Extended Electron in Constant Electric Field
Part 1 : The net electric force Fe produced on the extended electron

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Abstract : When an extended electron is subject to an external constant electric field **E** , the net electric force $\mathbf{F_e}$ is produced on it . The analysis on the extended model of the electron shows that $\mathbf{F_e}$ is the resultant of two opposite forces **F** and **F'** (i.e., $\mathbf{F_e = F + F'}$) , where **F** is the resultant of all elementary forces $\mathbf{f_e}$ which are produced on *surface dipoles* of the electron ($\mathbf{F = \Sigma f_e}$), and **F'** is the electric force produced on *the core* ($-q_0$) of the electron .
We will calculate **fe** , **F** and **F'** by applying boundary conditions on the surface of the extended electron . The effective electric charge Q of the electron will be deduced from the expression **Fe** = Q **E** .
Part 2 discusses the radiation process of the extended electron in the electric field **.**

Keywords : electric dipoles , surface dipoles , the core , electric and magnetic boundary conditions , radiation by forces **,** radiation cone , conditions for radiation .

1. Introduction :

The readers are recommended to read the previous article [1(a)] : "**A new extended model for the electron "** to have a view on the *extended model* of the electron and the *assumptions for calculations* ; since all the calculations in this article will be based on this model and the assumptions on the electric and magnetic boundary conditions . In a nutshell , the extended model of the electron is a spherical composite structure consisting of the point-charged core ($-q_0$) which is surrounded by countless electric dipoles (-q,+q) as schematically shown by Fig.1 and other figures in this article .

Since this article " **Extended electron in constant electric field** " is rather long , it will be divided into two parts : Part 1 : Determination of the net electric force **Fe** ,
Part 2 : The radiation of the extended electron in electric field .

To reduce the length of the main text , long calculations are put into the **appendices** , only the results of these calculations are shown in the main text . (Appendices A and B are placed at the end of part 2 , the readers can read them later if they want to) .

When a *point electron* of electric charge e is subject to an external electric field **E** , the Lorentz force $\mathbf{F_L}$ = e **E** is a single force ; i.e., it cannot be decomposed into simpler components . But for an *extended electron* , the net force **Fe** is more complicated because it consists of countless point charges : the electric dipoles (-q , +q) and the core ($-q_0$) , and hence lots of single forces are produced on it when it is subject to the external field .
To determine the net electric force **Fe** produced on the extended electron , we will first calculate the "elementary" force **fe** which is developed on *a surface dipole* , then the resultant $\mathbf{F = \sum fe}$ of all forces **fe** produced on all surface dipoles of the electron (section 2) . Then we will calculate the electric force **F'** which is produced on the core ($-q_0$) of the electron (section 3) , and finally the net force **Fe** = **F + F'** (section 4) .
Section 5 discusses the variability of the relative permittivity ε of the extended electron .
Section 6 discusses the variability of the effective electric charge Q of the extended electron .
Section 7 discusses the equation of motion of the extended electron in the external electric field .

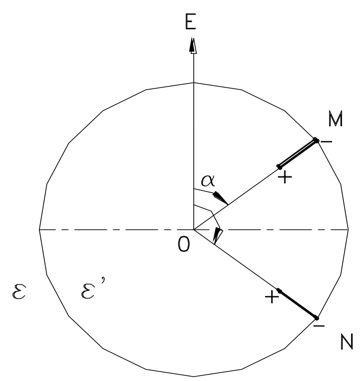
2. Determination of the elementary force fe produced on a surface dipole and the resultant $\mathbf{F = \sum fe}$.

Let **E** be the external electric field which exerts on the extended electron **; E** creates the electric field **E'** inside the extended electron . Boundary conditions **1(a)** on the electric field allow us to determine the electric field **E'** from the components of the external field **E** which is supposed to be a known field .
First , let us calculate two elementary electric forces **fe** produced on *two arbitrary surface dipoles* M and N on the *upper and lower hemispheres* of the electron , respectively . (Fig.1)
For the surface dipole M on the upper hemisphere, the angle α is $0 < \alpha < \pi/2$ (Figs. 4 and 5) .
The force **fe** is the resultant of two forces **fn** and **f'n** which are developed on two ends -q and +q of the dipole M , respectively . The calculations are shown in the **Appendix A** . The results are :

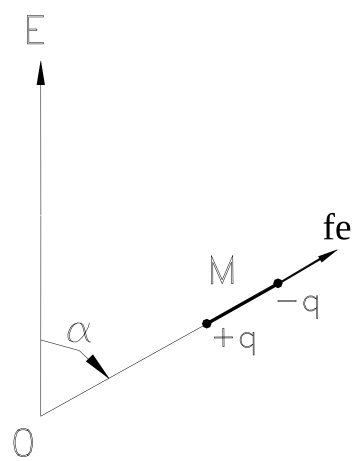
* when $\varepsilon < 1$ (Fig. 4) , $fe = f'n - fn = (1/\varepsilon - 1) q E \cos\alpha$, **fe** is centrifugal , (1-a)

* when $\varepsilon > 1$ (Fig. 5) , $fe = fn - f'n = (1 - 1/\varepsilon) q E \cos\alpha$, **fe** is centripetal , (1-b)

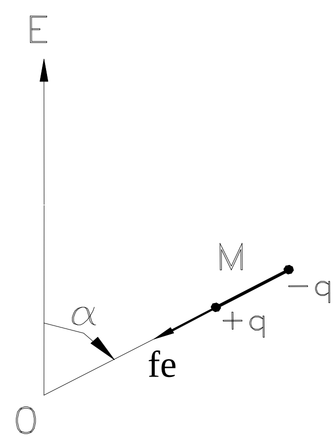
Where ε is *the relative permittivity* of the extended electron (ε') to the free space (ε_0) ; i.e., $\varepsilon = \varepsilon' / \varepsilon_0$.



F.1 : Two surface dipoles M and N on the upper and lower hemispheres of the extended electron .
(<u>Error</u> : permittivity of free space outside the electron is ε_0 , not ε as shown in F.1).



F.4: When $\varepsilon < 1$: the resultant force **fe** acting on dipole M is centrifugal .

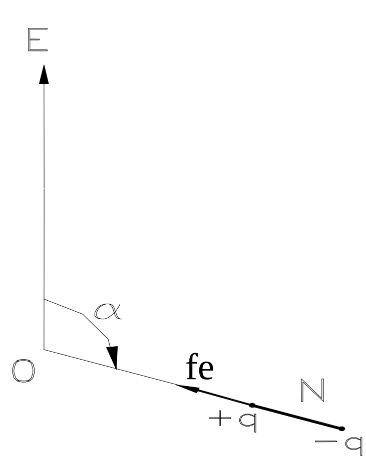


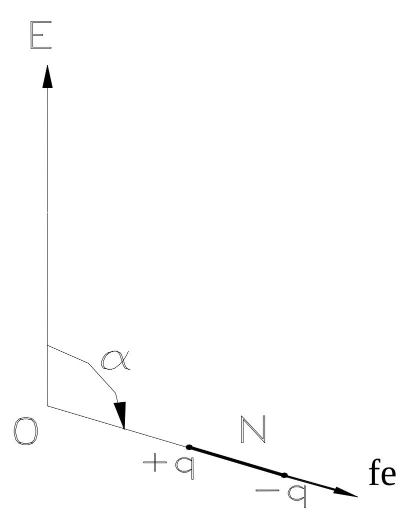
F.5 : When $\varepsilon > 1$: the resultant force **fe** acting on dipole M is centripetal .

Now let us calculate the resultant force **fe** acting on the surface dipole N on the *lower hemisphere* of the electron (Figs. 8 and 9) : $\pi/2 < \alpha < \pi$, (hence $\cos\alpha < 0$) (See **Appendix A**) . The results are :

* when $\varepsilon < 1$ (Fig. 8) : $fe = f'n - fn = (1/\varepsilon - 1) q E (-\cos\alpha)$, **fe** is centripetal, (1-c)

* when $\varepsilon > 1$ (Fig. 9) : $fe = fn - f'n = (1 - 1/\varepsilon) q E (-\cos\alpha)$, **fe** is centrifugal . (1-d)





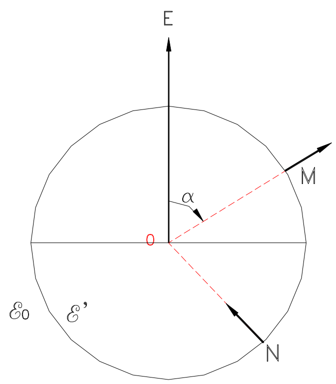
F.8 : When $\varepsilon < 1$: the resultant force **fe** acting on dipole N is centripetal .

