International Journal of Mathematics and Physical Sciences Research ISSN 2348-5736 (Online)
Vol. 7, Issue 1, pp: (44-53), Month: April 2019 - September 2019, Available at: www.researchpublish.com

MASS AND QUANTUM THEORY

Francisco Martínez Flores.

Physicist, Chemical Engineer and Physics-Chemistry Teacher (retired). June 2019.

C/ Manuel Font de Anta, 55. GINES (Sevilla). 41960. Spain. Tel. 954717473 – 638775430.

Abstract: **Relativity provides the right approach to clarify the true meaning of mass: elementary particles (leptons), with no internal structure, have mass of electromagnetic nature and "virtual" (not inertial), whose interactions occur in an abstract or "inner" space established by Quantum Field Theory.**

This space, connected to the phases of the wave functions or fields, is established from an interactive network corresponding to the strong interaction and completed by weak interaction (with the concourse of the electromagnetic one), giving rise to the compound particles (hadrons), which are able to form the atoms and molecules, whose structure provides the necessary condition for the "inertia" corresponding to the mass of tangible bodies, that are manifested at the "exterior" space, according to the laws of Classical Mechanics and Chemistry.

Keywords: **relativistic mass, inertial mass, charge and symmetry gauge.**

1. INTRODUCTION

Taking into account that many controversial questions arise around the concept of matter, thanks to physical magnitud that represent it, that is the mass, we are trying to investigate its true meaning in Modern Physics, where it appears as a sort of "money" in physical processes in the microscopic level, corresponding to subatomic particles.

The mass comes to be like the Hitchcock's Mc Guffin in a hypothetical film "matter-energy in the universe", since it may be "everything" and "nothing" at the same time; so, in Special Relativity, mass is everything, since it could increase to infinity, and to be considered intrinsically as energy to any particle, but it is nothing for Classical Mechanics, in the sense that it is dissolved in vibrations; in other words, there is no indication of what we call corporeal mass.

For this reason, is integrated in Quantum Field Theory, while de "inertial" mass does the same in Classical Mechanics, so that it does not seem possible the Unification of all physical laws, as the modern philosopher's stone, that constitutes the main issue in Theoretical Physics for almost a century.

On the other hand, the surprising explanation given to justify the inertial mass conferred to the Higgs bosons, as well as the gauge particles in the weak interaction, together with the existence of dark mass and dark energy in the Universe, are sufficient reasons to carry out a critical analysis about the nature of particle's mass.

2. EMPIRICAL DATA

a) The mass of an atom is practically concentrated in the nucleus, that is, the total mass of nucleons (protons and neutrons) is much greater (99,9%) than that corresponding to electrons, whose masses can be considered negligible.

b) Nucleon have a mass much greater than the sum of masses of its three quarks components, so that practically the quantity of matter (mass) of the nucleon is due to an interactive network that constitutes color charges gluons (both massless) and the phenomenon called "confinement", with what true corporeal mass appears as something different to what happens in Classical Mechanics, ie, the total mass is not the sum of the masses of the constituent particles.

c) Proton's mass is 1.67×10^{-27} kg, while that of the electron 1836 times lower, being both values dependent on electromagnetic variables and implicitly on the velocity of the particles when the measurement is taking place; but only protons together with neutrons contributes to the mass of macroscopic substances through the Avogadro's Number.

d) The energy achieved at LHC particle accelerator for protons is 7 TeV = 7000 GeV = $7x10^{12}$ eV, being its own mass next to 1 GeV (938.2 MeV).

The masses of the forces carriers in weak interaction, that is, the gauge particles is 80 GeV for W^+ or W^- and 90 GeV for the neutral one, Z^o; such masses are considered due to the so-called Higgs boson, which mass has been recently measured about 125 GeV and its existence like the other particles is about 10^{-18} *s".*

e) The magnitude of electromagnetic interaction relative to the gravitational one, is about 10^{37} and it turns out surprising that the Unification proposed by relativistic theory are still held without any objection.

3. MASS OF THE PARTICLES

The mass of the macroscopic bodies is clearly manifest thanks to gravity force, namely, the weight, whose unity is kilopond (kp).

The precise formulation of this physical magnitude was carried out by Newton in the second law of dynamics, F = ma, from where is defined the kilogram (kg) as the unit of mass when 1 N (newton) produces an acceleration of 1 m/s^2, so that 1 kp = mg = 9,8 N.

This mass must be "inertial", according to the first Newton's law or Inertia's law, that is, the internal resistence that each material body opposes to any change in its kinematics situation, whether at rest or in motion, which completes the point of view of Galileo (only movement).

In this sense, the mass is considered as a constant parameter defining the material characteristic of any macroscopic body, that may change its velocity when a force acts on it; it does not matter that the origin of such force is purely mechanical, electrical, thermal, etc., since all of them may act on that mass.

