particles. Might it be possible also to explain other phenomena in terms of our scheme?

For example, could the Lamb shift of spectral lines in atoms be explained, in terms of the small self-energy of an electron as $1/(137 \times 2p)$? That tiny shift of spectral lines is thought to measure how much mass is lost, when an electron overlaps a charged nucleus and feels the full force of electricity (3,21). Hence if $1/(137 \times 2p)$ is actually the small fraction of stable mass due to electrical self-repulsion, that should be the amount which is lost when such repulsion disappears.

Let us see first how infinite QED deals with the Lamb shift, and then compare that with our scheme. According to QED, the electron as a randomly-moving, dimensionless point will overlap the charged nucleus for some tiny fraction of the time, whenever it lies at an orbital radius of precisely $r = 0$. While in direct contact with the nucleus, it will lose just $Z/(2 \times 137^2)$ of its electrical self-energy, where Z is the nuclear charge. Finally, the total self-energy of an electron in this scheme, as a sum over all charge-light frequencies from 0 to mc^2, is postulated to equal a large $8 \times mc^2$ (Fig. 7a).

Now when such a large self-energy of $8 \times mc^2$ is multiplied, both by the fractional loss of electricity as $Z/(2 \times 137^2)$, and also by the probability that an electron will lie at $r = 0$, one obtains an estimate

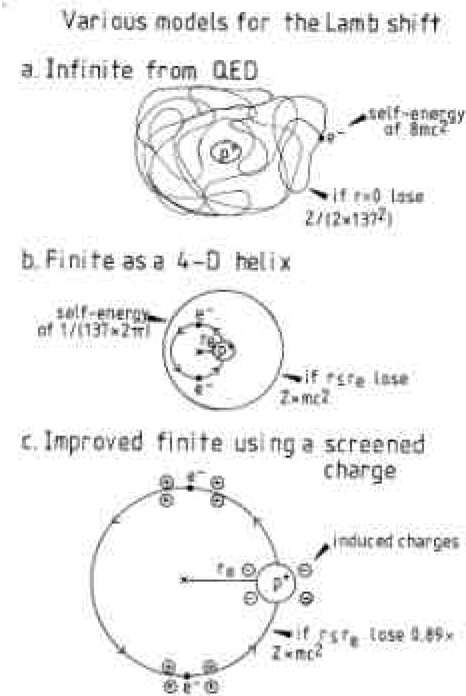

Figure 7. Models for the Lamb shift as infinite from QED, or finite by the present scheme. By infinite QED, a point-electron with self-energy $8 \times mc^2$ loses $Z/(2 \times 137^2)$ of its electrical energy when it contacts the proton at $r = 0$. Yet by finite theory, a periodic electron with stable self-energy $1/(137 \times 2\pi)$ loses almost all of that electrically derived "mass" as $Z \times mc^2$ when it contacts the proton at $r = r_e$ or less. To be precise, just 0.887 of the total electrical mass of $1/(137 \times 2\pi)$ is lost, due to screening by partial charges from the vacuum.

for the Lamb shift of hydrogen 2*s* as 1050×10^6, which lies close to experiment as 1085×10^6.

Let us see next how our finite scheme deals with the Lamb shift. First, we can imagine that an electron of radius $r_e = 1.92 \times 10^{-13}$

meters will overlap the nucleus with a small probability, that can be calculated from its 1*s*, 2*s* or 2*p* wavefunctions. Next, if such an electron lies within a distance *re* of the nucleus, we can postulate that it will lose precisely $Z/(137 \times 2p)$ of its mass, due to loss of its electrical self-repulsion through time as $e^2/(4p \times r_e)$ on account of the p^+ contact (Fig. 7b).

The probability that any electron will lie within a sphere of radius r_e from a point-like nucleus may be calculated as $P(1s) = 1/(6 \times 137^3)$, $P(2s) = 1/(48 \times 137^3)$, or $P(2p) = 1/(1280 \times 137^5)$ for a hydrogen atom with $Z = 1$. The third probability $P(2p)$ is essentially zero, in accord with the observation that a Lamb shift affects mainly orbitals such as 1*s* or 2*s* but not 2*p*.