F.9 : When $\varepsilon > 1$: the resultant force **fe** acting on dipole N is centrifugal .

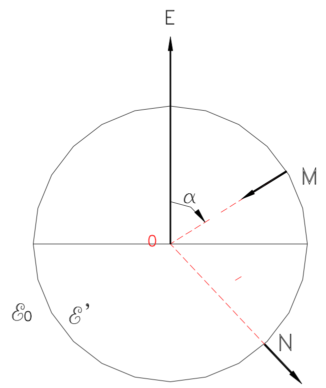
Now let us combine the results from four figures above to show the directions of the elementary forces **fe** produced on two surface dipoles M and N :

* when $\varepsilon < 1$: Fig. 10 shows two forces **fe** at M and N ; and Fig.10-a (from Fig.10) shows all forces **fe** on the upper and lower surface of the electron .

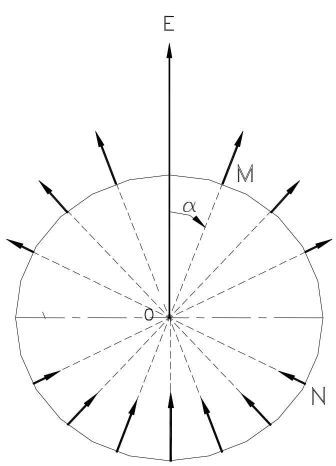
* when $\varepsilon > 1$: Fig. 11 shows two forces **fe** at M and N ; and Fig.11-a (from Fig.11) showing all forces **fe** on the upper and lower surface of the electron.



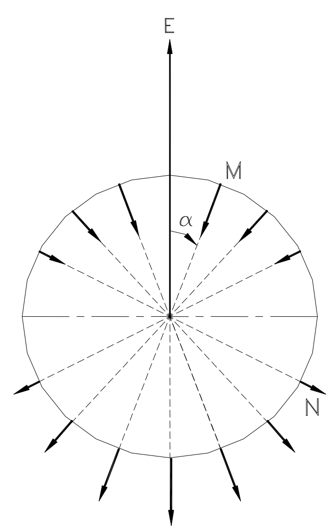
F.10 : When $\varepsilon < 1$:
- on the upper hemisphere , **fe** is centrifugal
- on the lower hemisphere , **fe** is centripetal



F.11 : When $\varepsilon > 1$:
- on the upper hemisphere , **fe** is centripetal
- on the lower hemisphere , **fe** is centrifugal

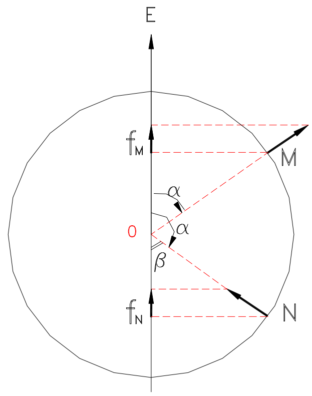


F.10-a (from F.10) When $\varepsilon < 1$:
- on the upper hemisphere : all **fe** are centrifugal
- on the lower hemisphere : all **fe** are centripetal

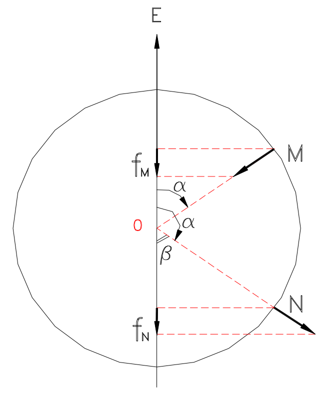


F.11-a (from F.11) When $\varepsilon > 1$:
- on the upper hemisphere : all **fe** are centripetal
- on the lower hemisphere : all **fe** are centrifugal

We have finished determining the magnitude and the direction of the elementary forces **fe** in two cases when $\varepsilon < 1$ and $\varepsilon > 1$. Now we will determine the direction and magnitude of the resultant force **F** = $\sum$ **fe** which exerts on the surface dipoles of the extended electron in these two cases .



F.12: $\varepsilon < 1$:
Projections of **fe** at M and N onto the axis **OE** : $\mathbf{f_M}$ and $\mathbf{f_N}$ point upwards .



F.13 : $\varepsilon > 1$:
Projections of **fe** at M and N onto the axis **OE :** $\mathbf{f_M}$ and $\mathbf{f_N}$ point downwards .

Because all forces **fe** are symmetric about the axis **OE** (as shown in two Figs.10-a and 11-a) , their resultant force **F** = $\sum$ **fe** lies on **OE** and is equal to the sum of all projections of **fe** onto **OE .**
So , to determine the magnitude of **F ,** we have to calculate first the projection of **fe** onto **OE .**

Let $\mathbf{f_M}$ be the projection of **fe** at M onto the axis **OE** and $\mathbf{f_N}$, the projection of **fe** at N onto **OE .**

When $\varepsilon < 1$ (Fig. 12) , $\mathbf{f_M}$ and $\mathbf{f_N}$ point in the direction of **E** ; their magnitudes are :

$$f_M = fe \cos\alpha = (1/\varepsilon - 1)\, q\, E \cos\alpha \cos\alpha = (1/\varepsilon - 1)\, q\, E \cos^2\alpha \tag{1}$$

$$f_N = fe \cos\beta = fe\,(-\cos\alpha) = (1/\varepsilon - 1)\, q\, E\,(-\cos\alpha)(-\cos\alpha) = (1/\varepsilon - 1)\, q\, E \cos^2\alpha \tag{2}$$

The magnitudes of $\mathbf{f_M}$ and $\mathbf{f_N}$ in two Eqs. (1) and (2) have identical form but in Eq.(1) : $0 < \alpha < \pi/2$ and in Eq.(2) : $\pi/2 < \alpha < \pi$. So, **F** = $\sum$ **fe** = $\sum \mathbf{f_M}$ if α varies from 0 to π ; that is

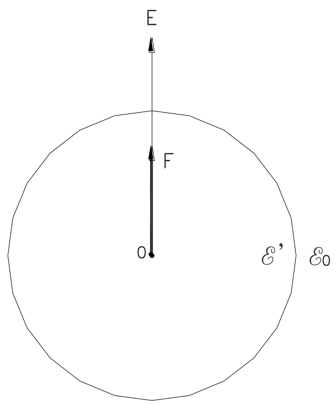
$$\boxed{F = \sum_{i=1}^{n} (1/\varepsilon - 1)\, q\, E \cos^2\alpha_i = (1/\varepsilon - 1)\, q\, E \sum_{i=1}^{n} \cos^2\alpha_i} \tag{3}$$

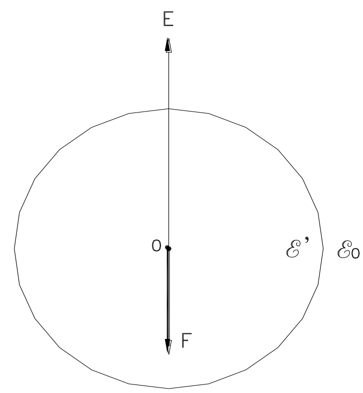
F points in the direction of **E** (Fig.14)
where n is number of surface dipoles on the surface of the electron ;
α_i is the angular position of a surface dipole , varying from 0 to π ;
ε is the relative permittivity of the electron : $\varepsilon = \varepsilon' / \varepsilon_0$;
q is electric charge at the end of a surface dipole ;

When $\varepsilon > 1$ (Fig. 13) $\mathbf{f_M}$ and $\mathbf{f_N}$ point in the opposite direction to **E** , so the resultant **F** = $\sum$ **fe** = $\sum \mathbf{f_M}$ also points in the opposite direction to **E** . The same reasoning as above gives

$$\boxed{F = \sum_{i=1}^{n} (1 - 1/\varepsilon)\, q\, E \cos^2\alpha_i = (1 - 1/\varepsilon)\, q\, E \sum_{i=1}^{n} \cos^2\alpha_i} \tag{4}$$

