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The Story of the Electric Charge ‘e’ of the Electron

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1. Introduction

In the mainstream of Physics, the electric charge e of the electron is considered as a universal constant. Its numerical value has been determined by the oil-drop experiment of Millikan: e = 1.602 x 10^{-19} C. In his Nobel lecture (1923) he said this value mainly depended on the physical conditions of the experiment: the velocity of the oil-drop and the electric field used in the experiment. So, if these physical conditions change, the measured value of e would change accordingly. In other words, the constancy of e is a mere assumption or postulate for the convenience of the research of physics.

That’s why in the contemporary physical literature we can find various statements by prominent physicists who expressed the variability of the electric charge of the electron in different ways:

- **Bekenstein** " *Thus, every particle charge can be expressed in the form* $e = e_0\ \epsilon(x^\mu)$*, where e0 is a constant characteristic of the particles and* ϵ *a dimensionless universal field."*
- **Rohrlich** wrote in the topic of renormalization: *“The effective charge e, which is the physical (renormalized) charge, is defined to be*

$$e = Z_1 Z_2^{-1} Z_3^{-1/2} e_0$$

where Zi are renormalization constants .”

- **David Griffiths wrote** in the textbook Introduction **to Elementary Particles**: *“The effective charge of any particle is somewhat reduced:* $q_{eff} = q / \varepsilon$*” where* ε *is the relative permittivity of the particle*. Interestingly, Figure13.1 in the textbook **Nuclear and Particle Physics by W.S.C. Williams shows that the electric charge | e | of the electron changes with the distance r.**

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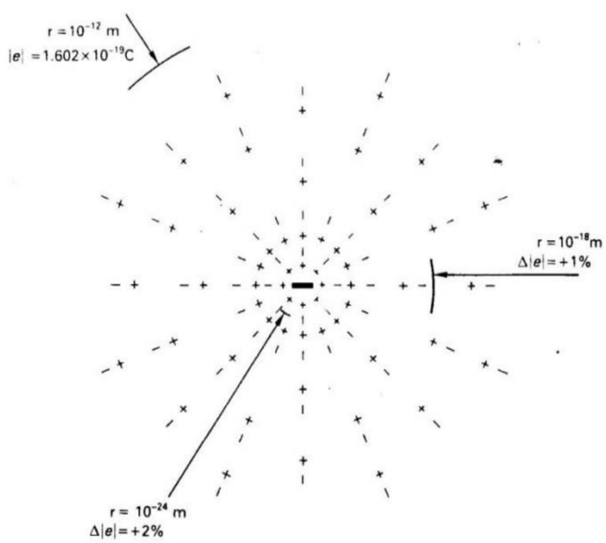

This is Figure 1 of the electron in the textbook "**Nuclear and Particle Physics" by W.S.C. Williams**. This figure explains the phenomenon of vacuum polarization and at the same time suggests that the variability of the electric charge e of the electron is physically plausible.

It is the unique figure that supports the idea that the magnitude |e| of the electric charge of the electron is an effective one: it changes with the probing distance r. This means that e is actually a multi-valued factor, not a single-valued constant.

Therefore if we consider the electron as an extended particle, composing of a negatively charged core (-q0), surrounded by a cloud of tiny electric dipoles (-q, +q) as shown in the above figure, we can prove that its effective electric charge e depends on its velocity , external applied field, its permittivity ε, its permeability μ and also on the stage of emission & absorption of photons of the electron [1].

