Equations of the Effective Electric Charge of the Electron

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Abstract
If we think of the electron as an extended particle, its electric charge would be varying in an external field . This article presents three plausible equations for the effective electric charge of the extended electron in external fields.

1 . Introduction

Mainstream physics considers the electric charge of the electron as a fundamental constant of physics : e = 1.602 × 10 $^{-19}$ C . This value was determined in the oil-droplet experiment performed by Milliken in 1920 ' s . In his Nobel lecture (1924) , Milliken never said that the electric charge e was a constant , but it was only a specific value , being determined at low velocity of a fraction of a millimetre per second , in the electric field of 6000 volts per cm .

So , we can speculate that if we could perform the experiment at other values of velocity and electric field , we would get other values of e . This means that the electric charge of the electron is not an invariant , but an effective charge , varying with velocity and the applying field .

In the literature , we can find prominent physicists who expressed the effective electric charge of the electron by simple expressions :

Bekenstein [1] wrote in his investigation of the variability of the fine structure α and its consequences on the variability of the electric charge :
" Since $\alpha = e^2 / \hbar c$, where e is the electron charge , α variability means that e depends on the spacetime point . ... Thus every particle charge can be expressed in the form $e = e_0 \in(x^\mu)$, where e_0 is a constant characteristic of the particles and ∈ a dimensionless universal field ".

Rohrlich [2] wrote in the topic of renormalization :
"The effective charge e , which is the physical (renormalized) charge , is defined to be

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

where Z_i are renormalization constants ."

These expressions depict the effectiveness of the electric charge of the electron , written in different forms because they were derived from different bases .
Therefore , the variability of the electric charge is not a new topic ; physicists have discussed it before .

In the following sections , we will demonstrate *three other equations* for the effective electric charge of the electron which are revealed in the theory of the extended electron **.**

The first equation is derived from existing expressions of classical physics by a *heuristic argument* on the electric charge of the electron (section 2) .

The second and third equations will be derived from the electric and magnetic forces which are produced on the extended electron (sections 3 & 4) .
A thought experiment is proposed to demonstrate the variability of the electric charge of the electron by an applying magnetic field (section 5) .

2 . Heuristic equation for the effective charge of the electron

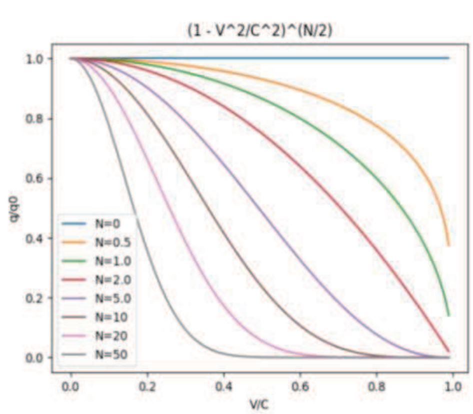
The oil-droplet experiment of Milliken suggests that the electric charge of the electron must link to its velocity and the electric field in which it is measured .
In an article of the theory of the extended electron [3] we have come to the heuristic equation

$$\boxed{q = \gamma^{-N} q_0 = (1 - v^2/c^2)^{N/2} q_0} \tag{1}$$

where $q_0 \equiv e$ is the charge of the electron at low speed (or at rest) , $\gamma = (1 - v^2/c^2)^{-1/2}$ is the Lorentz 's factor and the real number $N \geq 0$ represents the applying field .
Its graph plotted by computer is shown in Fig.1 . From the graph we notice that the higher the velocity and /or the stronger the applying field , the lower the effective charge q .
As $v \to c$, $q \to 0$ for N = 2.0 , 5.0 , 10 , 20 , 50 , ... while for lower fields (N = 0.5 , 1.0) q does not reduce to zero as $v \to c$.
In very high field ($N \to \infty$) , $q \to 0$ for all values of v : the electron is devoid of electric charge and becomes a free particle e^0 .

We call Eq.(1) **"heuristic equation "** because it discloses not only the variability of the electric charge of the electron , but also reveals that muon (μ^-) and tau (τ^-) particles are versions of the electron with reduced and varying electric charge , and *time dilation* is not a real physical nature of time [4] . The electric charge is a function of velocity and applying field ; both variables (v and N) have nothing to do with the physical structure of the electron .

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



3. Equation of the effective electric charge of the electron in the electric field

Now we examine another equation of the electric charge which is derived from the physical structure of the extended electron when it is subject to an external electric field **E** .

Electron is an spatially extended particle , not a mere point charge . The extended model of the electron is *a version* of the screened electron created by the vacuum polarization in the concept of QED : the electron is a spherical extended particle composing a negatively charged core ($-q_0$) surrounded by an assembly of real static electric dipoles ($-q$, $+q$) (Fig.2) .
When the extended electron is subject to an external field , forces are produced on these point charges ($-q_0$, $-q$, $+q$) to give rise to various features of the electron such as its effective electric charge , spin & radiation and other consequences .

