Quantum Dynamics of Elementary Particles

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Abstract

In the previous paper "Thermodynamics of elementary particles" we analysed the thermodynamic behavior of single elementary particles in the order of a continuous paradigm. Already we know elementary particles have in electrodynamics a few quantum features above all in regard to the emission of electromagnetic energy when they are accelerated. We want now to specify better this quantum behavior making use of particular mathematical functions and expanding successively this study from electrodynamic phenomena to thermodynamics.

1. Introduction

It is known that bound electrons inside atom have a quantum electrodynamic behavior determined by the quantization of electron orbits[1]. As per our studies concerning free electron accelerated into a field of force, also accelerated free electron has a quantum behavior when it is in the state of stability, that happens when its velocity is lower than the critical velocity[2][3]. As per our present knowledges we are unable to understand if its behavior is quantum also when it is into the state of instability, for greater speeds than the critical velocity.

Electromagnetic field and macroscopic electromagnetic processes generated by variable densities of charge and of current have continuous statistical nature and they are described efficiently by "Maxwell's generalized equations"[4][5]. Similarly also gravitational field and macroscopic thermodynamic processes, relating to complex physical systems, have continuous nature. But electromagnetic nanofield and e.m. nanowaves generated by single accelerated elementary charges have quantum nature when they are inside atom structure, and in the order of the Theory of Reference Frames they have quantum nature also when they are free. Untill now we have maked use of a non-quantum continuous paradigm in order to describe physical phenomena concerning electrodynamics and thermodynamics of elementary particles: in particular I make reference to variation with the speed of electrodynamic mass, of temperature and of entropy[6]. In order to define a quantum description of those processes it needs to introduce a new type of mathematical function that is used largely in the study and in the dynamic analysis of physical systems: the step function.

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2. Considerations on electromagnetism

Classical electromagnetism, represented by Maxwell's equations, describes the behavior of electromagnetic field generated by a source, that can coincide with a density of static charge (electrostatic field), with a density of stationary current (electric field and magnetic field), with a density of variable current (electromagnetic field). In all those physical situations the field is always continuous whether in space or in time and in the event of variable current, electromagnetic waves regard the frequency band as far as microwaves. In that case Maxwell's classical equations are

$$\mathrm{div}\,\mathbf{E} = \frac{\rho}{\varepsilon_o} \qquad (1)$$

$$\mathrm{div}\,\mathbf{B} = 0 \qquad (2)$$

$$\mathrm{rot}\,\mathbf{E} = -\frac{\delta\,\mathbf{B}}{\delta\,t} \qquad (3)$$

$$\mathrm{rot}\,\mathbf{B} = \mu_o\,\mathbf{J} + \frac{1}{c^2}\frac{\delta\,\mathbf{E}}{\delta\,t} \qquad (4)$$

We underlined[4][5] these equations have a problem relative to the equation (2) that actually is rather an identity than an equation. But above all those equations (1)..(4) don't consider the Lorentz force and field. On this account in the Theory of Reference Frames[4][5] we opted for a "new group of equations", in which the (2) is replaced with the (8):

$$\mathrm{div}\,\mathbf{E} = \frac{\rho}{\varepsilon_o} \qquad (5)$$

$$\mathrm{rot}\,\mathbf{B} = \mu_o\,\mathbf{J} + \frac{1}{c^2}\frac{\delta\,\mathbf{E_t}}{\delta\,t} \qquad (6)$$

$$\mathrm{rot}\,\mathbf{E_t} = -\frac{\delta\,\mathbf{B}}{\delta\,t} \qquad (7)$$

$$\mathbf{E_t} = \mathbf{E} + \mathbf{u}\Lambda\mathbf{B} \qquad (8)$$

Maxwell's equations defined by the group [(5)....(8)] describe completely electromagnetic phenomena generated by two types of physical source: the density of variable charge ρ and the density of variable current J. The (8) then defines the Lorentz field and the total force $\mathbf{F_t}=q\mathbf{E_t}$ that acts on an electric charge q (with speed **u)** that is into an electromagnetic field defined by the vector electric field **E** and by the vector magnetic