First, let us define the meaning of the following letters that are used in this article:

- (-q, +q): electric charges at two ends of the electric dipoles which form the extended electron,
- q or Q or e: effective electric charge of the extended electron,
- q0: constant electric charge of the core of the electron: q0 = e0 = 1.602×10^{-19} C

2. Three New Equations of the Effective Electric Charge

In this article, I introduce three new equations that I created to describe the variability of the effective electric charge of the electron. Since the calculations are lengthy, only the results (i.e., the equations) are given here; the proofs of calculations are referred to the references at the end of the article

2.1.A Heuristic Mathematical Expression of the Electric Charge:

$$\boxed{q = \gamma^{-N} q_0} \qquad (1)$$

where γ = $\mathbf{(1-v^2/c^2)^{-1/2}}$ is the Lorentz factor, N ≥ 0 is the real number representing the external applied field. This equation is the result of a heuristic argument, it is not derived from the calculation on the extended electron [2]. The equation shows that the effective electric charge of the electron is a function of its velocity v and the applied field represented by the positive real number: N ≥ 0.

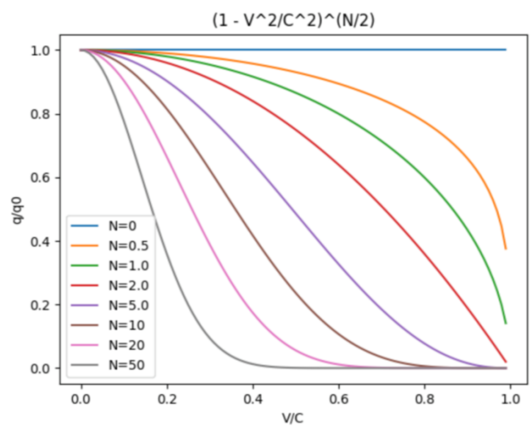

Figure 2: $q / q_0 = (1 - v^2 / c^2)^{N/2}$

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 ≈ 0.8. This means that the electron can become a free electron (has no electric charge at all) at the velocity less than c (e.g., v ≈ 0.8 c) provided that the applied field must be high (N = 20 to 50).

The equation $q / q_0 = (1 - v^2 / c^2)^{N/2}$ shown in Figure 2 illustrates the effect of the applied field N on the effective charge q, especially for very high N. Because $(1 - v^2 / c^2) < 1$ for any value of the velocity v, the factor $(1 - v^2 / c^2)^{N/2}$ tends to zero when N is very high, and hence q tends to zero. This equation is the unique equation in physics that depicts the change of the electric charge of the electron with the applied field (just because mainstream physics assumes the electric charge of the electron is a constant!).

2.2. Equation of the Effective Electric Charge in Electric Field:

$$\boxed{q = \left(\frac{a-1}{\varepsilon} - a \right) q_0} \qquad (2)$$

where ε is the relative permittivity of the electron, 'a' is the dimensionless form factor derived from the structure of the extended electron in electric field [3].

Method of calculation: since the extended electron has two charged components: the surrounding cloud of electric dipoles (-q, +q) and the core (-q0), when it is subject to the applied electric field E, two different forces are produced on these two components:

$\mathbf{F} = \Sigma \mathbf{f_e}$ is the resultant of all electric forces fe produced on *surface dipoles* (-q, +q), and $\mathbf{F'} = -(1/\varepsilon)\, q_0 \mathbf{E}$ is the electric force produced on the core (–q0) of the electron (Figures. 2 &3)

Hence the net electric force $\mathbf{Fe} = \mathbf{F} + \mathbf{F'} = (\frac{a-1}{\varepsilon} - a)\, q_0 E$ (See Ref. […])

Therefore, the effective charge of the electron is

$$q = (\frac{a-1}{\varepsilon} - a)\, q_0 \quad \text{since} \quad \mathbf{Fe} = q\,\mathbf{E}.$$

2.3. Equation of the Effective Electric Charge in Magnetic Field

$$q = [\,\mu\,(b-1) - b]\, q0 \tag{3}$$

where μ is the relative permeability of the electron, 'b' is the dimensionless **form factor** derived from the structure of the electron in magnetic field [4].

Method of calculation: we calculate the net magnetic force F_m that is produced on the extended electron when it moves perpendicular to the magnetic field B with the velocity v.

