HADRONIC JOURNAL 43, 135 - 151 (2020)
DOI 10.29083/HJ.43.02.2020

HOW TO BREAK THE LIGHT SPEED BARRIER IN A PARTICLE ACCELERATOR

Patrick Cornille
Retired Physicist from the C.E.A.
Advanced Electromagnetic Systems
7 Rue de la Perdriere
59320 Ennetieres-en-Weppes, France
patrick.cornille@libertysurf.fr

Received March 9, 2020
Revised April 23, 2020

Abstract

Relativistic mechanics differs from classical mechanics by the presence of the gamma factor in the equation of motion of a charged particle. This gamma factor results from experimental measurements done in the laboratory frame when one observes the acceleration of charged particles in a particle accelerator. This gamma factor has nothing to do with the gamma factor of the special relativity theory used in a Lorentz transformation done between inertial frames in relative motion where the velocity is constant in this transformation.

We will show in this paper that one can rewrite the relativistic motion equation as a classical motion equation plus a braking force. This allows to calculate the variation of the kinetic energy of the charged particles in a classical way where the work of the braking force appears now as a dissipative term in the energy equation. By using a very old physical principle and a stepping method, one demonstrates how we can cancel the dissipative term opening the way to break the light speed limit for the motion of charged particles in a particle accelerator.

Keywords: Light speed limit; Capacitor problem; Energy transfer; Special relativity theory

1 INTRODUCTION

The gamma factor $\gamma[\mathbf{U}(\mathbf{t})]$ in the equation of motion of a charged particle accelerated in a particle accelerator has no relation with the gamma factor $\gamma[\mathbf{V}]$ of the special relativity theory used in a Lorentz transformation.

We recall that this transformation is defined for a change of reference frame between two inertial frames in relative motion where the velocity $\mathbf{V}$ is uniform. Moreover, the transformation implies also a change of the space-time units in order to obtain the presence of the gamma factor in the transformation. We must point out that in all experiments done in a particle accelerator as in the case of the Bertozzi's experiment [1], all the measurements are done by an observer located in the laboratory reference frame, therefore no change of reference frame and space-time units is implied in the experimental measurements.

All the mathematical formulation explicated in this paper is written for quantities defined with respect to the laboratory reference frame. Therefore, we shall propose another explanation to understand why there is a speed limit for a charged particle accelerated in particle accelerators. In a first step, we prove that the relativistic equation of motion can be written in a classical way if a braking force is introduced in the equation. In a second step, we present a general equation of motion for a charged particle with a mass depending on time where the relation $m(t) = \gamma(t)\, m_0$ is a special case obtained if we apply a given constraint which was first introduced in our paper [2].

2 PHYSICAL ASPECTS ON THE ROLE PLAYED BY VACUUM

The fact that a particle is not a point particle has been proved by electron scattering experiments done by Hofstadter [3] in 1956 who proved that all elementary particles have a measurable finite size, an internal charge distribution and can deform themselves in interaction. Hofstadter received the Nobel Prize in 1961 for his important discovery.

With a different approach, the structure of an elementary particle was analyzed by H. Dehmelt [4] from 1976 to 1990. In these experiments, an electron, almost at rest, was isolated and closely confined in a ultrahigh-vacuum

Penning trap. These experiments permitted to measure the dimensionless gyromagnetic factor g with an incredible accuracy.

We can find in the literature only a few model of the electron morphology, the first one by Parson [5] in 1915 where the author proposed a model for the electron with a ring-shaped geometry where an elementary charge moves around the ring with the speed of light generating a magnetic field.

We have to wait until 1985, to see the ring electron model revisited by Bostick [6] where the angular momentum of the electron or spin has for value $\hbar/2 = \alpha\hbar\, ln[R/r]$ where $2r$ is the diameter of the toroidal shell and R the radius of the toroid and α the fine-structure constant. A ring electron model was also presented by Bergman [7] in 1990 where the spin has now for value $\hbar/2 = \alpha\hbar\, ln[8R/r]/2\pi$. In this last model, the instability of the electron is cancelled by the presence of a magnetic Pinch effect where the magnetic pressure compensates exactly the electrostatic pressure. Several researchers, such as Jennison [8], Kanarev [9], and Lucas [10] proposed similar models. More recently Consa [11] in 2018 proposed an helical solenoid electron model where the electron has a toroidal moment, a feature that is not predicted by quantum mechanics.

