

The Theory of the Extended Electron (Anti-Particles of Dirac and Majorana)

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Abstract

This theory proposes an extended model of the electron based on the image of the screened electron in the concept of vacuum polarization of QED. The extended electron consists of a negatively charged core $-q_0$ which is surrounded by an assembly (an aggregation) of tiny static electric dipoles $-q, +q$. When subjected to an external field, electromagnetic forces are produced on these point charges to give rise to various properties of the electron. Three major properties of the electron that will be explored in this theory are: 1) the effective electric charge of the electron; 2) the mechanism of the spin of the electron; 3) the mechanism of radiation of the electron. The investigation of these properties leads to various innovative explanations for the generation of anti-particle, the orbital of the electron, the strong nuclear forces between nucleons ... Other topics are also listed in the following content.

Keywords

The Extended Model of the Electron, The Core $(-q_0)$, Static Electric Dipoles $(-q, +q)$, The Effective Electric Charge Q , the Permittivity ϵ , The Permeability μ

1. Introduction: The Extended Model for the Electron¹

The model which will be used for discussion in this article is *a version* of the screened electron created by the vacuum polarization which is a concept of QED: The electron is a spherical extended particle composing a negatively charged core $(-q_0)$ which is surrounded by an assembly of static electric dipoles $(-q, +q)$; (**Figure 1**). When the extended electron is subject to an external field, electric/magnetic forces are produced on these point charges $(-q_0, -q, +q)$ to give

¹For more details, please read the article “**A new extended model for the electron**” at https://www.vixra.org/author/hoa_van_nguyen.

rise to various features of the electron such as its effective electric charge, spin & radiation and other consequences. It is a spinning spherical particle.

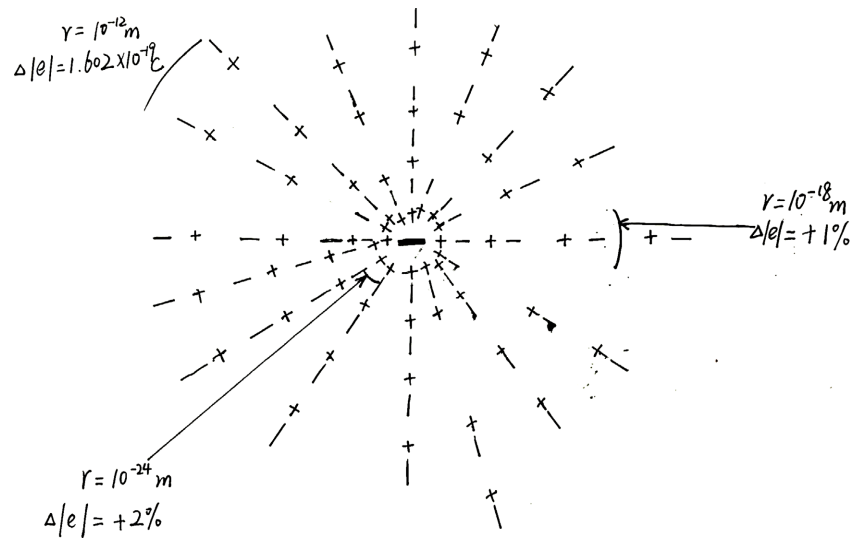


Figure 1. The electron is screened by virtual pairs (e^-, e^+) in the concept of vacuum polarization of QED. This figure is scanned from Figure 13.1 in the textbook “Nuclear and Particle Physics” by W.S.C. William.

Let's note that in this figure the magnitude of the electric charge “ e ” changes with the distance r . That is, it is an effective electric charge, (not a constant), depending on other physical factors, e.g., the applying field, the velocity, and the permittivity ϵ or the permeability μ of the electron.

This article attempts to explain this subtle phenomenon by proposing a heuristic equation for the effective electric charge of the electron and its consequences.

This theory of the extended model of electron will be presented in the framework of classical physics: the electron is assumed to be a particle and hence there will be no wave features in the discussion. This assumption is based on the results of the studies of J.J. Thomson on the cathode ray tube and the oil-experiment of Millikan. Two numerical values of e and m (electric charge and mass) of the electron produced by these two experiments are strong indications that they are solid particles: $e = 1.602 \times 10^{-19}$ C and $m = 9.109 \times 10^{-31}$ kg, because waves have no charges, nor masses.

This theory is an attempt to continue the works of these two famous physicists to explore more features that can be ascribed to the electron.

We note that in the physical literature, most of the models that physicists investigated, are the point electrons. Only some of them are of extended types: these are the early models of Lorentz, Abraham and Poincare', and the recent model of relativistically spinning sphere of Mac Gregor [1]: “*This is a quantum-mechanical model. It consists of a mechanical sphere of matter with a point charge e on its equator. The rest mass and radius of the sphere are $m_e = 340.270 \text{ eV}/c^2$ and $R = 6.6962 \times 10^{-11} \text{ cm}$ ”.*

Frank Wilczek [2] admitted in his article “*The enigmatic electron*” that the electron has structure, size, mass, spin, magnetic moment and electric dipole moment: “*An electron’s structure is revealed only when one supplies enough energy to unleash electron-positron pairs - at least 1 Mev.... The electron is effectively a spinning ball of charge and elementary electromagnetism tells us that this generates a magnetic dipole field. The size of that ball can be estimated to be roughly $2.4 \times 10^{-12} \text{ m}$.*”

2. The Electric Force F_e and the Generation of Antiparticles

When the extended electron is subject to an external electric field E , the net electric force F_e is produced on it. The calculations on the extended model of the electron show that F_e is the resultant of two opposite forces F and F' , i.e., $F_e = F + F'$, where F is the resultant of all electric forces f_e produced on *surface dipoles* $(-q, +q)$ of the electron ($F = \sum f_e$) and F' is the electric force produced on *the core* $(-q_0)$ of the electron. The results² are: (Figure 2 & Figure 3)

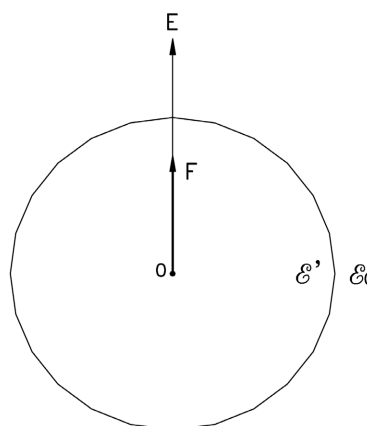


Figure 2. $\varepsilon < 1$: the resultant force $F = \sum f_e$.

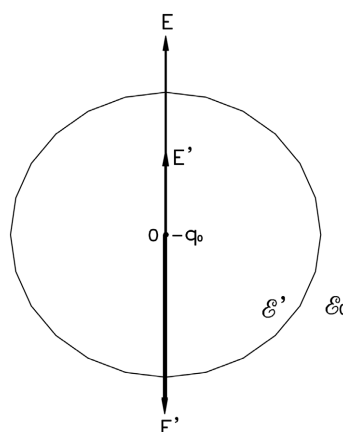


Figure 3. $\varepsilon < 1$: F' is the electric force produced on points in the direction of E : $F \uparrow \uparrow E$ the core $(-q_0)$, it is always negative: $F' \downarrow \uparrow E$.

