

# A PROBE INTO THE NATURE OF MASS, CHARGE, AND ENERGY, UNVEILS ALPHA ( $\alpha$ ) –

## THE FINE STRUCTURE CONSTANT

Jaswant Rai Mahajan

An ab initio scrutiny of the structure and genesis of the electromagnetic radiation (EMR) and a close look into its rare ‘materialization’ to produce a pair of electron ( $e^-$ ) and positron ( $e^+$ ), coupled with the examination of the relationships among their various dynamic parameters, have revealed that just like torque ( $F \times r$ ), angular momentum ( $mv \times r$ ), and spin ( $m_0c \times r$ ), the charge interaction ( $E_{\text{pot}} \times r$ ) also has a cross product relation between the potential energy and the lever arm of the interacting particles. Further, it has been found that the EM frames of photons and leptons, herein called the ‘Energetic Capsules’, have higher energy with respect to the zero-energy state of the vacuum, determined by the quantum relations:  $E = \hbar c/r$  (photons) and  $E_0 = \hbar c/2r$  (leptons). This means that the inner and surface energy potential of these ‘Energetic Capsules’ is higher than that of the normal vacuum and their charge interaction is given by  $\hbar c = e^2$ , the square of the intrinsic charge ( $e$ ). Consequently, the ‘Close Contact’ or Strong Force interactions of these ‘Energetic Capsules’ should reflect this difference, when compared with their long-range interactions through the free space / vacuum. Therefore, as the elementary charge interaction (in vacuum) is given by  $e^2$ , while the ‘Close Contact’ strong force interactions correspond to  $\hbar c$ , the ratio between these two parameters provides the value of alpha,  $\alpha = e^2/\hbar c = 1/137$ , which resolves the century-old enigma of the Electromagnetic Coupling Constant.

### Introduction

Historically and from the perspective of Physics, **mass** was recognized as a fundamental property of matter by Isaac Newton – the father of Classical Physics. Right from the beginning of his discovery of the Laws of Motion and the Universal Gravitation, Newton neatly tied up mass with the notions of inertia, momentum, force, acceleration, weight, work and energy, etc. Later on, these concepts were extended and incorporated into the derivation and definition of numerous other physical constants of electricity, magnetism, and the related disciplines, to quantify the charge, fields, current, flux, voltage, resistance, potential, and power, etc. Consequently, a multitude of properties and their physical constants: coulomb, ampere, ohm, volt, watt, gauss, tesla, weber, and several others, derived from the basic concepts of mass and charge, constitute the very roots and foundations of the modern science, technology, and their innumerable gadgets and inventions.

However, in spite of the very impressive advances and strides of science & technology in the past 150 or so years, the fundamental nature of mass & charge have stayed obscure even after a couple of centuries’ intensive theoretical studies and arduous experimental research. And,

unfortunately, the uncertainties & doubts still persist even after the July 2012 fantastic news from the scientists at the Large Hadron Collider (LHC), announcing the discovery of a “Higgs Boson” – an evidence for the presence of “Higgs Field”, which is theoretically responsible for the mass of fundamental particles and hence that of all matter [1].

But for the skeptic and the diehard dissidents, the main questions about the **Ultimate Source of Energy** and its extremely choosy incarnation into **Mass and Matter** are still aflame and remain unanswered. Relegating these creative roles to a “**Primordial Singularity**” and “**The Big Bang**” is as good as or rather worse than attributing these “Divine Functions” to an Almighty God. Thus, although Science & Religion are said to be at odds, yet both have arrived at the same “Dead End”. Moreover, the presently known “Black Hole” and “Singularity” at the center of our own galaxy and many more found elsewhere, are ejecting jets of energy from their centers, providing no evidence for the “Mini Bangs” of the kind speculated for the “Big Bang” [1].

Now coming to the nature of the **electric charge**, the situation is even more confusing. For instance, the charges on electron, proton, and other charged particles, as well as their antiparticles, are all equal in magnitude but opposite in their sign ( $\pm e$ ). However, the tinier constituents of protons, neutrons, and other fundamental particles, – the six kinds of quarks, have been allotted fractional charges,  $\pm 1/3e$  or  $\pm 2/3e$ , and distinguished by their distinct colors and flavors. The situation is further complicated with the eight varieties of “gluons”, which have specific color charge attractions, and are needed to ‘glue’ the quarks in the nucleons and other composite particles [1]... Thus, as this subject is rather involved and very complex, I will return to it a bit later in this report, after I have introduced and treated some other related matters.