A more complete wave model of the electron was developed by Mills [12] in 2003 where the classical wave equation is solved with the constraint that the bound state electron cannot radiate energy. With the assumption that physical laws including Maxwell's equation apply to bound electrons, the hydrogen atom was solved exactly from first principles. The remarkable agreement across the spectrum of experimental results indicates that this is the correct model of the hydrogen atom. In a second paper [13], the physical approach was applied to multi-electron atoms that were solved exactly. The general solutions for one-through twenty-electron atoms are given. The predictions of the ionization energies are in remarkable agreement with the experimental values known for 400 atoms and ions.

This paper does not deal with several experiments [14-19] done from 1983 to 1993 to demonstrate that superluminal speeds do exist. The light speed barrier is an experimental fact in particle accelerators which must be understood if one wish to break it. The subject has been already discussed by Santilli [20] who reviews the compatibility of superluminal speeds with special relativity. The author made some interesting remarks that are worth to be analyzed again. First, the author insists on the fact that nucleons must be deformable charge distributions and he points out rightfully that there is no point like wave packet in nature.

In a second step, Santilli conceives space as an universal substratum for all electromagnetic waves and all particles. He tries to explain the reason why the rest energy of the neutron is $0.78\,MeV$ bigger than the sum of the rest energies of the proton and electron. To solve this problem, he supposes that energy is transmitted from space to the neutron via a longitudinal impulse.

Santilli [21] was also the first physicist to raise the question of the rigidity of space in 1957 to explain the high value of the speed of light, a problem that most physicists avoid to speak since they are unable to explain how vacuum can sustain the propagation of transverse electromagnetic waves. A transverse wave can only travel through solid, then why transverse light wave can travel through air and vacuum. This implies that vacuum must behave as if it were an elastic solid with a rigidity which had to be incredibly high in order to transmit waves at the fantastic speed of light. On logical grounds, such a medium was compelled to slow down planetary motions around the Sun.

A search in the scientific literature concerning the answer to that question was given by Bekefi [22,p.150] in plasma physics where the author notes that a longitudinal wave can create a transverse wave: *In an infinite homogeneous plasma, the energy exchange between longitudinal and transverse waves occurs at the microscopic level, and is essentially the result of the medium's grainy nature.* Thus, it is not necessary to consider the vacuum as a kind of elastic solid to sustain transverse waves. We give a more complete answer to this question in two papers published in 1990 and 1994 [23-26] where we assume the presence of scalar inhomogeneous waves in vacuum. This scalar longitudinal field is characterized by the definition of the phase

$$\varphi(\mathbf{r},t) = \int_{t_0}^{t} \alpha(\mathbf{r},t')\omega(\mathbf{r},t')dt' - \int_{\mathbf{r}_0}^{\mathbf{r}} \alpha(\mathbf{r}',t_0)\mathbf{k}(\mathbf{r}',t_0)\cdot d\mathbf{r}' \qquad (1)$$

where the quantity $\alpha(\mathbf{r},t)$ is an integrating factor. In this approach, there is no space-time curvature of vacuum but a space-time deformation of the standing longitudinal waves making the vacuum. This approach has two merits: first if a Fourier mode is solution of a scalar wave equation, then one can deduce the Maxwell's equations [27,p.356] by using successively more complicated potential definitions, hence sound generates light so to speak. Secondly, we prove that the deformation of the scalar wave is quantized. Thus the picture of light as a transverse vibration in the ether, analogous to transverse waves on a string, can be reconciled with the existence of the ether. We can conclude this section by pointing out the fact that numerous experiments have proved that vacuum is a vibrational medium able to explain the Casimir effect, the Lamb shift and the Van de Waals forces.

3 RELATIVISTIC ENERGY LAW WRITTEN IN A CLASSICAL FORM

The fact that a particle has an internal structure implies that this particle can have an interaction with the medium which is taken into account by the existence of an internal force. The splitting of forces between internal and applied forces is examined in the appendix. The existence of the internal force is taken into account by considering that the mass of a particle is a function of time where the momentum is now $\mathbf{P} = m(t)\mathbf{U}$. It is important to point out again that all the following calculation is done in the laboratory reference frame where the particle velocity $\mathbf{U}$ is also defined. The equation of motion of this particle has for expression:

$$\frac{d\mathbf{P}}{dt} = \mathbf{F} \tag{2}$$

where the force $\mathbf{F}$ is applied to the particle which is accelerated in an electrostatic accelerator. If the preceding equation is scalarly multiplied by $\mathbf{U}$, then we obtain

$$\mathbf{U} \cdot \frac{d\mathbf{P}}{dt} = m\mathbf{U} \cdot \frac{d\mathbf{U}}{dt} + \frac{dm}{dt}\mathbf{U}^2 = \mathbf{F} \cdot \mathbf{U} \tag{3}$$

