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Renormalizing the Mass and the Electric Charge of the Electron (The Mystery of the Heavy Mass of the Muon)

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Abstract

In this article we will discuss the renormalization of the mass and the electric charge of the extended electron in the interaction of the electron with the external fields.

Originally, the renormalization procedure was introduced in the decades 20's and 30's of 20th century as a mathematical process used to remove infinity terms in the calculations in quantum mechanics (Section 3). But now many contemporary physicists have used the term "renormalization" in a simpler meaning: it simply means modification or adjustment of the original mass or electric charge of the electron by a dimensionless factor, called renormalizing factor (Section 4). The article contains 10 sections:

Section 1: *Old concept of mass and charge: the mass of the electron varies with velocity, while its electric charge is a fundamental constant of physics.*
Section 2: *Contemporary concept: physicists maintain that the mass of the electron is invariant in all physical conditions, while its electric charge varies with velocity and external field.*
Section 3: *Renormalization of mass is problematic.*
Section 4: *Renormalization of electric charge is innovative.*
Section 5: *Search for the renormalizing factor for the electric charge.*
Section 6: *Renormalizing Lorentzian force (FL) and Newtonian force (FN).*
Section 7: *A thought experiment to demonstrate the variability of the electric charge.*
Section 8: *The mystery of the heavy mass of the muon.*
Section 9: *The controversial concept of time dilation.*
Section 10: *The field reaction does not exist physically.*

Conclusion.

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Introduction

Old Concept of Mass of an Elementary Particle (e.g. an Electron): the Mass Varies with Velocity

This idea came from the theory of the electron of Lorentz in which he proposed (1904) an extended model of the electron as a uniform spherical surface charge. When this electron moved through the "ether", its transverse dimension remained unchanged, but its length in the direction of motion was contracted and the variation of the mass with velocity was derived as

$$\mathbf{m = (1 - v^2/c^2)^{-1/2}\, m_0} \qquad (1)$$

We can also find various expressions which describe the variation of the mass with velocity in current textbooks. For example, in the textbook ***"Introduction to the Theory of Relativity"*** by ***Bergmann*** [1] (1976) we can read the topic "***Relativistic Force***" p.103:

"In general, the force thus defined is not parallel to the acceleration. It is parallel only when the acceleration is either parallel or perpendicular to the velocity.
When it is parallel, it takes the form

$$\mathbf{f_s = (1 - u^2 / c^2)^{-3/2}\, m\, a} \qquad (2)$$

When the force and velocity are orthogonal, it becomes

$$\mathbf{f_s = (1 - u^2 / c^2)^{-1/2}\, m\, a} \qquad (3)$$

The coefficients of the acceleration on the right-hand sides of these two equations are occasionally referred to as "longitudinal mass" and "transversal mass", respectively".

So , from (2) the longitudinal mass is $\mathbf{m_l = (1 - u^2 / c^2)^{-3/2}\, m = \gamma^3\, m}$, **when** $\mathbf{a \,//\, v}$ **(4)**

and from (3) the transversal mass is $\mathbf{m\,t = (1 - u^2 / c^2)^{-1/2}\, m = \gamma\, m}$, **when** $\mathbf{a \perp v}$ **(5)**

where the velocity is denoted by u or v and $\gamma = (1 - v^2 / c^2)^{-1/2}$ is the Lorentz factor ; m_l and m_t thus depend on the velocity and also on the direction of motion of the particle relative to the external field.

We can also find these two expressions (4) and (5) of the longitudinal and transversal masses in the textbook "Classical Dynamics of Particles and Systems" by Marion and Thornton [2] (1995), p.576.

Today, the expressions of mass in Eqs. (1), (4) and (5) all are considered as old-fashioned, but as we will see in the following section 5, they can help to deduce another expression to replace them: it is the mathematical expression of electric charge: $\mathbf{q = \gamma^{-N}\, q_0}$

Contemporary concept: the mass of an elementary particle is always constant

Like in politics, physicists always confront with the opposition! The opposite concept is that the mass of a a particle is always constant in all physical conditions.

Let 's read the following quotations to see how contemporary physicists confirm the invariability of the mass of a particle.

Okun [3], " The concept of mass", Physics Today ,1989
"In the modern language of relativity theory there is one mass, the Newton mass m, which does not vary with velocity".