field **B**. It is manifest that the equation (8) represents an electrodynamic law inside the structure of Maxwell's equations and if there aren't moving electric charges the e.m. field is described only by [(5)...(7)]. Those same equations [(5)...(7)] define also the continuous electromagnetic wave with frequencies into the range from long waves to the common sub-interval of microwaves and of infrared rays[4][7][8].
The equation (6) caused a big problem in physics due to the mistaken interpretation of this equation from the relativistic viewpoint according to which that equation established electromagnetic waves and light propagated always with the same speed c independently of the reference frame. In actuality that equation establishes it is right only with respect to the reference frame where the propagation happens. Consequently the propagation with respect to a different reference frame occurs according to the relative speed of the two reference frames like it is was proved in the order of theTheory of Reference Frames.
The electromagnetic nanofield begins with range of frequency from infrared rays to δ-Y rays. The e.m. nanofield is due to an accelerated charged elementary particle, whether free or bound inside atom, that generates an e.m. nanowave with energy E=hf. The e.m. nanofield is described by Maxwell's two following equations

$$\text{rot}\,\mathbf{e} = -\frac{\delta\,\mathbf{b}}{\delta\,t} \qquad (9)$$

$$\text{rot}\,\mathbf{b} = \frac{1}{c^2}\frac{\delta\mathbf{e}}{\delta\,t} + \mu_o\mathbf{j} \qquad (10)$$

in which **j** is the density of variable nanocurrent that is represented by the accelerated charged elementary particle.
We have to consider the question that in classical electromagnetism wave is continuous while in e.m. nanofield the nanowave has quantum nature and respects Planck's relation. In the event of electron nanowave is generated whether when electron is bound inside atom and jumps from an energy level to another or when it is free and is accelerated by a force field.

3. Relativistic electrodynamics of moving massive elementary particles

We have demonstrated in TR that a charged massive elementary particle (CMEP) accelerated by a force field undergoes a variation of its electrodynamic mass given by

$$m = m_o\left(1 - \frac{1}{2}\frac{v^2}{c^2}\right) \qquad (11)$$

where m_o is the resting electrodynamic mass and v is the particle's speed. The variation of the electrodynamic mass with the speed is represented in the graph of fig.1.

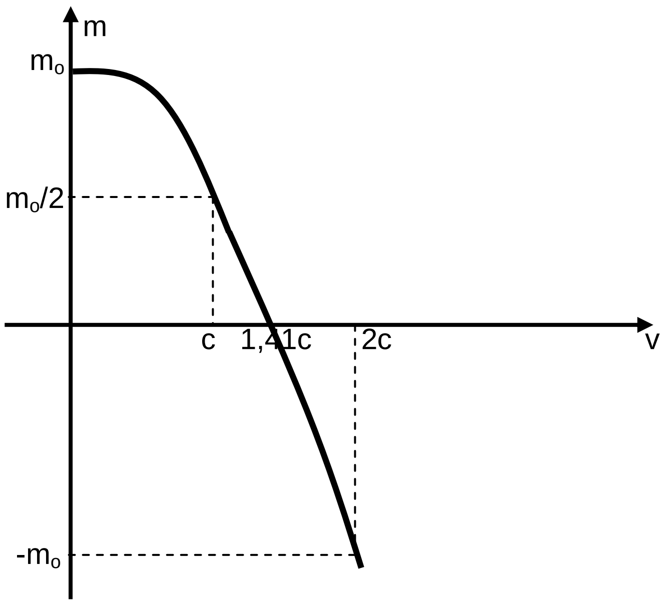

Fig.1 Diagram of electrodynamic mass of an accelerated particle

If acceleration is caused by a field of constant force, because mass is variable and decreasing then necessarily also acceleration has to be variable but increasing with the speed. The acceleration is given therefore by

$$a = \frac{a_o}{1 - \frac{1}{2}\frac{v^2}{c^2}} \qquad (12)$$

and it is graphed in fig.2, where a_o is the acceleration when the speed is null.
At the critical speed $v_c=\sqrt{2}\,c=1.41c$ the graph of acceleration has a discontinuity that is due to the fact that at the critical speed electrodynamic mass of the particle is null. This particular state of discontinuity has briefest duration because it is characterized by instability. In fact if the particle is free it tends spontaneously to go back to a stability state ($v<v_c$) by means of a decay process with emission of an energy quantum while if the particle is forced acceleration changes sign like electrodynamic mass. When then the speed increases further negative acceleration continues to increase untill the its annulment for greatest speeds where negative electrodynamic mass becomes greatest in absolute value.
We know motion of the accelerated particle is characterized also by emission of quantum electromagnetic energy for two particular values of speed: the physical speed c of light and the critical speed $v_c=\sqrt{2}\,c$. In consequence of this last consideration graphs of fig.1 and of fig.2 don't seem adequate to describe the phenomenon of quantum electromagnetic emission.
They are a simple approximation in the continuous shape of a physical process that in actuality is quantum. We will search for describing now the process considering its physical reality that is quantum.