We have the identity:

$$\frac{1}{2}\frac{dm\mathbf{U}^2}{dt} = m\mathbf{U} \cdot \frac{d\mathbf{U}}{dt} + \frac{1}{2}\frac{dm}{dt}\mathbf{U}^2 \tag{4}$$

The second term in the right hand side of the preceding equation is a dissipative term if we verify the condition $dm/dt > 0$.

If we substitute the preceding equation in equation 2 and integrate, we get the relation:

$$\frac{1}{2}\int_0^T \frac{dm\mathbf{U}^2}{dt}\,dt + \frac{1}{2}\int_0^T \frac{dm}{dt}\,\mathbf{U}^2\,dt = \int_0^T \mathbf{F}\cdot\mathbf{U} \tag{5}$$

The preceding equation is an exact mathematical formulation where the first term in the left hand side of the equation is the classical variation of the kinetic energy of the particle while the second term is a dissipative term. In the right hand side, we have the work of the external force. The speed limit results from the braking force included in the dissipative term if the condition $dm/dt > 0$ is verified.

3 STUDY OF THE GAMMA FACTOR

The experimental fact that an elementary particle has a structure justifies the definition of an internal kinetic energy which is the sum of the vibrational energy $E_V = 0.5 * m_0c^2$ and the rotational energy $E_R = 0.5 * m_0c^2$ in the reference frame where the center of mass of the particle is at rest. Therefore, the total internal kinetic energy of the particle has for value $E_K = m_0c^2$ in the rest frame of the particle or in the laboratory frame for the initial condition $\mathbf{U}(0) = 0$. We can easily calculate the frequency of the oscillatory motion of the electron with the formula $m_0c^2/2 = \hbar\omega$ which gives $F = 0.62\,10^{10} Hz$.

Let us now assume that the internal kinetic energy of the particle in the laboratory reference frame is $E_K(t) = m(t)c^2$ and we impose the constraint [2]

$$\mathbf{U}\cdot\frac{d\mathbf{P}}{dt} = \frac{dE_K}{dt} \tag{6}$$

The preceding equation means that both the internal and external kinetic energies of the particle increase at the same rate. We must point out that the quantity $m[t]$ is an unknown function. Therefore, equation 5 imposes a relation between two independent functions $m(t)$ and $\mathbf{U}(t)$ which can be solved by adding equation 1. Knowing that $\beta = U/c$, the above equation can be written in the form:

$$\frac{m}{2}\frac{d\beta^2}{dt} = \frac{dm}{dt}(1-\beta^2) \tag{7}$$

The above equation has many important consequences that will be now examined. First, we note that any increase of mass is the consequence of the acceleration of the particle. The equation 6 is very clear: no acceleration no mass increment. We can demonstrate how the function $m(t) = \gamma(t)m_0$ is obtained in relativistic mechanics. If we define the gamma factor as usual $\gamma(t)^2 = 1/(1-\beta^2)$, we get:

$$\frac{\gamma^2}{2}\frac{d\beta^2}{dt} = \frac{1}{\gamma}\frac{d\gamma}{dt} = \frac{1}{m}\frac{dm}{dt} \tag{8}$$

it results the definition:

$$Log[\gamma] = Log\frac{m}{m_0} \quad \Rightarrow \quad m(t) = \gamma(t)m_0 \tag{9}$$

Provided we use the initial condition $m(0) = m_0$ for $\mathbf{U}(0) = 0$. Therefore, the mass function $m(t) = m_0\gamma(t)$ results from the definition of equation 5 but we need equation 1 to calculate the numerical velue of the gamma factor. It follows the relation:

$$\Big[E_K\Big]_0^T = m_0c^2\,(\gamma - 1) \approx \frac{1}{2}m_0\,\mathbf{U}^2 \tag{10}$$

Bertozzi [1] performed an experiment in 1964 in which the speed of electrons with kinetic energies in the range 0.5 to 15 MeV was determined by measuring the time required for the electrons to traverse a given distance while the kinetic energy $E_K = m_0c^2(\gamma - 1)$ was determined by calorimetry measurements. His result shows that the dependence of the kinetic energy on the speed of the electrons is in good agreement with the above formula:

$$\beta^2 = 1 - \Big[\frac{1}{1 + E_K/m_0c^2}\Big]^2 \tag{11}$$

The experiment demonstrates without ambiguity that accelerated charged particles gain large kinetic energies as they approach the speed of light which results in an apparent increase of mass $m = \gamma m_0$. This variation of mass with respect to the velocity of the particle is certainly not a consequence of the special relativity theory since all the measurements are done in the laboratory frame. This conclusion cannot be challenged from an experimental point of view.