²For detailed calculations please read the article: “**Extended electron in constant electric field**” at https://www.vixra.org/author/hoa_van_nguyen.

$$F = \left(\frac{1}{\varepsilon} - 1 \right) q E \sum_i^n \cos^2 a_i, \quad \varepsilon = \frac{\varepsilon'}{\varepsilon_0} < 1 \text{ is the relative permittivity of the electron} \quad (1)$$

$$F' = -(1/\varepsilon) q_0 E, \quad F' \text{ is always negative} \quad (2)$$

$$F_e = F + F' = \left(\frac{1}{\varepsilon} - 1 \right) q E \sum_i^n \cos^2 a_i - \frac{1}{\varepsilon} q_0 E, \text{ or} \quad (3)$$

$$F_e = \left[\left(\frac{1}{\varepsilon} - 1 \right) (q/q_0) \sum_i^n \cos^2 a_i - \frac{1}{\varepsilon} \right] q_0 E \quad (4)$$

$$\text{Let's set } a = (q/q_0) \sum_i^n \cos^2 a_i \quad (5)$$

“ a ” is thus a dimensionless positive number since q , q_0 and $\sum_i^n \cos^2 a_i$ are positive numbers, “ a ” represents *the form factor* of the extended electron in electric field.

By plugging “ a ” into Equation (1) and Equation (4), they become Equations (6) and (7):

$$F = \left(\frac{1}{\varepsilon} - 1 \right) a q_0 E \quad (6)$$

$$F_e = \left(\frac{a-1}{\varepsilon} - a \right) q_0 E, \quad a > 1 \quad (7)$$

For $\varepsilon \geq 1$: F , F' and F_e all are negative,

For $1-1/a \leq \varepsilon \leq 1$: F is positive, F' and F_e are negative,

For $\varepsilon < 1-1/a$: F_e is positive; i.e., electron becomes positron.

For the purpose of this article, we explore the net force F_e in the intervals: $\varepsilon \leq 1$ and $a > 1$:

- F_e is negative in the interval $1-1/a \leq \varepsilon \leq 1$: the electron behaves as a negative particle,

- F_e becomes positive if $\varepsilon \leq 1-1/a$: the electron changes its electric charge to positive: it becomes the positron e^+ , which is Dirac's antiparticle.

- $F_e = -q_0 E$ if $\varepsilon = 1$: the extended electron reduces to a point charge ($-q_0$); this means that the point electron is only a particular case of the extended electron when $\varepsilon = 1$.

- $F_e = 0$ if $\varepsilon = 1-1/a$: this is the point of transition between e^- and e^+ : $e^- \leftrightarrow e^0 \leftrightarrow e^+$

The ephemeral state e^0 appears to be the Majorana particle, which is its own antiparticle. At this state, the particle (e^-) coincides with its antiparticle (e^+). This is the state of the electron at the point B: $\varepsilon = 1-1/a$, $Q = 0$, $V = c$ as shown in the next section.

Therefore, the variability of the permittivity ε of the extended electron under the action of the applying field changes its effective electric charge Q and hence the direction of F_e . Owing to the direction of F_e with respect to the field E , we recognize the particle being an electron or a positron. The consequence is that the electron can undergo different states from e^- to e^+ via e^0 . In short, antiparticle originates

from its particle due to the variability of its permittivity ε which causes the change in its effective charge.

Note: Let's note that Dirac speculated the existence of the antiparticle (e^+) from his wave equation, but he did not elaborate how it was created; *i.e.*, what was the mechanism of its generation. In later sections, we will find out that the antiparticle is generated from its particle by the high field of the nucleus in the atom. Antiparticle originates from its particle: they have opposite charge (+ and -) but two charges are not necessarily equal in magnitude (as we usually assumed so far) because electric charge changes continuously, not discretely by unit charge e . As for the theoretical particle Majorana: it is its own antiparticle; this is the state of transition between particle and antiparticle when its charge tends to zero and its velocity tends to c (at B: $\varepsilon = 1 - 1/a$, $F_e = 0$ and $v = c$ in **Figure 4**).

3. Correlation between the Velocity v and the Permittivity ε

From Equation (7) we can deduce the effective electric charge Q of the extended electron as

$$Q = \left(\frac{\alpha - 1}{\varepsilon} - a \right) q_0, \text{ since } F_e = QE \quad (8)$$

The factor $\left(\frac{\alpha - 1}{\varepsilon} - a \right)$ is negative since F_e is negative in the interval $(1 - 1/a \leq \varepsilon \leq 1)$ and positive in the interval $\varepsilon \leq 1 - 1/a$ (from **Figure 4**).

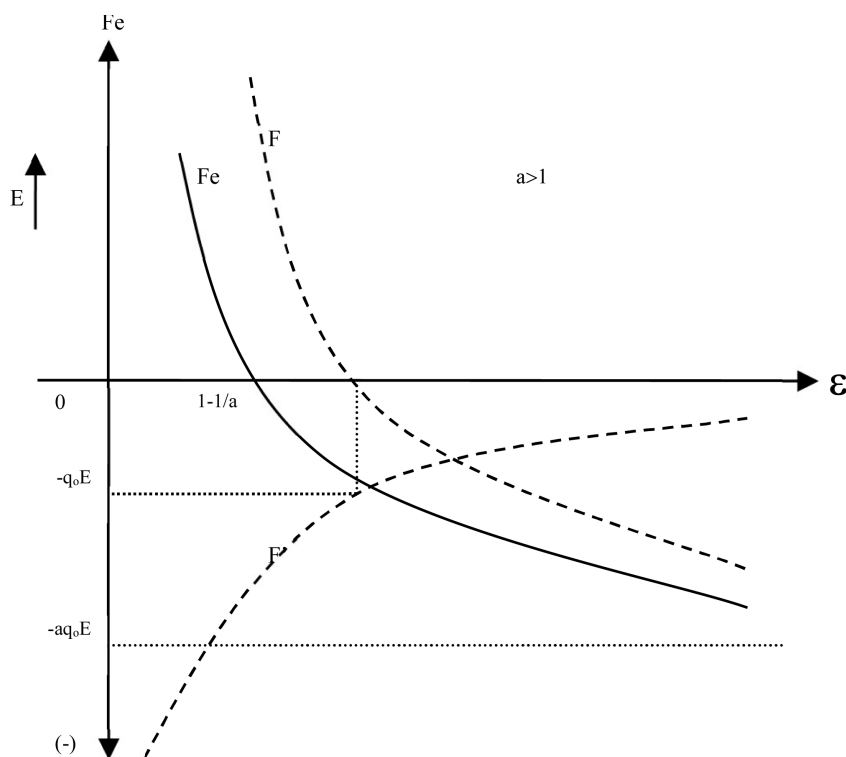


Figure 4. It shows F , F' and F_e as functions of ε .