But, in the case of subatomic particles, the following questions arise:

- *How to measure its mass and velocity?*
- *Can we apply any mechanical force to change its speed?*
- *Is it possible follow its trajectory?*

The solution is given by the fact that almost all these particles are endowed with "charges" subjected to the action of electric and magnetic fields, which is generally expressed through the so-called Lorentz force, $\boldsymbol{F} = q(\boldsymbol{E} + \boldsymbol{v}x\boldsymbol{B})$ (1), where we can see the magnetic field, **B**, acts perpendicular to the velocity, **v,** of the carrier particle of charge, *q*.

3.1. Relativistic mass

The mass as an essential parameter of the particles, takes an active role due to Relativity, where from the so-called "rest" mass, m_o, it is established the so-called, "proper" or intrinsic Energy: $E_o = m_oc^2$ (2), which corresponds to the one obtained from the Energy equation: $E^2 - c^2\boldsymbol{p}^2 = (m_oc^2)^2$ (3), when the momentum, **p**, is zero.

This equation appears as the most general formula of the energy applicable to any particle, so the mass, m_o, should be "inertial", although introduces a new aspect with respect to newtonian dynamics: it is assigned to any particle as a "proper" or intrinsic energy, under the principle of "mass-energy equivalence".

Let's see how this interpretation may be questioned:

The previous formula is in consonance with those corresponding to the energy,

$E = mc^2 = m_oc^2/\sqrt{(1-v^2/c^2)}$ (4) and the momentum, $\mathbf{p} = m\boldsymbol{v} = m_o\boldsymbol{v}/\sqrt{(1-v^2/c^2)}$ (5), since the foprmula (3) is fulfilled when they are introduced:

$(m_oc^2)^2/(1-v^2/c^2) - c^2(m_o\boldsymbol{v})^2/(1-v^2/c^2) = (m_o^2c^4 - c^2m_o^2v^2)/(1-v^2/c^2) = (m_oc^2)^2$.

But, m_oc^2 is obtained by a simply algebraic calculation, disappearing E and c**p**, so, the

Equation (3) or its equivalent, $E = \sqrt{[c^2\boldsymbol{p}^2 + (m_oc^2)^2]}$ are really "identities", as long as (4) and (5) are involved.

However, it have been accepted as an equation under the mathematical formalism introduced by Minkowki space, after defining the four-momentum as the Interval, *p* = const., becoming a "conservation law" (Lorentz's invariant). In this

sense, (3) it is usually written: $p^2 = E^2 - c^2\mathbf{p}^2 =$ const (6), where the variation of momentum, **p** implies that of the energía, E; so, the mass, m_o, is attached to the particle located in the moving frame, which is called Inertial, since the body (observer) placed there will be at "rest".

But, the variations involved in the previous equation are already contained in the relativistic mass, $m \equiv m_o/\sqrt{(1-v^2/c^2)}$ (7), which in reality is no more than an "identity", which explains why this characteristic has been transferred to the formula (3), with the result that the observer at the moving frame is redundant and the name "proper" can not be appropriated, as we shall see in what follows.

Could anyone who rides on a projectile to know anything about its dynamics?.

Actually, we can obtain such information by placing ourselves in other frame (fixed respect the moving one), but according to relativistic postulates, laws are the same for an observer situated at any moving frame, which now is summarized by the constant m_oc^2, that would be the dynamical "final" state, although is presented as the "initial" one; in short, we have a "monster": m_oc^2, with two "heads": $E = mc^2$ and $\boldsymbol{p} = m\boldsymbol{v}$, whose expressions are hard to understand, since we are obliged to admit a corporeal mass increasing indefinitely with its velocity.

However, a brief analysis of the "identity": $E^2 - c^2\boldsymbol{p}^2 \equiv (m_oc^2)^2$, allows us to clarify such confusion:

a) Velocity in relativistic equations is not something that you get, but it is given ("boost") in the transformation corresponding to Lorentz's Group, while the energy, $E = mc^2$, includes such velocity in the relativistic mass, m, according to (4).

b) The "misunderstanding" comes from considering (7) as an equation, so that we can not help to admit that for $v = 0$ ==> $m = m_o$, but in that case we do not realize that the existence of m is due to the velocity, v, so, when $v = 0$, the mass, m should also disappear, that is, in relativity no physical magnitude may be at "rest".

Actually, the moving frame is unnecessary or "redundant" and m_o, may be considered as an "empty" mass, associated with vacuum, from which is produced the relativistic mass, m, just as it happens with bosons and fermions in Quantum Field Theory; but it is not **inertial,** since can not be "at rest": this is the Newtons's first law that completes Galilero's on moving bodies.