The equation 6 imposes that the derivatives of the speed and the mass have the same sign. It is now interesting to consider the opposite case where the derivatives of both the speed and the gamma factor are negative in experiments relating to the dilation effect for a radioactive clock.

Time dilation has been experimentally verified by means of a first experiment performed by Rossi and Hall in 1941 [28] with particles called mu-mesons or muons which are generated by cosmic rays impacting the Earth atmosphere. These particles move with velocities close to the speed of light. However, most of these particles shortly disintegrate. Thus what can be expected is that a few of them survive long enough to reach the Earth surface. However, this is not what happens and this can be understood if we admit that the muon disintegration process is in fact a measurement of the time flow modified by the motion of the particle. Indeed, the unstable particles disintegrate following an exponential law having the form $N(t) = N_0 e^{-t/\Delta t_0}$ where N_0 is the number of particles present at instant $t = 0$ and Δt_0 the mean lifespan of the unstable particle in the reference frame where it is at rest. If the disintegration rate of the muons decreases, this means that their lifespan has increased and thus, that they could travel further and farther. The comparison of the mean lifespan of moving muon Δt with muons at rest Δt_0 allows to verify the time dilation formula $\Delta t = \gamma \Delta t_0$ where both measurements Δt and Δt_0 are performed in the Earth reference frame.

The dilation formulation above predicts that if, after a measurement on the moving muons has been made, we slow down them to rest, then we will recover the lifetime of muons at rest. This experiment has been done in 1963 [29] and confirms the validity of the deceleration effect, let us quote the authors:

"In addition, actually simultaneously, we slowed down and stopped a sample of m-mesons and measured the distribution of their decay times when they were at rest relative to us. Comparison of their rate of decay at rest with their rate of decay in flight showed that the moving mesons decay much more slowly". The experiment by Frisch indicates without ambiguity that the time behavior of the radioactive clock, once brought to rest, is the rest time in the laboratory frame where $\mathbf{U}(0) = 0$. That is the reason why we think that the result of the twin paradox must be zero as explained in our paper [30].

4 STEPPING METHOD TO CANCEL THE DISSIPATION TERM

We can use equation 2 to rewrite equation 4 in the form:

$$\frac{1}{2}\int_0^T \frac{dm\mathbf{U}^2}{dt}\,dt + \frac{1}{2}\int_0^T \frac{dm}{dt}\,\mathbf{U}^2\,dt = \int_0^T \mathbf{U}\cdot\frac{dm\mathbf{U}}{dt}\,dt \tag{12}$$

By definition, we have:

$$E_K[T] + E_D[T] = E_W[T] \tag{13}$$

Where $E_K[T]$ is the classical kinetic energy of the particle, $E_D[T]$ is the dissipative term and $E_W[t]$ is the work term.

Hereafter, we will examine how to decrease the dissipative term $E_D[T]$ by using a very old physical principle which was examined in a recent paper [31]. In this paper, we discussed the transfer of energy between a power supply and a capacitor when a dissipative term such as the resistance R of the wires is present. We demonstrated that one can minimize the heat losses during the transfer of energy between a power supply and a capacitor by processing the energy transfer by small steps. A fact which has been known for a long time but not often quoted in modern physic textbooks in spite of the fact that this principle has many important applications. Indeed, any dissipative system which is irreversible can become reversible if the transformation involved in the system is carried out by a stepping process as the number of steps N increases to infinity.

Gupta [32] in 1984 did an experiment where a linear spring is loaded with a total mass M but in N equal steps each time by a mass $m = M/N$ to demonstrate that the energy dissipated in the form of heat is given by the relation $E_D[N] = MgH/2N$.