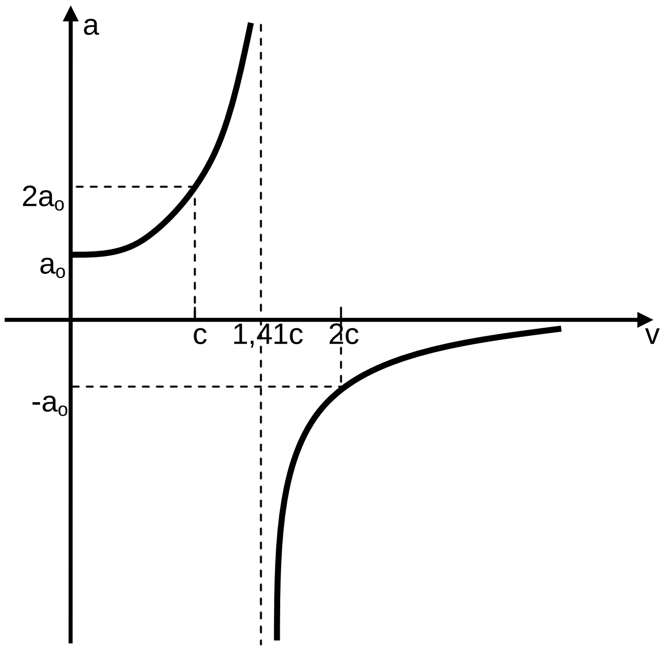

Fig.2 Graph of variation of acceleration with the speed of an electrodynamic particle

4. Quantum electrodynamics of moving massive elementary particles

Until now we have considered electrodynamic mass of an accelerated particle changes with the speed in continuous manner (relation (11) and fig.1). In actuality we know the variation of electrodynamic mass is connected with the variation of intrinsic energy and with the emission of electromagnetic energy that happens in the quantum shape in regard to two different values of speed. It induces to think also the variation of mass happens in more realistic manner in the quantum shape in regard to both the physical speed of light and the critical speed, like it happens for the emission of the two energy quanta on the part of accelerated particle. To that end we need a suitable mathematical model that allows to define the quantum behavior of accelerated particle.

We know the mathematical analysis provides us with a very interesting particular function: the step function, that in that case has the expression $m_o[v]$. This function is graphed in fig.3.

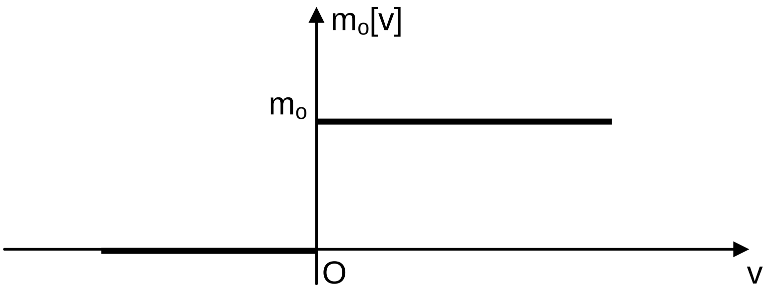

Fig.3 Graphic representation of the step function $m_o[v]$.

This function has a discontinuity for v=0 where there is a left limit $m_o[0^-]=0$ that is different from the right limit $m_o[0^+]=m_o$.
Similarly it is possible to define the step function $m_o[v-v_o]$ that has the graph of fig.4 and it has the same discontinuity for $v=v_o$.