Sternheim & Kane [4], "General Physics ", 1991
"The correct definition of the relativistic momentum of an object of mass m and velocity v is p mv $(1 – v^2 / c^2)^{-1/2}$ *. In this equation, m is the ordinary mass of the object as measured by an observer in its rest frame. (Some books refer to this quantity as the rest mass and also define a velocity-dependent mass. We do not do this)".*

Marion & Thornton [2], "Classical Dynamics of Particles and Systems",1995, p.555
"Scientists spoke of the mass increasing at high speeds. We prefer to keep the concept of mass as an invariant, intrinsic property of an object. The use of two terms relativistic and rest mass is now considered old-fashioned. We therefore always refer to the mass m, which is the same as the rest mass".

Kacser [5], " Encyclopedia of Physics ", by Lerner & Trigg, 2005, topic: "Relativity, Special Theory".

"Mass – a notational issue - yet profoundly important. In many relativity presentations (but generally not in Einstein's own works), a misleading set of mass definitions was created – rest mass, relativistic mass (an abomination), transverse mass, etc. It has been strongly and correctly argued by Okun that these confusions should not be propagated. So here I will use m as the one-and-only mass of a particle being what is often called the rest mass and written m0. This mass m (by others often called m0 or the rest mass) is the same as the Newtonian mass at low velocities. Most important, m is a scalar or invariant, it has the same value for all observers of the particle, and is a constant parameter for the particle. It is to be determined by experiment, and by use of relativistic dynamics".

Adler [6], Am. J. Phys. 55, (1987); "Does mass really depend on velocity, dad?"
In the letter to Lincoln Barnett, 19 June 1948, Einstein wrote (in German): *"It is not good to introduce the concept of mass* $M = m / (1 – v^2/c^2)^{1/2}$ *of a moving body for which no clear definition can be given. It is better to introduce no other mass concept than 'the rest mass' m. Instead of introducing M, it is better to mention the expression for the momentum and energy of a body in motion."*

Conclusion: From these quotations we draw the conclusion that in the contemporary physics there exists an obvious conflict in the concept of mass as to whether or not it is invariant. This is a fundamental problem in physics and a plausible solution is presented in the following sections. To do this, first we notice that the measurements of the value of the ratio e / m of the electron show that " its value decreases (owing to increase in mass) as the velocity of the electron approaches that of light " [7].

But since the mass of the electron is regarded as an invariant (as stated by physicists in this section 2), it is reasonable to say that the decrease of the ratio e / m is caused by the decrease of the electric charge by its velocity and external field, but not by the increase in mass m.

Therefore, we can replace the concept of varying mass by the concept of varying charge in phenomena involving the motion of the electron in external field.

Renormalization of Mass is Problematic

The renormalization of the mass m as shown in Eqs. (1), (4) and (5) sends it to infinity: $m \to \infty$ as $v \to c$. To avoid all kinds of infinity terms caused by the mass, many physicists have come up with the renormalizing procedure, which many other physicists regarded as a disaster:

Dirac (1975): *" This so-called 'good theory ' does involve neglecting infinities which appear in its equations, ignoring them in an arbitrary way. "*

Feynman: (1985)*" It is still what I would call a dippy process! ... I suspect that renormalization is not mathematically legitimate."*

Ryder: " *In the Quantum Theory, these [classical] divergences do not disappear, on the contrary, they appear to get worse. "*
(From Wikipedia: Renormalization)

This is the reason why we try to switch to the renormalization of electric charge to avoid all infinities caused by the mass m.

Renormalization of electric charge is innovative

The ideas of renormalizing the electric charge appeared early in the literature of physics with Schwinger, Jackson, Bekenstein, Rohrlich, David Griffths:

Schwinger [8].
" Now one of the most important interaction aspects of quantum electrodynamics is the phenomenon of vacuum polarization ... The implication that physical charge is weaker than bare charge by a universal factor is the basis for charge renormalization."

Jackson [9] wrote in the textbook Classical Electrodynamics:
"Since charged particles are always surrounded by this cloud of virtual electron-positron pairs, their observed charges must be interpreted as their renormalized charges".

Bekenstein [10]:
"Thus, every particle charge can be expressed in the form $e = e_0 \epsilon(x^\mu)$ *, where* e_0 *is a constant characteristic of the particles and* ϵ *a dimensionless universal field."*

Rohrlich [11] 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."*

David Griffiths [12] wrote in the textbook Introduction to Elementary Particles:
"The effective charge of any particle is somewhat reduced: $q_{eff} = q / \varepsilon$*". (The factor* ε *is called the dielectric constant of the material).*

Conclusion: So, physicists rejected the concept of varying mass ($m = (1 - v^2/c^2)^{-1/2} m_0$) and suggested the concept of varying electric charge to replace it.

To contribute to their work, this article intends to search for a suitable expression to describe the variability of the effective electric charge in external field. And as a result, a renormalizing factor for the effective electric charge will be applied for the modern classical physics.

