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On the Electrodynamics of Stationary Events

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Abstract

The present paper traces the consequences of a natural reinterpretation of the allowed energy states of the Dirac electron. It is argued that a physical model should not rely upon quantity and number. That constraint is met by the substitution of the mathematical opposites of positive and negative with the physical opposites of actual and potential, which leads naturally to a picture of elementary particle behaviour which conforms with special relativity, and exhibits many well-known counterintuitive features of quantum mechanics. Individual elementary particles oscillate between actual and potential states. The oscillation requires that geometrical relations and other observables are discrete. In addition, stationarity is generalized to all system variables. The oscillation is serial one-particle creation and annihilation, in which particle position changes not by continuous motion but by stochastic re-localization in time and space. Spacetime for the electron is serially absent and continuous. The energy of an elementary particle can only be known for the duration of a complete cycle of the oscillation and not at an instant. Energy is bounded from below and is always non-negative. The model physically restricts particle interactions to two-particle antisymmetrical ensembles, which therefore comply naturally with Pauli exclusion.

Keywords: Discrete electron, Physical model, Quantum mechanics, Special relativity, Mathematics and reality

1 Introduction

Efforts to understand the electron within the framework of quantum theory have proceeded in the absence of underlying principles which lead naturally to the kinematics of quantum systems. Such principles might assist in making the distinction between classical and quantum concepts and their relevance to elementary particle behaviour. Einstein's opinion of the absence of a foundation for quantum mechanics and the limitation of classical theory as the source of those principles is well known:

> 'It is to be expected that behind quantum mechanics there lies a lawfulness and a description that refer to the individual system. That it is not attainable within the bounds or concepts taken from classical mechanics is clear' [6].

Several fundamental questions about quantum mechanics, that have remained unresolved since the nineteen-thirties, go beyond an explanation for the strange and counterintuitive behaviour of quantum systems. For example, it is by no means settled whether quantum mechanics is a complete theory or not, or quite what it is a theory of [15], and a description of individual quantum events remains outside the scope of the quantum formalism [12]. Importantly, it may be the case that the quantum analogues of the mathematical categories of classical physics are yet to be found [3].

The physical interpretation of the meaning of mathematical models and their relation to phenomena is not always simple or clear cut. The problem of the unreal consequences of the Dirac equation for the electron is an example of the difficulties that can arise when trying to gain a physical understanding of the mathematics. The equation is rightly regarded as a high point of achievement in the development of quantum theory, but in the early years following its discovery three of its physical consequences were regarded as problematic: (i) energy values of less than zero, (ii) the motion of the electron at the speed of light and (iii) an equal role for time with space in its description. How were the mathematics and physical reality to be reconciled? Dirac's response is well-known, he chose in favor of the retention of the prevailing picture of reality and dealt with the inconsistency by an extension of the mathematics. He proved that by a unitary symmetry transformation negative energy solutions could be transformed into positive energy solutions with opposite charge and the same mass [4]. This strategy preserved for quantum theory the concept of energy that had been developed by classical physics.

The alternative to Dirac's approach is to assume that the original mathematics were an adequate representation of the quantum electron and that the inconsistency arose from the inadequacy of the understanding of matter in the quantum domain. The implication being that negative energy and the other two problematic consequences of the equation may pertain to elements of quantum behaviour that are outside but underlie the domain of classical phenomena.

For this reason it is appropriate to reanalyze the problem of the physical consequences of the original, untransformed Dirac equation with the aim of arriving at a logical and consistent model of electron behaviour that harmonizes with the physical consequences of the equation and is: (a) simple and clearly defined (b) economical of postulates and (c) in agreement with phenomena. It is also appropriate that initially the analysis not be mathematically formalized.

The paper is divided into 7 sections. In section 2 the non-mathematical analogue of positive and negative energy states is developed in terms of the actualization of potential. The concept of potential differs fundamentally from physical potentials such as potential energy or electric potential. It follows from the concept of potential, of the Aristotelian type, suggested by Heisenberg as an aid to understanding quantum mechanics [10]. In section 3 the oscillation of the electron is derived from the potential–actual concept and generalized to the photon and proton. It is argued that absolute discreteness in the form of serial events arises naturally from the oscillation. In section 4 the special relativistic constraint and the real and virtual photon are described. Event interactions are generalized from the electron self interaction in section 5. Pauli exclusion is a consequence of particle interactions. Section 6 outlines how the model deals with the mass difference of the photon and the electron. Section 7 is a brief discussion of the model.