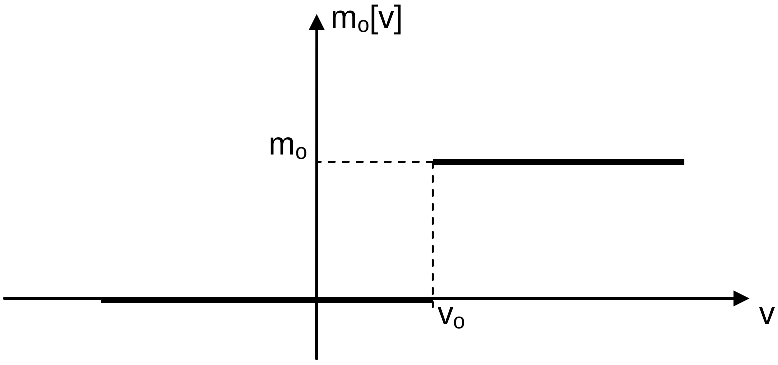

Fig.4 Graphic representation of the step function $m_o[v-v_o]$ with discontinuity for $v=v_o$.

Conseguently the graph of fig.1 has to be modified like in fig.5 in the stability zone of accelerated particle. In the instability zone the accelerated particle doesn't emit but absorbs energy and there aren't at the moment reasons for thinking the graph has to change. In the physical situation that we are considering it is manifest that there are two discontinuities in regard to both the physical speed c of light and the critical speed $v_c=\sqrt{2}\,c$.

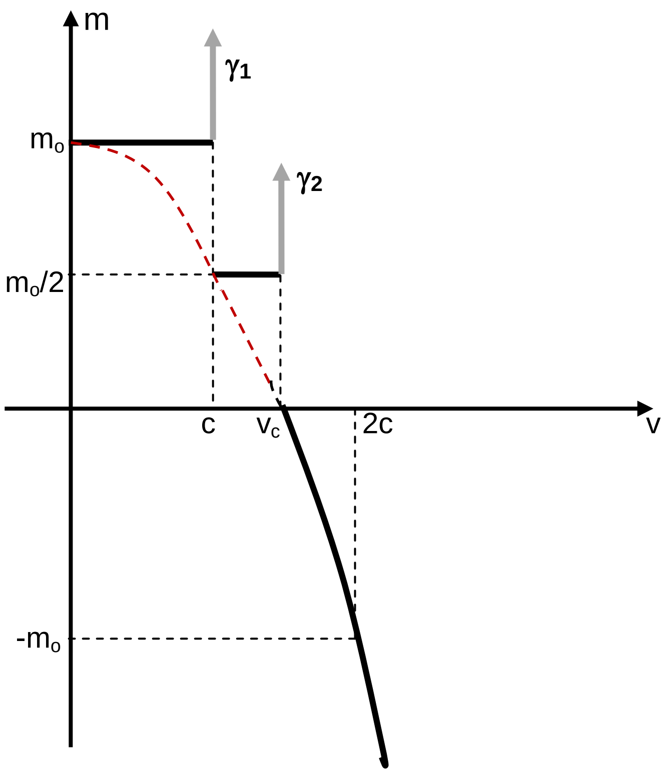

Fig.5 Mass of accelerated charged elementary particle has a quantum behavior in the stability state that happens when its speed is smaller than the critical speed and it has a presumably continuous behavior when it is in the instability state where it has negative mass ($v>v_c$).

It is manifest that the modification on the graph iimplies a correspondent modification in the relation (11) that therefore becomes as per the new mathematical model

$$m = m_o - \frac{m_o}{2}\left(1[v-c] + 1[v-v_c]\right) + m_o\left(1 - \frac{1}{2}\frac{v^2}{c^2}\right) 1[v-v_c] \qquad (13)$$

If electrodynamic mass in the stability state has a quantum behavior it follows that necessarily also acceleration must have a quantum behavior and in the event that the field force is constant we have the graph of fig.6.