Search for a Mathematical Expression that describes the Effective Electric Charge of the Electron in External Field.

We notice in the equations of motion of the electrons in the external field that e and m appear together in the ratio e / m, rather than emerging separately. Now if we want to adjust these equations of motion to express the effect of relativistic mass of the electron, we write this ratio in the form **$e / (\gamma m)$. Since $e / (\gamma m) \equiv (\gamma^{-1}) e / m$** , this means that the equation of motion does not change mathematically if we write this ratio in either form: **$e / (\gamma m)$ or $(\gamma^{-1}) e / m$.**

If we write the ratio in the form **$(\gamma^{-1}) e / m$**, this physically means that we choose to express the concept of varying charge **($\gamma^{-1} e$)** instead of the concept of varying mass **(γm).**

We Notice that the Renormalizing Factor for the Electric Charge (γ^{-1}) is the Inverse of the Renormalizing Factor for the Mass (γ)

This means that if γ is known, we can deduce the inverse γ -1 .

Below we will use this statement to search for a mathematical equation which describes the variability of the electric charge of the electron in external fields, in relativistic regime.

We have seen in section 1: the renormalizing factor γ for the mass has two different exponents: 3 and 1 in two particular cases:

- γ^3 for the longitudinal mass : **$m_l = \gamma^3 m$, when $a // v$, from Eq (4)**

- γ for the transversal mass : **$m_t = \gamma m$, when $a \perp v$, from Eq (5)**

And thus , the renormalizing factors for the electric charge in these two particular cases are γ^{-3} and γ-1 (these are the inverses of γ^3 and γ respectively) . So , we can write :

$$q = \gamma^{-3} q_0 \quad , \text{ when } a // v \quad (\text{electron in electric field } E) \qquad (6)$$

and

$$q = \gamma^{-1} q_0 \quad , \text{ when } a \perp v \quad (\text{electron in magnetic field } B) \qquad (7)$$

Two exponents 3 and 1 (without the minus sign) in Eqs (6) and (7) originate from two particular cases of direction between the velocity v and the acceleration a : a // v and a ⊥ v .

Now , we use heuristic argument* to generalize two equations (6) and (7) for any relative direction between *v and a* , and in any external field by replacing these two exponents 3 and 1 by a unique real positive number N to unify two equations (6) and (7) , we get :

$$\boxed{q = \gamma^{-N} q_0 = (1 - v^2 / c^2)^{N/2} q_0} \qquad N \geq 0 \qquad (8)$$

where $\gamma = (1 - v^2/c^2)^{-1/2}$ is the Lorentz factor , $q_0 \equiv e$ (electric charge of the electron)

Note : We can come to Eq.(8) by reasoning on the classical equation of Lorentz force :

$$\mathbf{ma = e [E + v \times B]} \qquad \mathbf{(9)}$$

If $\mathbf{m = \gamma m_0}$ **, (9) becomes** $\mathbf{(\gamma m_0)\, a = e [E + v \times B]}$ **(10)**

Equation (10) means that the mass m_0 of the electron is renormalized by γ .
Now , by moving γ to the right hand side , (10) becomes

$$\mathbf{m_0\, a = (\gamma^{-1} e) [E + v \times B]} \qquad \mathbf{(11)}$$

In (11) we set $q = \gamma^{-1} e$: $\mathbf{m_0\, a = q [E + v \times B]}$

Equation (11) means that the charge e is renormalized by the factor γ^{-1} .
Therefore , (10) or (11) remains mathematically the same (i.e., unchanged) after either its mass is renormalized by the factor γ or its charge is renormalized by the factor and γ^{-1} .
This physically means that when the electron is accelerated in the accelerator , its mass remains unchanged while its electric charge decreases by the factor γ^{-1} .

In short , $\mathbf{m = \gamma m_0}$ **paves the way to** $\mathbf{q = \gamma_{-1} e}$ **.** **(12)**

If $\mathbf{m = \gamma^3 m_0}$ **, the same reasoning as above leads to** $\mathbf{q = \gamma^{-3} e}$ **(13)**

Heuristic argument * allows us to generalize two expressions of q in (12) and (13) into a unique expression with exponent N :

$\mathbf{q = \gamma^{-N} e = (1 - v^2 / c^2)^{N/2}\, q_0}$ **, where** $\mathbf{N \geq 0}$ **and** $\mathbf{q_0 \equiv e}$ **:** this is the equation (8) above .