We get: $\mathbf{F_m} = [\,\mu\,(b-1) - b]\, q0\, v\, \mathbf{B}$ (See Ref. […])
Hence the effective electric charge $q = [\,\mu\,(b-1) - b]\, q0$ since $Fm = q\,\mathbf{v}\,\mathbf{B}$.

By associating these three equations we will discuss two subjects that are closely related to the effective electric charge of the extended electron:

1 / Renormalizing the Lorentz' s force equation to expand it into the relativistic regime.
2 / The conversion Particle ↔ Anti-Particle of Dirac & Majorana

2.4. Renormalizing the Lorentz' s Force Equation

The Lorentz 's force FL is a non-relativistic force, it is valid only for v << c:

$$\mathbf{F_L} = q0\,(E + \mathbf{v} \times \mathbf{B}),$$

To expand its validity into relativistic domain we have to renormalize it's the electric charge q0 by the expression

$$q = \gamma^{-N} q_0 = (1 - v^2 / c^2)^{N/2} q_0, \quad N \geq 0 : \text{this is Eq.(1).}$$

Hence the renormalized Lorentz' s force is:

$$\mathbf{F_L} = (1 - v2 / c2)\ N/2\ q0\ (\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

This is the relativistic equation of Lorentz' s force.

Therefore, the heuristic equation of motion of the particle in the relativistic regime is

$$m_0\, dv / dt = (1 - v^2 / c^2)^{N/2} q_0\, (\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

That is, Classical Newtonian force = Relativistic Lorentzian force [5]. The immediate consequence of renormalizing Lorentz ' s force is that the electric force

- **Fe** and the magnetic force Fm **tend to zero as v → c** for any value of the applied field N:
- $\mathbf{Fe} = (1 - v^2 / c^2)^{N/2} q\, 0\, \mathbf{E}$: Fe decreases with v (from v = 0) and tends to zero as **v → c.**
- $\mathbf{Fm} = (1 - v^2 / c^2)^{N/2} q\, 0\, \mathbf{v} \times \mathbf{B}$: Fm increases with v (from v = 0) reaches its maximum at $v = c\,(N + 1)^{-1/2}$, then decreases and tends to zero as **v → c**.

Notes:

- The maximum point of Fm is an intriguing point: there are two different values of velocities V1 and V2 (on either sides of the maximum point) that give **the same value of Fm**.
- I would like to call on the readers who are proficient in computer graphics: please delineate the graphs of Fe and **Fm** with N = 0, 1, 2…50 …100… as functions of the velocity v to see how t**hey tend to zero** as **v → c**. We also notice that when we renormalize the Lorentz 's force, both Fe and Fm move down and lie below the familiar forces **Fe** and **Fm** in non-relativistic regime (Fe = q0 **E** and **Fm** = q0 **v** × **B**).

Discussion: In classical physics, physicists noticed that **Newtonian force FN** is not equal to **the Lorentzian force FL**: it is lower than the Lorentzian FL. They tried to bring them to equality <u>by increasing FN</u> (by renormalizing the mass m0 in FN) by the factor

$$\gamma = (1 - v^2 / c^2)^{-1/2} > 1: \qquad \mathbf{FN} = \gamma\, m_0\, dv/dt.$$

But the procedure of renormalization of mass is problematic: it sends the mass to infinity as v → c. The consequence of the renormalization of mass is the **heavy mass of the muon:**

mμ = 207 me (which is still a mystery until today)

Hence physicists take another way to bring **FN and FL** to equality <u>by lowering the Lorentzian force FL</u> (by renormalizing the electric charge q0 in **FL**) by the factor $\gamma^{-1} < 1$: $\mathbf{FL} = \gamma^{-1} q_0 (\mathbf{E} + \mathbf{v} \times \mathbf{B})$. The renormalization of electric charge is innovative: it sends the electric charge of the electron to zero as v → c. The consequence of the renormalization of electric charge is: the muon is the electron with reduced electric charge [6].

mμ = me, qμ = γ^{-N} **qe**

That is: the mass of the muon is equal to the mass of the electron, but its electric charge is γ^{-N} time smaller than that of the electron. The idea that all muons which are created in different conditions (in the labs or in the upper atmosphere …) have the same charge and the same lifetime (2.2 µs) is incorrect. Thereby, the concept of time dilation, which relies on the idea that all muons have the same lifetime (2.2 µs), is wrong and superfluous for physics.