### **Electromagnetic Radiation (EMR)**

Well, one of the long standing pioneer fields, involving some important wave / particle controversies, which eventually introduced Quantum Mechanics into physics, is the intensely studied phenomenon of the Electromagnetic Radiation (EMR). The Light and Colors we see are just a tiny fraction of this almost endless family, whose identity was discovered by James Clerk Maxwell in the 1860s. His theoretical studies of the electromagnetic phenomenon led him to predict the existence of Electromagnetic Waves, which soon received approval by their experimental production by Heinrich Hertz in 1887. Since that time, it is well known that the Electromagnetic Radiation (EMR) is produced when electric charges are subjected to acceleration, as the un-accelerated charges do not provide this radiation. The usual or the most common sources of EMR are the electrons in antennas or similar devices, but accelerated protons, gamma decay, radioactivity, nuclear fission, and nuclear fusion reactions also produce EMR, which has much higher energies than that of the ordinary electronic devices. Presently, the almost unlimited spectrum of EMR has been well-studied and extensively exploited commercially for numerous practical purposes: Radio, TV, Radar, Microwave Ovens, Cell

Phones, GPS, Internet and Satellite Communications, X-Ray, MRI, and CT Scans, etc., just to name a few [1].

EMR or the EM waves travel at the speed of light ( $c$ ), have a characteristic wavelength ( $\lambda$ ), possess momentum ( $mc$ ), angular momentum ( $mc \times r$ ), carry quanta ( $h$ ) of energy ( $E = hf = hc/\lambda$ ), and even suffer the tug of gravity. Yet, as the EM waves are produced from other types of energy by the EM polarization of the neutral, zero mass/energy state of the Universal Medium (vacuum), they are not allotted any mass. Nevertheless, their energy is intrinsically wedded to mass by the famous and well-celebrated equation of Einstein:  $E = mc^2$ . The powerful proof of this mighty relationship was brought home to the Japanese People and amply demonstrated to the world at large by the two “Big Bombs”, exploded during the unforgettable early August of 1945!

However, after this belligerent introduction and extremely destructive use, the immense amount of energy released by the fission of radioactive elements has been harnessed subsequently for peaceful purposes to provide the energy needs of the developed and the developing nations for the last 50 or so years.

But, from the perspective of basic or pure science, the great importance of EMR and its associated energy lies in its primordial link with the very birth of our Cosmos, as it is strongly believed that the essential Building Blocks of our Universe: Electrons ( $e$ ), Protons ( $p$ ), and Neutrons ( $n$ ), arose from the Primordial Energy as implied by the reverse of the above cited popular equation:  $m = E/c^2$ .

Presently, however, we witness mainly the conversion of mass into energy, during both the fission reactions of the radioactive or fissile elements and especially the fusion reactions, going on at an immense scale in the trillions upon trillions of the stars, which initially fuse hydrogen into helium, followed by the successive fusion of the lighter chemical elements into the heavier ones.

### **The Structure of EMR and its Critical Analysis**

The EM waves are generally represented by the sine curves of the electric field ( $\mathbf{E}$ ), fluctuating along the  $\pm y$ -axis and moving in the  $x$ -direction. The corresponding sine curves of the magnetic field ( $\mathbf{B}$ ), along the  $\pm z$ -axis, are generally omitted to avoid cluttering of the illustration. Moreover, the generation of EMR is usually treated in the absolute vacuum, which bestows it the maximum speed of light ( $c$ ). Thus, *the absolute vacuum, generally called just vacuum*, has been assigned some standard EM properties or physical constants, such as the Vacuum Permittivity or Electric Constant ( $\epsilon_0$ ) and the Vacuum Permeability or Magnetic Constant ( $\mu_0$ ), which are related as,  $\epsilon_0 = 1/\mu_0 c^2$ . The familiar Coulomb Force Constant ( $k_0$ ) is related to the vacuum permittivity by  $k_0 = 1/4\pi \epsilon_0$ .