The energy states of the electron are given a logically equivalent, non-mathematical, physical description. The other two *unreal* physical consequences of the equation are then seen to be necessary elements of the same analysis. The description is achieved by a transformation of mathematical opposites, as applied to the values of physical variables, expressed in the usual way by the use of the symbols (+) and (–), into a physical analogue. When combined with the oscillation of the Dirac electron the result is a serial coupling of elementary particle properties with their opposites, that take the form of the actualization of potential. The analysis shows that quantum behaviour can comply with special relativity at a non-classical as well as the classical level.

2 The physical meaning of positive and negative energy states

Energy for the present model is defined, as in classical physics, as: The quantity that is the measure of the capacity of a system for doing work. In addition, energy is always the energy of something; it always belongs to an object or system. Dirac introduced the concept of positive and negative energy states with his relativistic equation for the electron, which allows the possible results of a measurement of kinetic energy to be positive or negative. The mathematical representation of the allowed energy states, denoted in the usual way by positive (+) and negative (-) symbols, gives them the relation of opposites. Here, the physical analogue of the mathematical relation of opposites is the Aristotelean physical opposites of actual and potential [1].

Positive energies are those associated with real, or actual, objects such as the classical electron—physical states have positive energy. The central postulate of the model is expressed as follows: the opposite of the energy of the actual electron is identical with the energy of the opposite of the actual electron. The opposite of the actual (or real) electron is the potential electron. Thus, the energy of the electron may be actual or potential, dependent upon its being attributed to an actual electron, or its opposite, a potential electron.

3 The electron oscillation

When outlining the features of his relativistic equation for the electron, Dirac remarked: “It is found that an electron which seems to us to be moving slowly, must actually have a very high frequency oscillatory motion of small amplitude superposed on the regular motion which appears to us.” [5] It is this oscillation that couples the actual and potential energies of the electron.

The physical consequence of the coupling is to transform the electron into serial phases of physical actuality and immaterial potential. The frequency of the oscillation is given by $2f_0 = 2\text{mc}^2/h$ which is about 2.5 x 10^{20} cycles per second. The amplitude of the oscillatory motion of the electron was shown by Schrödinger to be given by $1/2\hbar/mc$, which is about 1.9 x 10^{-13} meters. For the present purposes the the electron may be analyzed in terms of the oscillation of its two phases.

3.1 The potential phase of the oscillation

For the potential phase of the oscillation, the values of all physical quantities, including energy, are zero. For a single electron, an allowed energy of a magnitude of less than zero is interpreted as a potential to achieve real energy of that magnitude in a subsequent actual phase. The physical opposite of actual energy is the potential to achieve actual energy. The realization of the energy potential is the actualization of the electron, together with its other properties.

The potential of the electron is motivated by a single imperative which is simply and entirely its own self-actualization This follows from the fact of the persistence of material reality. The imperative of the potential is the origin of the oscillation which gives rise to the actual phase. The potential includes the capacity to achieve the realization of every possible physical property that could characterize an actual event in the life of the electron.[1] The potential of the oscillating electron is not exhausted by an individual actual event. In the case of an electron event there always remains scope to have been otherwise, within the constraint of its potential. For example, an electron event might actualize as a particle-event or a wave-event. What is important about wave–particle duality is not the realized fact but rather the retained potential for the unrealized alternative which did not actualize The possession of potential is a necessary but not a sufficient condition for its realization in some event. It might be neither a particle- nor a wave-event.

[1] The event is the sum of the constituent variables realized by the actualization phase of one oscillation. 'Event' includes the stationary state at the termination of 'actualization'; which is the classical aspect of the electron.