Let us recall that in the previous article³, we have obtained the general expression for the magnitude of the effective electric charge of the electron when it is subject to an external field represented by the positive real number N :

$$Q = \left(1 - v^2/c^2\right)^{N/2} q_0, \text{ where } q_0 \equiv e \quad (9a)$$

Its graph, plotted by computer programming, is showed in **Figure 5**.

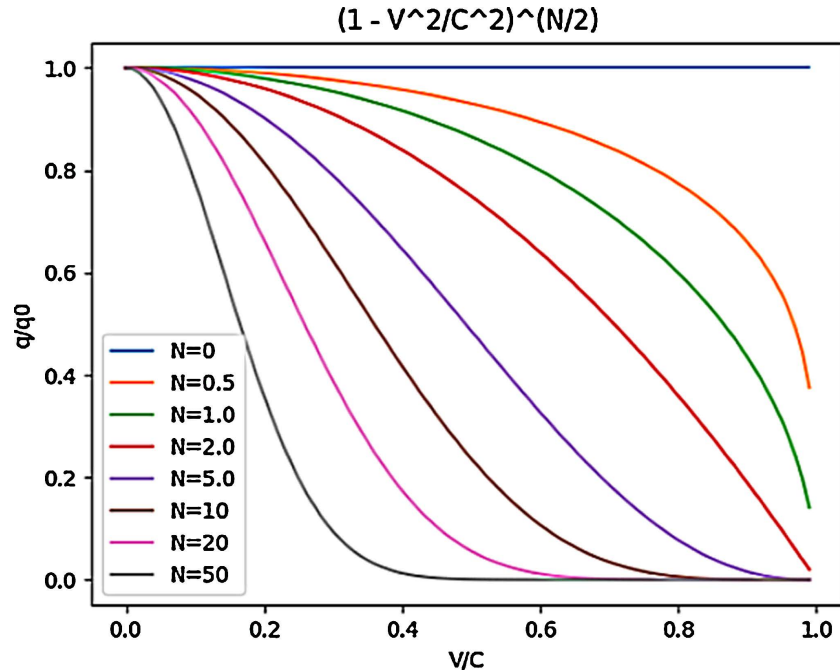


Figure 5. $q/q_0 = \left(1 - v^2/c^2\right)^{N/2}$.

Note: in this graph the effective charge Q is denoted as q , hence Equation (9a) is also written as

$$q = \left(1 - v^2/c^2\right)^{N/2} q_0, \quad q_0 \equiv e \quad (9b)$$

From the graph we notice that the higher the field (larger N) and / or the higher the velocity, the more the electric charge approaches zero. In low fields ($N = 0.5, 1.0$) the electric charge does not become zero even when v tends to c . In higher fields ($N = 10, 20, 50$) the electric charge of the electron becomes zero when $v/c \approx 0.8$.

The continuous variation of the electric charge of the electron (from 0 to e) includes all possible fractional charges such as $1/3, 2/3, \dots$; so, the concept that e is indivisible unit of electric charge is false. This also means that the concept of charge quantization (*i.e.*, electric charge of any particle must be a multiple number of e) is incorrect.

Now if we regard these two expressions (8) and (9) as correlated to each other, we get the correlation between v and ε :

³See article: “**Electron’s Mass and Electric charge, which one changes with velocity?**” at https://www.vixra.org/author/hoa_van_nguyen.

From Equation (8) and (9) we have: (a minus sign is added on the right hand side)

$$\left(\frac{\alpha-1}{\varepsilon}-a\right) = -\left(1-v^2/c^2\right)^{N/2} \quad (10)$$

$$v=0 \rightarrow \left(\frac{\alpha-1}{\varepsilon}-a\right) = -1 \rightarrow \varepsilon=1; \text{ this is point A in Figure 6} \quad (11)$$

$$v=c \rightarrow \left(\frac{\alpha-1}{\varepsilon}-a\right) = 0 \rightarrow \varepsilon=1-1/a; \text{ this is point B} \quad (12)$$

Now, in the interval $\varepsilon \leq 1-1/a$ F_e is positive, hence the factor $\left(\frac{\alpha-1}{\varepsilon}-a\right)$ is positive, Equation (10) is rewritten as (without the minus sign on the right hand side):

$$\left(\frac{\alpha-1}{\varepsilon}-a\right) = \left(1-v^2/c^2\right)^{N/2} \quad (13)$$

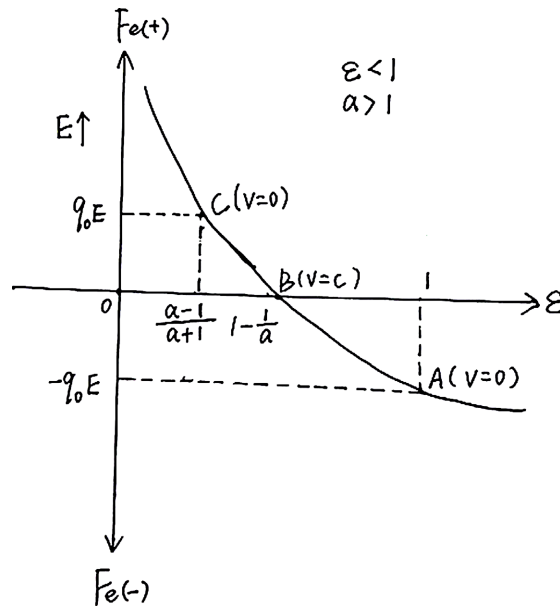


Figure 6. Electric force F_e vs ε .

$$v=c \rightarrow \left(\frac{\alpha-1}{\varepsilon}-a\right) = 0 \rightarrow \varepsilon=1-1/a; \text{ this is the point B}$$

$$v=0 \rightarrow \left(\frac{\alpha-1}{\varepsilon}-a\right) = 1 \rightarrow \varepsilon=(\alpha-1)/(\alpha+1); \text{ this is the point C}$$

Therefore, the applying electric field E causes the permittivity ε to oscillate in the interval $(\alpha-1)/(\alpha+1) \leq \varepsilon \leq 1$ and the electron oscillates between two states A and C via B (**Figure 6**)

At state A: $v=0$, $\varepsilon=1$, $F_e = -q_0 E$, $Q = -q_0$,

At state B: $v=c$, $\varepsilon=1-1/a$, $F_e = 0$, $Q = 0$,

At state C: $v=0$, $\varepsilon=(\alpha-1)/(\alpha+1)$, $F_e = -q_0 E$, $Q = q_0$

Let's examine the change of the acceleration of the electron while it oscillates between A and C via B:

- at A ($v = 0$): e^- is accelerated by the negative force F_e to the state B where $v = c$,
- at B ($v = c$): e^- changes into e^+ and is decelerated by the positive force F_e ; e^+ slows down to the state C where $v = 0$, (the turning point),
- at C ($v = 0$): e^+ is accelerated by the positive force F_e to B where $v = c$,
- at B ($v = c$): e^+ changes into e^- and is decelerated by the negative force F_e , it slows down to state A where $v = 0$ (the turning point) to complete the cycle.