Now returning to the main topic, let us bear in mind that it costs a quantity of energy ( $E$ ) to polarize the neutral vacuum to generate in it, during time  $T = h/E$ , a particle of EMR. The resulting photon carries energy ( $E = h/T = hf = mc^2$ ), linear momentum ( $mc$ ), and angular momentum ( $L = mc \times r = \hbar$ ). Well, just as the linear momentum is force multiplied by time ( $mv = ma \cdot t = F \cdot t$ ), the angular momentum means the product of torque and time:  $mv \times r = Ft \times r = \tau \cdot t$ . Both torque and angular momentum require an axis, a center, a pivot or fulcrum to provide the central force. Then, how come the photon manages to move in a straight line, galloping at the top speed of light, instead of toppling over or going into a circle? Moreover, even to follow a straight trajectory, the extremely mobile, mutually inducing, and rhythmically fluctuating EM fields of a photon need two central forces, one to keep their EM frame coherent and the other to stay on tracks. Consequently, it is understood or taken for granted that the local (almost flat) curvature of space provides the necessary force to keep the EMR train on a straight path. But, the EM structural coherence and stability – like any other structure, have to be guaranteed by some elements embedded in its frame. I will treat this matter at the end of this study, when the subject has matured for conclusions. But, the main question still persists: **how does a photon subdue its rotating tendencies to sprint along a straight line?**

Furthermore, there are other lingering doubts and objections. For instance, how and why the isotropic absolute vacuum or space, having the property of “Symmetry” or even the “Super Symmetry”, permits its lop sided EM polarization into two opposite halves, with their centers separated by a distance of  $\lambda/2$ ? We may not expect the spherical field symmetry of the bulk mass or charges, but the energy, momentum, and the incipient charges confined within the EM bounds of a photon, though having some elements of symmetry, are certainly lacking a symmetry plane. In fact, the mirror halves of the **E** (and **B**) sine curves are shown devoid of any field or polarization. Something is surely missing or hidden in this perplexing EM skeleton or frame!

And up and down the list of inquiry, there are more questions, such as: If the mass and energy of a photon are wedded together, what about its latent charges? We know that the “pair” of particles are born with equal rest mass energy ( $E_0 = m_0c^2$ ) and their respective plus or minus ( $\pm$ ) charges. Therefore, **“how” the Charges are related to Mass, Energy, Torque, and the Angular Momentum, becomes a natural question.**

And then there is the very important related puzzle: It is a well-known that the spectrum of energy (EMR) is virtually continuous and unlimited. But its “Materialization” is extremely limited and highly selective! **WHY?** After all, there is only **just one example of a gamma ray producing a pair of stable leptons:  $e^-$  and  $e^+$** ! Consequently, due to their extraordinary stability, these leptons ( $e^\pm$ ) are also the “end-of-decay” destination for all the short-lived particles. The next members, the ephemeral muons ( $\mu^\pm$ ), which finally end up as  $e^+$

or  $e^-$ , result both from the cosmic ray showers and the decay of other transitory entities produced by the high energy physics. And still higher on the 'Lepton Flavors' scale, the "Taus" are just a curiosity on the list... And I would like to add here that though there is presently no justification or any known valid reasons for the extraordinary stability or the particular mass / energy of the electron and positron ( $m_0 = 0.911 \times 10^{-27}$  g; 0.511MeV), yet only the threshold energy of the progenitor photon is "*materialized*" as  $e^\pm$ . Any excess goes towards the respective kinetic energy of the pair [1, 2]. Accordingly, ***nobody has found their slightly lighter or heavier "isotopes"***. And it is interesting to note that this peculiar behavior is encountered both in the lab and also in Nature, for instance, the Cosmic Ray Showers. Equally mystifying, the next immediate members of the lepton family, the short-lived muons, are ~207 times heavier than the electron! But, "**Why**" there is this particular number or ratio between the electrons and muons? Presently, there is no clue, much less an answer or even an explanation. Well, so far I have provided few answers, but raised many questions. Therefore, let us take a break to search for the solutions.

### **Looking for Clues and the Possible Solutions**

In order to find some clues, let us investigate the reasons for the straight path journey of the EMR (Photon) and follow it by a visit to the rare scene of a photon's "**Materialization**" into a pair of particles. This will enable us to carefully examine the relationships among the various physical parameters of the **precursor photon** and the **offspring pair of particles ( $e^-$  and  $e^+$ )**, which may provide some clues or even a solution.