On the other hand, the formula (6) is in consonance with the tensorial formalism, thanks to the definition of the four-momentum, p: $p^2 = p_\mu p^\mu = E^2\text{-}c^2p^2 =$ const, where $p_\mu = (E,-cp)$ is the covariant vector, while $p^\mu = (E,+cp)$ is the contravariant one; but the constant is just eventual, since it must be different for each value of the velocity, v, that is, an increase or decrease of v, will also affect the constant and therefore to m_oc^2, as we can show below:

The constant would imply: $(m_2c^2)^2 - c^2(m_2\mathbf{v}_2)^2 = (m_1c^2)^2 - c^2(m_1\mathbf{v}_1)^2$; but if $v_2 > v_1$ ==> $m_2 > m_1$, and then, the variation of the energy will be greater than that of the momentum: $(m_2c^2)^2 - (m_1c^2)^2 > c^2(m_2\mathbf{v}_2)^2 - c^2(m_1\mathbf{v}_1)^2$ ==> $(m_2c^2)^2 - c^2(m_2\mathbf{v}_2)^2 > (mc^2)^2 - c^2(m\mathbf{v})^2$, that is, $E_2^2 - c^2\mathbf{p}_2^2 > E_1^2 - c^2\mathbf{p}_1^2$.

The result is that the formula (3) can not be accepted as an equation of Energy , so that the only thing we may affirm, is that there is a relationship between the quantities**,** $E = mc^2$,

$\mathbf{p} = m\mathbf{v}$ and m_oc^2 , but they are all variables, so that is it not possible to perform any calculation; this is the meaning of the "identity", in which case the **relativistic mass**, m, turns out the appropriate parameter to represent the mass and not m_o.

3.2. Particle Accelerators: the "fake" Data.

Subatomic particles may acquire large amounts of energy, thanks to the the so-called Accelerators, which is the experimental method to get the description and properties of those particles, as well obtaining the new one; for this purpose, electric and magnetic fields are used, so that the increase of energy is carried out by the first one, while the magnetic field makes the moving particles to describe a closed orbit (circular or spiral).

The charge, q, as a parameter of the particle and the potencial, $V = \nabla.\boldsymbol{E}$, as function of the electric field, $\boldsymbol{E}$, are both necessary to produce the interaction undertaken by the particle to increase its energy through $\Delta E = q\Delta V$, while the magnetic field, $\boldsymbol{B}$, perpendicular to the velocity, $\boldsymbol{v}$, of the particle is keeping it in a circular orbit of radius r, according to the expression: $mv^2/r = Bqv$ (8) where it is admitted the classical kinetic energy, $E = 1/2mv^2$, with m = constant.

This equation is perfectly valid for the acceleration of protons by means of the Cyclotron, since they are composite particles (hadrons), that have inertial and constant masses, as we will show below.

But, the relativistic formula (3) is considered for electrons, so that when the energy measured out of the Cyclotrón is 100 MeV, the relativistic mass, *m*, shall be 200 times of

m_o = 0.51 MeV and the corresponding velocity, v > 0.9999c (I.Kaplan: "*Física Nuclear*"). *How could we check that?.*

It turns out a purely theoretical data based on the relationship : $m/m_o = 1/\sqrt{(1-v^2/c^2)} = 200$; the value of v obtained, it is a clear example of a "fake" Data, since the relationship between both quantities must be maintained whatever the value of velocity, which implies that both m and m_o will increase or decrease simultaneously.

This is consistent with the identity represented by the formula (7), according to which the measured value for the mass of the electron should be the corresponding to the relativistic ones, m = 0.51 MeV, variable, it is only a reference value in relation to the constant mass of proton, which as the most stable compound particle is the base of nuclei atomic and as such conforms to Newtonian Dynamics, after accessing the macroscopic world through the Avogadro Number.

Then we are able to understand that electrons require a different accelerator, the Betatron, which actually works like a transformer, since the physical magnitudes are purely electromagnetic: variation of flux (electric field) and of magnetic field.

In this sense, it is well known that many problems are quickly solved when the causes that produce them are eliminated; in this case, we must forget the mass and attend only to the charge, q and the acquired energy of the particle is given by $\Delta E = q\Delta V$, which increases as it does the potential, whose final value will be the number of turns carried out by the particle. As we can see the mass does not appear at all; but this reappears, since according to the relativistic approach, has been established electron-Volt unit, *eV*, based on $eV = mc^2$ (9).

It is worth noting that for getting the final energy what really matter is the number of times, n, that the particle passes through the place where it is applied the electric potential, *V*, so that the final potential, $V' = nV$, from which can be reached the energy $E' = qV' = m'c^2$. Obviously, the increase in energy that the particle may experience, will be given by:

$\Delta E = (m' - m)c^2 = \Delta mc^2$.

3.3. Electromagnetic mass of electron

Performing the serie expansion of the energy, when v ≪ c, it may be obtained:

$E = mc^2 = m_oc^2/\sqrt{(1-v^2/c^2)} \cong m_oc^2 + 1/2m_ov^2$ ===> $mc^2 - m_oc^2 = 1/2m_ov^2 = E_c$; this kinetic energy is being considered as a proof of the inertial nature of the mass, m_o; but, it is only a mathematical result, whose physical meaning is contradictory: the terms involved are not homogeneous quantities, since m_o can not be linked at the same time to c (absolute) and v (relative).

However, it seems correct when the masses are removed, as Einstein himself did in his article: *Does the inertia of a body depend upon its energy-content?*, where the previous formula becomes: $E - E_o = (E_o/c^2)v^2/2 = 1/2)m_ov^2 = E_c$; but the incongruence continues because $m_o = E_o/c^2$, although it is curious the meaning given to this mass: it turns out the inertia of the radiation as "energy-content".