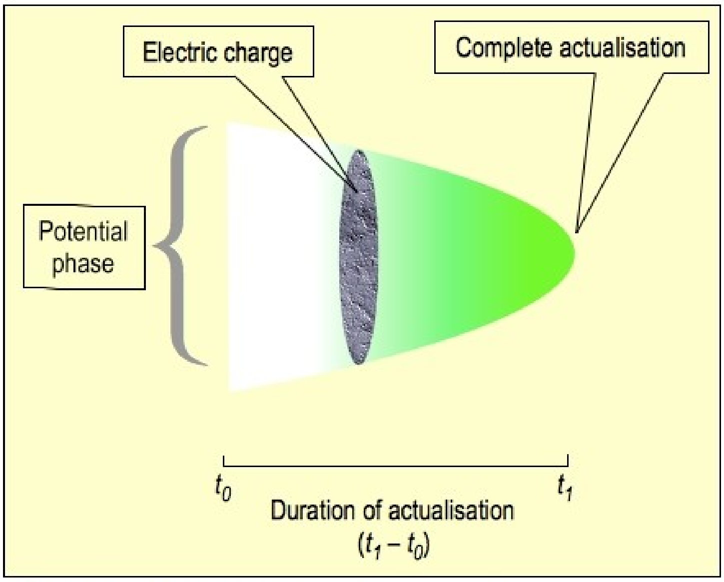

Figure 1: The actualization of potential.
Colour on line.

Figure 1 illustrates the actualization of potential during one oscillation, which constitutes an event. Complete actualization at t_1 represents the classical aspect of the event. The part of the event prior to complete actualization is non-local. The properties of the event include electric charge and the internal and external geometric relations of the event. The internal geometric relations of the electron chiefly concern the distance, duration and direction that separate its own contiguous actual events. External geometric relations are those that relate each event in the life of the electron to every other elementary-particle actual event in the universe. Both sets of geometric relations arise within the constraint of the initial conditions which are part of the potential for an actualization that derives from its immediate antecedent event. The potential of the isolated oscillating electron is not static. Each actualization in the series of oscillations contributes anew to the *content* of the potential for the ensuing actualization (see below).

The potential phase of the oscillation is bereft of all space-time relations, both internal and external. Consistent with the absence of energy in any form, the potential electron has neither mass nor any other physical property, including position in space or time. Geometric relations, mass, energy and electric charge are all absent from the oscillating electron during its phase of pure immaterial potential; some or all of which maybe energetically developed during the actualization phase.

The oscillation renders every property of the real electron, including its geometrical relations with its own antecedent events, discrete in space and time. The process of the actualization of potential is separated from its immediate antecedent event, not in space and time, but by the absence of space and time,[2] which characterized the intervening potential phase—it is nonlocal. The electron in its potential phase occupies an immaterial vacuum state, which is unrelated to any material actual event by distance, direction or duration.[3]

3.2 The actual phase of the oscillation

The electron potential begins to actualize without any physical features or properties. The actualization is energetic and it takes time. It culminates as an instantaneous actual particle with any or all of its usual properties of electric charge, angular momentum, mass and internal and external geometric relations. The total energy of the ideal electron exclusively performs the work of its own actualization. The completion of actualization is the classical aspect of the discrete electron.

Each serial, complete actualization of the electron is a stationary event, which is spatially and temporally separated by distance, direction and duration from all the other events of the universe, including the antecedent stationary events of which the electron is composed. The geometric separation of a stationary event and its antecedent is realized upon the completion of actualization. When complete, the energy and all of its properties instantaneously decay to zero, whereupon the electron oscillation is again in the phase of immaterial potential, from which it then begins to actualize. The electron lacks the potential to physically extend beyond actualization, there is no continuous being in the life of an elementary particle..

3.3 The energy of the discrete electron

The model has important consequences for the concept of the energy of the electron. Energy is only active; it continually converts potential to actuality, changes the locus of the system in space and time and is converted into the mass of the system. It follows from the model that energy is not directly observable and

[2]In the present scheme, consistent with the economy of introduced postulates, there is neither space nor time, apart from geometrical relations among objects. The domain that is bereft of space and time is the vacuum. Like distance, direction and duration, 'vacuum' is relative to a system that occupies such a state. Vacuua do not contain real objects.