### **How does a photon subdue its rotating tendencies and sprint along a straight line?**

One obvious answer is that the two opposite halves of the sine curve carry along with them their respective centers as well as their common center of energy / mass. Consequently, there is no fixed pivot or axis, as the respective centers are chasing their EM field structure. This artifice or maneuver cancels the spin tendencies of the two halves and permits them to slip along a straight line.

This explanation can possibly justify the one-sided alternate polarization of space in the mutually opposite directions. Each half is independent and following the local curvature of space. The flight is curbing their spinning tendencies, while some element or feature embedded in their EM frame is maintaining their integrity, as described in a later part of this study.

However, an alternative solution **postulates** the balancing "*conjugate*" E & B sine curve partners in the empty opposite halves of the usual EM wave. Such a 3D balanced structure would be in accord with the isotropic nature of the Universal Sea of Vacuum – And the Maxwell Equations won't mind handling the  $\pm$  signs of the conjugate pairs on the opposite ( $\pm$ )

sides of the y and z planes. Furthermore, just like the unbalanced case above, the respective centers of the balanced sine wave are not fixed but are following their runaway EM frame.

In support of these arguments, I offer two well-known facts:

1. “The angular momentum of a particle or rigid body in rectilinear motion (pure translation) is a vector with constant magnitude and direction. If the path of the particle or center of mass of the rigid body passes through the given origin, its angular momentum is zero”. *This verbatim quote from Wikipedia aptly applies to both of the above explanations* [3].
2. The **Pair Production**: When a gamma ray photon, having energy above the threshold value needed to produce a pair of electron and positron, meets an adequate EM obstacle, its two halves are jolted apart and disengaged, *enabling the pivot and releasing the central force*. Consequently, their linear momentum is thwarted and channeled into their angular momentum, resulting in the two oppositely fluctuating “Standing EM Waves”, called electron ( $e^-$ ) and positron ( $e^+$ ). ***The opposite direction of their angular momentum, spin, and the associated torque give them their opposite charges – meaning that the particle and its antiparticle polarize / impact their ambient space in an opposite manner, resulting in the oppositely directed central forces. This is “how” the imminent but latent mass, spin, and charge of the photon become manifest and are born into our universe as a pair of particle and antiparticle.***

In other words, these discrete packets of vibrant energy, embodying the “Standing EM Waves” of particles and antiparticles, now possess a distinct identity, capable of having secondary interactions with their ambient space and through it with each other, which confers them their mass, inertia, and charge interaction.

Now returning to our principal quest, let us focus again on the very significant fact that the *dormant* Inertial Mass, Spin, and Charges of the photon *wake up* during the process of Pair Production. Thus, a careful examination of the interrelations among the known physical constants of the EMR and those of the offspring pair of leptons could possibly shed some light on their intimate nature. Therefore, these parameters are detailed in the Tabulation below [4].

- A. **EMR**: The Apparent Spin or Angular Momentum is **Zero** due to the equal but opposite spin tendencies of its two halves, thus allowing EMR to follow a straight path. But the energy-wise or “Conventional Spin” is **one**, that is,  $\hbar = h/2\pi = mc \times r$ .

Wavelength,  $\lambda = 2\pi r$ ;

Reduced Wavelength  $r = \lambda/2\pi$ .

Frequency,  $f = c/\lambda = 1/T$ ;

Period,  $T = \lambda/c = 1/f$ ;  $T/2\pi = t = r/c$ .

Angular Velocity,  $\omega = c/r = 1/t$ ;

**Energy**,  $E = mc^2 = hf = hc/\lambda = \hbar c/r = \hbar/t$ ;

*The rest mass and the apparent charge of a photon are Zero.*

At rest the photon

‘dies’ and ceases to exist!

B. **Leptons:** Angular Momentum or Spin is:  $\pm\hbar/2 = r \times mc/2 = r \times m_0c$ ; the lever arm 'r' (the radial distance) and the instantaneous linear momentum  $m_0c$  are perpendicular to each other; the clockwise or anticlockwise direction of the linear momentum ( $m_0c$ ) determines the plus or minus sign of the spin and that of the associated original torque.