In fact, this formula was used to explain the **Photoelectric Effect**: $h\nu - W = 1/2m_ov^2$, where $E = h\nu$ is the energy of quantum action energy, while $E_o = W$, is the binding energy of electrons in the metal.

Then, the kinetic energy is measured in units eV (electron-Volt), like the relativistic mass m, on account of the homogeneity terms, but now it has a funcional sense, because it really implies the electric potential, V, applied to the charge of the electron: $eV = 1/2m_ov_{max}^2$, where the maximun velocity corresponds to a minimun energy, $W = const$; in this sense, we will have: $V = h\nu/e$ - const, which fits the experimental data, so the role of the kinetic energy has led to consider the inertial nature of the mass, m_o.

But, it has been overlooked that it is actually a problem of Quantum Theory, according to which it must be fulfilled: $h\nu = E - E_o = mc^2 - m_oc^2$ ==> $h\nu + m_oc^2 = mc^2$, that is, the radiation energy (photons), $h\nu$, acts on the bound electrons,

$W \equiv m_o c^2$, giving rise to the electrons with energy, mc^2; now, it makes sense the application of *eV units*, $mc^2 = eV$ and $m_o c^2 = eV_o$, so we will have: $eV - eV_o = h\nu$ ===> $V = h\nu/e + const$ (10).

It turns out the "true" equation of the Photoelectric Effect, because the difference of potential, $V\text{-}V_o$, is produced by the radiation energy, $h\nu$, so the constant has the right physical meaning and the energy of electron correspond to the relativistic mass, m, while the kinetic energy, $1/2m_o v^2$, does not appear, that is, is "redundant".

In the same way electrons are manifested, according to the experimental method used by J.J.Thomson, for the measurement of its mass, where the electrons (cathode rays), launched at a speed, v, and thanks to its charge, e, they are subjected to electric and magnetic fields, $\boldsymbol{E}$ and $\boldsymbol{B}$, originating the forces, $e\boldsymbol{E}$ and $e\boldsymbol{v}\wedge\boldsymbol{B}$, so that is verified: $eE = evB$, from which to the velocity of these particles could be obtained $v = E/B$, and from this it was possible to determine the relation between the charge and the mass, e/m, and finally, after obtaining the charge of the electron through the Millikan experiment of the charged oil drops (ions), the mass of the electron, m, could be obtained.

On the other hand, if we take the mass as a fundamental characteristic of the particle, it should be a constant parameter, which in the relativistic treatment that have been accepted up to now, it must correspond the so-called "rest" mass, m_o; but, in line with the arguments given above, the relevant quantity is the relativistic mass, m, which actually contain, m_o, because the formula (7) is just an "identity".

However, the measured mass, 0.51 MeV is the corresponding to the formula:

$eV = mc^2$, must be variable and not be considered as a minimun, but just an eventual value with respect to the proton's mass, as we have state above. In this sense, the mass might be smaller or bigger according the velocity of the electron, a fact which is confirmed with experimental data of beta decay, which consist of differents relativistic mass measured according to the magnetic field applied, setting the well known energy graph, which can be explained considering all the possible values of that mass, without lower limitation of 0.51 MeV.

All this induces us to point out that the pretension of Relativity, where the mass is dependent of the velocity, to be couple to Classical Mechanics, has to pay a price: remove it from the "exterior" space (t,x) and put it in the "inner" phase space (w,k); so, the true nature of this mass has its origin in the charges.

The confusion between both spaces comes from the fact that in the latter the phase velocity, c = w/k, is an absolute, which can not be relativized with respect to any velocity,

v = dx/dt, corresponding to any tangible mass moving in the ordinary space; this exclusion of the two spaces, which forced to suppress the "ether", had been overlooked when relativistic theory was established, where they are clearly "mixed", thanks to space-time of Minkowski and "hidden", by the skillful resource of the so-called natural units: c, h.

In short, there are enough reasons to arrive at the conclusion that the relativistic **mass** is **electromagnetic** in nature**,** for its derivation from charge and other electromagnetic magnitudes, and **virtual,** since the quantity, c, acts dimensionally as a true velocity; this is not against the "reality" of the energy; indeed, in the same way that thoughts are always real, even when they deal with imaginary things, the **energy,** $E = mc^2$, is "real", even if the mass is "virtual".

This is the only reality assumed by electrons and other elementary particles, just as it happens witrh the electromagnetic properties of macroscopic bodies, where we can find "charges", which although not being true (real), may fulfill the same role as those attributed to electron and proton; but the latter is a composite particle, that is, ity has structure and therefore inertia, which allows us to understand that electrons, as elementary particles, require a special accelerator (betatron), different of the ciclotron for protons.

3.4. Inertial mass of proton

Relativity is actually a refinement of electromagnetic theory, which produces an integration between that theory and the dynamic behavior of electrons or other subatomic particle; its extension to any composite particle and macroscopic body comes from a statement given by Einstein: *"...any particle or electrically charged body*..", without realizing the great difference between an electron (without structure) and any other ion, where its charge is linked to a "structure" (volumen), that is the condition to provide a real or true (inertial) mass of the "material" points in Classical Mechanics.