[3]By contrast with the present concept of the potential of an isolated system, the de Broglie-Bohm potential is seemingly separate from both the wave function and the continuously moving particle. The motion of the particle is guided by the combined effects of the wave function and the potential [11, 2]. In the present scheme, wave functions are unreified mathematical objects which are concerned with the potential of the system for which they are written, not components of the oscillating physical system. The potential, in the present scheme, is inseparable from the particle whose kinematics do not entail real waves or fields.

neither does it have a definite value at an instant; all that can be said of the energy of the system is that it is always non-negative and relates to a duration, not an instant. The lower bound of the energy of the electron is zero. Measurability of any variable, including energy, only *follows* each discrete burst of action of the system, i.e. an oscillation.

Prior to the completion of the action of the energy there is neither time nor space for the system or its observables, without which there is nothing to measure. Evolution in time is not continuous - nothing happens continuously or classically. Observable classical variables are necessarily derivative. Measurable classical data do not include energy at an instant; definite energy can only be known for the duration of one or more oscillations.

4.1 The geometric constraint

According to Einstein, in the absence of matter there is neither space nor time [7]; there is no geometry. In classical physics space and time seemingly extend continuously throughout the universe, thus the above assertion is somewhat contradictory. However, it is a necessary element of the discrete model. Following the completion of actualization, the oscillating electron consists entirely of immaterial potential because its energy has decayed to zero. From the standpoint of the electron in the potential phase there can be no space or time. This state of affairs is consistent with the concept of relational space and time, in which space is the distances and direction and time is the duration that relate serial actualizations of the matter particles of the universe. There is neither space nor time for the electron between its serial actualizations.

For the oscillating electron, Lorentz invariance emerges upon the completion of actualization, when the classical, material electron occupies a fixed position and is at zero energy. It and the rest of the universe of events, also at zero energy, are geometrically related by flat spacetime. The process of actualization does not belong to the universe of observable events. At the completion of the actual phase of the oscillation charged particles emit the photons that enable their observation (see below). Thus, the geometric conditions for Lorentz invariance of the co-ordinate system of the electron arise with flat Minkowski spacetime together with the creation of the photons that enable its observation. It does not follow from this argument that special relativity does not constrain the process leading to complete actualization—it does.

4.2 The kinematic constraint

The rules that relate to the speed of light, mass and the mass–energy transformation relation provide the special relativistic constraints on the actualization phase of the oscillation. Those three elements of special relativity all concern the concept of mass. It is of interest that Einstein considered his new concept of mass to be the most important result of special relativity [8].

Special relativity requires that mass limit the rate at which a particle can change its position; which in continuous physics is the speed at which it moves. A particle with mass cannot change its position as fast as a massless photon; one consequence of which is that it cannot overtake a photon that it has emitted. The difference between their speeds is absolute, irrespective of the speed of the charged particle.[4]

According to this analysis, the nineteenth-century field theory requirement that a particle interact with itself, which is absolute, is rendered relative by the twentieth-century advent of special relativity. Indeed, there never was a consistent theory of the action of a particle on itself [16]. In the present model a charged particle cannot interact with itself via its own emitted electromagnetic boson—the photon. The relative–absolute distinction is an effect of the concept of mass, as understood in the theory of special relativity.

The speed at which a particle changes its position, in the discrete scheme, is inversely related to the duration of its actualization. This follows because the zero-energy, nonlocal component of the oscillation makes no contribution to the duration of the journey of the particle, whether it has mass or not. The particle tunnels instantaneously [14, 13] between the loci at which serial, stationary events form. The photon, being the fastest moving component particle of the atom, therefore, has the shortest duration of actualization, which follows from its being uniquely of zero mass.

4.3 The real photon and electric charge

Charge is defined to be a property of some elementary particles that enables them to exert forces on one another. For present purposes, the property enables charged particles to annihilate photons. The physical interpretation of the concept of opposites is applied to charge in the same manner that it is applied to energy. Therefore, the opposite of the charge of the electron is the charge of the opposite of the electron, which is zero charge of the potential electron. Energy and charge are each properties of a single oscillating electron that actualize and then decay to the opposite status of immaterial potential.