Note : * **Heuristic :** allowing or assisting to discover (Oxford dictionary).
* **Heuristic argument** (From Wikipedia) :
" It is a speculative , non-rigorous argument that relies on analogy or intuition , and that allows one to achieve a result or an approximation that is to be checked later with more rigor . Otherwise , the results are generally to be doubted , it is used as a hypothesis or a conjecture in an investigation ".

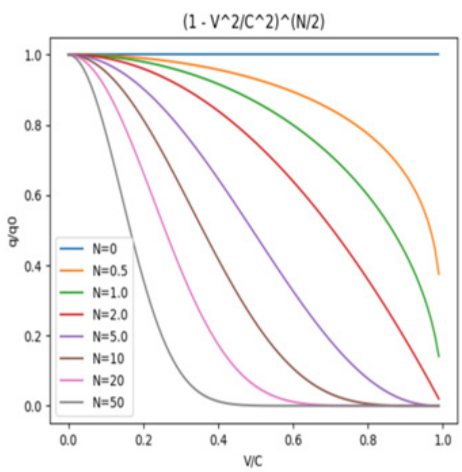


Fig.1 : $q / q_0 = (1 - v^2 / c^2)^{N/2}$

Figure 1: the graph of Eq (8) shows the magnitude of the electric charge of the electron as function of its velocity and the applied field which is represented by the real positive number N.
From the graph we notice that the higher the velocity and / or the stronger the applied field (N), the lower the effective charge q of the electron becomes. This means that when the electron is subject to an external applied field, its effective electric charge q drops below its original charge q0 (which is conventionally denoted as e).

Some Remarks on the Graph

At low velocity: $v << c$, $q \approx q_0$ for all values of N; i.e., for all applied fields. This is the case of Millikan ' soil-drop experiment. In this experiment, electrons (on oil drops) fall down at low velocity of a fraction of a millimeter per second in the electric field of 6000 volts per cm. And as a result, Millikan experiment could only give the unique value $q \approx q_0$ ($\equiv$ e) for the electric charge of the electron.

Mainstream physicists considered this value e as the only value for the electric charge because after Millikan, they could not perform this experiment at higher velocities or in stronger fields which might give the effective charge q other values different from e. *

* It is interesting to read the following remarks that Millikan made on his experiment of oil-drop:
"In order to be able to measure very accurately the force acting upon the charged oil-droplet it was necessary to give it about a centimeter of path in which the speed could be measured. This is one of the most important elements in the design, the overlooking of which has caused some subsequent observers to fall into error … The field strength too, about 6,000 volts per cm, was vital, and new in work of anything like this kind. It was the element which turned possible failure into success. Nature here was very kind.

She left only a narrow range of field strengths within which such experiments as these are all possible." (Millikan's Nobel lecture, 1924)

We notice that in his Nobel lecture, Millikan never said that the electric charge of the electron was an invariant. So, if this experiment could be carried out at higher velocities and/or in a much stronger electric field, would it result in other values different from e ?

At high velocity near c ($v \to c$), q depends on the intensity of the applied field N:

- if N = 0 (in free space) : $q = q_0$ for all velocities.
- if N = 0.5 or 1.0 , the charge q drops but does not reach zero when $v \to c$;
- if N = 2.0 , $q \to 0$ when $v \to c$;
- if N = 5.0 , 10 , 20 , 50 , $q \to 0$ at velocities less than c.

In intense fields: the curves with N = 5.0, 10, 20, 50 ... demonstrate that in intense fields, electrons could be devoid of their charge and become free particles ($q \approx 0$) at velocities less than c. Equation (8) is the only equation that shows the impact of the applied field on the electric charge of the electron. Thus, while the electron is accelerated in the accelerators, its electric charge changes continuously; it does not remain constant as being thought so far.

The immediate consequence of Eq (8) is the renormalized Lorentz ' s force equations for relativistic regime:

$$\mathbf{F_L = (1 - v^2 / c^2)^{N/2} q_0 (E + v \times B)} \quad (14)$$

in which the electric force Fe and the magnetic force Fm tend to zero as $v \to c$:
$Fe = (1 - v^2 / c^2)^{N/2} q_0 E$: Fe decreases with v and tends to zero as $v \to c$. (15)

$Fm = (1 – v^2 / c^2)^{N/2} q_0 v \times B$: Fm first increases with v, reaches its maximum (16) at $v = c (N + 1)^{-1/2}$, then decreases and tends to zero as $v \to c$.
Note: The maximum point of Fm is an intriguing point: there are two different values of velocities V1 and V2 (on either sides of this maximum) that give the same value of Fm.

For v << c, $Fe \approx q_0 E$ and $Fm \approx q_0 v \times B$: these are familiar non-relativistic Lorentz ' s force equations.