F points in the opposite direction to **E** (Fig.15)

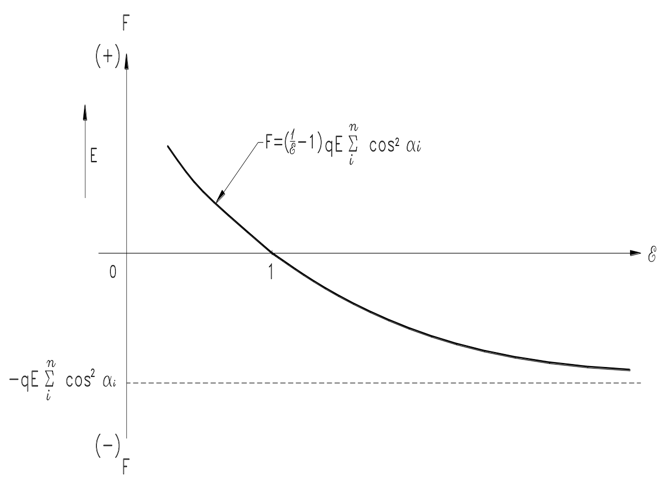




F.14 : $\varepsilon < 1$: the resultant force **F** (= Σ **fe**) points in the direction of **E** .

F.15 : $\varepsilon > 1$: the resultant force **F** (= Σ **fe**) points in the opposite direction to **E**.

In two equations (3) and (4) , the sum $\sum_{i=1}^{n} \cos^2\alpha_i$ depends on the number n of surface dipoles and the angular position α_i of the surface dipole , they represent the *physical structure* of the electron .
The magnitude and direction of **F** thus depend on ε as shown in Eqs. (3) & (4) and two Figs.14 & 15.
The magnitude and direction of **F** (with respect to the direction of **E**) is graphically shown in Fig.16
We have finished determining the magnitude and direction of the resultant **F** (= Σ **fe**) .



F.16 : The smooth curve shows the *magnitude and direction* of **F** versus ε : Eq. (3)

- for $\varepsilon < 1$: **F** is positive ; i.e., **F** ↑↑ **E** as shown by F. 14
- for $\varepsilon > 1$: **F** is negative ; i.e., **F** ↓↑ **E** as shown by F. 15

From two equations (3) and (4) we note that **F** exists only if $\varepsilon \neq 1$; this means that the absolute permittivity ε' of the extended electron is different from the permittivity ε_0 of the surrounding free space ($\varepsilon' \neq \varepsilon_0$) ; that is, they are two different media . Otherwise , if $\varepsilon = 1$, then $\varepsilon' = \varepsilon_0$ and $\mathbf{F} = 0$; this physically means that the electron has no electric dipoles around its core ; i.e., only the core exists : this is a point electron . Therefore , mathematically , the point electron is a particular case of the extended electron when $\varepsilon = 1$. For the extended electron $\varepsilon < 1$ as we will see below .

3. Determination of the net electric force produced on all interior dipoles and the electric force F' produced on the core $(-q_0)$ of the electron

3.1 The net electric force produced on all interior dipoles is zero .

The external electric field **E** produces the field **E'** inside the extended electron ; all *interior dipoles* and *the core* ($-q_0$) are thus subject to the field **E' .** Because the dipole is extremely small , two ends $-q$, $+q$ of an interior dipole are exerted upon by the same field **E'** and hence two electric forces **fe** and **f'e** are *equal and opposite* . The dipole may be slightly re-oriented (or polarized) but the resultant force **fe** + **f'e** produced on the dipole is cancelled out . This explanation applies to all interior dipoles , which are possibly polarized by the field **E'** , but the net electric force produced on all interior dipoles is zero .

3.2 Determination of the electric force F' produced on the core $(-q_0)$ of the electron .

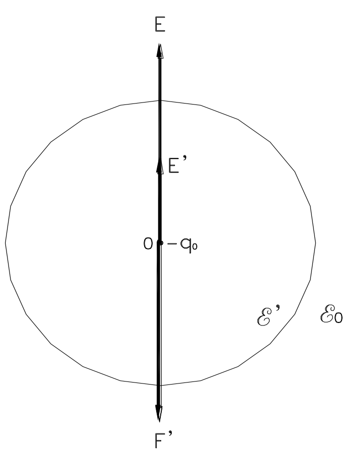
The core is a point charge ($-q_0$) which is subject to the field **E' .** To determine the electric force **F'** produced on the core , we have to calculate field **E'** first . The calculation is shown in **Appendix B** . It shows that the electric field **E'** is parallel to the external field **E** and has magnitude equal to :

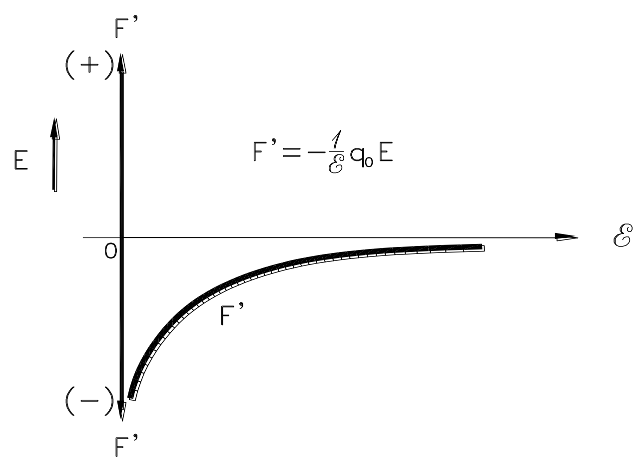
$$\mathbf{E'} = (1/\varepsilon)\,\mathbf{E} \qquad (12)$$

So , the electric force **F'** produced on the core ($-q_0$) is

$$\mathbf{F'} = -q_0\,\mathbf{E'} = -(1/\varepsilon)\,q_0\,\mathbf{E} \qquad (13)$$

F' is thus always negative ; i.e., it always points in the opposite direction to **E** (Fig.17) .
Fig.18 shows the variation of **F'** vs ε according to Eq.(13) .





F.17 : **E** is the external electric field ;
E' is the electric field produced on the core ($-q_0$) ,
F' is the electric force produced on the core ,
it is always negative ; i.e., **F'** ↓↑ **E** .

F.18 : The curve represents the magnitude and direction of the electric force **F'** versus ε.
F' is always negative ; i.e., **F'** ↓↑ **E** .

4. Calculation of the net electric force F_e produced on the extended electron

The net electric force **Fe** which is developed on the extended electron when it is subject to a constant electric field **E** is the sum **Fe = F + F'** .
F is given by Eq.(3) and **F'** by Eq.(13) . Since **F** and **F'** are collinear , their algebraic sum is

$$\text{Fe} = \left(\frac{1}{\varepsilon} - 1\right) q\, E \sum_i^n \cos^2\alpha_i \;-\; \frac{1}{\varepsilon}\, q_0\, E \qquad (14)$$

or

$$\text{Fe} = \left[\left(\frac{1}{\varepsilon} - 1\right) (q / q_0) \sum_i^n \cos^2\alpha_i \;-\; \frac{1}{\varepsilon}\right] q_0\, E \qquad (15)$$

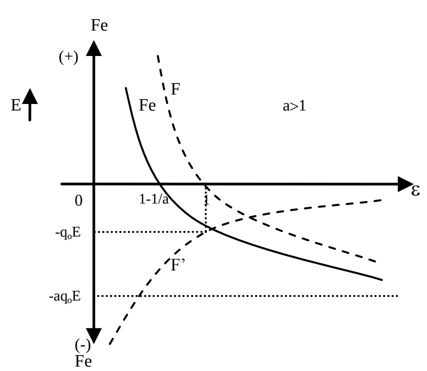
Let's set $a \equiv (q / q_0) \sum_i^n \cos^2\alpha_i$, (it is a factor inside the above square bracket) (16)

'a' is thus a dimensionless positive number since q , q_0 and $\sum_i^n \cos^2\alpha_i$ are positive numbers ;

Eq.(15) becomes

$$\boxed{\mathbf{Fe} = \left(\frac{a-1}{\varepsilon} - a\right) q_0\, \mathbf{E}} \qquad (\text{Fig . } 19) \qquad (17)$$