Let's look how the same thing happens in the purely electric case: it is well known that when a difference of potential acts on a conducting material, an electric current is produced, whose density is $j = nev$ (12), being n the number of electrons and v its velocity; but when it is considered the volume, will get the well known Ohm's law: $V = IR$, where the

resistence, *R*, have the same meaning of inertial mass, since it is opposed to the current, *I*, but it appears in the macroscopic bodies with an internal structure.

The real or **inertial mass** is produced by Strong Interaction and completed by Weak and Electromagnetic interactions.

In the Strong Interaction, the phenomenon called "confinement" of Quarks, so that it not possible for them to go out the "exterior" space, together with the forces originated by an "interactional network" of Gluons, are making up a cohesion that constitutes an "internal" resistence (**inertia)** to any alteration on the kinematic state of the composite particle (Hadron).

If we consider the proton as the most stable hadron, its mass must be the "cornerstone" on which the material bodies can be built after binding with neutrons, thanks to Weak and Electromagnetic Interactions to form the nuclei, whose unit of mass is the amu (atomic mass unit) that may access to macroscopic level ("exterior" space) by Avogadro's number ($6.23x10^{23}$) and then Classical Mechanics and Chemistry come into play.

The use of the atomic mass unit (amu*)* indiscriminately in all Nuclear Physics processes has led to the confusion about the nature of the mass that the "equivalence principle" do not help to clarify.

But it is possible to understand it if we consider that the mass difference between neutron (*u,d,d*) and proton (*u,u,d*) has to be attributed to the quarks, characterized by their fractional charges (*u = +2/3, d = -1/3)*, so that their masses are derived from them, that is, are of electromagnetic and virtual nature.

In this sense, the mass of proton may be considered at *eV* units, as a electromagnetic mass by virtue of its charge, it is interpreted as a reference energy, from which may be obtained the energy of the particles reponsible for the Weak and Strong Interactions and other phenomena (antiparticles).

But, when the mass was considered in *uma* units, will have the characteristics correspoding to the newtonian dynamics, that is, it is constant, because Avogadros's number is so high that the usual variations in the microscopic world ("inner" space) do not affect the macroscopic one ("exterior" space) , which established a "dichotomy" in the physical laws that leads us to the paradigm of **Duality** instead of Unification.

4. MASS AND QUANTUM THEORY

4.1. Photons

The electromagnetic mass is the only one that allows us to catch up at the same time, Relativity and Quantum Theory: any variation of the scalar potential on the charge, *e*, produces an energy, $e\Delta V$, that corresponds to a change in the relativistic mass, Δmc^2 and on the other hand if there is a large decrease in the energy level, it will be emitted radiation (X-rays), which can be measured thanks to the frequency, w, of the wave according to quantum formula, $\Delta mc^2 = \hbar w$ where $\hbar$ is the Planck constant.

Both processes may be summarized by the double formula: $e\Delta V = \Delta mc^2 = \hbar w$ (11), where the mass appear between two measurables quantities, such as potential and frequency, so can be considered as an "intermediary" quantity with no intrinsic value, just like "money", justifying once again the "virtual" characteristic.

In this sense, **photons**, $\hbar w$, may have electromagnetic mass, like electrons; this is against the widespread view since Eddington of the inertial nature of light, something questionable, as we may see through the following points:

a) The measurement of the angular deflection of light is taking place during a total solar eclipse and the apparent position of the star should be compared with the same position six month later when the star can be observed during the night, but Eddington made the second observation four month later and at different place. It is not surprising that almost half a century later, Max Born stated: *"..an exact agreement between theory and measurement has not yet been obtained"*

b) During the eclipse the light beam has to pass through the area, so-called corona, whose spatial extent is much greater than two or three solar diameters and consists of a very thin atmosphere of ionized gases; it is hard to admit that light can travel through the layer without undergoing any refractive or absorption and re-emission of light wave.

c) By claiming the measurements coincide with the approximated formula calculated according to General Relativity, $\Delta\phi = 4GM/c^2r_{min}$, where M is Sun's mass and r_{min} its radius, introduced more than reasonable doubt; otherwise, how many times have been repeated the experience when one of them requires half a year?.

d) "The fact that the scientific establishment believes that light in free flight produces a gravitational field continues to be a major conceptual roadblock in the ongoing effort to formally (mathematically) unify the forces" (J.A.Gowan:"General Systems and the unified field theory").

e) Despite all the attempts made up to now to, it has not been possible to "quantized" Gravitation.

4.2. Uncertainty Principle

The corpuscular aspect of the electron is usually associated with Momentum, mv = p, where the velocity v < c, in order of keeping up its individuality; but, it may behave as a wave, thanks to wave-particle Duality by the De Broglie equation:

$hk = 2\pi p$ ===> $\hbar k = p$ (13).