Let's note that $v = 0$ at two points A and C, where the electron reverses its course of motion: these are turning points. At B, the electron reaches maximum speed c : this is the transitional point where the electron keeps moving in the same direction as before because it is moving with speed c , but it changes from electron to positron; and so, it is decelerated after passing the point B to reach the point C with $v = 0$ (Figure 7).

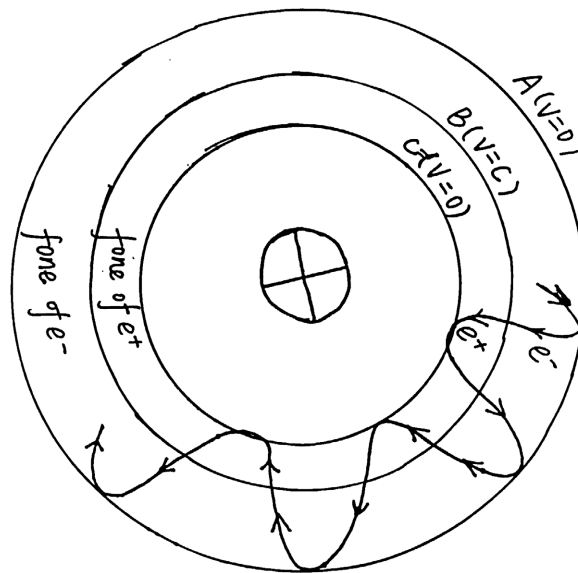


Figure 7. Orbital of e^- and e^+ around the nucleus p^+ of a hydrogen atom.

Conclusion: In the high field of the nucleus of the atom, as ε oscillates in the interval $(a-1)/(a+1) \leq \varepsilon \leq 1$, the electric charge of the electron alternatively changes from negative to positive, and thus the electron is alternatively subjected to attractive and repulsive forces. We will see this process in the following two phenomena: the orbital of the electron in the hydrogen atom and the strong force between nucleons (Sections 4 & 5).

4. Orbital of the Electron in the Electric Field of the Hydrogen Atom

Now, if we apply the above scheme to the movement of the electron in the electric

field E of the nucleus of the hydrogen atom (proton p^+) we find that the electron moves around the nucleus inside two spatial zones: the outer zone (where e^- is pulled inwards) and the inner zone (where e^+ is pushed outwards). These two zones of the orbital are separated by an intermediate region of e^0 where $e^- \leftrightarrow e^+$. **Figure 7** shows the imaginary zigzag (or spiral) orbit of an electron inside two zones of e^- and e^+ ; it is a speculative orbit.

According to this scheme, the electron never comes in touch with the nucleus, nor escapes it; and so, the atom remains stable at normal conditions. The e^- and e^+ can only escape the atom in turbulent conditions such as in collisions or in radioactive phenomena.

Therefore, the stability of the atom and the orbital of electrons can be explained by the variability of the permittivity ϵ and the ability of e^- to convert into e^+ and vice versa: the electron is thus alternatively subject to attractive - repulsive electric forces from the nucleus.

5. The Strong Forces between Nucleons

An extrapolation: not only can e^- convert into e^+ and vice versa (as we just discussed above), but p^+ in atomic nuclei also has this convertible feature. Here is an extract from current literature about the strong force between nucleons:

“In atomic nuclei, the strong force holds nucleons together in the nucleus. The short - ranged nucleons - nucleons interactions provide the strong attractive forces, which is counter- balanced by the structural integrity. That is, the nucleons are compressed together but not crushed by the attractive forces. The force is attractive at distances greater than about a fermi ($\approx 10^{-13}$ cm) but which turns strongly repulsive at shorter distances”.

The structural integrity (stability) of the atom is owing to the ability of the nucleon to convert into its own anti-nucleon by the strong field of the nucleus: $p^+ \leftrightarrow n^0 \leftrightarrow p^-$.

This phenomenon is analogous to the conversion of e^- into e^+ in the atomic orbital of the hydrogen atom: $e^- \leftrightarrow e^0 \leftrightarrow e^+$. This conversion discloses the existence of p^- and n^0 in the nucleus besides p^+ ; (the same as in the orbital of the hydrogen atom there exist not only e^- but also e^+ and e^0 : **Figure 7**). These anti-particles remain inside the atom in normal conditions; they break out of the atom when specific events such as collisions or radioactive phenomena occur.

These particles and anti-particles give rise to attractive - repulsive forces which are basically Coulomb forces for moving particles in short distances.

A prospect: if we can build in the lab an intense electric/magnetic field comparable to the natural strong field inside the nucleus, we can convert particles into anti-particles for the purpose of exploring the annihilation reaction to produce energy:

Particles (e^- or p^+) $\rightarrow$ High fields $\rightarrow$ Antiparticles (e^+ or p^-) $\rightarrow$ Annihilation reactor $\rightarrow$ Energy

$\uparrow$ Particles (e^- or p^+).

That is, the prospect of the generation of antiparticles (e^+ , p^- , ...) by high electric/magnetic fields is to generate a strong and controlled source of antiparticles to study the annihilation reaction in order to produce sustainable sources of energy.

Conclusion: The conversion of particle into antiparticle inside the atom offers an explanation of the existence of the attractive-repulsive interaction between short-ranged particles in the nuclei. In other words: the mechanism of the strong interaction between nucleons is due to the conversion of electric charge of the nucleons by the intense field of the nucleus.

By this way, we can avoid the exotic and confusing concepts like quark, gluon, color, flavour, Z' (Z primed), leptoquark, anyon, axion... of QFT or QCD.

Note: In 1973, three physicists: D. Gross, D. Politzer and F. Wilczek came up with a new theory, called “*Asymptotic freedom*”, to explain the strong interaction between nucleons in the nucleus (and between quarks inside the nucleon): when they come close to one another, the interaction is weak, but when they are far from one another, the interaction becomes so strong that the nucleon cannot get free from the nucleus: this is *confinement concept*. These three physicists were awarded Nobel prize in 2004 for the discovery of this theory.

6. Fractional Charge vs Charge Quantization

In the news of Nature Physics journal (03 July 2020) physicists reported the strong evidence for a quasiparticle called “anyon” which has $1/3$ the charge of the electron. We also learned that proton and neutron contain quarks which have fractional charges $1/3$ and $2/3$ of e . In the experimental study of the fractional quantum Hall effect, physicists speculated the existence of fractional charges: $1/3$, $2/5$, $3/7$, ... of e .