Note : If we insert 'a' from (16) into the expression of **F** in Eq.(3) , we get a simpler expression for **F :**
$\mathbf{F} = \left(\frac{1}{\varepsilon} - 1\right) a\, q_0 \mathbf{E}$ **,** in which the parameter 'a' absorbs the charge q and the sum $\sum_i^n \cos^2\alpha_i$.



$$\mathbf{F} = \left(\frac{1}{\varepsilon} - 1\right) a\, q_0 \mathbf{E} \quad , (\text{F.16})$$

$$\mathbf{F'} = -\,(1/\varepsilon)\, q_0 \mathbf{E} \quad , (\text{F.18})$$

$$\mathbf{Fe} = \mathbf{F} + \mathbf{F'} = \left(\frac{a-1}{\varepsilon} - a\right) q_0\, \mathbf{E} \;, (\text{F.19})$$

F.19 : **Fe = F + F'** .
For $\varepsilon > 1$: **F** and **F'** are both negative ; **Fe** is always negative , i.e., **Fe** points in opposite direction to **E**
For $1 - 1/a < \varepsilon < 1$: **Fe** is negative and tends to zero as $\varepsilon \to 1 - 1/a$
For $\varepsilon < 1 - 1/a$: **Fe** becomes positive ; i.e., **Fe** points in the direction of **E** : the extended electron behaves like a positron .

We have thus calculated the net electric force **Fe** that is produced on the extended electron when it is subject to the external electric field **E** . The magnitude and direction of **Fe** depend on two parameters ε and 'a' ; their actual (or physical) intervals of variation are discussed in the section 5 below .

We notice that for a *point electron* $\varepsilon = 1$, $\mathbf{F} = 0$, $\mathbf{F'} = - q_0 \mathbf{E}$, and hence $\mathbf{Fe} = \mathbf{F} + \mathbf{F'} = - q_0 \mathbf{E}$
This is the familiar value of the electric force produced on the point electron : $\mathbf{Fe} = e \mathbf{E}$.

But for an *extended electron* the magnitude of **Fe** is modified by the factor ($\dfrac{a-1}{\varepsilon}$ - a) which depends on two parameters 'a' and ε . And thus the electric force **Fe** does not vary linearly with **E** (as the Lorentz classical equation $\mathbf{Fe} = e \mathbf{E}$) .
The parameter 'a' , as defined by the expression (16) , characterizes *the physical structure* of the electron , and depends on q , q_0 , n and α_i
. q , the magnitude of electric charge on the end of a dipole ;
. q_0 , the magnitude of electric charge of the core ;
. n , total number of surface dipoles on the surface of the electron ;
. α_i , representing the angular distribution of the surface dipole i on the spherical surface of the electron; the angle α varies from 0 to π .

5. The actual (physical) intervals of variation of ε and a

Let us examine Fig.19 which shows the variation of the magnitudes of **F** , **F'** and their sum **Fe** versus ε.
If $\boldsymbol{\varepsilon = 1}$, $\mathbf{F} = 0$, $\mathbf{F'} = - q_0 \mathbf{E}$, $\mathbf{Fe} = \mathbf{F} + \mathbf{F'} = - q_0 \mathbf{E} = \mathbf{F'}$: the net force **Fe** is thus reduced to the force **F'** which is produced on the core of the electron ; this means that when $\varepsilon = 1$ the extended electron is mathematically equivalent to a point charge which is the core (as already noted at the end of section 2) .
So , for the extended electron , $\varepsilon \neq 1$; that is, either $\varepsilon > 1$ or $\varepsilon < 1$.

For $\boldsymbol{\varepsilon > 1}$, both **F** and **F'** are negative, and hence **Fe** is always negative . This means that the net electric force **Fe** produced on the electron is always different from zero, and as a consequence , from the Newton ' s second law of motion, the acceleration is always different from zero ; and hence the velocity of the electron will increase to infinity with time : this is the runaway behaviour . Since the velocity of any particle must be limited to c , so *we reject the interval of variation of* $\varepsilon > 1$

For $\boldsymbol{\varepsilon < 1}$, **F** becomes positive while **F'** is always negative ; $\mathbf{Fe} = \mathbf{F} + \mathbf{F'}$: (Fig.19)

* **Fe < 0** in the interval $(1- 1/a) < \varepsilon < 1$: **Fe** points in the opposite direction to **E** ; this means that the extended electron behaves like a real electron .
* **Fe > 0** for $\varepsilon < (1- 1/a)$: **Fe** points in the direction of **E** ; i.e., the extended electron behaves like a positive electron or **a positron** , so we reject this interval .

Thus we accept the interval $\boldsymbol{(1- 1/a) < \varepsilon < 1}$, for which **Fe** is negative , it accelerates the electron in the opposite direction to the external field **E .** This interval will be written shortly as $\boldsymbol{\varepsilon < 1}$**.**
Figs. 4 , 8 , 10 , 10-a , 12 , and 14 satisfy this condition ($\boldsymbol{\varepsilon < 1}$ **) .** They show the directions of the elementary forces **fe** and the resultant **F** (= Σ **fe**) : **F** is upward (positive) .
Fig. 17 shows **F'** always downward (negative) . Since **F** and **F'** vary with ε , when $\varepsilon = 1\text{-}1/a$, $\mathbf{F} = - \mathbf{F'}$ and $\mathbf{Fe} = \mathbf{F} + \mathbf{F'} = 0$ (Fig.19) : the electron reaches the speed limit c .

We note that the speed limit c is *a postulate of the special theory of relativity* : it has no physical interpretation . But here we can explain the physical reason why the extended electron's speed tends to c : when it is accelerated by an external electric field **E** , the magnitudes of two opposite forces **F** and **F'** tend to be equal when $\varepsilon = 1\text{-}1/a$, and the resultant force $\mathbf{Fe} \to 0$. From the Newton's second law of motion : if $\mathbf{Fe} = m\, d\mathbf{v}/dt \to 0$, then $d\mathbf{v}/dt \to 0$ and **v** tends to a constant that must be c because the electron is being accelerated . So , the variability of two opposite forces **F** and **F'** (with ε) helps explain why the speed limit c is reached .

In short , since ε varies in the interval $(1- 1/a) < \varepsilon < 1$, we come to the following results :

- The correction factor ($\frac{a-1}{\varepsilon}$ - a) of the electric force **Fe** in Eq.(17) varies from -1 to 0 .
- The magnitude of the net electric force **Fe** varies from $-q_0 E$ to 0.
- The velocity of the electron varies with ε and tends to c as ε → 1-1/a .
- Since the relative permittivity ε is a positive number , ε → 1-1/a means that 1-1/a > 0 i.e., **'a' is greater than unity (a > 1)** .

Four remarks related to the values of ε :

1. The positron . In this article we only investigate the properties of the electron (not the positron) ; this is when ε varies in the interval (1-1/a) < ε < 1 , where a > 1 . In the following , this interval is written shortly as **ε < 1.** From Fig.19 we notice that when ε < 1-1/a , the electron is accelerated in the direction of the applying field **E** ; i.e., the electron behaves like a positron . This transition suggests that e^- *and* e^+ *can be transformed from one to the other* if its relative permittivity ε is being changed around the value (1-1/a) where **F = - F'** , **Fe** = 0 and its speed is about c .

[For comparison , let us recall that Dirac revealed from his relativistic equation of the electron that the electron can have two energy states : positive and negative . He wrote in his Nobel lecture [2]:
"if we disturb the electron, we may cause a transition from a positive-energy state of motion to a negative-energy one ... ; they correspond to the motion of an electron with a positive charge instead of the usual negative one - what the experimenters now call a positron ". Thus , for Dirac , e^- and e^+ are not independent particles since e^- can be transformed to e^+ by a disturbance (he did not specify what kind of disturbance) ; in other words , the positron has its origin from the electron] .

The calculations of forces on the extended electron lead to Fig.19 which shows the variation of the net electric force **Fe** with ε ; it is the change of ε about the value (1-1/a) that transforms e^- to e^+ and vice versa , so the disturbance here is the abrupt change of ε . Moreover , the positron is not created alone, but together with the electron in the pair production e^- - e^+. This suggests that the positron may have the origin from the electron .