Conclusion: muon is not a heavy electron; its average lifetime tau is not always equal to 2.2 µs but changing with velocity and the external field where it is created. These findings lead to the ascertainment that the **concept of time dilation is wrong and redundant [7].**

3. The Conversion Particle ↔ Anti-Particle of Dirac & Majorana

3.1. Determination of the net Electric Force Fe Produced on the Extended Electron

When the extended electron is subject to an external electric field E, the net electric force Fe is produced on it. The calculations on the extended model of the electron show that Fe is the resultant of two opposite forces **F** and **F'**, i.e., **Fe** = **F + F'** , where **F** is the

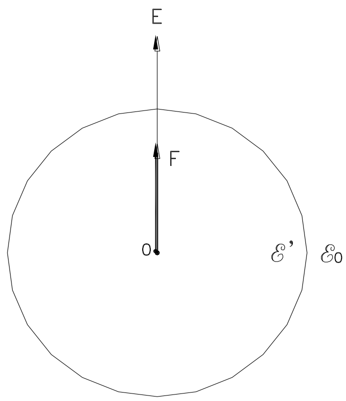

Figure 3 : $\varepsilon < 1$: the resultant force **F** ($= \Sigma$ **fe**) points in the direction of **E** : **F** ↑↑ **E** .

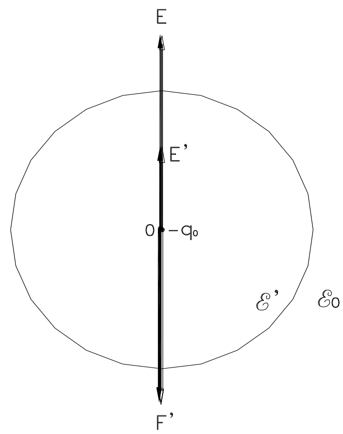

Figure 4 : $\varepsilon < 1$: **F'** is the electric force produced on the core $-q_0$: **F'** ↓↑ **E**

resultant of all electric forces $\mathbf{f_e}$ produced on *surface dipoles* (-q, +q) of the electron ($\mathbf{F} = \Sigma \mathbf{f_e}$) and **F'** is the electric force produced on *the core* (–q 0) of the electron. The results are:

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

$$\mathbf{F'} = -\, (1/\varepsilon)\, q_0\, \mathbf{E}$$, **F'** is always negative

$$\mathbf{Fe} = \mathbf{F} + \mathbf{F'} = \left(\frac{1}{\varepsilon} - 1\right) q\, \mathbf{E} \sum_i^n \cos^2 \alpha_i \;-\; \frac{1}{\varepsilon}\, q_0\, \mathbf{E} \;,$$

(or)

$$\mathbf{Fe} = \left[\left(\frac{1}{\varepsilon} - 1\right) (q / q_0) \sum_i^n \cos^2 \alpha_i \;-\; \frac{1}{\varepsilon} \right] q_0\, \mathbf{E} \quad (4)$$

Let's set

$$\boxed{a \equiv (q / q_0) \sum_i^n \cos^2 \alpha_i} \qquad (5)$$

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

By plugging 'a' into the above equations, we get

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

a>1

$$\boxed{\mathbf{Fe} = \left(\frac{a-1}{\varepsilon} - a\right) q_0\, \mathbf{E}} \qquad a > 1 \qquad (7)$$