**Rest or Intrinsic Mass Energy,**  $E_0 = m_0c^2 = E/2 = hf/2 = hc/2\lambda = \hbar c/2r = \hbar\omega/2 = \hbar/2t$ ;

Rest Mass,  $m_0 = E_0/c^2 = m/2$ .

The Charge,  $e^\pm = (\pm) 4.806 \times 10^{-10}$  Stat Coulomb (Stat C):  $[\text{dyne} \times \text{cm}^2 \text{ or } \text{erg} \times \text{cm}]^{1/2}$ .

The 'External' **Charge Interaction in Vacuum,**  $\pm e^2 = \hbar c\alpha = \hbar v_e = mv_e^2 \times r_e = (\pm) 23.1 \times 10^{-20}$  Stat C<sup>2</sup>:  $[\text{dyne} \times \text{cm}^2 \text{ or } \text{erg} \times \text{cm}]$ ;  $v_e$  is the velocity and  $r_e$  the radius of electron in the ground state of the H-atom in the Bohr model.

The 'Internal' or the 'Intrinsic Charge Interaction',  $\pm\hbar c = \pm mc \times r \cdot c = mc^2 \times r = (\pm) 3.165 \times 10^{-17}$  Stat C<sup>2</sup>:  $[\text{dyne} \times \text{cm}^2 \text{ or } \text{erg} \times \text{cm}]$ , as explained below in this report.

First of all, it may be worth alerting that the presence of  $2\pi$  in several relations described in the text and the above Tabulation, such as,  $h/2\pi = \hbar$ ;  $T/2\pi = t$ ;  $\lambda/2\pi = r$ , etc., indicates their cyclic or periodic nature, without implying a relation between the radius and circumference or the presence of a circle.

In the 2<sup>nd</sup> place, I would like to mention here that the dimensional equivalence of the units of energy ( $N \cdot m = \text{Joule}$  or  $\text{dyne} \cdot \text{cm} = \text{erg}$ ) and torque ( $N \times m$  or  $\text{dyne} \times \text{cm}$ ) can cause confusion, if the cross product relation is ignored. Therefore, this relation is made explicit in the above Tabulation [5]. In addition, I have included the alternative descriptions, such as,  $\hbar c = \text{torque} \cdot d = F \times r \cdot d = \text{energy} \times r$ , which can be helpful, if one recalls an alternative unit of torque:  $\tau = \text{energy/radian}$ ;  $E = \tau \cdot \theta$  radians.

Further, the energy of a photon can also be expressed in terms of its period (T) or the reduced time t, for example,  $E = hf = h/T = \hbar/t$ , which coincide with the mathematical definition of Torque, as the time derivative of the angular momentum. Therefore, convince yourself that these expressions also represent the energy of a photon, by reversing the steps (right to left) in the energy column of the above Tabulation. In fact,  $E = h/T = \hbar/t$  are more informative than  $E = hf = \hbar\omega$ , because the former expressions tell us that a faster EMR generating punch, imparts higher energy to the resulting photon. On the other hand,  $E = hf$  gives the impression as if one has to wait for a whole second, that is, the total number of cycles /second to obtain the full energy of a photon!

And finally, I draw your attention to the very familiar definition of pressure as the force per unit area:  $\text{Force/Area} = \text{Pressure}$ . But a similar expression or parameter does not exist for the product of force multiplied by area ( $F \times \text{Area} = \text{what?}$ ), which corresponds to one of the possible units of charge interaction (C<sup>2</sup> or Stat C<sup>2</sup>:  $N \times m^2$  or  $\text{dyne} \times \text{cm}^2$ ) in the above Tabulation. Well, 'Force x Area' may not seem to make much sense, but recall that a vertical force applied to the two ends of a rod or beam, or the four ends of a

crossbar, or on the sides of a flexible sheet would bend them. Similarly, weights hanging from the rim of a rubber plate would curve it. Conversely, a weight put on their center would also bend these objects. Therefore, may be that we have to rethink our concept of charges and their interactions. And let us remember that, while the **E** and **B** fields of EMR are pulsating orthogonally in the respective y and z directions, the EM frame is being impelled in the x-direction... *A strategic combination of three mutually orthogonal forces to achieve a powerful end!* A fact already utilized in the Maxwell equations.