A special call on the readers who are proficient in computer : will you please delineate the graphs of Fe and Fm (Eqs. (15) and (16)) with N = 0 , 1 , 2 …50 …100… as functions of the velocity v to see how they tend to zero as $v \to c$.

Section 6: Renormalizing Lorentzian force FL and Newtonian force FN

The Lorentzian force FL is renormalized by renormalizing the electric charge q :

$$q = \gamma^{-N} q_0 = (1 – v^2 / c^2)^{N/2} q_0 \quad N \geq 0$$

Hence the renormalized Lorentzian force is:

$$F_L = (1 – v^2 / c^2)^{N/2} q_0 (E + v \times B)$$

which is the relativistic equation of Lorentz' s force.

The Newtonian force FN is renormalized by renormalizing the momentum P :

$$\mathbf{P = m_0 (\gamma v) \text{ where } \gamma = (1 – v^2 / c^2)^{-1/2}} \qquad \textbf{(17)}$$

Hence the renormalized Newtonian force is:

$$\mathbf{F_N} = d\, \mathbf{P} / dt = d (m_0 \gamma v) / dt = m_0\, d (\gamma v) / dv \,.\, dv / dt$$

where dv / dt = a is the acceleration of the particle , we get

$$\mathbf{F_N = d P / dt = m_0 a\, d (\gamma v) / dv} \qquad \textbf{(18)}$$

If we carry out the differentiation in Eq.(18) with respect to v , we get an involved , unwieldy expression of the renormalized Newtonian force F_N.

In order to write the equation of motion of the particle in the applied field, we postulate that the Newtonian force F_N is equal to the Lorentzian force F_L . So, we have following options:

$$\mathbf{m_0 dv / dt = q_0 (E + v \times B)} \qquad \textbf{(19)}$$

In high energy (i.e., in relativistic regime : $v \to c$ or in high field : large N) : $\gamma \neq 1$, Newtonian force is no longer equal to Lorentzian force : $F_N \neq F_L$ because they are renormalized in two different ways:

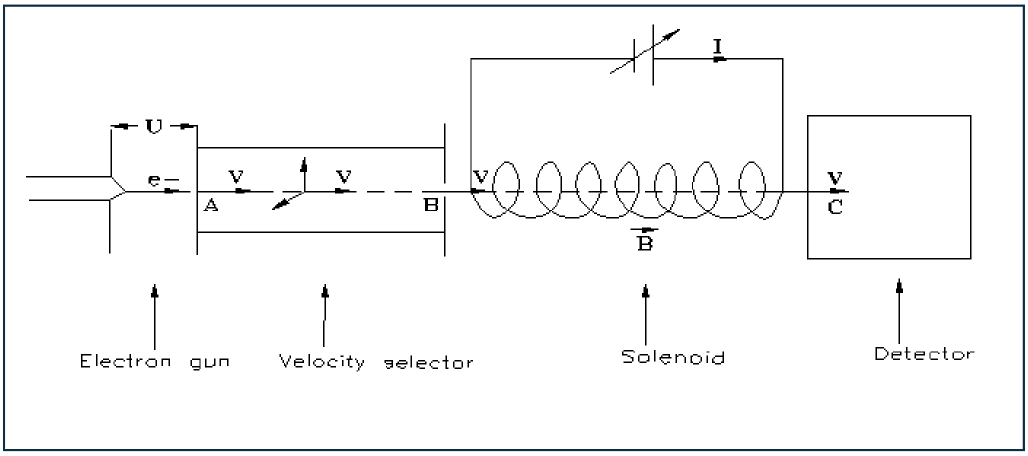
$$\mathbf{m_0 a\, d (\gamma v) / dv \neq (1 – v^2 / c^2)^{N/2} q_0 (E + v \times B)} \qquad \textbf{(20)}$$

The inequality seems to come from the renormalization of the Newtonian force $\mathbf{F_N}$. We can bring them back to equality $\mathbf{F_N} = \mathbf{F_L}$ by keeping $\mathbf{F_N}$ unchanged and renormalizing $\mathbf{F_L}$ alone :

$$m_0 \, dv / dt = (1 - v^2 / c^2)^{N/2} q_0 (E + v \times B) \qquad (21)$$

This is the heuristic equation of motion of the particle in extreme conditions of velocity and applied field. In short, in high energy, we should renormalize the electric charge q of the electron (that is, renormalize the Lorentz force), instead of renormalizing the momentum P and the Newtonian force FN because they belong to the renormalization of mass which causes problems as we have seen in section 3.

Section 7: A Thought Experiment to Demonstrate the Variability of the Electric Charge in Magnetic field.