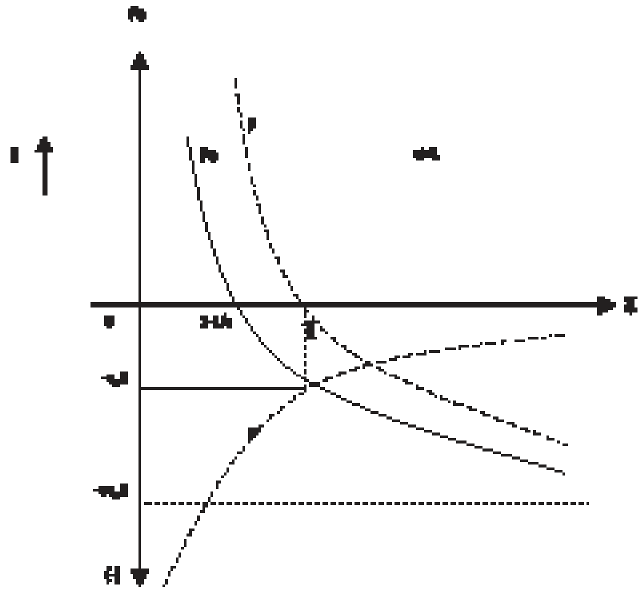

Figure 5: Shows **F, F'** and Fe as functions of ε.

For $\varepsilon \geq 1$: **F , F'** and Fe all are negative,
For $(1\text{-}1/a) \leq \varepsilon \leq 1$: **F** is positive, F' and Fe are negative,
For $\varepsilon < 1\text{-}1/a$: **Fe** is positive; i.e., electron becomes a positron.

- For the purpose of this article, we explore the net force **Fe** in the intervals: $\varepsilon \leq 1$ and a > 1:
  - Fe is negative in the interval $(1\text{-}1/a \leq \varepsilon \leq 1)$: the electron behaves as a negative particle, hence the factor $(\frac{a-1}{\varepsilon} - a)$ in Eq.(7) is negative .
- Fe becomes positive if $\varepsilon \leq 1\text{-}1/a$: the electron becomes the positron e^+, hence the factor $(\frac{a-1}{\varepsilon} - a)$ is positive : we get the antiparticle e^+ of **Dirac**.
- **Fe** = $- q_0$ 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 $\varepsilon = 1$.
- **Fe** = 0 if $\varepsilon = 1\text{-}1/a$: this is the point of transition between e^- and e^+ : $e^- \leftrightarrow e^0 \leftrightarrow e^+$

The ephemeral state e0 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 Figure 6 of 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 Fe. Owing to the direction of Fe 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 eo .

e0. In short, **antiparticle originates from its particle and vice-versa**, due to the variability of its permittivity ε which causes the change in its effective charge.

Note: Let 's note that **Dirac** predicted the existence of the antiparticle e+ from his relativistic wave equation, but he **did not elaborate how e+ was created physically; i.e., he did not explain what was the mechanism of its generation**. And yet he was awarded the Nobel prize in 1933 after e+ was discovered. As for the theoretical particle **Majorana**: it is the conversion point of particle and antiparticle; or in other words: it is the transition point where the particle coincides with its own antiparticle. This is the point B in Figure 6, where : $\varepsilon = 1 - 1/a$, Q = 0 , v = c ; meanwhile two points A and C are turning points , where v = 0 and the acceleration changes its signs

3.2. Fixing Three Points A, B and C on the Curve Fe (Equation 7)

Now let 's focus on the curve Fe in Figure 6: we are going to fix three states A, B, and C by <u>equating the effective charge q in two Equationss. (1) and (2):</u>

$$q = (1 - v^2 / c^2)^{N/2} q0 \tag{1}$$

$$q = (\frac{a-1}{\varepsilon} - a) \tag{2}$$

We get: $(\frac{a-1}{\varepsilon} - a) = \pm (1 - v^2 / c^2)^{N/2}$

The reason for ± is already mentioned above : the factor $(\frac{a-1}{\varepsilon} - a)$ in Eq. (2) or in Eq. (7) is negative in the interval $(1\text{-}1/a < \varepsilon < 1)$

(since **Fe** is negative) and positive in the interval $\varepsilon < 1-1/a$ (since **Fe** is positive) as shown in Figure 4 and Figure 6, while $(1 - v^2 / c^2)^{N/2}$ is always positive.