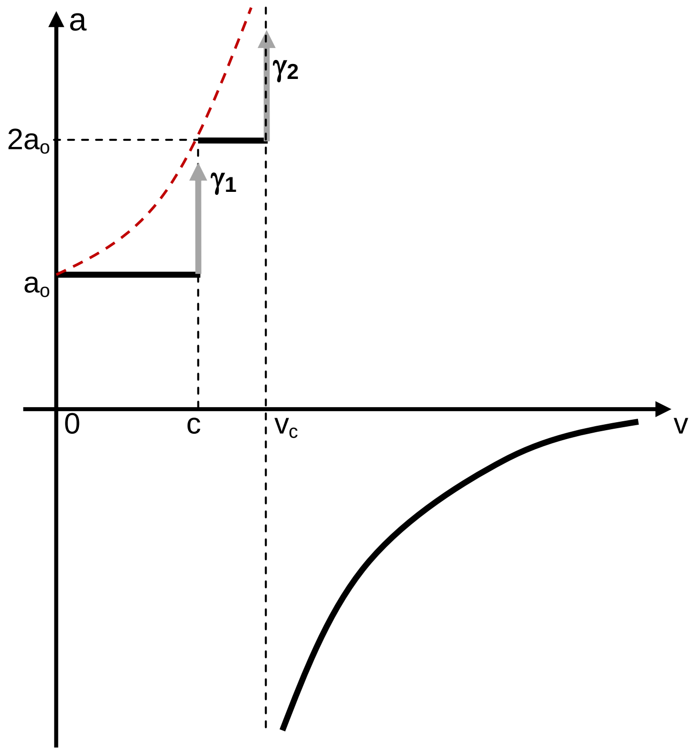

Fig.6 Graph of quantum acceleration of a particle into a constant force field

From the reading of the graph we deduce that in the range of speeds (0,c) acceleration is constant and therefore the speed is linear $v(t)=a_o t$. In the range of speeds (c,v_c) acceleration is double and consequently the linear speed is $v(t)=2a_o t-c$ with $c=a_o t_o$ and $t_c=(\sqrt{2}+1)t_o/2$.
Like mass, also for acceleration we can deduce from the (12) the quantum expression

$$a = a_o \left\{ 1 + 1[v-c] + \frac{1}{1 - \frac{v^2}{2c^2}} 1[v-v_c] - 2 * 1[v-v_c] \right\} \qquad (14)$$

It follows that accelerated particle in the stability state has a quantum behavior while in the instability state it would have an ordinary behavior according to a continuous paradigm. This double behavior is due to the fact that in the instability state $(v>v_c)$ we don't know a rule of quantization.

5. Rules of quantization

The noted main rules of quantization are:

1. For electrons that are bound inside atom the rule of quantization derives from De Broglie's equivalence for which we can associate a virtual nanowave to every electron that has relativistic electrodynamic mass m and speed v. The equivalent nano-wavelength λ is related to momentum p=mv of electron by the relationship

$$\lambda = \frac{h}{mv} \qquad (15)$$

It' s manifest the nano-wavelength of the virtual quantum depends on the speed of electron while the nano-wavelength of real quanta (for instance photons) is independent of the physical speed which is constant and equals c. For stability's sake of the electronic orbit, as per the above-mentioned equivalence it must be

$$2\pi\, r = n\, \lambda \qquad (16)$$

where n is an integer number with n=1, 2, …., r is the orbital radius and λ is De Broglie's equivalent nano-wavelength. This rule of quantization (16) derives from the necessity to preserve the phase state of the electron inside the considered equivalence and at the same time to assure the stability of the motion in the orbital model. It is manifest also that this virtual nanowave is completely different from the real nanowave emitted by the electron when it jumps from an energy level to another.

2. For accelerated free electrons, in the stability state, the rule of quantization is given by the quantum variation of electrodynamic mass with the speed (13), that here we rewrite

$$m = m_o - \frac{m_o}{2}\left(1[v-c] + 1[v-v_c]\right) + m_o\left(1 - \frac{1}{2}\frac{v^2}{c^2}\right) 1[v-v_c] \qquad (17)$$

for which relative to two particular speeds: the physical speed c of light and the critical speed, the accelerated electron emits two quanta of electromagnetic energy that are related to the electrodynamic mass of the resting electron.

3. For accelerated free electrons in the instability state we don't know if they have a quantum behavior and above all we don't know the prospective rule of quantization. Anyway we know main unstable particles of the subfamily of electron[9] have the following negative masses, with respect to the mass of resting electron, and speeds (in brackets):

-206.6 (20.4c); -273.1 (23.4c); -966.4 (55.1c); -3477.5 (60c); (18)

If these numbers and others, that here we don't have considered, hide a rule of quantization, it is a question that has to be discovered and explained.