(Fig.2)

In this thought experiment we keep the velocity of the 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 n the electron, so electrons travel with constant velocity v through the solenoid to the point C. And thus, there is no change in the mass and 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 detect the changing of the electric charge q of the electron when **B** changes its intensity.

At the entrance point C on the detector, the velocity of the electron is v, and its effective charge is q, which is expected to decrease when the magnetic field **B** significantly increases.

Since the energy loss per unit distance [4] in the medium of the detector is proportional to q^2 / v^2, (that is $\Delta K \propto q^2 / v^2$), if the intensity of **B** increases (N increases), the effective electric

charge q will 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.

In short, when we change the intensity of **B**, if the change in penetration responds to the change of **B**, this proves that q varies with the applied magnetic field.

We expect that the stronger the magnetic pulses, the deeper the penetration becomes, and when the magnetic pulses become sufficiently intense, $q \rightarrow 0$: the interactions between electrons and molecules of silver bromide of the detector vanish, the free electrons eventually traverse the medium without hindrance.

Section 8: Mystery of the Heavy Mass of the Muon.
Physicists considered the muon as a mystery:

- *" Muons even today represent something of a puzzle ... Only in its mass and stability does the muon differ significantly from the electron, leading to the hypothesis that the muon is merely a kind of ' heavy electron ' rather than a unique entity." (A.Beiser [13] Concept of Modern Physics, 1981)*

- *" The muon is a mystery; it is like an electron almost every way but its mass . There is no known reason why it must exist ... ... A complication is introduced by the magnitude of the charge , for both the rate of energy loss and the radius of the circle depend on how much charge the particle has. " (Lehrmann & Swartz, [14] Foundation of Physics, p.697, 1969).*

The last quotation tells us that the magnitude of the charge interferes in the determination of the mass of a particle. So, if we do not know how much charge the particle has, we cannot determine its mass accurately; this is the case in the determination of the mass of the muon.
An explanation of the mystery of the muon is to apply the concept of renormalization of the electric charge of the electron as presented in section 5.
In the determination of the mass of the muon, physicists assumed that its charge is invariant, equal to e, while its mass varies with velocity. This assumption certainly is the reason why their calculations resulted in the heavy mass of the muon:

In the determination of the mass of the muon, physicists assumed that its charge is invariant, equal to e, while its mass varies with velocity. This assumption certainly is the reason why their calculations resulted in the heavy mass of the muon:

$$\mathbf{m_\mu = 207\ m_e} \qquad (22)$$

This relation means that $m\mu$ is the renormalizing mass of the electron , in which the renormalizing factor is $\gamma = 207$

In section 5 , we have come to the result that **the equation of motion of the electron remains unchanged if we renormalize the electric charge by the factor γ-^{1} instead of renormalizing the mass by the factor γ .**

Hence , instead of renormalizing its mass by γ (= 207) as shown in Eq(22), let 's renormalize its electric charge by γ^{-1} ($= 207^{-1}$), we get

$$\mathbf{q_\mu = \gamma^{-1}\ q_0 = (207)^{-1}\ q_0 \text{ , where } q_0 \equiv e = 1.602 \times 10^{-19}\ C} \qquad (23)$$

$$\mathbf{\text{or } q_\mu = (207)^{-1}\ e = 7.739 \times 10^{-22}\ C} \qquad (24)$$

Therefore, the muon is the electron with reduced electric charge equal to 7.739×10^{-22} C . The muon differs from the electron by its reduced, varying electric charge; its mass remains unchanged, equal to that of the electron.
As for the varying electric charge: when the muon is created, the magnitude of its charge is 7.739×10^{-22} C; it increases to $e = 1.602\times 10^{-19}$ C in 2.2 μs (this is the lifetime of the muon). The variation of the electric charge follows a curve N shown in Fig. 1. Since the charge varies in a very short period of time (2.2 μs), the variation

cannot be revealed by any detector; hence, the charge of the muon is taken for granted as a constant, equal to e, which is its final charge.

As for the velocity of the muon: when the muon is created, its velocity v may be high; it slows down and eventually stops in the detector: v → 0 in 2.2 μs. At the end of its transformation, the muon becomes identical to the electron: μ- → e- (by following a curve N in Fig.1 which ends up at the terminal coordinates (v = 0, q = q_0) in 2.2 μs) . As for the mass of the muon: it is invariant, equal to the mass m0 of the electron through its transformation from muon to electron.

Conclusion: There are two different Paths for the Interpretation

If the muon is considered as a particle that has constant electric charge e = 1.602 × 10^{-19} C and its mass changing with velocity, then we will get a muon which is 207 times heavier than the electron : $m_\mu = 207\ m_e$. This is the " old " mainstream physics, for which all charged particles have constant charge : ± e. This way leads to the idea that muon is a heavy electron.