In the interval $(1-1/a < \varepsilon < 1)$ **Fe** is negative: $\left(\frac{a-1}{\varepsilon} - a\right) = -\left(1 - v^2 / c^2 \right)^{N/2}$ (8)

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

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

Now, in the interval $\varepsilon \leq 1-1/a$ Fe is positive, the factor $\left(\frac{a-1}{\varepsilon} - a\right)$ is positive :

we have $\left(\frac{a-1}{\varepsilon} - a\right) = \left(1 - v^2 / c^2 \right)^{N/2}$ (9)

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

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

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

At state A : $v = 0$, $\varepsilon = 1$, $Fe = -q_0 E$, $Q = -q_0$,
At state B : $v = c$, $\varepsilon = 1-1/a$, $Fe = 0$, $Q = 0$,
At state C : $v = 0$, $\varepsilon = (a-1)/ (a+1)$, $Fe = q_0 E$, $Q = q_0$

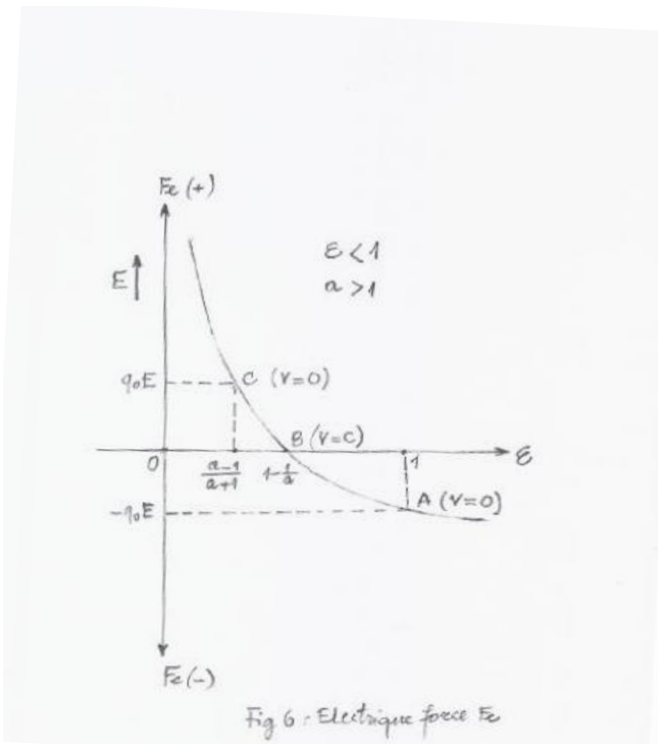

Figure 6: Electric force Fe vs ε (Equation7)

3.3. Magnetic Force Fm and Three Points A, B, and C

Using similar method of determining the force and fixing three points A, B and C, we will determine the magnetic force Fm which is produced on the extended electron by the applied magnetic field B and fix three points A, B and C on the curve Fm.

Now, let ' s investigate the magnetic force Fm which is produced on the extended electron when it moves ***normally*** to the external magnetic field B with velocity V. The results of calculations showed that the resultant force Fm composes of two opposite forces F and F' as shown in Figure 7.