This expression together with that corresponding to the corpuscular nature of radiation (Planck's law) $E = \hbar w$, integrated in (11), in accordance with the Uncertainty Principle: $dt.\Delta E \geq \hbar$; $dx.\Delta p \geq \hbar$, (14), equivalent to the usual one: $\Delta t.\Delta E \geq \hbar$; $\Delta x.\Delta p \geq \hbar$.

With this, Relativity is integrated into Quantum Theory, because they contain the conditions for carrying out the quantization of physical quantities associated with the particles, which we may call "quanta"; they are **bosons** and **fermions**, which obey the Klein-Gordon and Dirac equations, respectively, where both energy and momentum are put together, unlike Schrödinger's equation.

In this line, taking into account that $w/k = c$, according to the phase of the electromagnetic wave (radiation), $\exp(wt\text{-}kx)$, we may show that $v < c$ from the previous formulas: $dt \geq \hbar/\Delta E$ ==> $dt \simeq 1/\Delta w$; $dx \geq \hbar/\Delta p$ ==> $dx \simeq 1/\Delta k$, so that

$dx/dt \simeq \Delta w/\Delta k = v$; which can be identified with wave group velocity, always lower than of the wave phase (c), so $v < c$.

This can be adscribe to elementary particles, such as electrons, whose energy must be adjusted to $\hbar\Delta kv = \hbar\Delta w$, where the first side of the equation represents the momentum variation of the electron, while the second to the photon of the radiation involved.

4.3. Mass and vacuum

Klein-Gordon Equation: $\partial_\mu^2\,\phi - m_o^2\,\phi = 0$ (15) applies to functions or complex scalar field, $\phi(x)$, where $x = (ct,\mathbf{x})$, that corresponds to bosons, responsible for interactions between the particles themselves or fermions; strictly speaking, bosons are excitations or fluctuation of the quantum field.

This equation is derived from the expressions $E = \hbar w$ and $\mathbf{p} = \hbar\mathbf{k}$, which applied to the energy "equation" (8) becomes $w = \sqrt{(c^2k^2 + m_o^2c^4)}$ (16).

Given all the arguments above on m_o, we can remove it from the equation and make it match with ϕ_o; this a "vacuum" state, that is, the situation in which there are no particles, but may be considered as a condition of the system.

The usual procedure is to carry out the expansion of the field $\phi(x)$, in which case appears the coeficients, $a(\mathbf{k})$ that act as annihilation operators, defined by $a(\mathbf{k})\phi_o = 0$, while with $a^*(\mathbf{k})$ we will have the creation operator, such that $a^*(\mathbf{k})\phi_o = \phi_k$.

The creation operator, $a^*(\mathbf{k})$ produce a quantum particle, called boson with a specific **k** or momentum and consequently the energy, w, whose characteristics may be deduced through the conmutation relations between both operators.

Those operators acquires full meaning with a many-particle system, where the field has infinite degrees of freedom, as it is claimed in Quantum Field Theory.

When the field is writing down in its complex form, $\phi(x) = \phi_1 + i\phi_2$, the Noether's current takes a physical meaning, that is, the charge, q, configures an "inner" space; besides, Fourier analysis leads in a natural (mathematical) way to the

existence of antiparticles, which it is in line with the so-called charge conjugation (C), when a particle is turning into an antiparticle.

Therefore, the **Charge**, becomes the essential parameter of "quantum" particles (bosons), while the mass, m_o, is been relegated to vacuum and the relativistic mass, , results in frequency, w and the momentum, p, in the wavenumber, k.

4.4. Mass and Gauge Symmetry

The Gauge Theory turns out the right approach for **Weak Interaction**; to this end, we have to put the Klein-Gordon equation as a Lagrangian's density:

$$\mathcal{L} = \tfrac{1}{2} D^{\mu}\phi^{*} D_{\mu}\phi - \tfrac{1}{2} m_o^2(\phi^{*}\phi) - \lambda/4(\phi^{*}\phi)^2 \quad (17)$$

where the last term represents the interaction between fields, which together with the second one, form the potential energy, while the first constitutes the energy.

The dynamic behavior that Lagrangian represents is made through the arbitrary transformation of the phases over the complex fields, ϕ(x), $\phi(x)^{*}$, starting with the uniparametric and abelian symmetric group, U(1) = $e^{i\alpha(x)}$, following the electromagnetic model, $\phi' = e^{i\alpha(x)}\phi$, where $\alpha(x)$ indicates the "local" property of this transformation, unlike the "global" (electromagnetic) $\phi'(x) = e^{\alpha}\phi(x)$.

Applying the latter to Lagrangian equation, we have to introduce a potential electromagnético, A_{μ}, in order to achieve invariance (symmetry), so the normal derivative, ∂_{μ}, becomes the covariant one, $D_{\mu} = \partial_{\mu} + ieA_{\mu}$.