6. Quantum thermodynamics of elementary particles

The variation with the speed of the intrinsic Kelvin temperature of an electrodynamic elementary particle is given by the following relation[6]

$$T = T_o \left(1 - \frac{v^2}{2c^2}\right) \qquad (19)$$

and because for (11)

$$T = T_o \frac{m}{m_o} \qquad (20)$$

we have from (13)

$$T = T_o \left\{ 1 - \frac{1}{2}\left(1[v-c] + 1[v-v_c]\right) + \left(1 - \frac{1}{2}\frac{v^2}{c^2}\right) 1[v-v_c] \right\} \qquad (21)$$

The (21) can be graphed obtaining the diagram in fig.(7).

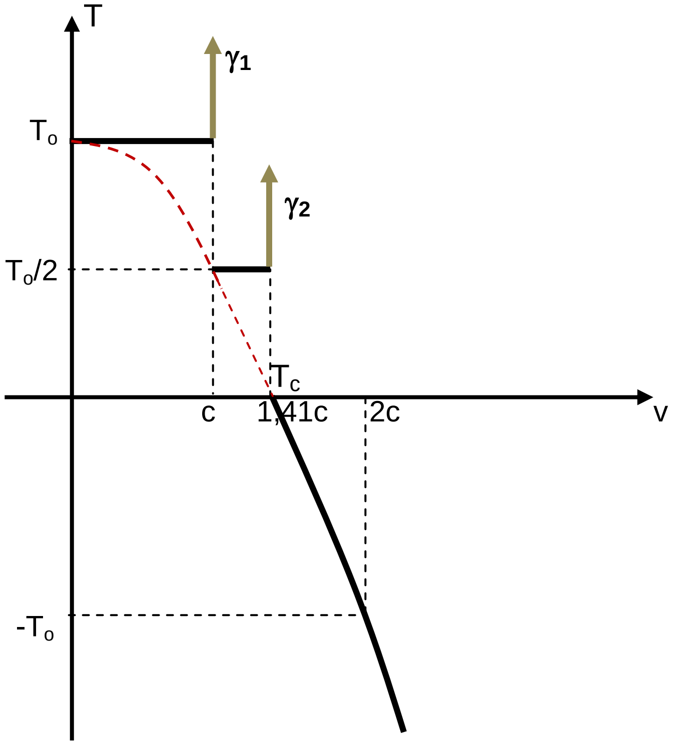

Fig.7 Quantum diagram of the Kelvin temperature of an electrodynamic particle at changing of the speed.

Besides the entropy at changing of the speed is[6]

$$S = S_{io}\left(1 + \ln\left|1 - \frac{v^2}{2c^2}\right|\right) \qquad (22)$$

and being

$$\left|1 - \frac{v^2}{2c^2}\right| = \frac{|m|}{m_o} \qquad (23)$$

we have

$$S = S_{io}\left(1 + \ln \frac{|m|}{m_o}\right) \qquad (24)$$

and consequently as per (17)

$$S = S_{io}\left\{1 + \ln\left(1 - \frac{1}{2}\left(1[v-c] + 1[v-v_c]\right) + \left|1 - \frac{1}{2}\frac{v^2}{c^2}\right| 1[v-v_c]\right)\right\} \qquad (25)$$

The (25) is graphed in fig.8.