### **Intrinsic Charge Interaction and the Rest Mass Energy**

Thus, you can easily verify from the above Tabulation that the potential energy or the energy content of all sorts of photons (EMR), whether they can “materialize” or not and despite their overall neutral charge, is given by  $E = \hbar c/r$ . And the rest mass energy ( $E_0$ ) of the offspring half spin ( $\hbar/2$ ) pair of leptons is given by  $E_0 = \hbar c/2r$ , where  $r$  represents the reduced wavelength of the threshold-energy precursor photon and also that of the resulting leptons. Therefore,  $E \times r = 2E_0 \times r = \hbar c$ , represent the intrinsic charge interaction of the photon with respect to the zero energy state of the vacuum in which it is created by the injection of a quantum of energy. Consequently, the charge interactions ( $E \times r$ ), whether external or internal, have a cross product component ‘ $r$ ’, inherited from their parent or related parameters: torque ( $F \times r$ ), angular momentum ( $L = mv \times r$ ), and spin ( $\hbar = m_0c \times r$ ). Unfortunately, the lever arm’s significance is often overlooked or gets lost in the names given to the electric charge (Coulomb and Stat Coulomb) and the units employed to describe its interactions:  $C^2 = \text{joule} \cdot \text{m}$  and  $\text{Stat } C^2 = \text{erg} \cdot \text{cm}$ . Therefore, I have shown explicitly the cross product relation in the above Tabulation [5]. Furthermore, I have mentioned the alternative descriptions, torque  $\cdot$  distance and energy  $\times r$  (lever arm), along with some extra notes for a better comprehension of the charge interaction.

In view of these explanations, I would like to renew here and stress again the gist or essence of my earlier arguments and suggestions, as advanced in my recent studies [6, 7]: that *‘while the compound constant  $\hbar c$  or  $mc^2 \times r$  corresponds to the intrinsic charge interaction of the respective EM energy packets of the EMR and the leptons, with respect to the original zero energy reference state of their internal vacuum,  $e^2$  represents the mutual interaction of the manifest elementary charges through the external empty space or vacuum’*. And, of course, the Fine Structure Constant ( $\alpha$ ) connects one to the other.

### **Strong Force and Coupling Constants**

It turns out that  $\hbar c$  ( $3.165 \times 10^{-17}$  erg  $\times$  cm or dyne  $\times$  cm<sup>2</sup>) is 137 times stronger than the conventional elementary charge interaction ( $e^2 = 23.1 \times 10^{-20}$  erg  $\times$  cm or dyne  $\times$  cm<sup>2</sup>) and thus corresponds to the estimated superiority (~100) of the **Strong Force** over the conventional EM



interaction. Moreover, just like the space-time bounds of the EM frames of photons and the fundamental particles, the range of this intrinsic EM interaction ( $\hbar c$ ) would be limited to very short distances – about the sum of the reduced wavelength ( $r_1 + r_2$ ) of the interacting particles, which nicely agrees with the very short range behavior of the Strong Force.

In fact, led by such logic and reasoning, I have employed the strength of the intrinsic charge interaction ( $\hbar c$ ) to forge protons, by the mutual electromagnetic compression of the oppositely charged “quarks” or “muons”, in my recent reports [6, 7]. But bearing in mind that most of the scientific literature on the Strong Force describes it as about 100 times stronger than the Electromagnetic Force Interaction, I would like to draw your attention to an important information I found recently in the Hyper Physics link on the “Coupling Constants for the Fundamental Forces”, which attributes to strong interaction a value of about 137. As a matter of fact, the Strong Force Coupling Constant is allotted the reference value ‘1’ and other coupling constants are assigned the relative values on a decreasing scale.

<b>Coupling Constants:</b> Strong, $\alpha_s = 1$ ;	Electromagnetic, $\alpha = 1/137$ ;
Weak, $\alpha_w = 10^{-6}$ ;	Gravity, $\alpha_g = 10^{-39}$ .

Moreover, the author(s) state explicitly: **“The body of data describing the strong force between nucleons is consistent with a strong force coupling constant of about 1:  $\alpha_s \approx 1$ ”** [8].

Thus, the above statement, coupled with the definition of the alpha constant ( $\alpha = e^2/\text{strong force}$ ) and its value in the cgs units:  $\alpha = e^2/\hbar c$ , identifies  $\hbar c$  as the Strong Force Interaction. And fortunately, this very important identification *answers positively* one of the inquiries proposed in my last publication: “Verification of the use of  $\hbar c$  in other Strong Force interactions and in the nuclear binding could be very instructive, but is beyond the scope of present report” [9].