The SU(2) Group as a generalization of U(1), is mapping over an "inner" two-dimensional space (which has its equivalence at the "exterior" space with SO(3) Group as it happens with spin), given by exp(i$\alpha(x)^a t^a$), where t^a are the generators of the Group, which in an infinitesimal (non-abelian) transformation leads to the Lie algebra:

$[t^a, t^b] = i\varepsilon_{abc} t^c$ (18). These generators are associated with the potential gauges, A_{μ}^1, A_{μ}^2, A_{μ}^3 used to obtain the covariant derivative: $D_{\mu} = \partial_{\mu} + igt^a A_{\mu}^a$, (19) where g is the coupling constant or "weak charge"

In order to obtain the coupling constants, we have to put A_{μ}^3 and A_{μ} together by the composition SU(2)xU(1) to get the neutral current field (gauge), *Z*, and the electromagnetic potential, *A*, through the transformations equations:

$$Z = -A_{\mu}sin\vartheta_w + A_{\mu}^3 cos\vartheta_w \; ; \qquad A = A_{\mu}cos\vartheta_w + A_{\mu}^3 sin\vartheta_w \quad (20)$$

being ϑ_w the weak "mixing angle", which has been determined experimentally, through $sin^2\theta_W \approx 0.222$; this angle allows to get, $g' = g\tan\vartheta_w$, where g' and g are the coupling constants of the symmetry group, SU(2)XU(1) and they really represent the "weak charges", related to electric charge, *e*, according to: $g' = e/\cos\vartheta_w$; $g = e/\mathrm{sen}\vartheta_w$

Weak interaction was first introduced by Fermi, through the phenomological equation: $\mathcal{L} \sim (G_F/\sqrt{2})JxJ'$ (21), which corresponds to the first term (Energy) of the Lagrangian and where $G_F = 1.02x10^{-5}/m^2_{proton} = 1.166x10^{-5}$ GeV^{-2} and *J* and *J'* are the currents representing the coupling constants, *g* and *g*'.

From the previous equation, we have $E^2 \sim \sqrt{2}g^2/G_F$, by which we can obtain the energy of "gauge" particles, after applying, $g = e/\sin\vartheta_w = 2.12e$:

$E \sim \sqrt[4]{2}g/\sqrt{G_F} = 37.3\,g$ ===> $E \sim 79$ GeV; this corresponds to W^+ or W^- particles.

Finally, to get the energy for *Z* is necessary to use both coupling constants, *g* and *g*' ,

in which case $E^2 \sim \sqrt{2}gg'/G_F$ ==> $E \sim 37.3gg'/\cos\theta_W \approx 90$ GeV.

The W^+, W^- particles are bosons, which are exchanged in an indefinite number through Weak Interaction in the "inner" space, represented by the isospin, *t*, according to which protons and neutrons are like two aspects of the same entity: nucleon or barion.

All this can be represented by the Charge formula : $Q = t^3 + Y/2$ (22), where Y is the hipercharge equal to B (baryon) + S (strangeness) and t^3 is the third component of isospin, which may have two values; so, for $t^3 = +1/2$ and B = 1 (proton) ==> Q = +1/2 + ½ = 1, that is the W^+ particle from proton while for $t^3 = -1/2$ and B = -1 (neutron) ==> Q = -1/2 -1/2 = -1, that is, the W^- particle from neutron.

Therefore, the "exchange" is a reversible process, p <---> n, adjusted to the characteristics of the Group and the Algebra of Lie.

Beta (β) decay, is perfectly compatible with the previous one, since it takes place spontaneously in an "irreversible" process, n ---> p, when there is an excess of neutrons in the atomic nucleus

As we have shown, the physical magnitudes are **charges** acting in the "inner" space; they are "weak" charges, that together with the potentials allows to calculate the energies attributed to the gauge particles, that correspond to the relativistic mass, *m*.

However, it has been built a very elaborate method, called Higgs Mechanism, by which the energies are ascribed to the mass, m_o, of the particles, but these are extracted from "vacuum" and although now it is explained by Symmetry Breaking, its physical meaning is the same as indicated above: **electromagnetic** and **virtual** mass**.**

5. CONCLUSION

Relativistic mass is always "virtual" and as such is corresponding to elementary particles and photons, perfectly consistent with the requirement of Quantum Theory.

The real or "inertial" mass is obtained by strong, weak and electromagnetic interactions, which are responsible for the formation of nuclei and atoms from which the material bodies is constructed, in consonance with the laws of Chemistry and Classical Mechanics; this mass is complementary to the relativistic one, establishing the Duality in Nature, instead of the very repeated Unification.

The accepted explanation of the energy involved in the weak interaction thanks to "particles gauges" having mass on account of Higgs Mechanism, due to symmetry breaking of "vacuum", may be assumed on the basis of being masses of electromagnetic and virtual nature; besides, to extract real or inertial mass from vacuum in a truly creative act and although it is intended to be based on a process of self-interaction of the fields, it is not so easy to admit in an experimental science.

But, it is unnecessary, fortunately, because the sources of Strong and Weak interactions are in the "charges" contained in an "inner space"; these interactions involves the "exchange" of energy particles and the strength of those is just obtained by the coupling constants together with the corresponding potentials.