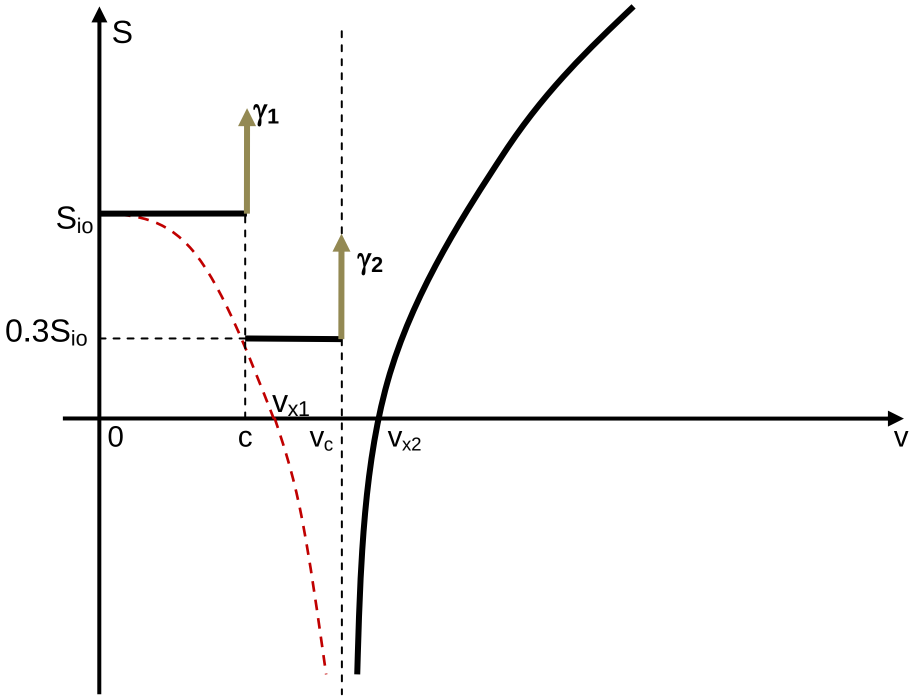

Fig.8 Quantum entropy of a charged elementary electrodynamic particle as function of particle's speed.

In diagram the value v_{x1}=0.79v_c=1.114c is virtual because in that zone the graph is quantum while the value

$$v_{x2} = 1.17v_c = 1.65\ c \qquad (26)$$

is real. Considering then the entropy as function of the temperature we have[6]

$$S = S_{io}\left(1 + \ln \frac{|T|}{T_o}\right) \qquad (27)$$

The (27) can be graphed and we have the diagram of fig.9, where

a. for $T=T_o$ $S=S_{io}$
b. for $T=T_o/2$ $S=0.3S_{io}$
c. for $T=0$ $S=-\infty$
d. for $T=-\infty$ $S=\infty$

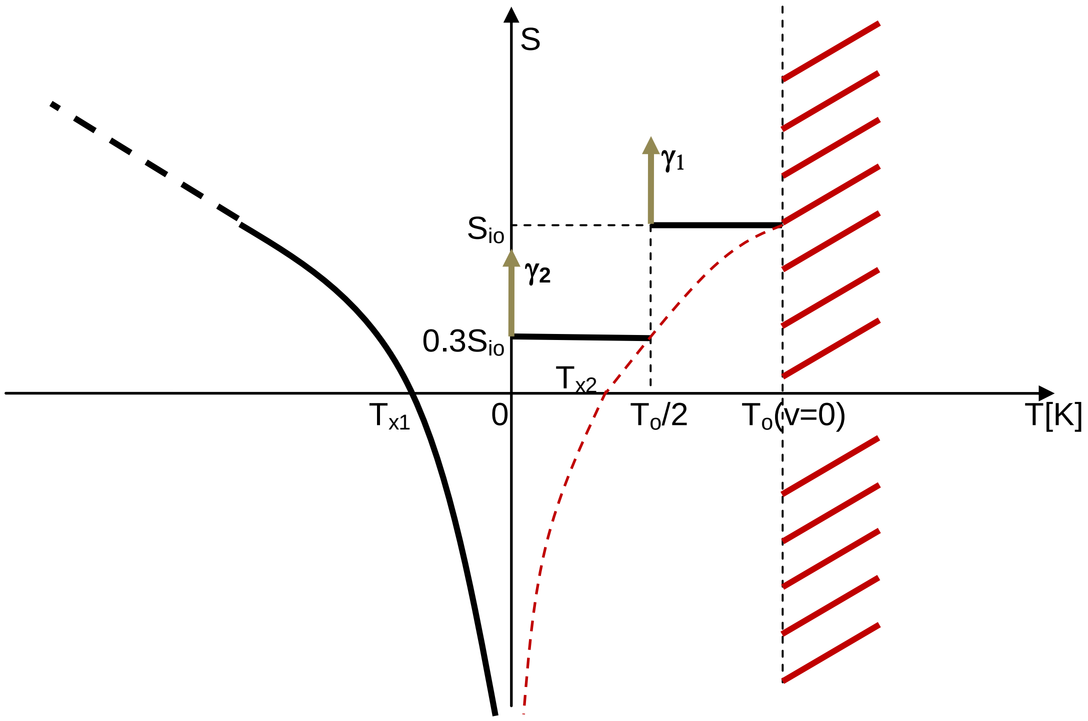

Fig.9 Quantum graph of entropy of a charged elementary electrodynamic particle as function of the Kelvin temperature