2. Why ε < 1 ?
We have come to the result ε < 1 such that the velocity of the electron is limited to c when it is accelerated in **E** ; (otherwise , if ε ≥ 1 , it will runaway ; i.e., its velocity tends to infinity) . Moreover , when ε < 1 , **Fe** is negative , it accelerates the electron in the opposite direction to the applying field **E,** this is a feature of the real electron .
This value of relative permittivity ε < 1 is specific to the "material " of the extended electron because common materials such as water , glass , mica … all have ε ≥ 1 ; e.g., for air ε = 1 , water (81) , glass (5-10) , mica (6) and **no material with ε < 1** is mentioned or listed in the current textbook [3] .
This may be because the extended electron is composed of *electric dipoles* meanwhile common materials are composed of *atoms or molecules* .

3 . The orientation (or polarization) of electric dipoles
Now from Eq. (12) : **E'** = (1/ε) **E** , since ε < 1 , **E'** > **E** . This means that when an external electric field **E** is applied on the extended electron , it creates an electric field **E'** parallel and stronger inside the electron . The reason for this is that the applying field **E** polarizes all electric dipoles inside the electron , giving rise to the field **E'** greater than **E** . This polarization causes the permittivity ε of the electron to vary in the interval (1-1/a) < ε < 1 . We can say that ε is a measure of the sensibility of the structure of the electron to the applying field **E** .

Since electric dipoles contain both charges – and + , the polarization of the ensemble of electric dipoles in the extended electron creates an *electric dipole moment* for the extended electron [4, 5] . A point electron with only negative charge cannot have an electric dipole moment .

4. The narrow interval of variation of the relative permittivity ε

The parameter ' a ' is a dimensionless positive number defined by the expression (16) :

$$a \equiv (q / q_0) \sum_{i}^{n} \cos^2 \alpha_i$$

The magnitude of ' a' increases with the number ' n ' of *surface dipoles* because $\sum_{i}^{n} \cos^2 \alpha_i$ is the sum of n positive terms ($\cos^2 \alpha_i$). For an extended electron , the number of surface dipoles is expected to be large (n >> 1) ; and hence , ' a' is also expected to be a large number (a >> 1) . If a >> 1 , then 1/a is an infinitesimal number , and hence (1- 1/a) is infinitesimally less than 1 ; therefore , the interval (1-1/a) < ε < 1 becomes a very narrow interval (1- < ε < 1) . And hence , we can say that ε is approximately constant and equal to 1- , (ε ≈ 1-) . (This approximation is needed for calculations in the **Appendix C**) .
We conclude that when the extended electron is subject to the external field **E** , its permittivity ε varies in the narrow interval (1-1/a < ε < 1) which causes the net electric force **Fe** to change in the interval ($-q_0$ E , 0) and the effective electric charge Q of the extended electron varies in the interval interval ($- q_0$, 0) as we see below .

6. The variability of the electric charge of the extended electron

From Eq.(17) which gives the net electric force **Fe**

$$\mathbf{Fe} = \left(\frac{a-1}{\varepsilon} - a \right) q_0 \mathbf{E} \qquad \text{(shown in Fig.19)}$$

the effective electric charge Q of the electron can be deduced as

$$\boxed{Q = \left(\frac{a-1}{\varepsilon} - a \right) q_0} \qquad a > 1 \tag{18}$$

From Fig.19 , 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) .

To find the correspondence between the velocity v with ε and Q , let us recall that on page 6 of the previous article entitled [1(b)] **" A Foundational Problem in Physics : Mass versus Electric Charge "** , we have obtained the general expression for the effective electric charge of the electron when it is subject to an external field :

$$\boxed{Q = - (1 - v^2 / c^2)^{N/2} q_0} \tag{19}$$

where N ≥ 0 is a real number representing the applying electric or magnetic field .
A minus sign is added on the right hand side of Eq.(19) to indicate the negative charge Q of the electron .
From (18) and (19) we get

$$\frac{a-1}{\varepsilon} - a = -(1 - v^2/c^2)^{N/2} \tag{20}$$

or
$$\varepsilon = (a-1) / [\, a - (1 - v^2/c^2)^{N/2} \,] \tag{21}$$

So, when $v \ll c$, $\varepsilon \approx 1$, $Q \approx -q_0$ and $Fe \approx -q_0 E$ (equivalent to a point electron)
and as $v \to c$, $\varepsilon \to 1 - 1/a$, $Q \to 0$ and $Fe \to 0$.

So, when it moves at $v \ll c$, the extended electron is mathematically equivalent to a point electron (in terms of electric charge and force, both are constant). But as $v \to c$ it behaves differently from the point electron: its effective charge Q and the net force **Fe** change with velocity, i.e., with time, while it is accelerated in the electric field **E**.

We note that Eq.(20) provides a relationship between three parameters 'a', ε and the velocity v of the electron. The **Appendix C** shows that this equation can suggest a way to relate the radiation and absorption of light of the extended electron to its velocity; that is, when the electron radiates, it slows down; and when it absorbs light, it speeds up.

7. Equation of motion of the extended electron in external electric field E

Equation of motion of the extended electron in the form of the Newton's 2nd law of motion is

$$m\,\mathbf{v}^{\cdot} = \mathbf{Fe} = \mathbf{F} + \mathbf{F'} = \left(\frac{a-1}{\varepsilon} - a\right) q_0\,\mathbf{E} \qquad \text{from Eq.(17)} \tag{22}$$

or
$$m\,\mathbf{v}^{\cdot} = -(1 - v^2/c^2)^{N/2}\, q_0\,\mathbf{E} \qquad \text{from Eq.(20)} \tag{23}$$

where $\mathbf{v}^{\cdot}$ $(= d^2x/dt^2)$. Hence, the equation (23) is a <u>second order differential equation</u> which obeys the Newton's first law of motion (law of inertia) and avoids the problems of runaway and preacceleration.

We should note that the **radiation reaction force** $\mathbf{F}_{\mathbf{rad}}$ (which is the recoil force produced by the radiation of an accelerating point charge) **does not exist in the radiation of the extended electron**.
The force **F'** which is produced on the core ($-q_0$), is not the radiation reaction force produced by the radiation of the extended electron.
Meanwhile the equation of motion of the *point electron* (Lorentz-Abraham-Dirac equation) including the radiation reaction force $\mathbf{F}_{\mathbf{rad}}$ is a <u>third order differential equation</u>

$$m\,\mathbf{v}^{\cdot} = \mathbf{F}_{\mathbf{ext}} + \mathbf{F}_{\mathbf{rad}} \tag{24}$$

where $\mathbf{F}_{\mathbf{rad}} = 2q^2\,\mathbf{v}^{\cdot\cdot}/3c^3$ (in cgs); $\mathbf{v}^{\cdot\cdot}$ $(= d^3x/dt^3)$ is the second time derivatives of the velocity **v**.
Eq.(24) does not obey the law of inertia and is involved in many problems including the runaway and preacceleration[6].

Summary and conclusion

More than 100 years ago, many physicists had proposed various extended model for the electron : Lorentz (1904), Poincaré (1906) ... All these models contained only negative charges.

The new extended model contains both types of charges (+ and -) in its volume. **It is a version [1(a)] of the image of the screened electron** by vacuum polarization such that calculations can be performed on it to determine its effective electric charge. We have come to the following results :

When the electron is subject to an external electric field **E** , two opposite electric forces **F** and **F'** are produced on it : **F** is the resultant of all elementary forces **fe** , **F'** is produced on the core ($-q_0$) .
The net force **Fe = F + F'** accelerates the electron in the opposite direction to **E** , varies with velocity and tends to zero as $v \to c$ **.**
The effective electric charge Q changes with the velocity and tends to zero as $v \to c$.

The investigation on this extended model leads us to following ideas :

1/ The concept of *screened electron by vacuum polarization* **1(a)** should be abandoned since it does not provide any form of calculation to determine the effective electric charge of the electron . The virtual pairs of (e^- , e^+) are fictitious , they must not have real effect on the electron . Whereas electric dipoles or photons are real particles (as conceived by Feynman) , which constitute the real part of the electron around its central core ($-q_0$) instead of those fictitious pairs of (e^- , e^+) .
2/ The old-fashioned *concept of mass varying with velocity* **1(b)** should be abandoned and replaced by the *concept of varying effective charge* which is derived from the new extended model of the electron .