By contrast, among the low-energy components of the atom, the opposite of the *polarity* of the charge of the electron is the polarity of the charge of the proton. Photons do not distinguish the polarity of the charges of the electron and proton. For a photon, the opposite of the electron charge is the absence of charge because the opposite of annihilation is endurance.

If the space separation and phases of the oscillations of an electron and a photon are suitably related, both potentials will couple in the actualization of a

[4]This limitation does not apply to an atom which can annihilate a photon it created, e.g. when one charged particle creates a photon and another annihilates it, and both particles belong to the same atom.

single event. Such a charge-dependent co-actualization energizes the electron and annihilates the photon. The ensuing potential phase of such an excited actual electron consists in the double potential of a photon and an electron, without any properties, including charge. The two components of the coupled potential begin to actualize simultaneously. The duration of actualization of the electron is absolutely greater than that of a photon because of their absolute mass difference. Therefore the photon potential completes its actualization before that of the electron—thus the electron has created a photon.

The crucial consequence of the absolute difference in the rates of actualization of the photon and electron potentials is, heuristically, that the charge of the oscillating electron does not become actual in time to effect the capture of the actualizing photon; their phase relations are no longer propitious for their co-actualization. Photon creation by an oscillating electron occurs in the potential phase and photon annihilation occurs during the actual phase. For photons and charged particles, electric charge is the discrete property which enables photon annihilation, and their absolute mass difference is the basis for photon creation. For a single isolated electron, photon creation and annihilation relate serially to one another; they do not occur simultaneously.

4.4 The virtual photon

The real photon oscillates between actual and potential phases when alone and effectively isolated from charged particles, during journeys of indefinite distance and duration, across a room or across a galaxy. The sum of the durations of the actual phases gives the photon the finite value of the speed of light; the nonlocal potential phases make no contribution to the duration of the journey[5].

By contrast, a virtual photon is created in the potential phase of one energized, charged particle and is annihilated by its co-actualization with another charged particle, without achieving photonic actualization between its creation and annihilation; virtual photon transfer is effected 'during' one potential phase of a single oscillation. Such a photonic potential, is a virtual photon tunneling between two charged particles, the one which created it in a potential phase of its oscillation and the one which annihilated it during an actual phase. Because the virtual photon tunnels during a single potential phase, from which space-time relations are absent, it does so instantaneously; which is the Hartman effect [9]. The special relativistic mass effect that prevents the photon emitter from recapturing its own photon paves the way for the one-way transfer of a virtual photon between two charged particles. There is no difference between individual potential phases of a real photon and the single potential phase of a virtual photon and neither is there a difference between their creation or annihilation. However, the virtual photon cannot in principle be observed.

[5]The duration of actualization is the equivalent of the dwell time; the time to traverse a potential barrier. In the present model: the time that separates two events between which the photon tunnels.

5.1 The discrete self-interaction

In continuous physics, there is no concept of a bond that maintains the enduring electron because the electron has no parts to be bound. By contrast, all isolated systems, whether classically divisible or indivisible, including the discrete oscillating electron consist of a series of motionless events. Those actual events are individual, material parts of the history of the enduring electron, separated both in time and space. Therefore, the discrete electron requires a bond between the events of which it is constituted in order to explain its endurance. That bond is the potential phase of its own oscillation, which binds a pair of contiguous events of the enduring electron. The immaterial potential phases of the electron have the rôle of binding the material parts of the oscillation, which gives the electron its temporal endurance. Accordingly, each phase of the oscillation is then either bosonic or fermionic. The same analysis applies to the proton and real photon.

The principle of elementary particle endurance, is that each motionless event that constitutes the particle is bound to the source of the potential which it actualizes; the bosonic potential forms the bond between a contiguous pair of fermionic events. The bond is the immaterial, nonlocal actualization of the potential derived from the immediate antecedent event. The potential, which includes the geometrical component of its initial conditions, provides the constraint upon where and when the event occurs, in relation to its antecedents. The potential of an elementary particle does not enable its constituent events to avoid compliance with Newton's laws of motion, or to behave chaotically. This is the elementary-particle self-interaction, which we are now able to generalize to include the electromagnetic interaction.