In previous sections, we have just showed that the particle and its antiparticle oscillate continuously between two states A and C, *i.e.*, the particle (e^-) may have any negative charge between $-q_0$ to 0, while its antiparticle (e^+) may have any positive charge between 0 to q_0 . Their charges change continuously between two limit values $-q_0$ and $+q_0$, and thus including all fractional charges. Therefore, fractional charges of anyons and quarks prove that there is no charge quantization (in the meaning that electric charge of an object must be a multiple number of unit charge e).

In 1931, Dirac proposed that if magnetic monopoles exist, then electric charge must be quantized. But so far scientists could not find any magnetic monopole, therefore the speculative idea of charge quantization is false.

Conclusion: the novel concept of continuous variability of the electric charge of the electron as defined by Equation (9) eliminates two concepts of charge quantization and magnetic monopoles, and at the same time, urges us to reconsider the law of conservation of electric charge at atomic or electronic level.

Note: The trembling motion of the electron (Zitterbewegung)

Now if the amplitude of the oscillation of the electron between two states A to

C becomes very small in addition to high frequency, then the electron trembles in the direction of the electric field $\mathbf{E}$; this is the trembling motion (zitterbewegung). It is a consequence of rapid change in the permittivity ε , causing a rapid change in the effective electric charge of the electron.

Here is some information related to the zitterbewegung found in the literature of physics: Zitterbewegung was predicted by Schrodinger in 1930.... Zitterbewegung of a free relativistic particle has never been observed directly, although there is strong evidence in favour of its existence.... The longitudinal zitterbewegung remains a mystery.... We arrive at the interpretation of the zitterbewegung as being caused by interference between positive- and negative-energy wave components.... It is currently impossible to detect the quivering of a free electron, which has an amplitude of just 10^{-13} m and a frequency of 10^{21} Hz. (Wikipedia Encyclopedia)

7. Why Is c the Upper Limit of Velocity?

Special theory of relativity postulated that c , the speed of light in vacuum, is the upper limit of velocity of all particles in all physical states. There is no proof for this assertion.

We can explain this postulate as follows: if e^- is considered as a point particle, when it is subject to an external electric field $\mathbf{E}$, the Lorentz force $\mathbf{F}_e = e\mathbf{E}$ would accelerate it to *infinite speed* in the long run; *i.e.*, there would be no upper speed limit. But if e^- is regarded as an extended particle (as we assume in this article), then two opposite electric forces $\mathbf{F}$ and $\mathbf{F}'$ will be produced on it: (**Figure 2** & **Figure 3**). From **Figure 4**, we have:

$$\mathbf{F} = \left(\frac{1}{\varepsilon} - 1 \right) a q_0 \mathbf{E}, \mathbf{F} \text{ is positive when } \varepsilon < 1, \text{ Equation (6)}$$

$$\mathbf{F}' = -(1/\varepsilon) q_0 \mathbf{E}, \mathbf{F}' \text{ is negative when } \varepsilon < 1, \text{ Equation (2) when } \varepsilon = 1 - 1/a,$$

$$\mathbf{F} = -\mathbf{F}', \text{ the net force } \mathbf{F}_e = \mathbf{F} + \mathbf{F}' = \left(\frac{a-1}{\varepsilon} - a \right) q_0 \mathbf{E} = 0$$

Therefore, the electron is accelerated by $\mathbf{E}$ until $\varepsilon = 1 - 1/a$, $\mathbf{F}_e \rightarrow 0$ or $\mathbf{F}_e = m dv/dt \rightarrow 0$ or $dv/dt \rightarrow 0$ or $v \rightarrow c$.

In short, as the electron is accelerated, the net force $\mathbf{F}_e$ decreases with ε until $\mathbf{F}_e \rightarrow 0$, since $\mathbf{F} = -\mathbf{F}'$, its acceleration vanishes and its velocity reaches the highest constant value c .

Note: In textbooks of classical physics: e^- is treated as a point particle with constant charge e : $\mathbf{F}_e = e\mathbf{E} = \frac{m dv}{dt} = \text{constant}$; as $v \rightarrow c$, $m \rightarrow \infty$ (according to the famous Lorentz's equation $m = m_0 (1 - v^2/c^2)^{-1/2}$), hence $dv/dt \rightarrow 0$ (that is, $v \rightarrow c$). In short, classically speaking, $v \rightarrow c$ because $m \rightarrow \infty$.

In the theory of extended electron⁴, we maintain that the mass m of the electron is invariant, but its effective charge changes with the velocity and the applying

⁴See article: "Extended electron in time-varying electric field" and article "Extended electron in time-varying magnetic field" at https://www.vixra.org/author/hoa_van_nguyen.

field according to Equation (9). Thereby, as $v \rightarrow c$, $q \rightarrow 0$ and hence the net force $F_e = qE = mdv/dt \rightarrow 0$, that is, $dv/dt \rightarrow 0$ or $v \rightarrow c$, the highest velocity.

Conclusion: the linear velocity v of the translational motion of a particle is limited at c because as $v \rightarrow c$, its charge tends to zero, hence the driving force F_e tends to zero, and the particle cannot be accelerated further.

(For this reason, only *charged particles* that are subjected to an *applying field* for a sufficient period of time can reach the velocity c . A massive object, such as a tennis ball or a rocket, can never reach the speed c by mechanical or chemical forces).

8. Limit of Rotation of the Relativistic Spinning Electron

Now, we can extrapolate the above explanation of the limit c (for the translational motion) to the limit Ω for the rotational motion of a spinning electron.

Quantum mechanics denies the idea of spin as the rotation of the electron. The reason for this denial is that if the electron rotates about one of its axis, a point on its surface (e.g., on its equator) will acquire a linear velocity that surpasses c in the long run: this is contrary to the postulate of the special theory of relativity. Unfortunately, this reasoning is false! The event would happen differently.

In the theory of extended electron⁴, the electron spins under the action of the net electric (or magnetic) torques (couple of forces) which are produced by a time-varying magnetic (or electric) field, as shown in **Figures 8-11**. The net torque tends to zero as the angular velocity ω of the spinning electron tends to the finite limit Ω . And thus, all points on the surface of the spinning electron reach finite velocities that do not surpass c . Therefore, the electron can be regarded as an extended particle which spins like a spinning top, a toy of children.

Conclusion: the angular velocity ω of the rotational motion of a particle is limited at a finite limit Ω because as $\omega \rightarrow \Omega$ the driving torque tends to zero:

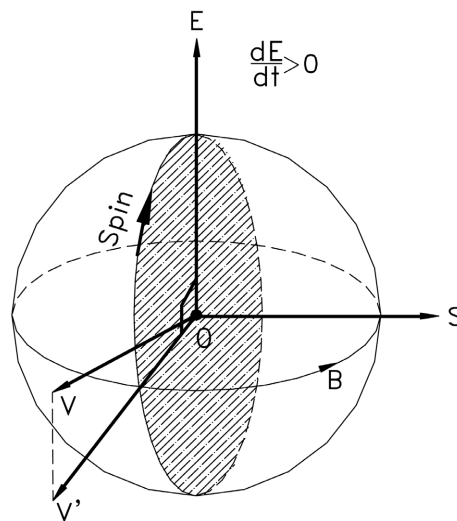


Figure 8. Direction of spin of the electron in the time-varying E when $dE/dt > 0$. axis OS is normal to the plane (E, V) .