Therefore, we can split the integrals of equation 11 in N equal time steps $dt = t_n - t_{n-1} = T/N$ as follows:

$$\frac{1}{2}\sum_{n=1}^{N}\int_{t_{n-1}}^{t_n} \frac{dm\mathbf{U}^2}{dt}\,dt + \frac{1}{2}\sum_{n=1}^{N}\int_{t_{n-1}}^{t_n} \frac{dm}{dt}\,\mathbf{U}^2\,dt = \sum_{n=1}^{N}\int_{t_{n-1}}^{t_n} \mathbf{U}\cdot\frac{dm\mathbf{U}}{dt}\,dt \tag{14}$$

We can now proceed in the same manner as in Gupta experiment where the mass of the particle is increased in small and equal step dm during each time step dt with the definition $m[n] = mo + n * dm$ while for the velocity, we have $\mathbf{U}[n] = \mathbf{U}[n-1] + d\mathbf{U}$. By taking into account these definitions, the relation above can be rewritten in the form

$$E_K[N] = \frac{1}{2}\sum_{n=1}^{N}[m[n]\mathbf{U}^2[n] - m[n-1]\mathbf{U}^2[n-1]] \tag{15}$$

$$E_D[N] = \frac{1}{2}\sum_{n=1}^{N}\int_{t_{n-1}}^{t_n}\frac{dm}{dt}\mathbf{U}^2\,dt \tag{16}$$

$$E_W[N] = \frac{1}{2}\sum_{n=1}^{N}[\mathbf{U}[n] + \mathbf{U}[n-1]]\cdot[m[n]\mathbf{U}[n] - m[n-1]\mathbf{U}[n-1]] \tag{17}$$

After calculation, we have:

$$E_K[N] = 0.5 * m_0 * d\mathbf{U}^2 N^2 - 0.5 * dm * d\mathbf{U}^2 * N^3 \tag{18}$$

$$E_W[N] = 0.5 * m_0 * d\mathbf{U}^2 N^2 - dm * d\mathbf{U}^2 * [4 * N^3 - N]/6 \tag{19}$$

$$E_D[N] = E_W[N] - E_K[N] \tag{20}$$

The quantities dm and $d\mathbf{U}$ are function of N and must be determined from the solution of the two coupled differential equations on the interval $dt = T/N$:

$$m\,\frac{d\mathbf{U}}{dt} + \frac{dm}{dt}\,\mathbf{U} = \mathbf{F} \tag{21}$$

$$m\,\mathbf{U}\cdot\frac{d\mathbf{U}}{dt} + \frac{dm}{dt}\,[\mathbf{U}^2 - c^2] = 0 \tag{22}$$

An electrostatic accelerator used a high voltage V to accelerate charged particles in an evacuated tube with an electrode at either end which are the plates of a capacitor. Since the charged particle passed only once through the potential difference, the output energy is determined by the accelerating voltage of the machine. In a stepping process, the constant electrostatic force has for expression $F(dt) = qV * dt/[T * D]$, knowing that q is the electron charge and V the voltage applied to the plates of the capacitor separated by the distance D. We use Mathematica to calculate the functions $m(t)$ and $\mathbf{U}(t)$ and their derivative over the interval

dt. Finally, the quantities dm and $d\mathbf{U}$ and are obtained from the relations $dm[N] = [dm(dt)/dt] * T/N$ and $d\mathbf{U}[N] = [d\mathbf{U}(dt)/dt] * T/N$.

The time T required for an electron to traverse the distance $D = cT = 30\,m$ at the speed of light $c = 3 * 10^8 m/s$ is about $T = 100\,ns$. Since the sampling time of the stepping process must be at least 10 times lower than this amount of time, we get a switching frequency about $100\,Mhz$ which is not an easy task to do from a technical point of view.

$T = 100\,ns$	$N = 10$	$N = 20$	$N = 30$	$N = 40$	Rel
$\mathbf{U} * 10^8\,m/s$	3.49	1.75	1.17	0.88	2.95
$\mathbf{R}m$	9.65	4.61	3.02	2.25	19.59
$m * 10^{-31}\,g$	9.70	9.17	9.12	9.10	54.28
$E_K\,MeV$	0.372	0.0886	0.0391	0.0220	1.47
$E_W\,MeV$	0.380	0.0888	0.0392	0.0220	2.52
E_D/E_K	0.02	0.0028	0.00085	0.00036	0.713