5.2 The real photon-electron interaction

The potential of the oscillating real photon may be analyzed as consisting of two elements. The first is its energy potential, which continually actualizes each of its constituent events. That component of its potential has its origin with the actual event that created the enduring photon, at the other side of the room or galaxy. The energy potential is repeatedly realized with each event in the life of the isolated real photon. The second element of its potential is the geometric component of its initial conditions which originates with the source of the potential that actualizes the event; which is its immediate antecedent event.

When the real photon is annihilated by a charged particle, e.g. an electron, both components of the photon potential co-actualize with the potential of the electron. The photon contribution to the event is supplied by both components of its potential. The photon energy excites the electron to a higher energy level and contributes to the energy that is converted into the mass of the event (see below).

The geometric component contributes to where and when the event actualizes, in accordance with Newton's laws. The internal geometric relations of the actual event are subject to the constraint of the geometric relations of both sources of the potential it actualized, viz. the immediate antecedent electron event and the immediate antecedent photon event; the latter is the last event in the life of the photon. The locus of the event is thus subject to the loci of its two antecedent events.

From the standpoint of the electron, the geometrical element brought to the event by the real photon is random with respect to the geometry of its origin. The influence of the photon on the geometric locus of the electron event will therefore depend upon the geometry of the separation of the two antecedent events, which were the sources of the potentials co-actualized. Such a real photon might have come from any direction. The outcome is consistent with the concept of 'zitterbewegung', viz. trembling motion of the oscillating electron.

5.3 Virtual photon-mediated electron pairing

The co-actualization of the potential of a virtual photon with the potential of an electron binds the resultant event to the sources of the two potentials it actualizes. In contrast with the origin of the transferred potential of a real photon, which is the last event in the life of an isolated photon, the transferred potential of a virtual photon has as its origin an event in the life of the charged particle that created it.

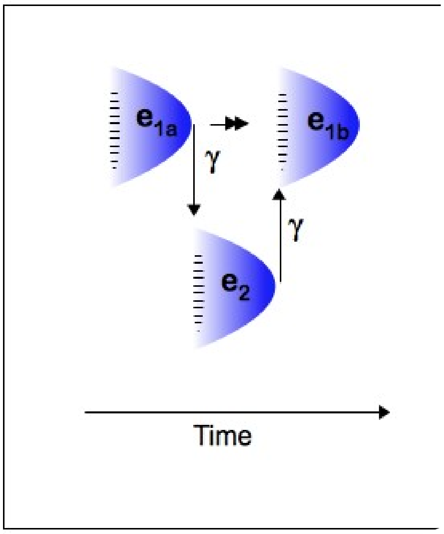

Figure 2: Electron pairing. *Colour on line.*

Figure 2 shows the scheme of the ideal two-particle electromagnetic interaction for an electron pair. Just as there is no classical connection between successive bound events, e_{1a} and e_{1b}, of a single electron, neither is there a classical connection between electrons 1 (e_{1a} and e_{1b}) and 2 (e_2), at any time; both bonds are nonlocal. The contribution of a virtual photon (γ) from event e_2 to the total potential of the event e_{1b} consists of (i) an energy contribution to the co-actualization of the electron event and (ii) the constraint of the geometrical relations of events e_{1a} and e_2. Those two elements of photon-mediated potential, both of which derive from event e_2, co-actualize with the potential (double arrow) of event e_{1a}. They are the charged-particle event that created the virtual photon and the immediate antecedent of the actualization of the event that annihilated it. Both (i) and (ii) derive from the same charged-particle event.

Where and when the co-actualization of the potentials of a charged particle and a virtual photon terminates is subject to the constraints of the geometrical relations of both charged-particle events which were the origins of the two components of the co-actualized potential. Bound pairs of interacting charged particles are where and when they are in relation to one another as the result of the repeated reciprocal one-way transfer of virtual photons between the stationary events of which they are constituted. A single principle explains the bond for (a) the enduring one-electron system, (b) the interaction of the two-particle, real photon-electron system and (c) the virtual-photon mediated electromagnetic bond between two charged particles.