*Therefore, in the light of these coincident conclusions, both from the theoretical considerations and the body of experimental data, that the parameter  $\hbar c$  expresses both the Strong Force and the Intrinsic Charge Interactions, let us now hope that it receives a kind and favorable review from the physicists accustomed to the Strong Force hypothesis, instead of the intrinsic charge interaction described by the compound constant  $\hbar c = mc^2 \times r$ .*

Nevertheless, apart from the natural resistance to a novel idea or an unconventional solution, the unorthodox explanation given above has raised some new questions:

**What are the Internal and External Media of photons and the fundamental particles? And how are they distinguished from each other?**

Well, let us promptly adopt *the free space (or the “Universal Sea of Vacuum”)* and *the ambient material media* (air, gases, liquids, crystals, glasses, metals, etc.), as the **External Media**. After

all, it is well known that EMR and elementary particles interact with and are strongly affected by the EM properties of the medium they encounter. Just ponder and reflect on some of the well-known phenomena: reflection, refraction, dispersion, diffraction, scattering, and polarization of EMR or the passage of charged particles through the E & M fields, and the strength of the charge interaction, when separated by diverse dielectric materials... Thus, we have to discover only the **Internal Medium or the Inner Reference** of EMR and that of its rather rare progeny - the pairs of leptons. To do this discovery, we need to focus on the stepwise generation of a photon. We already know that a photon is composed of two halves and each half carries energy ( $E/2$ ) and the associated momenta. Now, pay a close attention to the energy equation,  $E/2 = \hbar c/2r = m_0 c^2$ , which reveals the sought for solution. Let us recall and review our high school or college physics and discover that  **$\hbar c/2r$  corresponds to the energy stored in a Neutral Spherical Conductor ( $E_{\text{pot}} = q^2/2r$ ) [10]**. And of course, this much work or energy is spent to charge the neutral body, which involves either the supply of electrons or their removal from the conductor. The resulting excess (-) or deficit (+) of electrons at its surface causes mutual repulsion amongst the same-sign charges and makes the charging process an uphill task, needing work which is stored as the potential energy. And let us keep in mind that we are dealing here with the bulk material and the fully fledged “materialized” charges of electrons and protons.

In a sharp contrast, the genesis of a photon is a rather complex process. The complexity arises due to our ignorance about the nature and properties of the medium of its genesis, the very speedy nature of the photon, and its associated dynamic parameters:  $mc$ ,  $mc \times r$  ( $\hbar$ ),  $mc^2 \times r$ , and  $mc^2$ . Let us recall that though a photon does not show any apparent charge, yet  $\hbar c = mc^2 r$  (torque  $\cdot$  distance or *energy  $\times$  r*) represents its potential energy parameter:  $E_{\text{pot}} = \hbar c/r = mc^2 r/r = mc^2$ . This potential energy is with respect to the **original zero energy reference state** or the **un-polarized virgin state** of the vacuum in which it is generated by the injection of a quantum of energy.

At this point, I would like to draw your attention to the curious fact that, although we have been indoctrinated to think or focus only on the total energy of a photon, *without making any distinction between its kinetic and potential parts*, yet due to its extremely dynamic nature a photon certainly has kinetic, potential, and binding energy components. In fact, a judicious equilibrium and balance among these components of energy are essential to assure photon’s EM coherence and integrity and to prevent its ‘demise’ or fall back to the zero-energy state. Just convince yourself about this fact by the innumerable examples of countless galaxies in our Universe and the diverse energy levels of electrons in the chemical elements [11].