To state that weak interaction is of a "very short range" ($dt = 10^{-18}$ s) because of the inertial mass conferred to the gauge particles, is clearly induced by the Unifying paradigm of Theoretical Physics, trying to include Gravitation together with the other three interactions; but it is not necessary, since this elapsed time maybe justified by the Uncertainty Principle of Quantum Theory, where makes the appearance of "local" transformation, which leads to Covariant derivative, also used in General Relativity, but now acts in the "inner" space and the involved masses are electromagnetic and virtual.

Digital images produced by the CCD (Charge-Coupled-Device) are in line with the concept of "virtual" mass: otherwise, the answer given by the charges (electrons) to electromagnetic fields, that is, the reproduction waves almost instantaneously (similar to the speed of light), would be possible by means of particles with inertial mass?.

Finally, it is surprising that the Standard Model, based on the Unification of Symmetries Groups SU(3), SU(2) and U(1), have been questioned in favour of Supersymmetry; the only plausible explanation is that the meaning of the mass is not clear enough and the Unification paradigm might be only an idea of a desirous "reductionism".

We might add metaphorically, the very well known statement from Macbeth (Shakespeare): "Life (relativistic mass) is a tale told by an idiot full of sound and fury (energy) signifying nothing (virtual**).**

REFERENCES

[1] Michio Kaku: "Quantum Field Theory" . Oxford Student Ed. (1993)

[2] Ta-Pei, Ling-Fong: "Gauge Theory of Element Particles". Oxford Science Public. (1984).

[3] Mohapatra: "Unification and Supersymmetry". Springer (2002).

[4] Chris Quig.: "Spontaneous Symmetry Breaking as a basis of particle mass". (2007).

[5] A.Blechman: "Spontaneous Symm.Breaking and Higgs Mechan" (2012).

[6] Sheldon Glashow: "El encanto de la Fisica". Ed. Tusquets. (1995).

[7] Frank Wilseck: "Origins of the mass". (2012).

[8] R. Feynmann: "Lectures in Physics". Addison-Wesley Publishing Co. (1969).

[9] M. Gabella: "Non-abelian Gauges Theories with Spont.Symmetry Breaking". (2006).

[10] D.Hestenes: "Spacetime Structure of weak and electromagnetic interactions" (1982).

[11] Sokolov,Ternov,..: "Electrodinámica Cuántica". Editorial Mir. (1989).

[12] Panofsky: "Classical Electricity and Magnetism". Add. Wesley (1964).

[13] C. Möller: "The theory of relativity". Oxford University Press (1972).

[14] D. Hestenes: "Spacetime with geometric algebra" (2003).

[15] G. Wick: "Elementary Particles" . G.Chapman (1972).

[16] I. Kaplan: "Fisica Nuclear". Editorial Aguilar (1970).

[17] E. Segré: "Nucleos y Particulas". Editorial Reverté. (1972).

[18] Gionvanni Organtini: "Unveiling the Higgs Mechanism" (2012).

[19] Gerard't Hoof: "The Universe of Elementary Particles" (2002).

[20] E.T. Jaynes: "Scattering of light by free electrons" (1996).

[21] E.T.Jaynes: "Probability in Quantum Theory". (1996).

[22] P.Roman: "Advanced Quantum Mechanic". Add. Wesley.(1965).

[23] Landau-Lifshitz: "Teoria Clásica de Campos". Editorial Reverté. (1966).

[24] A.Einstein: "El significado de la relatividad". Espasa-Calpe. (1984).

[25] F.Mandl: "Introduction to Quantum Field Theory". Interscience Publishers. (1959).

[26] W.A.Tiller: "Towards Understand.internal space Gauge Symmetry". (2005).

[27] J.G.Williamson: "Is the electron a photon with toroidal topology?". (1997).

[28] R.F.Gauthier: "FTL Quantum Models of the photon and electron". (2006).

[29] Millman&Halkias: "Electronic Devices and Circuits". McGraw-Hill. (1967).

[30] Alonso-Finn: "Física (I, II y III)" . Aguilar Ed. (1971)

[31] A.Guay: "Geometric aspects of gauge symmetry". Pittsburg. (2004).

[32] A.Einstein: "The Principle of Relativity". Dover Publications. (1952).

[33] M. Born: "Einstein's Theory of Relativity". Dover Publications. (1962).

[34] R.B.Lindsay: "Concepts and methods of Theoretical Physics". Dover Publ.(1969).

[35] H. Goldstein: "Mecánica Clásica". Editorial Aguilar. (1963).

[36] P.G.Bergmann: "Basic Theories of Physics". Dover Publications (1962).

[37] A.Lichnerowicz: "Elementos de Calculo Tensorial". Ed.Aguilar (1965).

[38] J.W.Leech: "Mecánica Clásica". Edit.Hispanoamericana.México.(1968).

[39] Ander&Sonnesa: "Principles of Chemistry". Macmillan Co. (1965).

[40] M.A.Pomerantz: "Cosmic Rays". Van Nostrand Reinhold Co. (1971).

[41] A.Klein: "Masers y lasers". Nueva colección labor. (1969).