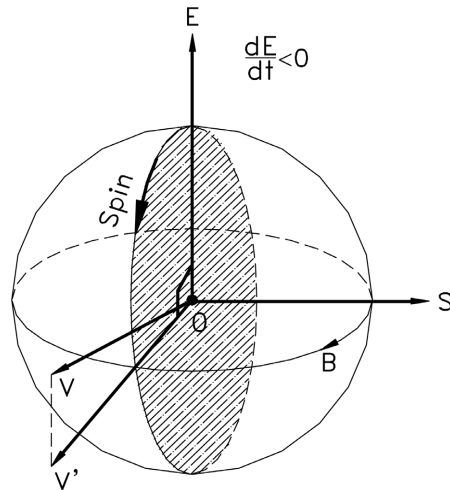


Figure 9. Direction of spin of the electron in the time-varying $\mathbf{E}$ when $dE/dt < 0$. Spin axis $\mathbf{OS}$ is normal to the plane $(\mathbf{E}, \mathbf{V})$.

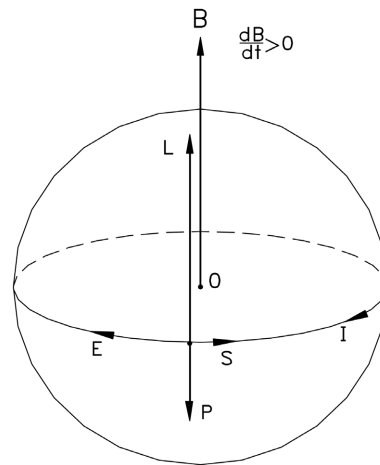


Figure 10. Direction of spin $\mathbf{S}$ of the electron in the time-varying $\mathbf{B}$ when $dB/dt > 0$. electron spins up: $\mathbf{L} \uparrow \uparrow \mathbf{B}$, spin magnetic moment: $\mu_s \downarrow \downarrow \mathbf{P}$.

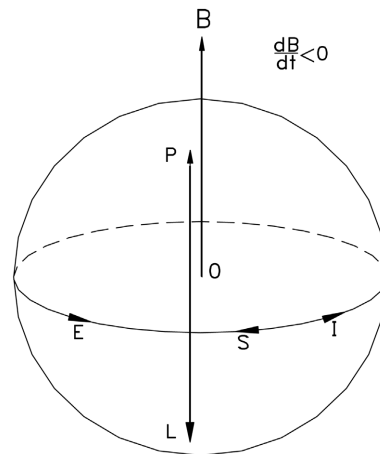


Figure 11. Direction of spin $\mathbf{S}$ of the electron in the time-varying $\mathbf{B}$ when $dB/dt < 0$. The electron spins down: $\mathbf{L} \downarrow \uparrow \mathbf{B}$. The spin magnetic moment: $\mu_s \uparrow \uparrow \mathbf{P}$.

the particle reaches its relativistic regime of spinning; it cannot rotate faster than Ω . (Hopefully, physicists will be able to determine the value of Ω in the future, in the same way they had determined the value of c).

Remarks:

***The electron is a rotating sphere:**

*“But the nature of the spin itself became a problem that has remained unsolved. The first assumption, as related by **Uhlenbeck** many years later (van der Waerden, 1960, p. 213), was that the electron must be a rotating sphere.” [1]*

****Figure 8 & Figure 9:** in the article “**Extended electron in time-varying electric field**” it is shown that a time-varying electric field $\mathbf{E}$ ($dE/dt > 0$ or $dE/dt < 0$) produces the rotational induced magnetic field $\mathbf{B}$, through which the extended electron traverses with velocity $\mathbf{V}$. Produced magnetic forces form *magnetic torques* which spin the electron in the direction **SPIN**. The spin-axis $\mathbf{OS}$ is normal to the plane $(\mathbf{E}, \mathbf{V})$.

*****Figure 10 & Figure 11:** in the article “**Extended electron in time-varying magnetic field**” it is shown that a time-varying magnetic field $\mathbf{B}$ ($dB/dt > 0$ or $dB/dt < 0$) produces the rotational electric field $\mathbf{E}$ which produces *electric torques* on surface of the electron that spin the electron in the direction $\mathcal{S}$. The spin-axis $\mathbf{L}$ points in the direction of the magnetic field $\mathbf{B}$.

********So, there are two different types of spin: spin by time-varying electric field $\mathbf{E}$ and spin by time-varying magnetic field $\mathbf{B}$. Therefore, we can control the spin of the electron by controlling either $\mathbf{E}$ or $\mathbf{B}$. When the spin reaches its relativistic regime, the *net torque tends to zero*, and its angular velocity $\omega \rightarrow \Omega$: the electron cannot rotate faster than Ω .

9. Different Models of the Electron and the Impact on the Coulomb Law

A model of the electron is analogous to an architectural plan of a house: many different plans are needed to describe different parts of the house; similarly, there must be different models to depict various aspects of the electron. Therefore, to reveal more exotic properties of the electron we have to figure out more plausible models.

Maxwell mentioned two kinds of model for particles: the ‘*robust*’ physical models and the ‘*pale*’ mathematical models:

“Truth could be grasped in many ways; in the robust imagery of a model or in the pale abstractions of mathematical equations, and neither was inferior to the other”.

Maxwell believed that these models could help us grasping the truth, although they are only creations of the human mind. History of contemporary physics shows that whether the electron is particle or wave, both have advanced our insight into this enigmatic particle.

Lorentz prophesied that: *“in speculating on the structure of these minute particles we must not forget that there may be many possibilities not dreamt of at*

present”. [3]

The model for the extended electron proposed in this article is one of these many possibilities: it is a spinning spherical particle.

Physicists noticed the impact on the Coulomb’s law:

Physicists noticed the invalidity of the Coulomb’ law at short separations, but did not know the real physical cause of it. Let’s read the following two excerpts:

Rutherford’s nuclear experiment showed the invalidity of Coulomb’s law.

“Rutherford’s experiment, in which he scattered alpha particles by atomic nuclei, showed that the equation $F = qq'/(4\pi\epsilon r^2)$ is valid for charged particles of nuclear dimensions down to separations of about 10^{-12} cm. Nuclear experiments have shown that the forces between charged particles do not obey the equation for separations smaller than this.” (Mc Graw-Hill Encyclopedia of Physics, 1993, “Coulomb’s law”)

Lamb shift is a manifestation of the invalidity of Coulomb’s law.