$T = 200\,ns$	$N = 10$	$N = 20$	$N = 30$	$N = 40$	Rel
$\mathbf{U} * 10^8\,m/s$	6.89	3.51	2.34	1.75	2.98
$\mathbf{R}m$	38.41	18.45	12.11	9.01	45.09
$m * 10^{-31}\,g$	11.60	9.41	9.19	9.14	107.41
$E_K\,MeV$	1.72	0.362	0.157	0.0882	2.98
$E_W\,MeV$	1.84	0.366	0.158	0.0884	5.49
E_D/E_K	0.0664	0.0109	0.0033	0.0014	0.844

In the two preceding tables, we calculate with Mathematica several quantities versus the number of steps N for two values of the final time T. In the last column, we give the corresponding values for the relativistic case with no stepping knowing that the force has for expression $F(t) = qV*t/[T*D]$ with $V = 4\,10^6$ Volt. The numerical calculations in the above tables prove that the ratio E_D/E_K decreases when N increases which is expected from the theory.

5 CONCLUSION

In the present paper, we proved that the relativistic equation of energy can be written in a classical way if we take into account the existence of a braking force resulting from the interaction of the accelerated particle with the medium. We have presented in this paper a rigorous mathematical demonstration showing that the dissipative term can be cancelled if we used a stepping process which allows the speed of the particle to break the speed of light.

6 APPENDIX:SPLITTING OF THE FORCES IN A PARTICLE ACCELERATOR

We can use the analogy with solid state physics to explain the apparent mass increased in a particle accelerator. It is a well-known fact that only external forces to the point particles are considered as applied forces in the equation of motion for electrons moving in a solid. The force which originates from the lattice periodic field remains hidden in the electron effective mass. The electron moving in a solid obeys a law of motion which is given by the equation:

$$\overset{\leftrightarrow}{\mathbf{M}} \cdot \frac{d\mathbf{U}}{dt} = \mathbf{F} \tag{23}$$

where $\overset{\leftrightarrow}{\mathbf{M}}$ is the effective mass dyadic and $\mathbf{F}$ the force applied to the electron which seems to be the only force taken into account in the calculation. However, we know that the electron is subjected to strong forces from the solid lattice which are hidden in the definition of the effective mass.

In vacuum, the motion of a massive particle, with a rest mass m_0, submitted to a Lorentz force $\mathbf{F}$ is described by the relativistic dynamic equation

$$\frac{d}{dt}\left[m_0\gamma\mathbf{U}\right] = \mathbf{F} \tag{24}$$

with the definition $\gamma^2 = [1 - \mathbf{U}^2/c^2]^{-1}$ which gives the following relation:

$$\frac{d\gamma}{dt} = \frac{\gamma^3}{c^2}\frac{d}{dt}\left[\frac{\mathbf{U}^2}{2}\right] \tag{25}$$

By using the preceding relation, we can rewrite equation 23 in a dyadic form

$$\frac{d\mathbf{U}}{dt} = [\overleftrightarrow{\mathbf{M}}]^{-1} \cdot \mathbf{F} \Rightarrow \overleftrightarrow{\mathbf{M}} \cdot \frac{d\mathbf{U}}{dt} = \mathbf{F} \tag{26}$$

where the direct and inverse mass dyads have for definitions:

$$\overleftrightarrow{\mathbf{M}} = m_0\gamma\,[\overleftrightarrow{\mathbf{I}} + \frac{\gamma^2}{c^2}\mathbf{U}\mathbf{U}] \Rightarrow [\overleftrightarrow{\mathbf{M}}]^{-1} = \frac{1}{m_0\gamma}\,[\overleftrightarrow{\mathbf{I}} - \frac{1}{c^2}\mathbf{U}\mathbf{U}] \tag{27}$$

where $\overleftrightarrow{\mathbf{I}}$ is the unit dyadic. The equation 25 shows that the force and acceleration are generally non-collinear in the high velocity motion of a point particle. The fact that the velocity of a material particle submitted to a constant force does not increase linearly with time means that the particle is submitted to a braking force from the medium. In solid-state physics, this braking force results from the interaction between the free moving particles and the lattice periodic field.

By analogy with the effective mass concept in solids, we can assume that the dyadic mass of an electron moving in the vacuum and the dependence of its mass upon velocity can be explained in the framework of classical mechanics. The analogy between solid state physics and the relativistic motion of an electron in the vacuum is a useful concept which has already been used by Dirac [33] to explain the so-called Dirac sea of electrons by regarding the vacuum as a close analog of a semi-conductor with two bands separated with an energy gap $2m_0c^2$.