Hence we can calculate for hydrogen 2*s* an estimate of its Lamb shift as $P(2s) \times$ (electron mc^2 as light) $\times (1/137 \times 2p) = 1/(48 \times 137^3) \times (1.23 \times 10^{20}) \times 1/(137 \times 2\pi) = 1157 \times 10^6$ which compares fairly well to data as 1085×10^6. For hydrogen 1*s*, our model predicts a Lamb shift which is eight times larger as $(8 \times 1157) \times 10^6$ *versus* data $(8 \times 1046) \times 10^6$. For nuclei of $Z = 2$ or 3, the Lamb shift as predicted for 2*s* should increase by $Z^4 = 16$ or 81. Thus we obtain values of $(16 \times 1157) \times 10^6$ or $(81 \times 1157) \times 10^6$ respectively, which still match data fairly well as $(16 \times 905) \times 10^6$ or $(81 \times 802) \times 10^6$.

Yet our predicted values do seem somewhat too large: by 10% for $Z = 1$, or 20% for $Z = 2$, or 30% for $Z = 3$. The most likely source of error in this preliminary model, would be the assumption that any direct proton-to-electron contact can reduce the internal electron self-repulsion by a full amount as $1/(137 \times 2p)$. In fact, any direct proton-to-electron contact should reduce that self-repulsion at most by $1/(1 + 2/5p) = 0.887$, due to a phenomenon known as vacuum polarization (21,22). Essentially, some of the electricity from a direct contact may be screened or not transmitted, due to its interaction with partial charges from the vacuum that lie between a proton and an electron along the curved helical path $4p \times r_e$ (Fig. 7c).

If one postulates a loss of self-energy by just $(0.887)^Z/(137 \times 2p)$, one can calculate improved values for the Lamb shift of 2*s* as 1026, 910 or 807 when $Z = 1$, 2 or 3, which now lie very close to experiment as 1046-1085, 905 or 802.

The reality of a small self-repulsion through time, equal to $1/(137 \times 2p)$ of the electron mass at rest, is seemingly confirmed. Interestingly enough, the large self-repulsion of 1/137 through space does not contribute to this stable mass, but remains only a temporary part of the structure that can be exchanged electrically with other particles. Other calculations of the Lamb shift may include second or third-order terms, most of which do not arise from self-energy *per se* (21).

10. A Finite Periodic Electron Versus Probabilistic Quantum Theory

It should be clear now from the derivations given, that the internal periodic structure of an electron may perhaps determine its outward properties such as electric charge, magnetic moment or Lamb shift. But how can we reconcile our finite periodic model with probabilistic quantum theory?

The electrical energies between proton and electron may be reconciled easily with our scheme, since they equal just $e^2/r = 1/(137^2 n^2)$, as would be expected for the two-way exchange of internal electrical self-repulsions of size $1/137n$ between interacting particles. But how can we explain the magnetic fine-structure energies? Also, how can the electron paths remain point-like and probabilistic by quantum theory, yet finite and well-defined by our scheme?

Here we suggest that a finite periodic electron may form *closed paths of well-defined end-to-end linkage* as it wraps continuously about a proton through space and time. By this view, it is the underlying periodic structure of an electron which actually *causes* those electrical and magnetic energies to become *quantized*: through finite self-energies of $1/137n$ for electricity, or through various closed paths for magnetism. Such closed paths then seem to explain well the variations of magnetic energy *s*, *p*, *d*, *f* as observed for a hydrogen atom, but they do not specify any deterministic geometries in space or time, because a wide range of geometries will be possible for any given end-to-end linkage.

Nor will an electron when wrapped into one of those closed paths emit light due to its accelerated state, because it is in a condition of *resonant exchange* with the proton, where discrete internal energies of $1/137n$ have been shared reciprocally.

Finally, when any bound electron exchanges light with the outside world, it can re-assemble into a new path of either higher or lower energy, whose *probability for formation* will vary in proportion to the *square* of the concentration of its constituent precursors in space, owing to the dimeric spin ½ nature of the underlying electron filament (1,2). This process seems analogous to "squaring of the wave function" as a complex conjugate in quantum theory or diffraction.

11. A Closed-Path View of Magnetic Fine-Structure Spectra

"It seemed to him absurd to claim that there was an electron path in the cloud-chamber, but none in the

interior of the atom." W. Heisenberg, *Encounters With Einstein* (1974).