In 1947 Lamb succeeded in measuring the small energy difference between two energy levels $2^3S_{1/2}$ and $2^3P_{1/2}$ of hydrogen atom. In his Nobel lecture (1955) Lamb pointed out the reason for the splitting of these two energy levels as follows:

“The exact coincidence in energy of the $2^3S_{1/2}$ and $2^3P_{1/2}$ states is a consequence of the assumed Coulomb law of attraction between electron and proton. Any departure from this law would cause a separation of these levels”. (Lamb, W.E. Junior, Nobel Lecture, December 12, 1955. ‘Fine structure of Hydrogen Atom’)

Physicists blamed the short separations for the invalidity of Coulomb’s law. But this is not the effect of the distance r between two charged particles, actually it is because the changing of the electric charge q or q' by the intense field at these short separations.

A digression: So far, physicists avoid thinking of the variability of the electric charge e of the electron. This is because if this variability existed, it could cause tons of difficulties for their study of the atomic world. The invariance of e , on the contrary, would simplify everything on their way to research, especially ascribing the positive charge $+e$ to the proton and all other positive particles, the ideas of charge quantization and the law of conservation of electric charge. These are established principles and physicists consider them as ultimate truths, although Louis de Broglie, a French Nobel laureate, reminded us to frequently and profoundly reconsider these principles.

The theory of the extended electron attempts to break up the mainstream concept of invariant electric charge e by proposing Equation (9) and its graph (**Figure 5**). This challenging endeavour stems from the belief that physics has no frontier and hence there is no ultimate truth.

10. Overall Conclusion

We have made a long journey through a lot of arguments, calculations and assumptions to get to this conclusion. The theory began with the proposal of a spatially spherical structure for the electron (as shown in **Figure 1**) and tried to

develop new features from this extended electron. The theory led to **novel view-points** on three main properties of the extended electron: its effective electric charge, its mechanisms of spin and radiation in external fields.

1/ **The electric charge of the extended electron is an effective one**: it changes by the action of the external field and the velocity. Consequences are that, in extreme conditions, the electron can convert itself into its antiparticle (the positron), and hence it is alternatively subjected to attractive and repulsive forces from the intense field of the nucleus. This feature explains the existence of the orbital of the electron around the atom (**Figure 7**).

If we extrapolate this feature from the electron to the proton, we come up with the conversion of proton into antiproton that leads to the strong force between nucleons.

If the effective charge of a particle is not known exactly, its mass cannot be accurately determined (this is the case of the mass of the muon). The change in the effective electric charge of the electron is described by Equation (9) and its graph in **Figure 5**. A thought experiment is proposed in section 4 of the article: “**A fundamental problem in Physics (Mass versus Electric Charge)**” to demonstrate the variability of the electric charge e by the external magnetic field (https://www.vixra.org/author/hoa_van_nguyen)

2/ **The mechanism of spin of the extended electron is by induced torques**: it spins like a top by the induced electric/magnetic torques which are produced by time-varying magnetic/electric fields (as shown by four **Figures 8-11**). The consequence is that when the driving time-varying field changes the direction, the electron reverses its spin direction and its spin axis flips up and down.

3/ **The mechanism of radiation of the extended electron is by its spin**: the radiation of the electron is due to its spin, not to its acceleration. This idea offers an answer to the following statements by three prominent physicists:

Feynman: “*We have inherited a prejudice that an accelerating charge should radiate.*” - **Jackson**⁴: “*Radiation is emitted in ways that are obscure and not easily related to the acceleration of a charge.*”

Pearle: “*A point charge must radiate if it accelerates, but the same is not true of an extended charge distribution.*”

A. Magnetic force F_m produced on the extended electron.

Up to this point, we have explored the electric force F_e and its consequences: the antiparticles, the orbital of the electron, the strong forces, the upper limits c and Ω ...

Now, let's investigate the magnetic force F_m which is produced on the extended electron when it moves **normally** to the external magnetic field B with velocity V . The results of calculations⁵ showed that the resultant force F_m composes of two opposite forces F and F' as shown in **Figure 12**.

⁵See detailed calculations in the article “**Extended electron in constant magnetic field**” at https://www.vixra.org/author/hoa_van_nguyen.

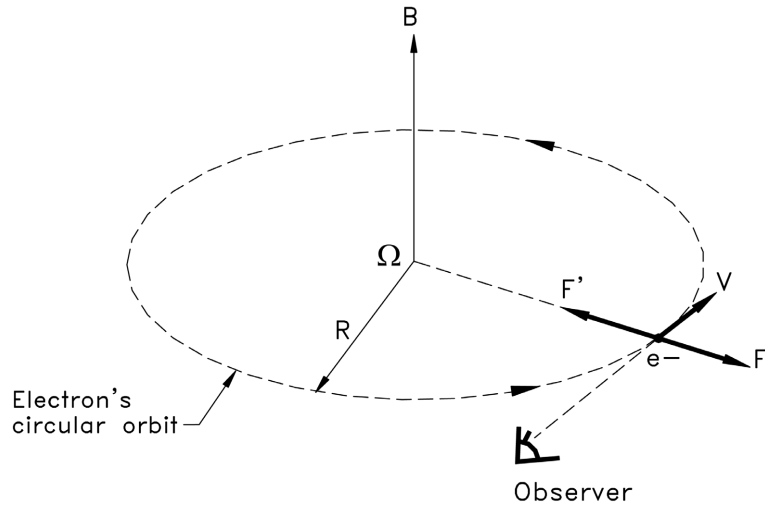


Figure 12. For $\mu > 0$: F points to the right-hand side of the observer: it is a positive force. F' points to the left-hand side of the observer: it is a negative force.

F is the resultant of all magnetic forces f_m produced on surface dipoles $(-q, +q)$ of the electron (i.e., $F = \sum f_m$), and F' is the magnetic force produced on the core $(-q_0)$ of the electron:

$$F = (\mu - 1)qVB \sum_i^b \sin \alpha_i \sin \beta_i \cos \gamma_i \quad \text{and} \quad F' = -\mu q_0 VB \quad (14)$$

For $\mu > 1$: F points to the right-hand side of the observer as shown in **Figure 12**: it is considered as a positive force; and hence the sum $\sum_{i=1}^n \sin \alpha_i \sin \beta_i \cos \gamma_i > 0$ F' is a negative force; it points to the left-hand side of the observer.