But if we consider the muon as a particle that has invariant mass and its charge is changing with velocity and applied field, then we will get a muon which has the same mass as the electron mμ = me = 0.511 Mev/c^2 but a reduced charge : $q_\mu = (207)^{-1}\ e = 7.739\times10^{-22}$ C.

This is an innovative way to explain the long-lived mystery of the mass of the muon: muon is not a heavy electron, it is the electron with reduced electric charge. And hence muon is much more penetrating than the electron.

Since being created in different fields and velocities (in the upper atmosphere or in different labs …), different muons have different charges and lifetimes, in spite of they have the same mass as the electron.

Note : The tau particle (tauon) τ^- is analogous to the muon: it is the electron having reduced electric charge : $\tau^- \rightarrow \pi^- \rightarrow \mu^- \rightarrow e^-$:

Since $m_\tau = 3491\ m_e$, $q_\tau = (3491)^{-1}\ e = 4.59 \times 10^{-23}$ C : Tauon ' s electric charge is much smaller than that of the electron and muon, hence it has more penetrating power than the electron and muon . Two values $m_\mu = 207\ m_e$ and $m_\tau = 3491$ me are taken from the list of fundamental constants in current textbooks.

Section 9: The controversial concept of time dilation

The following phenomena are often cited in the physical literature to prove that the increase of the lifetime of the muon with its velocity is a proof that the concept of time dilation is a real physical phenomenon.

- Experiments performed at CERN showed that muons at speed of 0.99 c were found to have an average lifetime 29 times as large as that of muons at rest.
- The finding of muons at sea level proved that due to their high speed (0.999 c), their lifetime has increased from 2 μs to 30 μs such that they can travel over 9000 m (instead of 600 m) to reach the sea level.

From these data, some physicists believe that time dilation is no doubt a real physical phenomenon.

The purpose of this subsection (v) is to show that the time dilation does not exist physically although the lifetimes of moving muons actually increase with their velocity.

First of all, physicists think that all muons, no matter where and how they are created, must have the same lifetime (the average is 2.2 μs) . So with the velocity v = 0.99 c = 0.99 × 3 × 108 m /s , the muon can travel

But since muons were found at sea level, i.e., they have travelled over 9000 m (from the upper atmosphere to the sea level). This means that their lifetime has increased from 2.2 μs to 30.3 μs. From this increase of the lifetime of muons, physicists concluded that the time dilation is a real physical nature of time.

Physicists have thus assimilated two different notions: the increase of lifetime (of the muons) and the time dilation. The mixing up of these two notions is superficial and hence incorrect because we can explain the increase of the lifetime of the muons by using the concept of variability of the electric charge of the electron (described in section 3), in which there is no place for the concept of time dilation.

The explanation is as follows: because the muons are created in different places (in the labs on Earth or in the upper atmosphere), they start their lives at different coordinates (v, q) on the chart of Fig.1, and finally they end up at the terminal point (v = 0 , q = q0) by following different curves N in Fig.1. By following different paths of transformation from muon to electron (μ- → e-), they spend different time to reach the terminal point: this means that they have different lifetime which has nothing to do with the nature of time.

In short, the concept of time dilation is unnecessary and redundant. Time does not dilate nor shrink: it is absolute as conceived by Newton. The concept of time dilation led to counter- intuitive ideas of " length contraction " and the so-called " twin paradox": both ideas are old-fashioned and superfluous for modern physics.

The field reaction does not exist physically

The electric charge of the electron creates an electromagnetic field around it. Many physicists in the decades 30's and 40's of the 20th century thought that this self-field could interact with the electron itself, giving rise to a force field, called the field reaction (FR).

The reason why the concept of field reaction is considered here is that its existence is related to the renormalization procedure which we are discussing in this article.

In his Nobel lecture 1965, Tomonaga reviewed different ideas on the existence of the field reaction which many physicists supported while many other opposed it.

According to Tomonaga, the field reaction (FR) appeared in several physical processes, e.g., the Lamb 's shift, the vacuum polarization and the scattering of the electron.

FR, if existed, causes the electromagnetic mass and the electric charge of the electron in the equations of these processes to become infinity. Hence, the renormalization procedure must be performed to eliminate those infinities.

Since the renormalization procedure for removing infinity terms were opposed by many physicists, considering it as a mathematically illegitimate one (as mentioned in section 3), the concept of FR is redundant and unnecessary; its existence merely complicates Physics.