A closed-path interpretation of magnetic fine-structure spectra may be illustrated through an analysis of the Sommerfield-Dirac model for hydrogen (23,24). There the total energy of any proton-electron interaction can be expressed by a series of terms of decreasing size (equation 53.27 of ref. 24):

$$E/mc^2=1-1/(2\times137^2n^2)+1/(2\times137^4n^4)\times(3/4)-1/(2\times137^4n^4)\times n/(1+c).$$

At first glance it might appear that nothing more remains to be done, since the mathematical expression shown above explains all spectral lines with excellent accuracy. Yet the underlying synthesis of quantum theory with special relativity which was used to derive that equation suffers from three internal contradictions: (a) a dynamic (q.m.) *versus* perceptive (s.r.) view of nature; (b) a probabilistic (q.m.) *versus* definite (s.r.) description of coordinates; and (c) an assumption of accelerated (q.m.) *versus* linear (s.r.) motion. Hence there still remains much to do in a physical sense, to understand the true conceptual nature of electron paths in atoms.

The first term of the expression above describes electricity at rest, which follows from a two-way exchange of internal self-repulsions of the kind $1/137n$. That process represents a kind of resonant exchange, which should not cause any electron to emit light due to its orbital motion *per se*. The second term describes a constant but small loss of electricity within any shell n, due to minor influences which will be discussed below. Finally, the third term describes an irregular but precise magnetism of the electron as it moves through space and time, by modulations of the kind $n/(1 + c)$ to a classical magnetic energy of $1/(2 \times 137^4n^4)$. Let us analyze those second and third terms to see how they come about.

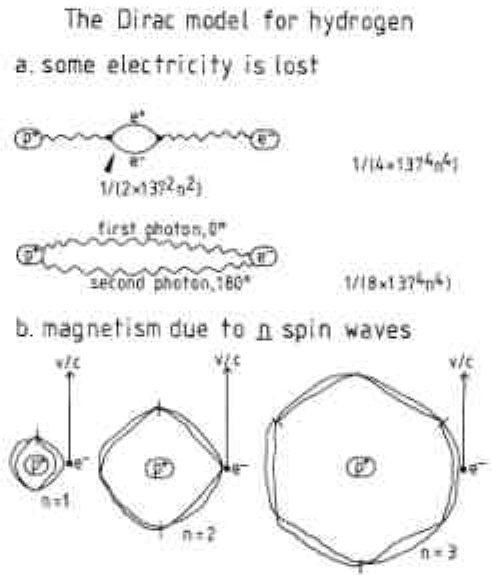

Figure 8. A finite model where crossovers *c* within any closed electron path determine magnetic energies in atoms. The Sommerfield-Dirac formula shows to second order: (a) a constant loss of electricity for any shell *n*, due to the formation of electron-positron pairs by a first-order photon, or cancellation of the first-order photon by a second; and (b) a gain of magnetism which increases with shell *n*, where *n* de Broglie waves add together to produce a path of greater angular momentum *mvr*.

The second term in the Sommerfield-Dirac formula describes a slight loss of electricity as $(3/8)\times 1/(137^4 n^4)$ of mc^2. Recall from calculations of electron magnetism that the probability for light to dissociate into an electron-positron pair equals $(½)\times 1/(137^2)$ for $n = 1$. Hence that same expression should equal $(½)\times 1/(137^2 n^2)$ for $n = 2, 3$, *etc.*, and so two-thirds of the second term is accounted for as $1/(4\times 137^4 n^4)$ when multiplied by total electricity (Fig. 8a, upper). The remaining one-third of lost electrical energy may come about if

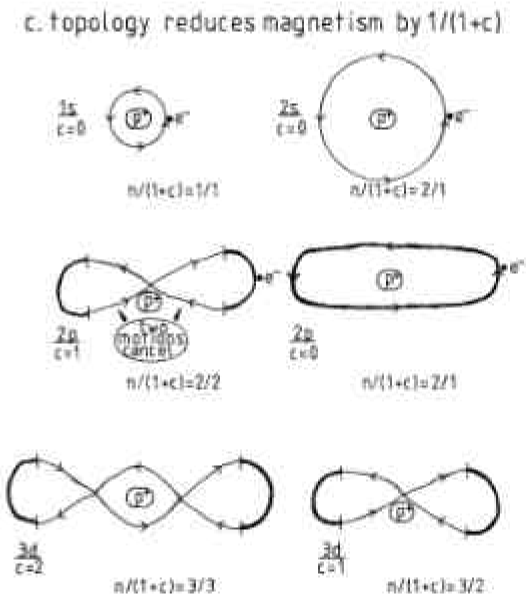

Figure 8 (cont.). But then those magnetic energies *n* are reduced by another factor of 1/(1 + *c*), where *c* is a integral parameter which tells how many times the closed electron path "crosses over itself" through space and time. Each crossover reduces net angular momentum by 1/(1 + *c*), and thereby reduces the energy of magnetism by a proportional amount as *n*/(1 + *c*).

the proton and electron exchange two photons at once, where one photon cancels the other in phase (Fig. 8a, lower). Since the probability for exchanging a single photon equals $1/(2 \times 137^2 n^2)$, then the probability for exchanging two photons should equal $e^2/2r = 1/(8 \times 137^4 n^4)$.