The dyadic masses may be diagonalized, for a velocity $\mathbf{U}$ directed along the $\mathbf{x}$ axis, we get:

$$\overleftrightarrow{\mathbf{M}} = m_0\begin{pmatrix}\gamma^3 & 0 & 0\\ 0 & \gamma & 0\\ 0 & 0 & \gamma\end{pmatrix} \qquad [\overleftrightarrow{\mathbf{M}}]^{-1} = \frac{1}{m_0}\begin{pmatrix}\gamma^{-3} & 0 & 0\\ 0 & \gamma^{-1} & 0\\ 0 & 0 & \gamma^{-1}\end{pmatrix} \tag{28}$$

We recover the so-called longitudinal $m_l = \gamma^3 m_0$ and transverse $m_t = \gamma m_0$ masses of the particle. There is no direct proof that the relativistic dependence of mass on velocity has been established since one can transform the above equation of motion written in dyadic form as a classical equation of motion:

$$\frac{d}{dt} m_0 \mathbf{U} = m_0 \, [\overleftrightarrow{\mathbf{M}}]^{-1} \cdot \mathbf{F} = \mathbf{F}_e + \mathbf{F}_b \tag{29}$$

where the force applied to the particle has been partitioned in two forces, one is the applied force $\mathbf{F}_e = \mathbf{F}$ and the other one is the braking force $\mathbf{F}_b = \overleftrightarrow{\mathbf{G}} \cdot \mathbf{F}$ with the definition:

$$\overleftrightarrow{\mathbf{G}} = \begin{pmatrix} \gamma^{-3} - 1 & 0 & 0 \\ 0 & \gamma^{-1} - 1 & 0 \\ 0 & 0 & \gamma^{-1} - 1 \end{pmatrix} \tag{30}$$

which is a velocity depending force tending to zero then we have $U \longrightarrow 0$.

Since the braking force depends on the velocity, it is therefore a magnetic force. This force cannot be a magnetic Lorentz force since the Lorentz force is transverse to the direction of motion of an electron as shown in the pinch-effect.

However, we know that the Ampère force has a longitudinal component along the direction of motion of the electron. Bush [34] was the first author to use the Ampère force for calculating the transverse motion of a charged particle in Bucherer's experiment. Later, Moon and Spencer [35] and Assis [36] rediscovered the same calculation. These authors were able to explain the Bucherer's experiment with a calculation valid up to second-order in U/c. However, their calculation concerns the transverse mass and they did not verify that this calculation applies also to the case of the longitudinal mass.

We can explain the mass velocity law from a classical point of view by using the Weber theory as demonstrated by Cornille [2,27]. However, this theory faces a difficulty since the demonstration depends on a parameter a which is not the same for both the transverse and longitudinal masses. The braking force and the non-isotropic effective mass seem to provide support for a medium in space having a lattice structure. One could quote the "epola" model of Simhony [37] concerning an electron-positron lattice with a NaCl structure.

7 BIBLIOGRAPHY

[1] W. Bertozzi, Speed and kinetic energy of relativistic electrons, American J. of Physics, Vol. 32, p. 551, [1964]

[2] P. Cornille, G. Galeczki, Mass-increase with velocity is a dynamical effect, Journal of Theoretics Comprehensive Papers Section

[3] R. Hofstadter, Review of Modern Physics, Vol. 28, p.14, [1956]

[4] H. Dehmelt, Experiments on the structure of an individual elementary particle, Science, Vol.247, p.539, [1990]

[5] L.A. Parson, Magneton Theory of the Structure of the Atom. Smithsonian Miscellaneous Collections, Vol.65, N°11, p.2–80, [1915]

[6] W. H. Bostick, The morphology of the electron, International Journal of Fusion Energy, Vol.3, N°1, p.9, [1985]

[7] R.C. Jennison, A new classical relativistic model of the electron. Phys. Letters A., Vol.141, p.377–382, [1989]

[8] D.L. Bergman, J.P. Wesley, Spinning Charged Ring Model of Electron Yielding Anomalous Magnetic Moment, Galilean Electrodynamics, Vol.1, N°5, p.63, [1990]

[9] P. Kanarev, Model of the Electron. Apeiron, Vol.7, p.184–194, [2000]

[10] R.L. Mills, Classical Quantum Mechanics, Physics Essays, Vol.16, N°4, p.433, [2003]

[11] R.L. Mills, Exact Classical Quantum-Mechanical Solutions for One-through Twenty-Electron Atoms, Physics Essays, Vol.18, N°3, p.321, [2005]