It is possible also to obtain the quantum expression of entropy as function of the temperature

$$S = S_{io}\left\{1 + \ln\left(\frac{|T|}{T_o}1[-T] + \frac{1}{2}1[T] + \frac{1}{2}\,1\left[T - \frac{T_o}{2}\right]\right)\right\} \qquad (28)$$

where the function 1[-T] has the graph like fig.1

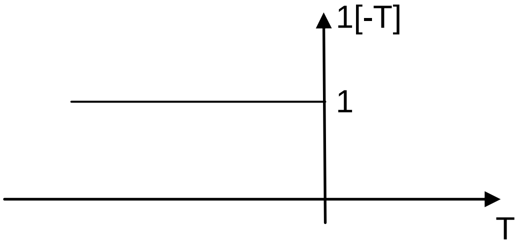

Fig.10 Step function 1[-T]

7. Reaction forces of particles due to radiation

When a force F is applied to a free massive physical system, together with motion reaction forces are produced and they coincide with inertial forces when resistant forces of medium where motion happens are null (k=0)[2][10]. According to the Newton law we can write

$$F=m_o a_o=ma \qquad (29)$$

where m_o and a_o are initial mass and acceleration, m and a are mass and acceleration during motion. In that event $F_i=-ma$ represents the reaction inertial force.
Let us consider a few cases:

7a. If the force F is constant then dF=0 and the speed is variable. In the event of ordinary bodies, mass and acceleration are constant and also the reaction inertial force is constant. In the event instead of charged massive electrodynamic particles, mass and acceleration change with the speed and therefore we have

$$dF = mda + adm \qquad (30)$$

where dF is the applied differential force, $dF_a=-mda$ is the reaction differential force due to the variation of acceleration and $dF_m=-adm$ is the reaction differential force due to the variation of mass[10]. Because dF=0 then we have

$$dF_m = - dF_a \qquad (31)$$

and for continuous and non quantum behavior of particle it is[10]

$$dF_m = - dF_a = \frac{m_o avdv}{c^2} \qquad (32)$$

Considering that in actuality particles have a quantum behavior in regard to two particular speeds (the physical speed c of light and the critical speed v_c) it is interesting to see what happens relative to these two speeds, considering incremental variations.
The reaction incremental force of mass ΔF_m produces the emission of a gamma quantum of electromagnetic energy in regard to these two speeds.
For v=c, from (13) and from the fig.5 and fig.6 we deduce

$$\Delta F_m = - a\Delta m = - a_o\left(\frac{m_o}{2} - m_o\right) = \frac{m_o a_o}{2} \qquad (33)$$

$$\Delta F_a = - m\Delta a = - m_o a_o \qquad (34)$$

For $v=v_c$

$$\Delta F_m = - a\Delta m = - 2a_o\left(- \frac{m_o}{2}\right) = m_o a_o \qquad (35)$$

$$\Delta F_a = - m\Delta a = + \infty \qquad (36)$$

We observe the two inertial incremental forces of reaction, ΔF_m and ΔF_a, are different in the two considered cases. Besides the singularity in (36) could imply a quantization also for $v>v_c$.

7b. If the force F isn't constant then $dF \neq 0$. In that case the two differential forces of reaction are not equal and opposed. With regard to incremental forces we observe the mass variation is the same as in case constant force while the acceleration variation depends on the applied force.

For v=c

$$\Delta F_m = - a_c\Delta m = - a_c\left(\frac{m_o}{2} - m_o\right) = \frac{m_o a_c}{2} \qquad (37)$$

$$\Delta F_a = - m_c\Delta a = - m_o\Delta a \qquad (38)$$

in which a_c is the particle's acceleration for v=c and $m_c=m_o$ is the mass before the emission.

For $v=v_c$

$$\Delta F_m = - a_{vc}\Delta m = - a_{vc}\left(0 - \frac{m_o}{2}\right) = \frac{m_o a_{vc}}{2} \qquad (39)$$

$$\Delta F_a = - m_{vc}\Delta a = - \frac{m_o}{2}\Delta a \qquad (40)$$

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