Now the third term in the formula above of size $1/(2 \times 137^4 n^4) \times n/(1 + c)$ is the main term of interest here, since it describes an extra energy of magnetism which is generated by the complex and poorly understood motion of any electron about a proton (23,24). In a classical sense, one might expect an increase of electricity by $(e^2/2r)\times(1+v^2/c^2)$ or else $mc^2\times(v^2/2c^2)\times(1+v^2/c^2)$. For simple circular motion, the extra magnetic part would then equal $v^4/(2\times c^4) = 1/(2\times 137^4 n^4)$.

Yet that classical value of $1/(2\times 137^4 n^4)$ is multiplied in the Sommerfield-Dirac formula by another term $n/(1+c)$ (often written as n/k), which generates increased values of magnetism by $n = 1, 2, 3, 4$, *etc.* for different shells n; or decreased values of magnetism by $n/1$, $n/2$, $n/3$, $n/4$, *etc.* for different paths *s*, *p*, *d* or *f* which show different values of *c*.

It seems clear why the magnetic energies should increase with *n*, since each successive shell by a de Broglie view will contain a greater number of spin (or orbital) waves as one for $n = 1$, two for $n = 2$, or three for $n = 3$. Hence multiple waves within any shell *n* may add together in phase, to produce a path of larger radius *r* or larger magnetic moment *evr* (Fig. 8b).

But why should that magnetic energy vary further as $1/(1+c)$, where the joint contribution of *n* waves may be reduced by a factor of 1/1, ½, ? , 1/4, *etc.* depending on *c*? To understand the physical situation more clearly, we can think of *c* in terms of the number of times by which any electron path "crosses over itself" within a continuous closed domain, in order to relieve any torsional stress imposed by end-to-end joining. For example $c = 0$ for an idealized open circle, or $c = 1$ for a singly-crossed figure-eight, or $c = 2$ for a doubly-crossed figure-eight. Each crossover will reduce the net angular momentum by $1/(1+c)$, and hence should reduce the magnetism essentially as observed.

Let us see how this scheme might work for various kinds of closed path such as *s*, *p* or *d*. Within any *s* path (Fig. 8c, upper), the electron may join to itself in a relaxed stress-free fashion, thereby producing an approximate open circular shape with no crossovers or $c = 0$. Hence each extra wave n should contribute to magnetism by its full amount as $L = 2S$ (where L and S are orbital or spin momenta, giving equal magnetism for $g = 2$); and so the net angular momentum will equal simply $n/1$, or specifically 1/1 for 1*s*, 2/1 for 2*s*, *etc*. This agrees well with experimental data, since *s* paths show in general a greater attractive magnetic energy than any other path *p*, *d*, *etc*. for any given shell n.

Next within any *p* path, the electron may join to itself after having lost one turn of 360° rotation or phase about its minor magnetic axis (equivalent to two turns of 720° about its major electrical axis). This will provide for either of two approximate shapes: (a) an open-circle which remains torsionally stressed with $c = 0$; or (b) a figure-eight which has crossed-over itself to remove that torsional stress by means of one crossover or $c = 1$ (Fig. 8c, centre).

In the former case, net angular momentum will equal $n/1 = 2/1$ as its maximum possible value $L = 2S$. But in the latter case, net angular momentum will be reduced by one-half to $n/2 = 2/2$, since it will add in phase over only half of the contour length at the two semicircular ends (shaded in Fig. 8c, centre left). Within all other parts of the path, vectors for angular momentum will cancel, owing to opposing directions of motion as produced by a single crossover at the centre. Those are the two kinds of *p* path as proposed by Dirac, which he called 2*p*(½) for $c = 0$ or 2*p*(3/2) for $c = 1$. The $c = 0$ path 2*p*(½) shows the same magnetic energy as $c = 0$ for 2*s*(½), while that of $c = 1$ for 2*p*(3/2) is only half as great.