[12] C.W. Lucas, A Classical Theory of Elementary Particles Electromagnetic Part 2, intertwining Charge-Fibers. The Journal of Common Sense Science, Vol.8, p.1–7, [2005]

[13] O. Consa, Helical Solenoid Model Model of the Electron, Progress in Physics, Vol.14, Issue 2, N°4, p.80, [2018]

[14] H. W. Milnes, Faster than light, Raio Electrnics, Vol.54, N°1, p.55, [1983]

[15] P.T. Pappas, A.G. Obolensky, Thirty six nanoseconds faster than light, Electronics Wireless World, Vol.94, N°12, p.1162, [1988]

[16] G.C. Giakos and T.K. Ishii, Rapid Pulsed Microwave Propagation, IEEE Microwave and Guide Wave Letters, Vol.1, N°12, p.374, [1991]

[17] T.K. Ishii and G.C. Giakos, Transmit radio messages faster than light, Microwaves and RF, N°8, p.114, [1991]

[18] A. Enders, G. Nimtz. On superluminal barrier traversal, Journal de Physique I, EDP Sciences, 2, N°9, pp.1693-1698, [1992]

[19] A. Ranfagni, P. Fabeni, G.P. Pazzi and D. Mugnai, Anomalous pulse delay in microwave propagation: A plausible connection to the tunneling time, Physical Review E, Vol.48, N°2, p.1453, [1993]

[20] R. M. Santilli, Compatibility of Arbitrary Speeds with Special Relativity for Interior Dynamical Problems, American Journal of Modern Physics, Special Issue: Issue II: Foundations of Hadronic Mechanics, Vol.5, N° 2-1, p.143-160, [2016]

[21] R. M. Santilli, "Why space is rigid," (in Italian), Il Pungolo Verde, [1957]

[22] G. Bekefi, Radiation processes in plasmas, J. Wiley and Sons, [1966]

[23] P. Cornille, On the propagation of inhomogeneous waves, J. Physics. D: App. Physics, Vol. 23, p.129, [1990]

[24] P. Cornille, Is the Physical world built upon waves ?, Phys. Essays, Vol.6, N°2, p.289, [1993]

[25] P. Cornille, Inhomogeneous waves and Maxwell's equations, p.138, Essays on the Formal aspects of Electromagnetic theory, Eds. A. Lakhtakia, World Scientific, Singapore, [1993]

[26] P. Cornille, An electromagnetic wave approach to matter and radiation, Journal of electromagnetic waves and Applications, Vol.8, N°11, p.1425, [1994]

[27] P. Cornille, Advanced Electromagnetism and Vacuum Physics,
World Scientific, 21, New Jersey, ISBN 981-238-367-0, [2003]

[28] B. Rossi and D. B. Hall, Variation of the rate of decay of mesotrons with momentum, Phys. Review, Vol. 59, N° 3, p.223, [1941]

[29] D.H. Frisch and J.H. Smith, Measurement of the relativistic time dilation using Mesons, Am. J. Phys., Vol.31, p.342 [1963]

[30] P. Cornille, The twin paradox and the Hafele and Keating experiment, Phys. Letters A, Vol. 131, N°3, p.156, [1988]

[31] P. Cornille, How to minimize energy loss during an energy transfer between a source and a receiver, Boson Journal of Modern Physics, Vol.4, N°1, 299-312, [2018]

[32] Gupta, V.K., Shankar, G., Sharma, N.K., Reversibility ans steps processes: An experiment for the undergraduate laboratory, Am. J. Phys., Vol.52, N°10, p.945-947, [1984]

[33] R. E. Prange and P. Strance, The semiconducting vacuum, American J. of Physics, Vol. 52, N° 1, p. 19, [1984]

[34] V. Bush, The force between moving charges, J. Math. Physics, Vol.5, p.129, [1926]

[35] P. Moon and D. E. Spencer, On the Ampere Force, J. of the Franklin Ins., Vol.260, p.295, [1955]

[36] A. K. T. Assis, Weber's law and mass variation, Phys. Letters A, Vol. 136, N°6, p.277, [1989]

[37] M. Simhony, The electron positron lattice model of space and the reincarnation of physics as a natural science, p. 269, Physics as a Science [Eds. G. Galeczki, P. Marquardt and J. P. Wesley], Hadronics Press, Inc., Palm Harbor, [1998]