F is the resultant of all magnetic forces fm produced on surface dipoles (-q, +q) of the electron (i.e., F = Σ **fm**), and F' is the magnetic force produced on the core (-q0) of the electron:

$$F = (\mu - 1) \, q \, V \, B \sum_{i}^{n} \sin\alpha_i \, \sin\beta_i \, \cos\gamma_i \quad \text{and } F' = -\mu \, q_0 \, V \, B$$

For μ > : **F** points to the right-hand side of the observer as shown in Figure 7: it is considered as a positive force; and hence the sum

$$\sum_{i=1}^{n} \sin\alpha_i \, \sin\beta_i \, \cos\gamma_i \quad > \; 0$$

F' is a negative force; it points to the left-hand side of the observer.

The resultant magnetic force is Fm $= \mathbf{F} + \mathbf{F'}$:

$$Fm = F + F' = (\mu - 1)\, q\, V\, B \sum_{i}^{n} \sin\alpha_i \; \sin\beta_i \; \cos\gamma_i \; - \; \mu\, q_0\, V\, B \qquad \text{or}$$

$$Fm = \left[(\mu - 1)\, (q / q_0) \sum_{i}^{n} \sin\alpha_i \; \sin\beta_i \; \cos\gamma_i \; - \; \mu \right] q_0\, V\, B \qquad (10)$$

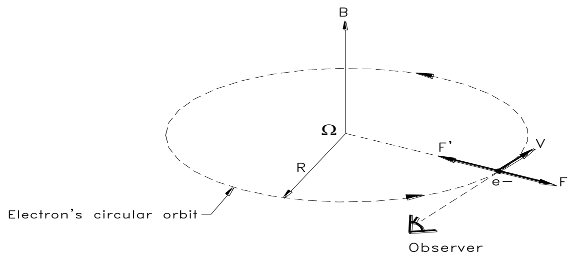

Figure 7: For $\mu > 1$:

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.

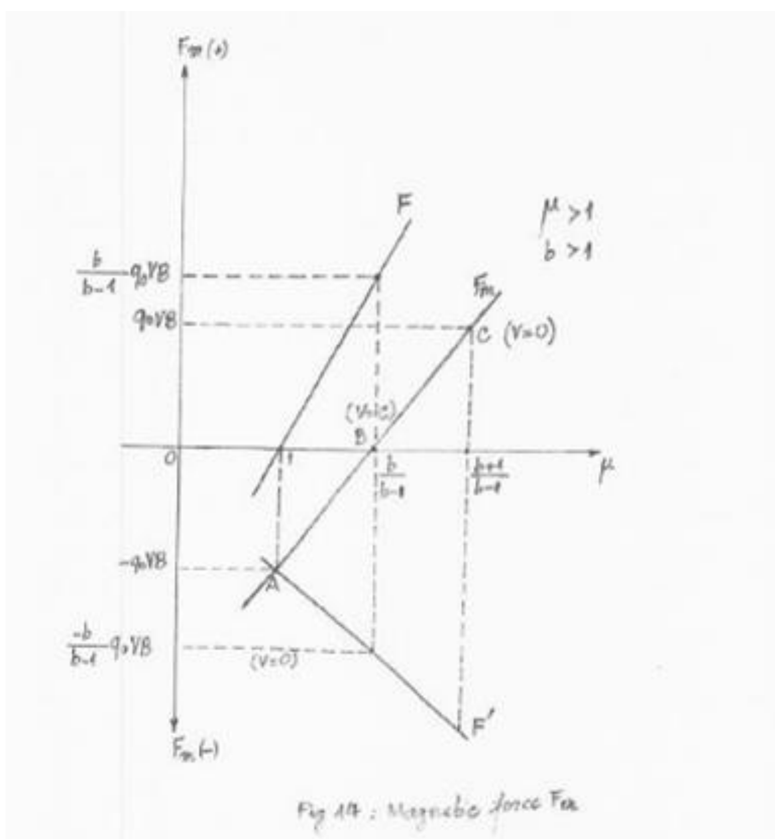

Figure 8: The resultant force **Fm = F + F'** is negative in the interval $1 < \mu < b / (b-1)$ and positive in the interval $b / (b-1) < \mu < (b+1) / (b-1)$.