One might imagine that the relative direction of angular motion within those two end-loops could be reversed, when the path crosses over itself to give $c = 1$ instead of $c = 0$. Yet a single crossover by *one turn* about the minor magnetic axis actually requires *two turns* of phase or rotation about the major electrical axis, due to spin ½ symmetry. Hence the vectors for angular momentum within each of those two end-loops will continue to add in phase, with a reduced value of $n/(1 + c)$ for any values of n and c found in atoms.

Similar arguments could be made concerning the d path, where the electron may join to itself after having lost either one or two turns of rotation or phase, about its minor magnetic axis (equivalent to two or four turns about the major). That situation yields either one or two crossovers as $c = 1$ or $c = 2$ (Fig. 8c, lower), which represent the two kinds of d path proposed by Dirac as $3d(3/2)$ or $3d(5/2)$. The $c = 1$ path $3d(3/2)$ shows the same magnetic energy as $c = 1$ for $3p(3/2)$, while that of $c = 2$ for $3d(5/2)$ is only two-thirds as great.

In summary, the experimental nature of magnetic fine-structure spectra suggests most simply a "closed-path interpretation," where the electron may join to itself end-to-end for various values of n and c. The parameter n tells how many orbital or spin waves have joined in phase to create an open circle; while the parameter c tells how many times that open circle may have crossed over itself to reduce any torsional stress of end-to-end joining, and to reduce the net angular momentum and magnetism in discrete steps as observed (*cf*. the instability of twisted magnetic fields). Certain details of this model will require further study, yet the overall picture seems clear at present.

11. Wr-Lk-Tw and Entanglement

When written in terms of the symbols used for *topology* (25-27), the parameter $c = (l + s - ½)$ as taken from the Dirac equation for a hypothetically closed electron path seems to provide for a relation similar to $Wr = Lk - Tw$ of a closed ribbon or ring. Here $c = Wr$ describes any integral *writhe* or crossover of the ring through space and time (*i.e.*, the extent to which coiling of the path has replaced local twisting); while $l = Lk$ describes its total loss of end-to-end turns or *linkage* when joined; and $(s - ½) = -Tw = 0$ or -1 describes any remaining torsional stress or *twist* not cancelled by *Wr*.

The loss of turns *Lk* would equal 0 for *s*, 1 for *p*, or 2 for *d*, *etc.* We argue here that the integral nature of *Lk*, and similarly the quantized nature of magnetic energies in atoms, may arise due to an underlying periodic structure for the electron on a very small scale, where the two ends of any closed path can only join using an integral $m \times 360^{\circ}$ of phase or rotation about its minor magnetic axis. We argued previously that the quantized nature of electrical energies in atoms could be derived similarly from an underlying periodic electron structure, due to a reciprocal exchange between separate particles at a distance, of finite electrical self-energies equal to $1/137n$. The extent of crossover *Wr* may in fact adopt quantized values for certain three-dimensional shapes in general (27), but no specific studies have yet been done on higher-dimensional topological isomers to look for a quantization such as $1/(1 + c)$.

Other authors have suggested that the electron paths may be well-defined and not purely random. For example, Bohm and Hiley (28) refer to a "quantum wholeness" which permits action-at-a-distance between different parts of the electron that are widely separated in space. According to the present model, any two parts of an electron which are widely separated in space may still be linked in a topological sense; so that any action which is taken on one part may affect the other without concern for light-speed *c*.

For example, the action-at-a-distance effects as seen for "entanglement" (29,30) could come about, if two entangled photons 1 and 2 somehow remain linked in a topological sense over great distances, to yield $Lk = 0$ for the pair as a whole. Disentanglement of that 1-2 pair due to measurement at a detector might then release a pre-existing topological linkage, to leave $Lk = -1$ for photon 1 but

$Lk = +1$ for photon 2 (or *vice-versa*) in an apparently instantaneous fashion. The very phenomenon of entanglement argues strongly for a *continuity* of photon structure over long distances through space, in accord with the present model.

This work is not intended by any means to be the last word on finite periodic structures, but merely a naïve and somewhat controversial starting point for others to continue both theoretically and experimentally (31). For example, a detailed particulate model for the electron, which postulates 128 monomers for every two turns, leads to a calculation of bare electric charge as 1/129 and screened electric charge as 1/137.036.

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