The resultant magnetic force is $F_m = F + F'$:

$$F_m = F + F' = (\mu - 1)qVB \sum_i^n \sin \alpha_i \sin \beta_i \cos \gamma_i - \mu q_0 VB$$

$$\text{or } F_m = \left[(\mu - 1)(q/q_0) \sum_i^n \sin \alpha_i \sin \beta_i \cos \gamma_i - \mu \right] q_0 VB \quad (15)$$

In Equation (15) let's set

$$b = (q/q_0) \sum_{i=1}^n \sin \alpha_i \sin \beta_i \cos \gamma_i \quad (16)$$

b is thus a dimensionless, positive number because the sum $\sum_i^n \sin \alpha_i \sin \beta_i \cos \gamma_i$ is positive as mentioned above. The parameter b is called form (or structure) factor of the extended electron. By plugging b in (16) into Equations (14) and (15), F and F_m become:

$$F = (\mu - 1)bq_0VB \quad (17)$$

$$F_m = \left[\mu(b - 1) - b \right] q_0VB \quad (18)$$

where $\mu > 1$, $b > 1$

Figure 13 delineates F , F' and F_m as functions of μ , the relative permeability of the extended electron in magnetic field B . It shows that:

F_m is negative in the interval $1 < \mu < (b - 1)$

F_m is positive in the interval $b/(b - 1) < \mu < (b + 1)/(b - 1)$

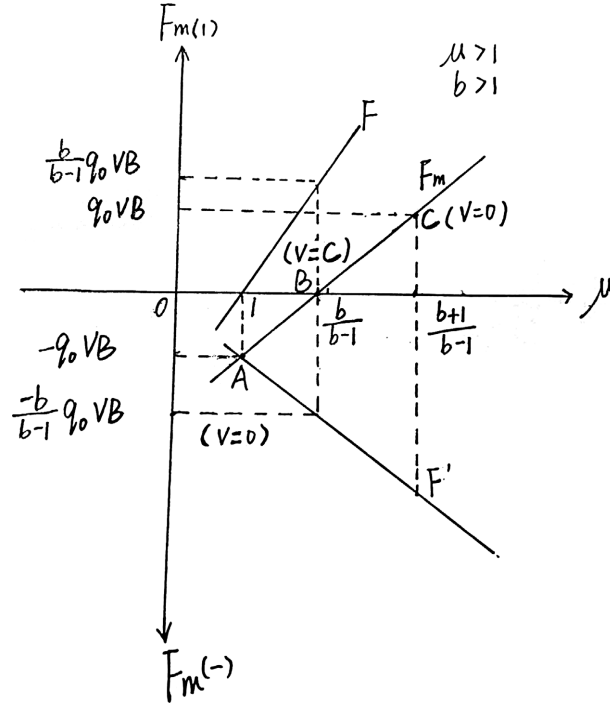


Figure 13. The resultant force $F_m = F + F'$ is negative in the interval $1 < \mu < b/(b-1)$, and positive in the interval $b/(b-1) < \mu < (b+1)/(b-1)$.

$F_m = -q_0VB$ at $\mu = 1$: this is the point A

$F_m = 0$ at $\mu = b/(b-1)$: this is the point B

$F_m = q_0VB$ at $\mu = (b+1)/(b-1)$: this is the point C

From Equation (18) we can deduce the effective charge Q of the extended electron as

$$Q = [\mu(b-1) - b]q_0 \text{ because } F_m = QVB \text{ (} V \perp B \text{)} \quad (19)$$

Therefore, from **Figure 13**, the effective charge Q of the electron can change from negative to positive and vice-versa, due to the change of μ by the applying magnetic field.

If an electron is introduced normally into the magnetic field B with velocity V , its effective charge Q can be defined by both Equation (9) and Equation (19); hence we have the correlation:

$$Q = [\mu(b-1) - b]q_0 = (1 - v^2/c^2)^{N/2} q_0 \quad (20)$$

When Q is negative, we have:

$$[\mu(b-1) - b]q_0 = -(1 - v^2/c^2)^{N/2} q_0 \quad (21)$$

$v = 0 \rightarrow \mu = 1$ and $Q = -q_0$: this is the point A, **Figure 13**.

$v = c \rightarrow \mu = b/(b-1)$ and $Q = 0$: this is the point B

When Q is positive, we have:

$$[\mu(b-1) - b]q_0 = +(1 - v^2/c^2)^{N/2} q_0 \quad (22)$$

$v = c \rightarrow \mu = b/(b-1)$ and $Q = 0$: this is the point B

$v = 0 \rightarrow \mu = (b+1)/(b-1)$ and $Q = q_0$: this is the point C

In summary, the analysis on the magnetic force F_m leads to the following results:

1/ In magnetic field: $1 \leq \mu \leq (b+1)/(b-1)$ and $-q_0 \leq Q \leq q_0$ (Figure 13).

2/ In free space (no field at all): $\mu = 1$, $Q = -q_0$.

3/ The electron can be converted from particle into its antiparticle:

$e^- \leftrightarrow e^0 \leftrightarrow e^+$ when subjected to an intense magnetic field at high velocity (Figure 7).

4/ The electron oscillates (vibrates) between A and C in the direction perpendicular to the magnetic field B while moving in circular motion around the field B .

5/ If the form factor b is a large number, (i.e., $b \gg 1$) then $(b+1)/(b-1) \approx 1_+$ and $1 \leq \mu \leq 1_+$ or $\mu \approx 1_+$: $F \approx 0$, $F' \approx -q_0 V B$, the extended electron is mathematically equivalent to a point charge $-q_0$: this is the point A in Figure 13.

B. The permittivity ε and the permeability μ of the extended electron.

This theory is about the extended model of the electron which is shown in Figure 1. To do calculations to determine the electric and magnetic forces F_e and F_m produced on the extended electron, I have applied the electric and magnetic boundary conditions [4] to the spherical surface of the electron, which is assumed to be dielectric having relative permittivity ε and permeability μ . This is the reason why ε and μ appeared in the expressions of F_e and F_m :

$F_e = \left(\frac{\alpha-1}{\varepsilon} - \alpha \right) q_0 E$ in Equation (7); $F_m = [\mu(b-1)-b] q_0 V \times B$ in Equation (18)

If $\varepsilon = 1$ or $\mu = 1$, we get familiar Lorentz's force equation:

$F = -q_0 (E + V \times B)$ for the point-like electron $(-q_0)$.

But since the electron is actually an extended particle, two structure (form) factors 'a' and 'b' are present in the equations as the range of variation of ε and μ , hence they are always different from unity.

In general, ε and μ vary by the external fields as shown in the graphs of Figure 6 and Figure 13. The physical reason for the variability of ε and μ of the extended electron is the changing in the polarization of the assembly of electric dipoles $(-q, +q)$ that surrounds the core $(-q_0)$.

11. Conclusion

As mentioned in the introduction (section 1): this theory intends to explain the variation of the electric charge " e " of the electron as shown in Figure 1, (which is scanned from Figure 13.1 in the text book "Nuclear and Particle Physics" by W.S.C. Williams) that interprets the idea of screening by the vacuum polarization. The theory does not need the creation of virtual pairs (e^+, e^-) by the vacuum polarization: they are replaced by real tiny static electric dipoles $(-q, +q)$. A thought experiment is proposed in section 4 of the article: "A fundamental problem in Physics (Mass vs Electric charge)" to demonstrate the variability of ' e ' in

the external magnetic field (https://www.vixra.org/author/hoa_van_nguyen).

The extended model of the electron is a hypothesis which leads to the innovative concept that the electric charge “ e ” of the electron is not invariant, it changes by the external field. This idea is against the mainstream physics, but without new concept, there is no innovation and hence no advancement.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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