In Eq.(10) let 's set $\boxed{b \equiv (q / q_0) \sum_{i}^{n} \sin\alpha_i \; \sin\beta_i \; \cos\gamma_i}$ (11)

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 using b in (11), F and Fm become:

$$F = (\mu - 1)\, b\, q_0\, VB \quad (12)$$

$$\boxed{Fm = [\mu (b-1) - b]\, q_0\, V B} \quad (13)$$

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

Figure 8 delineates F, F' and Fm as functions of μ, the relative permeability of the extended electron in magnetic field B. It shows that:

- Fm is negative in the interval $1 < \mu < b / (b-1)$
- Fm is positive in the interval $b / (b-1) < \mu < (b+1) / (b-1)$
- $Fm = - q_0 VB$ at $\mu = 1$: this is the point A
- $Fm = 0$ at $\mu = b / (b\ 1)$: this is the point B
- $Fm = q_0 VB$ at $\mu = (b+1) / (b\ 1)$: this is the point C

From Eq.(13) we can deduce the effective charge Q of the extended electron as

$$Q = [\mu (b-1) - b]\, q_0 \text{ because } Fm = Q\, VB\ (V^{'} \perp B) \quad (14)$$

Therefore, from Fig.8 , 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 Eq.(1) and Eq.(14) ; hence we have the correlation :

$$Q = [\mu (b-1) - b]\, q_0 = \pm (1 - v^2 / c^2)^{N/2} q0 \quad (15)$$

When Q is negative , we have :

$$[\mu (b-1) - b]\, q_0 = - (1 - v^2 / c^2)^{N/2} q_0 \quad (16)$$

$v = 0 \rightarrow \mu = 1$ and $Q = -q_0$: this is the point A , Fig.8
$v = c \rightarrow \mu = b / (b-1)$ and $Q = 0$: this is the point B

When Q is positive , we have :

$$[\mu (b-1) - b]\, q_0 = + (1 - v^2 / c^2)^{N/2} q_0 \quad (17)$$

$v = c \rightarrow \mu = b / (b-1)$ 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

4. Search for the Point B

On two Figs. 6 and 8 three points A, B and C represent three particular situations of the electron: while two points A and C represent the turning points of the electron (where v = 0), **the point B represents the situation (or state) where electron is converted into positron and vice versa :**

We think that the point B physically exists, we can experimentally determine the point B , at which electron is converted into positron and vice versa .

We can perform experiments to demonstrate the existence of the point B by **changing ε or μ** by **using laser to impact** electrons before injecting them through the applied electric or magnetic field. When ε or μ reaches the point B: $\varepsilon = 1- 1/a$, or $\mu = b/ (b-1)$, electron turns into positron: it reverses its direction of motion in the electric field E, or it deflects to opposite direction in the magnetic field B.

This is the conversion: particle ↔ antiparticle. This conversion occurs at a specific point, called point B or Dirac-Majorana point.

In contemporary physics there are two similar phenomena: The **Curie point (Curie temperature)** at which a magnetic material is transformed from non-magnetic into magnetic: paramagnetic ↔ ferromagnetic. Also, in the superconductivity, there exists a very low temperature near zero K0 that changes a normal conductor into a superconductor.

All these phenomena link to the change in the electric charge (or the magnetic moment) of a single electron which undergoes a change in its permittivity ε or its permeability μ.

I would like to call on researchers around the world to carry out this experiment to spot the point B of the electron in E and B.

If the experiment succeeded, it would explain the mechanism of the conversion of particle ↔ antiparticle which Dirac and Majorana had predicted.

5. Conclusion

This is a short story of the effective electric charge 'e' of the extended electron. It is a part of more important features of the electron: the spin & radiation of the electron, the emission & absorption of photons. These subjects are presented in my book: "**A new theory of the extended electron**" which will be published this year (2026) by SCIRP, attempting to open a new road to the new physics.

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