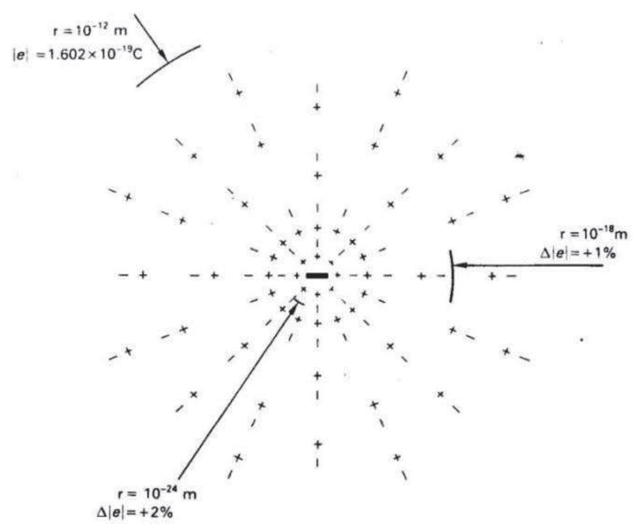


Fig.2 : The electron is screened by virtual pairs (e^- , e^+) in the concept of vacuum polarization of QED . This figure is a copy from the textbook " Nuclear and Particle Physics" (Vacuum polarization) by Williams , W.S.C

When the electron is subject to an electric field **E** , the net electric force produced on the electron [5] has been calculated to be :

$$\mathbf{Fe} = \left(\frac{a-1}{\varepsilon} - a \right) q_0 \, \mathbf{E} \qquad (2)$$

where ε is the permittivity of the electron : $\varepsilon < 1$; the parameter ' a ' characterizes the *physical structure* (structure factor) of the electron in the electric field : $a > 1$.

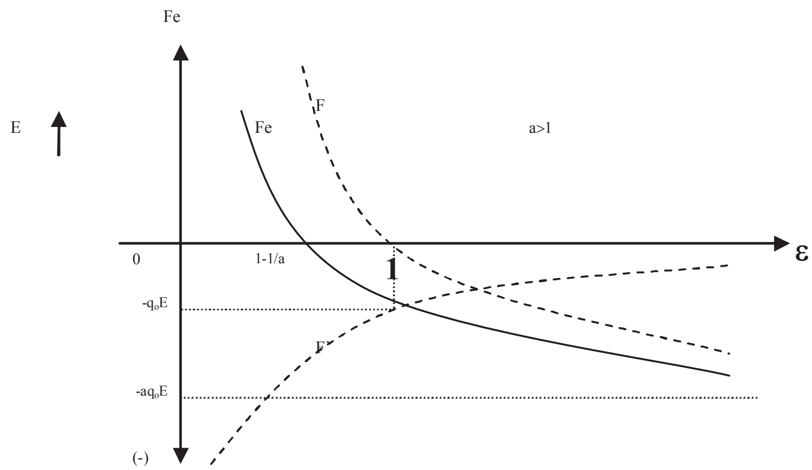


Fig.3 : Fe is a function of ε ; for the electron ε varies in the interval (1- 1/a , 1) .

From Eq.(2) we can deduce the effective electric charge of the electron since **Fe** = q **E :**

$$\boxed{q = \left(\frac{a-1}{\varepsilon} - a \right) q_0} \qquad a > 1 \ , \quad \varepsilon < 1 \qquad (3)$$

For the electron (**Fe** is negative) , ε varies in the interval (1-1/a) < ε < 1 and hence q is negative and varies in the interval (- q_0 , 0) : the electron accelerates in opposite direction to the electric field **E** .

From Fig.3 : if ε drops below the value (1-1/a) , **Fe** becomes positive , that is the electron becomes the positron ; this is the process which generates anti-particles .
If ε = 1 , **Fe** = - q_0 **E** and q **= -** q_0 : the electron is reduced to a point charge ; the point electron is thus a particular case of the extended electron if ε = 1 .
For the extended electron , its permittivity must be less than 1 ; i.e., 1-1/a < ε < 1 .
If ε = 1- 1/a , **Fe** = 0 and q = 0 : the electron is devoid of electric charge , it becomes a free particle e^0 .

Since the electric field **E** can cause a change in the permittivity ε , it can transform a particle into its anti-particle and vice versa [6] .