3/ The extended model of the electron can help explore more experimental properties of the electron , such as its radiation and spin in external electric and magnetic fields .

Part 2 : Radiation of the extended electron in constant electric field .

1. Introduction : radiation by forces

Radiation process is a tough topic to discuss because of the dual nature of light and the unknown structure of the electron that emits light . In this part 2 , the extended model of the electron**1(a)** will be used in the discussion of the radiation process . As for light , it is assumed that the electron emits light , and light may be **particles** (called photons) , as conceived by **Feynman*** or it may be **a chunk of self-sustaining field**** which detaches from the electron and travels through space , as conceived by the classical theory of radiation .
In this article and subsequent ones, we choose to consider **light as particles** which are identified as tiny needles carrying two opposite charges -q and +q at their two ends ; these **"electric dipoles"** form the outer part of the extended electron **1(a)** . When the electron emits its electric dipoles into the surrounding space , we say it is radiating .
The following sections will introduce the readers to *a novel way of explaining the radiation process* : *this is radiation by forces* .

2. Radiation of the extended electron by electric forces

Before discussing the radiation process and defining the conditions for radiation , let us review two electric forces **fe** and **G** which are produced on *surface dipoles* of the extended electron when it is subject to an external constant electric field **E** . These two forces will help explain the radiation process .
First , the elementary forces **fe** produced on all surface dipoles are shown in F.10-a when $\varepsilon < 1$ **:**
fe are centrifugal on the upper hemisphere and centripetal on the lower hemisphere ; their magnitude is

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***** **Feynman** : " *I want to emphasize that light comes in this form – particles . It is very important to know that light behaves like particles , especially for those of you who have gone to school , where you were probably told something about light behaving like waves . I'm telling you the way it does behave – like particles* . " (Optics , E.Hecht , p.138)

****** " *If the point charge is subjected to a sudden acceleration caused by some external force , then pieces of the electric and magnetic fields break away from the point charge and propagate outward as a self-supporting electromagnetic wave pulse* . " (Classical Electrodynamics , 1988 , H. C. Ohanian , p. 411)

$$fe = (1/\varepsilon - 1)\, q\, E \cos\alpha \;, \quad \varepsilon < 1 \;, \qquad 0 < \alpha < \pi$$

Second are the cohesive forces **G** which attract all surfaces dipoles toward the core of the electron ; i.e., they are centripetal and produced by the self-field $\mathbf{E_0}$ of the electron ; their magnitude is

$$G = [(1/\varepsilon) - 1]\, q\, E_0 \quad , \quad \text{Eq.(16)}$$

which had been calculated in Fig.19 of the article [1(a)] **"A New Extended Model for the Electron ".**

These two forces **fe** and **G** are shown together in Fig.20 and Fig.21 below .

On the upper hemisphere, while **fe** are centrifugal , the cohesive forces **G** are centripetal . So , if the magnitude of **fe** is stronger than that of **G** (**fe > G**) , these surface dipoles can break away from the surface of the electron ; that is, the electron emits these electric dipoles upwards **.** This means that the electron radiates upwards , from the upper hemisphere , while the electron is moving downwards in the opposite direction to the applying field **E** .
Meanwhile , on the lower hemisphere, since both **fe** and **G** are centripetal , these surface dipoles cannot break free from the surface of the electron ; that is , there is no radiation from the lower hemisphere

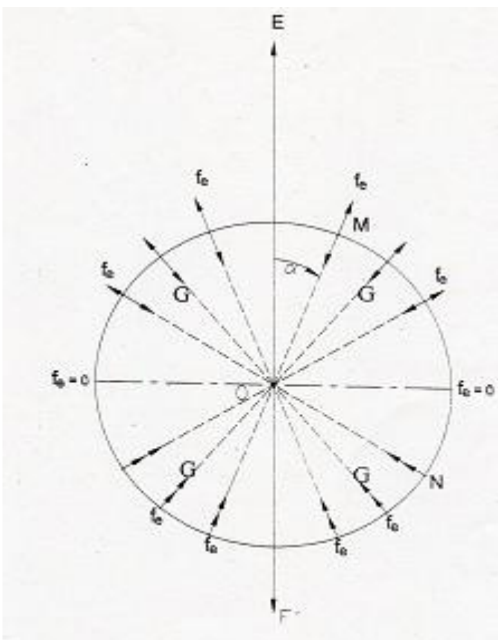
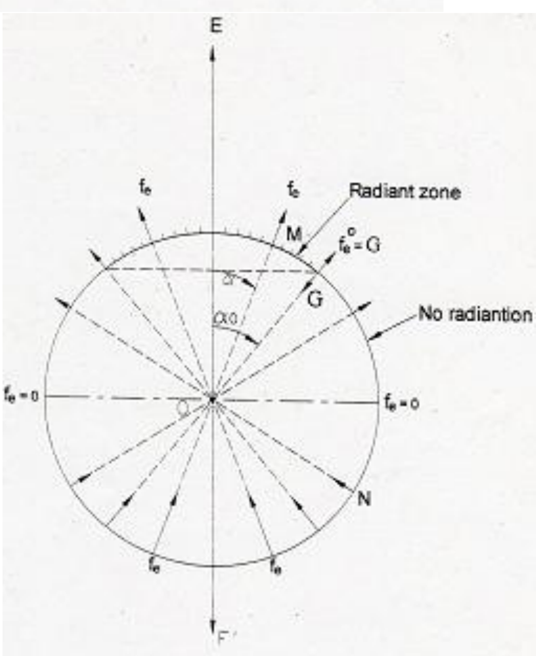


Fig. 20 shows when $\varepsilon < 1$:
- electric forces **fe :** centrifugal on the upper hemisphere and centripetal on the lower hemisphere ,
- cohesive forces **G :** all are centripetal ,
- electric force **F'** acting on the core ($-q_0$) ,
- the direction of the applying field **E** .



F.21 shows when $\varepsilon < 1$:
the radiant zone limited by the angle α_o where $\mathbf{fe^0 = G}$.
The cone of radiation is upward (in the direction of **E**) while the electron moves downwards .

In short , the extended electron does not radiate from its entire surface , but only from a limited zone around the north pole , on the upper hemisphere of the electron as shown in Fig.21 .
In the following , we will determine this radiant zone around the north pole and define the conditions for radiation of the extended electron in the electric field **E** .

3. The cone of radiation - Conditions for radiation .

Now let us determine the radiant zone on the upper hemisphere as shown in Fig.21 .
Let us recall that the magnitude of **fe** produced on a surface dipole M of the upper hemisphere has been calculated in part 1 (Fig.4) ; **fe** is centrifugal , its magnitude is

$$fe = \left(\frac{1}{\varepsilon} - 1 \right) q\, E \cos\alpha \quad , \quad \text{where} \quad \varepsilon < 1 \quad \text{and} \quad 0 < \alpha < \pi/2 \qquad (25)$$

fe thus depends on the angular position α of the surface dipole .

Let α_0 be the value of the angle α at which $\mathbf{fe^0} = \mathbf{G}$ (in magnitude) (26)

then the condition $fe > G$ (for the radiation to occur as stated above)
is rewritten as $fe > fe^0$

or $$\left(\frac{1}{\varepsilon} - 1 \right) q\, E \cos\alpha > \left(\frac{1}{\varepsilon} - 1 \right) q\, E \cos\alpha_0 \qquad (27)$$

or $$\cos\alpha > \cos\alpha_0$$

or $$\alpha < \alpha_0 \qquad (28)$$

Fig.21 shows *the radiant zone* on the upper hemisphere , restricted in a zone around the north pole of the electron , limited by the angle α_0 which is defined by the relation (26).

All rays radiating from the radiant zone are contained inside *a radiation cone* of half- angle α_0 at the vertex O . So , the existence of the angle α_0 means the existence of the radiation cone .

Now let us determine the condition for the existence of the angle α_0 . From (26) we have

$\left(\frac{1}{\varepsilon} - 1 \right) q\, E \cos\alpha_0 = G$ where **E** is the applying electric field .

The magnitude of **G** has been calculated to be equal to

$G = \left(\frac{1}{\varepsilon} - 1 \right) q\, E_0$ where $\mathbf{E_0}$ is the self field of the electron .