5.4 Pauli exclusion

Photon annihilation and creation by the oscillating electron enables electron pairing which does not violate Pauli exclusion. The electron-pairing interaction, depicted in Figure 2, shows the phase relations that enable a virtual photon to be created by one electron and annihilated by a second electron; their geometric relations must enable the instantaneous photon transfer between the potential phase of the creator and the actualizing charge of the annihilator. Their phase relations mean that one electron is fermionic and the other is not. The generalized interaction obeys Pauli exclusion naturally, it is restricted to antisymmetrical two-particle ensembles—all others are excluded. The bound ensemble is temporally discrete, with a duration of $\tau = \sim 10^{-20}$ s.

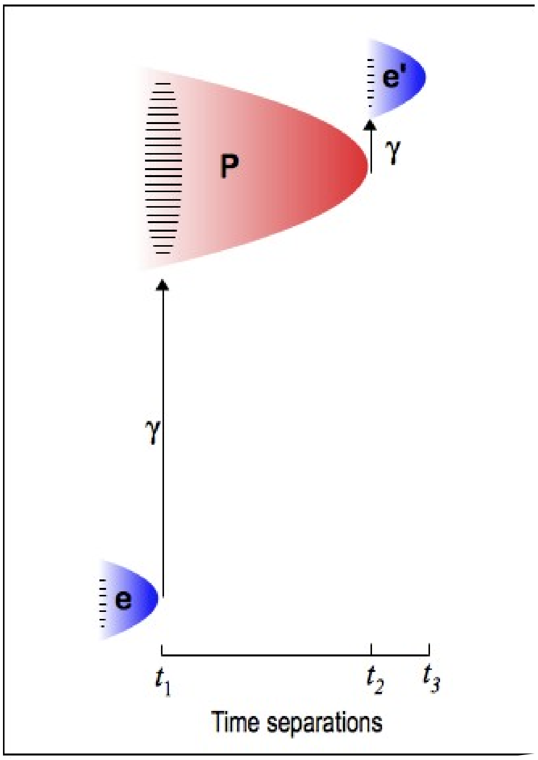

Figure 3. The discrete hydrogen atom. *Colour on line.*

5.5 The hydrogen atom

It follows from the relation between mass and the duration of actualization, that for a two-particle interacting system that consists of charged particles of equal mass, the repeated time separations of their constituent events are not constrained to differ. By contrast, the mass difference of the proton and electron, of the hydrogen-atom bound state, causes different durations of their actualizations. Figure 3 depicts the electromagnetic interaction for the hydrogen atom, in which the transfer of a virtual photon (γ) from the electron designated e to the proton (P) results in a greater temporal separation (t_1 to t_2) between them than the separation (t_2 to t_3)

following a transfer from the proton back to the electron designated e'. The longer duration of the proton actualization causes a greater separation in time between the classical aspects of the electron which created the virtual photon and the proton which annihilated it. Thus, the electron of the hydrogen atom alternately occupies a space-time locus that gives it a fluctuating greater and smaller separation from the proton in spacetime, as shown in Figure 3. The mass-induced variable separations for the hydrogen atom assumes a serial switch in direction of virtual-photon transfer. The observed spectral splitting in the hydrogen atom is consistent with the two different electron-proton separations.

The electron does not undergo continuous motion between the two positions relative to the proton; the oscillation between the two electron-proton separations is consistent with the observed discrete, emission spectral-line splitting of the unperturbed hydrogen atom. Because the electrons of neutral atoms interact with protons of the nucleus, by directionally-alternating, one-way transfers of virtual photons, all the emission spectral lines of any atom should exhibit splitting. The discreteness of atomic electron energies which is reflected by the discrete nature of line spectra is consistent with the present model of stationarity, in which the modeled hydrogen atom electron only has two energy levels. The observed line spectra are fully consistent with photon emission that only occurs at the termination of actualization. There are no interphenomena for the electron which is only ever at e and e'.

The electron and proton durations of actualization act as a constraint on the two separation intervals. In the discrete model of the hydrogen atom bound state, the electron cannot collide with (spiral into) the nuclear proton because of the electron mass and the instantaneous transfer of virtual photons. The minimum condition for such a collision is that both actualize simultaneously. It can be seen in Figure 3 that the interaction does not allow simultaneity of actualization. The interaction manifests naturally as Pauli repulsion.