4. Equation of the effective electric charge of the electron in the magnetic field

Another equation of the electric charge of the electron can be derived from the physical structure of the electron when it is subject to the magnetic field **B** .
When the electron is subject to a magnetic field **B** , the net magnetic force produced on the electron [7] has been determined as :

$$\mathbf{Fm} = [\, \mu (b-1) - b \,] \, q_0 \, \mathbf{V} \times \mathbf{B} \qquad (4)$$

where μ is the permeability of the electron : $\mu > 1$ and ' b ' characterizes the physical structure of the electron in the magnetic field : $b > 1$

From the expression of **Fm** we can deduce the effective electric charge q of the extended electron in the magnetic field :

$$\boxed{q = [\, \mu(b-1) - b \,] \, q_0} \qquad (5)$$

where $\mu > 1$ and $b > 1$

If $\mu = 1$, $q = -q_0$, $\mathbf{Fm} = - q_0 \, \mathbf{V} \times \mathbf{B}$: the electron behaves like a point electron .
If $\mu = b / (b-1)$, $q = 0$, $\mathbf{Fm} = 0$: the electron is devoid of its electric charge and becomes a free particle : e^0 .
For the extended electron , the permeability μ varies in the interval $1 < \mu < b / (b-1)$, and the effective electric charge q varies in the interval $(-q_0 , 0)$.

Conclusion : we have just presented three plausible equations (1) , (3) and (5) to express the variability of the electric charge of the extended electron by external fields . Now we need an experiment to justify this new idea .

5. A thought experiment demonstrating the variability of the electric charge of the electron

To show that an external field can cause a change in the electric charge of the electron , the following thought experiment is proposed , which is based on the idea that the penetrating power of the electron into matter depends on its electric charge .

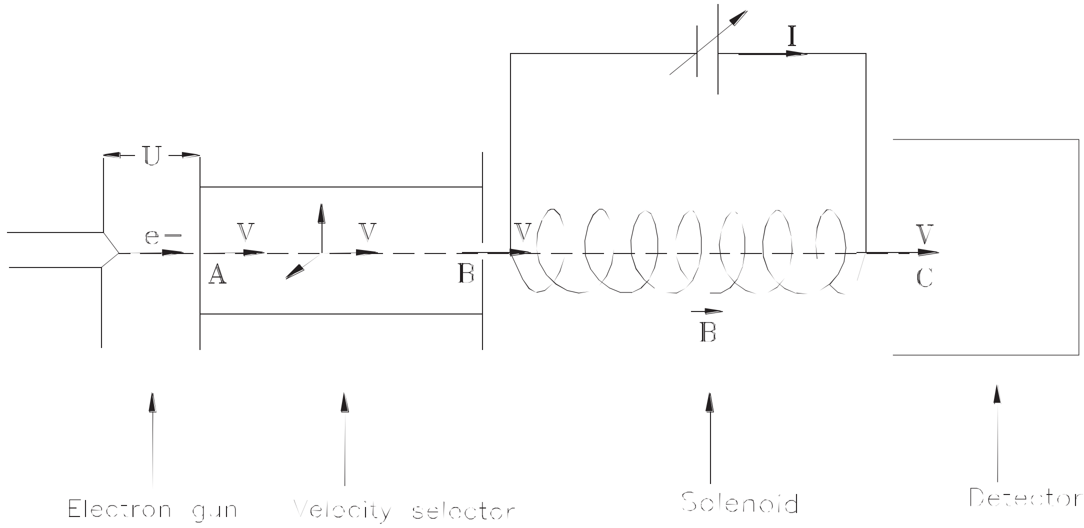


Fig 4

In this thought experiment we keep the velocity of electrons unchanged while we change the strength of the magnetic field **B** in the solenoid by changing the intensity of the current I .

- An electron gun produces electrons with various velocities at the point A .
- A velocity selector allows only electrons with velocity **v** to travel to the point B .
- A solenoid produces a uniform magnetic field **B** along its axis which coincides with the trajectory of the electron beam . The intensity **B** of the magnetic field can be regulated by the current I . Since **v** // **B** , there is no net (magnetic) force produced on the electron , electrons travel with constant velocity **v** through the solenoid to the point C . And thus , there is no change in the mass or the kinetic energy of the electron with velocity .
- A detector , which can be a thick block of silver bromide (photographic emulsion), is installed at the exit C of the solenoid to record the penetration of the electron and thereby verifying the changing of the electric charge of the electron when **B** changes its intensity .

At the point C on the detector , the velocity v of the electron remains constant , but its charge q is expected to decrease when the strength of the magnetic field **B** significantly increases . Since the energy loss per unit distance[8] in the medium of the detector is proportional to q^2 / v^2 (that is $\Delta K \propto q^2 / v^2$) , the increase of the intensity **B** (N increases) causes the effective electric charge q to drop (according to the curves in Fig. 1) and hence ΔK decreases , resulting in a deeper penetration of electrons into the block of photographic emulsion .

Therefore , when we change the intensity of **B** , if the depth of penetration responds to the change of **B** , this proves that q varies with the applying magnetic field .
This is a qualitative test .

Let us speculate that the stronger the magnetic pulses , the deeper the penetration becomes , and when the magnetic pulses are sufficiently intense , $q \to 0$: the interactions between electrons and molecules of silver bromide vanish , free electrons eventually traverse the medium of the detector .

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