Hence $\left(\frac{1}{\varepsilon} - 1 \right) q\, E \cos\alpha_0 = \left(\frac{1}{\varepsilon} - 1 \right) q\, E_0$ or $\boxed{\cos\alpha_0 = E_0 / E < 1}$ (29)

The condition for the radiation to occur is thus $\boxed{E > E_0}$ (30)

Therefore ,

i) if $E < E_0$, $\cos\alpha_0 > 1$; α_0 does not exist : no radiation emits from the electron while it is accelerated in **E** ; this also means that in free space (**E** = 0) the electron cannot radiate .

ii) if $E = E_0$, $\cos\alpha_0 = 1$, $\alpha_0 = 0$: the radiation cone reduces to a ray (or a beam) of light emanating from the north pole of the electron .

iii) if $E > E_0$, $\cos\alpha_0 < 1$, $0 < \alpha_0 < \pi/2$: radiation occurs around the north pole of the electron ; a radiation cone emanates from the electron as shown in Fig.21 .

iv) if $E \to \infty$, $\cos \alpha_0 \to 0$, $\alpha_0 \to \pi/2$: the radiant zone expands to cover the entire upper hemisphere (this is only a limit case since **E** can never tend to infinity).

Thus $E > E_0$ is the condition for the existence of the angle α_0 (which implies the condition for the emission of radiation) . So, while it is accelerated in **E** , the extended electron <u>can or cannot radiate</u> * , ** depending on the strength of the applying field **E** compared to that of its self- field $\mathbf{E_0}$ **, but not on its acceleration** *****.**

We note that in the case i) $E < E_0$: the electron is accelerated by the applying field **E** but it does not radiate because $\cos \alpha_0 > 1$ (i.e., α_0 does not exist) ; therefore, the radiation of the extended electron does not depend on its acceleration .

(The **Larmor 's formula** links the power radiated ($P = 2q^2 a^2 / 3c^3$) by a radiating *point electron* to its acceleration ; this formula does not applied to the extended electron).

Following are statements of three eminent physicists about the radiation and acceleration :

* **Pearle**[7] : " *A point charge must radiate if it accelerates , but the same is not true of an extended charge distribution* ."

****Jackson**[8] : " *Radiation is emitted in ways that are obscure and not easily related to the acceleration of a charge ."*

*** **Feynman** : " *We have inherited a prejudice that an accelerating charge should radiate . "*

We also note that the **radiation reaction force** $\mathbf{F_{rad}}$ (which is the recoil force produced by the radiation of a radiating point electron) **does not exist in the radiation of the extended electron** .

The force **F'** produced on the core (**-** q_0) , although pointing in the opposite direction to the radiation , *is not produced* by the radiation of the extended electron .

As mentioned in section 7 of part 1 , if the radiation reaction force $\mathbf{F_{rad}}$ is included in the equation of motion of the electron , the equation becomes a <u>third order differential equation</u> ; this is Lorentz-Abraham-Dirac equation for the point electron which is involved in such problems as runaway and preacceleration .

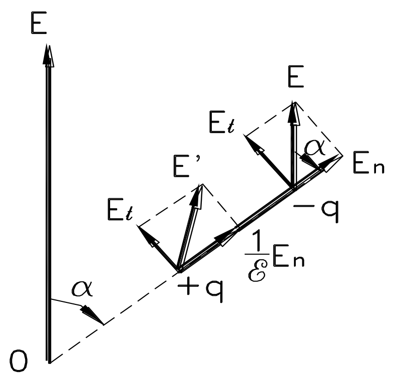
Conclusion

This article presents the theory on a new extended model of the electron [1(a)] , it reveals some features which are quite different from those of the point electron .

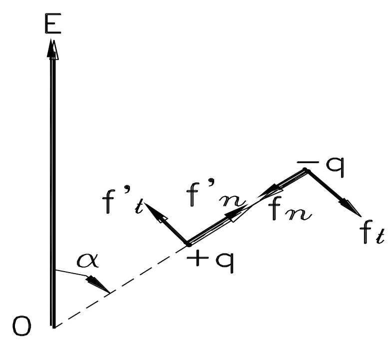
In part 1 , the net electric force **Fe** developed on the extended electron is not a single force , but the resultant of two opposite forces **F** and **F'** ; **Fe** and the effective electric charge Q change with velocity of the electron and tend to zero as $v \to c$.

Part 2 introduces a novel way of explaining the radiation process of the extended electron : radiation by electric forces . When the extended electron is subject to an external field **E** which is stronger than the self-field $\mathbf{E_0}$ of the electron , the electron radiates in the direction of **E** by the elementary forces **fe** that emanate from the upper hemisphere of the extended electron (Fig. 21) ; the radiation does not depend on the acceleration of the electron and produces no radiation reaction force .

Appendix A : Calculation of the elementary force fe



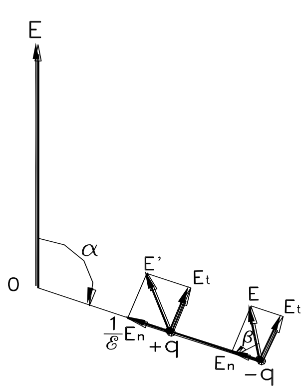
F.2 : Normal and tangential components of **E** and **E'** on two ends of surface dipole M

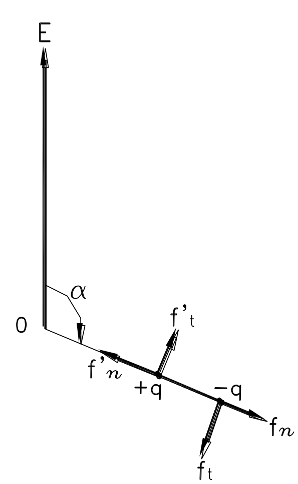


F. 3 : Normal and tangential components of the electric forces on two ends of surface dipole M

First , we use boundary conditions to determine the electric field **E'** inside the electron , then we calculate the electric force **fe** .
Fig. 1 shows two arbitrary surface dipoles M and N : M on the upper hemisphere, N on the lower hemisphere .
Boundary conditions applied on dipole M give (Fig. 2)
E = En + Et acting on the negative charge –q of the surface dipole M ,
E' = E'n + E't = (1/ε) **En + Et** acting on the positive charge +q ,
where En = E cosα , $0 < \alpha < \pi/2$ and Et = E sinα .
Since **Et = E't** , two tangent forces **ft** and **f't** produced on two ends –q and +q of dipole M are equal and opposite (Fig. 3) : ft = f't = q Et = q E sinα .
Two normal forces **fn** and **f'n** have magnitudes
fn = q En = q E cosα , **fn** is centripetal ,
f'n = q E'n = (1/ε) q En = (1/ε) q E cosα , **f'n** is centrifugal .
Since the dipole is extremely small , these forces can be considered as if they apply on the same point on the dipole M . Their resultant force **fe** acting on the dipole M is thus
fe = fn + f'n + ft + f't = fn + f'n since **ft** and **f't** are equal and opposite .
Since **fn** and **f'n** are in opposite directions, the magnitude and direction of **fe** depend on ε :
* when ε < 1 (Fig. 4) , f'n > fn , hence : fe = f'n - fn = (1/ε - 1) q E cosα , **fe** is centrifugal , (1-a)

* when ε > 1 (Fig. 5) , fn > f'n , hence : fe = fn - f'n = (1 – 1/ε) q E cosα , **fe** is centripetal , (1-b)





F.6 : Normal and tangential components of **E** and **E'** on two ends of surface dipole N

F. 7 : Normal and tangential components of the electric forces on two ends of surface dipole N

Now we calculate the resultant force **fe** acting on the dipole N , on the lower hemisphere of the electron : $\pi/2 < \alpha < \pi$, (hence $\cos\alpha < 0$) , < Fig. 6 & Fig.7 .
Since $\alpha + \beta = \pi$, En = E cos β = - E cosα and Et = E sinβ = E sinα .
Boundary conditions give **Et = E't** ; so , two tangent forces **ft** and **f't** produced on two ends –q and +q of the dipole N are equal and opposite : ft = f't = q E sinα .
Two normal forces **fn** and **f'n** have magnitudes
fn = q En = q E (-cosα) , **fn** is centrifugal ,
f'n = q E'n = (1/ε) q E (- cosα) , **f'n** is centripetal .
Since cosα < 0 , (-cosα) is a positive number ; the resultant force **fe** acting on the dipole N is
* when ε < 1 (Fig. 8) : fe = f'n - fn = (1/ε - 1) q E (-cosα) , **fe** is centripetal, (1-c)
* when ε > 1 (Fig. 9) : fe = fn - f'n = (1 – 1/ε) q E (-cosα) , **fe** is centrifugal . (1-d)

We have used four expressions (1-a) , (1-b), (1-c) and (1-d) in the determination of **fe** in the main text .