"There were even those with the extreme view that the concept of field reaction itself had nothing to do at all with the true law of nature" (Tomonaga, Nobel Lecture 1965).

On the other hand, in 1946, Sakata (in Japan) and Pais (in US) proposed the existence of an unknown force field, called cohesive force field, which co- existed with the self -field of the electron could compensate the infinity of the electron mass (caused by the field reaction) and hence stabilize the electron. Tomonaga called this compensating force "a plus - minus cancelation".

Comment on the field reaction and the cohesive force field of Sakata:

The reason why the infinities (or divergences) of mass and electric charge exist is because the electron is viewed as a point particle with invariant electric charge. Now if we change our mind and consider the electron as an extended particle with variable electric charge as described by equation (8)

$$\mathbf{q = \gamma^{-N} q_0 = (1 - v^2 / c_2)^{N/2} q_0 , N \geq 0 , q_0 \equiv e , \gamma \text{ is the Lorentz factor .}}$$

and its graph shown in Fig.1, then both the field reaction and the cohesive force field of Sakata do not exist physically.

In the article **"A new extended model for the electron"** [15] Fig. 9 shows a spherical electron with its self field $\mathbf{E_0}$. This self field $\mathbf{E_0}$ interacts with a surface dipole (-q , +q) giving rise to the electric field $\mathbf{E_0}$' inside the electron. $\mathbf{E_0}$' exerts a centripetal force G on the surface dipole and keeps it attached to the electron; hence G is called cohesive force. Its magnitude is calculated as:

$$\mathbf{G} = [1/\varepsilon - 1] \, q \, \mathbf{E_0}$$

where ε is the relative permittivity of the extended electron. Since the electron is stable, G must be centripetal like $\mathbf{E_0}$, i.e., **G** is parallel to $\mathbf{E_0}$, so [1/ε - 1] > 0 or ε < 1 .

In short, the self field $\mathbf{E_0}$ of the electron interacts with the electron itself to give rise to the field $\mathbf{E_0}$' which (together with the self field $\mathbf{E_0}$) give rise to the cohesive force **G** to keep the electron stable. The field reaction and the cohesive force field of Sakata do not exist physically, they are merely other names of the field $\mathbf{E_0}$'.

Conclusion: In free space (i.e., in a perfect vacuum where there is no field) the electric charge of the electron produces two electric fields: the self field Eo that interacts with the electron itself to give rise to the cohesive force field **E'o**.

(Readers are invited to read this article "A new extended model for the electron" [15]
for more information)

Conclusion

Physics advances and has no frontier. Eliminating an old-fashioned concept is as crucial for science as inventing a new concept. This article proposes to replace the old concept of varying mass ($\mathbf{m = \gamma\, m_0}$) by the novel concept of varying electric charge **($\mathbf{q = \gamma^{-N} q_0}$).** The replacement leads to the renormalization of the Lorentzian force, but not to the Newtonian force, in the relativistic regime.

The ideas of the extended electron and its variable electric charge would help physicists to ameliorate the determinations of the magnetic moment of the electron and the muon, and hence adjust the anomaly of g – 2. It may possibly give a novel concept to the new physics.

The exploration of the extended model of the electron also paves the way to investigating enigmatic features of the electron, especially its spin and radiation [15].

References

1. Bergmann P G (1976) "Introduction to the Theory of Relativity. 103.
2. Marion J B, Thornton S T (1995) "Classical Dynamics of Particles and Systems. 4: 555-576.
3. Okun L B (1989) The concept of mass. Physics Today 42: 31-36.
4. Sternheim MM, Kane J W (1991) General Physics 2: 850.

5. Kacser C (2005) ‘Relativity, Special Theory’, “Encyclopedia of Physics”, by Lerner & Trigg 3: 2267.
6. Adler C G, A m (1987) “Does mass really depend on velocity, dad?” J. Phys. 55: 739.
7. Illingworth V (1991) The Penguin Dictionary of Physics, 2nd Ed.
8. Schwinger J (1965) (Nobel Lecture. Relativistic quantum field theory.
9. Jackson, Classical Electrodynamics, Introduction and survey, section 1.3: 12.
10. Bekenstein J D (1982) Fine-structure constant: Is it really a constant?, Physical Review D. Vol.25: 1527-1529.
11. Rohrlich F (2005) Encyclopedia of Physics, by Lerner & Trigg ,3 rd Ed. Quantum Electrodynamics 2083.
12. Griffths, D “Introduction to Elementary Particles Fig.2.2.
13. A Beiser (1981) Concept of Modern Physics.
14. Lehrmann, Swartz (1969) Foundation of Physics 697. www.viXra.org/author/hoa_van_nguyen