6 The mass–energy transformation relation and the origin of electron mass

The relativistic mass–energy transformation relation is important for the conversion of energy into mass during the actualization phase of the oscillation. The energy of the electron exclusively performs the work of its actualization during each of its oscillations. From the simplicity of the postulated oscillation process it follows that the energetic actualization of elementary particles with and without mass must differ absolutely. The need for an absolute difference arises from the observation that the quantity of energy of an elementary particle is unrelated to its transformation into mass; photons of all energies have zero mass. Regardless of the energy of the real photon, none is converted into mass during the series of events between its creation and annihilation.

Each actualization between creation and annihilation of an isolated, and therefore real, photon is the realization of a one-particle potential. There is neither co-actualization with additional potential nor conversion of its energy into mass; the two are correlated. Of the oscillations of the three matter particles and the photon, which constitute the low-energy atom, only that of the photon occurs without co-actualization and without conversion of energy into mass. The exception for the photon is its annihilation by a charged particle when the potential of each combines to form the double potential of the photon and the charged particle. The two co-actualize as a single event and energy is converted into the mass of the charged-particle event.

The electron, although without constituent parts, in the classical sense, is expected to continually co-actualize with and therefore annihilate photons of its immediate environment, whether as a single particle or part of an atom or electron plasma.[6] The model predicts that co-actualization of electron potential with ambient photon potential is the source of the mass of the electron. If an electron were able to be shielded from all photons in its environment it should have zero mass. If such an observation were made, it would be support for the theory.

7 Discussion

When seeking a physical meaning for a mathematical statement employed to describe natural phenomena we are faced with the issue of how and to what degree number and quantity are to be replaced by a non-mathematical physical description. Efforts to reduce a lack of harmony between mathematical and physical descriptions of reality usually focus on some kind of mathematical supplementation rather than casting doubt on seemingly clear and distinct phenomena. That response to the problem of negative energies has not been dispelled during the eighty years since the creation of the Dirac equation. In the case of the Dirac electron, we drew on the Aristotelean relation of opposites explicit in the terms 'actual' and 'potential' as a physical analogue of the mathematical opposites of 'positive' and 'negative' as commonly used of energy as a mathematical quantity. This substitution, when combined with the oscillation and applied to the electron, led to a physical description that is consistent with the rules of quantum mechanics and special relativity without relying on number or quantity. The analysis exhibits, naturally, several of the well-known counterintuitive aspects of elementary particle behaviour in a fully discrete framework.The form of the discreteness that arises for the electron is non-classical.

It does not entail lattice spaces that abut at boundaries. The phase of immaterial pure potential of the oscillation places individual elementary particles in a frame

[6] The annihilation of a real photon by an electron, in contrast to a virtual photon, does not form a bond between the charged particle that created the photon and the electron that annihilated it. Because an actual event of the energized electron is bound to the source of the potential it actualized; the electron is bound to the last isolated actualization of the photon and is unaffected by the photon's creator. The consequent electron behaviour is consistent with the concept of Zitterbewegung.

that is initially discrete in space and time. Following which, the complete actual event is geometrically related to all the other such events of the universe—classical continuity is thus restored. The latest event in the life of the particle joins the world of geometrical continuity. That discreteness is absolute due to the requirement that the actualizing event is separated from its antecedents by the absence of space and time. Space and time are relational and not always everywhere for the elementary particle.

Particle potential is neither real nor material but it exists. Virtual particles are not physical objects; they are materially unreal. However, in the present scheme, it is not inconsistent that the non-physical virtual photon is the electromagnetic boson.

The present analysis is of interest because it gives a natural explanation of a number of non-classical elements of quantum mechanics that confound continuous models. Examples include general stationarity of quantum states, Pauli exclusion, the time-energy uncertainty relation, the splitting of atomic spectral lines and instantaneous photon and electron tunneling are all instances of explanations that arise naturally in the discrete scheme, they are not put in by hand. The direction of the present analysis may prove fruitful in further demystifying aspects of quantum mechanics. Energy is bounded from below, is always non-negative, and never infinite.

Acknowledgment: I am grateful to Vincent Powell for helpful discussions.

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