Appendix B : Determination of the force F' produced on the core of the electron

The core is a point charge ($-q_0$) subject to the field **E'** **.** Because of the spherical symmetry of the structure of the of the electron , **E'** at the core must be parallel to the external field **E** . And hence we can write

$$\mathbf{E'} = k\,\mathbf{E} \tag{5}$$

where k is a positive number different from 1 : $0 < k \neq 1$.
k is positive because **E'** is parallel to **E** ; k ≠ 1 because if k = 1 , Eq.(5) becomes **E'** = **E** ; and this means that the electric field inside the electron is independent of the material of the electron . But since the extended electron has a permittivity (ε') different from that of the surrounding free space (ε_0) , it is reasonable to think that **E'** depends on the medium of the electron ; i.e., **E'** differs from **E** in magnitude or k ≠ 1 .
Now let's apply boundary conditions to two points on both sides of the interface : M on the surface of the electron and the center O

$$\text{At M : } \mathbf{E} = \mathbf{En} + \mathbf{Et} \tag{6}$$

$$\text{At O : } \mathbf{E'} = (1/\varepsilon)\,\mathbf{En} + \mathbf{Et} \tag{7}$$

Equations (5) and (6) give

$$\mathbf{E'} = k\mathbf{E} = k\,\mathbf{En} + k\,\mathbf{Et} \tag{8}$$

Comparing (7) and (8) we get (9) and (10)

$$(1/\varepsilon)\,\mathbf{En} = k\,\mathbf{En} \;\rightarrow\; k = 1/\varepsilon \neq 1 \quad \text{and} \tag{9}$$

$$\mathbf{Et} = k\,\mathbf{Et} \;\rightarrow\; (k-1)\,\mathbf{Et} = 0 \;\rightarrow\; \mathbf{Et} = 0 \quad \text{since } k-1 \neq 0 \tag{10}$$

$$\text{Since } \mathbf{Et} = 0 \text{ , Eq.(6) becomes } \quad \mathbf{E} = \mathbf{En} \tag{11}$$

$$\text{and Eq.(7) becomes } \boxed{\mathbf{E'} = (1/\varepsilon)\,\mathbf{En} = (1/\varepsilon)\,\mathbf{E}} \tag{12}$$

So , the electric force **F'** produced on the core ($-q_0$) is

$$\boxed{\mathbf{F'} = -q_0 \mathbf{E'} = -(1/\varepsilon)\, q_0 \mathbf{E}} \tag{13}$$

F' is thus always negative ; i.e., it always points in the opposite direction to **E** (Fig.17) .
Fig.18 shows the variation of **F'** vs ε according to Eq.(13) .

Note : The above results **Et** = 0 (in Eq.10) and **E** = **En** (in Eq.11) imply that the point M must be located at either the north pole ($\alpha = 0$) or the south pole ($\alpha = \pi$) of the electron because $Et = E \sin\alpha = 0$, hence $\sin\alpha = 0$. This result comes from the fact that the electron is spherically symmetric : **E** and **E'** are collinear (12) and normal (11) to the spherical surface only at the north and south poles of the electron .
If M takes an arbitrary position on the surface of the electron , we cannot solve the equations of boundary conditions for the field **E'** at the core O .

We have used two Eqs. (12) and (13) in the determination of **F'** in the main text .

Appendix C : Radiation and absorption of light (or photons)

In part 2 we maintained that light is composed of particles called photons which are identified as electric dipoles that form the outer part of the electron [1(a)] . In the determination of the net electric force **Fe** , we defined the parameter 'a' by the expression (16)

$$a \equiv (q / q_0) \sum_{i}^{n} \cos^2 \alpha_i \ , \tag{16}$$

which represents the structure of the extended electron , in which n is the number of surface dipoles .
The parameter 'a' is thus a positive dimensionless number which increases monotonically with the number n of surface dipoles because $\sum_{i}^{n} \cos^2 \alpha_i$ is the sum of n positive terms $\cos^2 \alpha_i$.

This expression suggests the idea that the radiation and the absorption of light of the extended electron are linked to n and 'a' in the following manner :

* when the electron radiates , it emits its surface dipoles into space ; this means that the number n (of surface dipoles) decreases , and thus the parameter 'a' decreases accordingly ,

* when the electron absorbs photons (e.g., by irradiation) , it collects dipoles onto its surface ; this means that n increases , and thus the parameter 'a' increases accordingly .

As mentioned on page 11 (section 6 , part 1) that the equation (20)

$$\frac{a-1}{\varepsilon} - a = -\left(1 - v^2/c^2\right)^{N/2} \tag{20}$$

can suggest a way to relate the radiation and absorption of light of the extended electron to its velocity ; that is , when the electron radiates , it slows down ; and when it absorbs light , it speeds up .
To prove this statement , let us extract v^2/c^2 from Eq.(20)

$$v^2/c^2 = 1 - [\, a - (a-1)/\varepsilon \,]^{2/N}$$

As mentioned on page 10 that since $a >> 1$, $\varepsilon \approx 1-$ (infinitesimally less than 1) ; so if ε is considered approximately constant , we can take the derivative of v^2 / c^2 with respect to 'a' :

$$d (v^2 / c^2) / da = (2/N) [(1/ \varepsilon) - 1] [a - (a - 1) / \varepsilon]^{(2/N) -1}$$

For $N > 0$; $a >> 1$ and $\varepsilon \approx 1-$ or $(1-1/a) < \varepsilon < 1$, we have

$(2/N) > 0$; $[(1/ \varepsilon) - 1] > 0$; $[a - (a - 1) / \varepsilon]^{(2/N) -1} > 0$ for all values of the

exponent $(2/N) - 1$, therefore we get $\boxed{d (v^2 / c^2) / da > 0}$

This means that v^2 / c^2 and 'a' <u>increase monotonically</u> , that is

* <u>when the electron radiates</u> : <u>'a' decreases</u> , <u>and v^2 / c^2 decreases as well</u> ; this means that the electron slows down ; i.e., it loses its (kinetic) energy . (For example , in the synchrotron accelerator , electrons radiate and lose their energy) .

* <u>when the electron absorbs photons</u> : <u>'a' increases</u> , <u>and v^2 / c^2 increases as well</u> ; this means that the electron speeds up ; i.e., it gains energy . (In the photoelectric effect , electrons absorb photons via irradiation and gain energy) .

These results are not new findings , they are already known in the classical theory of radiation .
What is new here is that they can be deduced from a few mathematical expressions which are derived from the extended model of the electron [1(a)] .

References

1 . **Nguyen H. V.**
  (a) " **A New Extended Model for the Electron** " ,
  viXra.org > Classical Physics > viXra: 1305.0025
  (b) " **A Foundational Problem in Physics : Mass versus Electric Charge ",**
  viXra.org > Classical Physics > viXra:1304.0066

2 . **Dirac P.A.M** , " **Theory of Electron and Positron " ,** Nobel lecture , December 12 , 1933

3. **Sadiku M** , " **Elements of Electromagnetics"** , 1994 , 2nd Edition , p , 783

4. Hudson J. J. et al , "**Improved measurement of the shape of the electron"**
Nature 473 , p. 493 – 496 , May 26, 2011, Published online May 25 , 2011

5. Johnston H , "New technique narrows electron dipole moment",
Physicsworld . com 46085 , May 26 , 2011

6. Rohrlich F , " Dynamics of a charged particle" , *Phys. Rev.* ***E 77***, 2008, 046609

7. Pearle P , " When can a classical electron accelerate without radiating ? "
Foundation of physics , Vol. 8 , No. 11/12 , 1978 , p . 879

8. Jackson J.D. , **" Classical Electrodynamics "**, 2nd Edition, Chap.15, p.702