Nevertheless, in spite of this apparent complexity and the balancing acts of the potential, kinetic, and binding energies, photon’s total available energy corresponds to its potential

energy with respect to the zero-energy state of the vacuum, *because bereft of its energy content, the photon 'dies' and ceases to exist! But, its immortal energetic contents are passed on to another particle or atom!*

However, as mentioned earlier, the total energy of a photon is commonly represented by  $E = hf = mc^2 = \hbar c/r$ , which is the total of its two halves:  $E = 2 \times \hbar c/2r$ . And this brings us back to the spherical conductor [10], because its potential energy,  $E_{\text{pot}} = q^2/2r$ , is comparable to the energy stored in one half of a photon and corresponds to that of a lepton:  $\hbar c/2r = E_0 = m_0 c^2$ . Therefore, let us evaluate the  $E_{\text{pot}} = q^2/2r$ , by plugging in the known elementary charge ( $e = 4.806 \times 10^{-10}$  Stat C) and the reduced wavelength of electron,  $r = \hbar/2m_0 c = 0.193 \times 10^{-10}$  cm [4]. It provides  $E_{\text{pot}} = e^2/2r = 23.1 \times 10^{-20}$  erg cm /  $0.386 \times 10^{-10}$  cm =  $59.845 \times 10^{-10}$  erg, which is 137 times smaller than the known rest mass energy of electron:  $E_0 = m_0 c^2 = 8.199 \times 10^{-7}$  erg. But, as stated earlier,  $E_0 = \hbar c/2r = 3.165 \times 10^{-17}$  erg cm /  $0.386 \times 10^{-10}$  cm =  $8.199 \times 10^{-7}$  erg, correctly reproduces the known figure.

Well, before I proceed to the next step of unveiling the exotic properties and the identity of the Inner Medium, I would like to confess here that when I first arrived at these results in 2005-2006 [12], I imagined for a while two kinds of charges: the experimentally found elementary charge  $e$  ( $4.806 \times 10^{-10}$  Stat C) and the intrinsic one  ${}^i e$  ( $\hbar c/2$ )<sup>1/2</sup>, which differed in their EM interaction by a factor of 68.5. However, I was not happy and content with this “hypothesis” and continued groping for a better explanation. Further reasoning and reflection convinced me that the intrinsic charge  ${}^i e$  is the only “Real” thing, but it has two kinds of EM interactions: the Internal or “Intra Particle” interaction, which determines its intrinsic energy content ( ${}^i e^2 = \hbar c = 3.165 \times 10^{-17}$  erg x cm), and the External or “Inter Particle” interaction, **reflecting its secondary potential energy, which depends on the EM properties of the medium of its interaction**:  $e^2 = 23.1 \times 10^{-20}$  erg x cm (in vacuum). But again, I soon got stalled in this reasoning, because we are at best familiar with only one ultimate generating site or “womb” for EMR and by extension that for the Elementary Particles: the so called Absolute Vacuum or the Universal Sea of Vacuum, which has been assigned the standard EM properties ( $\epsilon_0$ ,  $k_0$ , and  $\mu_0$ ), as already mentioned in the earlier part of this study. Furthermore, this medium also serves as the repository of everything – indeed the whole Universe. **So what and where is the Inner Medium?**

Finally, it dawned upon me that when a quantum, or in fact, just one half of a quantum of energy is deposited in the **Normal or Virgin State of the Vacuum**, it polarizes (energizes) it and “impregnates” the **Neutral Super Conductor**. The second half of the energy quantum balances and completes a wavelength or a particle of EMR. And there may be just a single photon, a nanosecond pulse or an interminable train of EM waves, depending on the duration of the exciting source. Each member of the resulting train of the interconnected “Balloons or Bubbles”

has higher potential energy than that of the originally neutral vacuum, which serves both as its origin and reference. Thus, in its attempt to collapse or fall back to its ground state, the interconnected **“Conservation Laws of Energy, Momentum, Angular Momentum, and Charge”** compel and enable it to run at the characteristic speed ‘c’ permitted in vacuum, as already formulated by the Maxwell Equations. ***In essence, there is no choice. A photon must fly at velocity ‘c’ to avoid its crash into the zero-energy state of non-existence!*** Well, this (untiring?) “Marathon race” continues till the photon can find an *appropriately resonant* low energy candidate to whom it can pass on its “gift or burden”! Needless to add that what travels in a wave is its ‘energy and momenta’, but not its medium.

Thus, it is verified that all the above mentioned interconnected Conservation Laws, as well as the mutual electric and magnetic induction of the Maxwell equations – *in other words, the reciprocal exchange of energy and its transport* –, result from and attest to the infallible **“Supreme Fidelity”** of the **Universal Vacuum** as a **“Super Conduit”** and a **charge-free “Energy Exchange”**. The absorption and emission spectra of the chemical elements, for instance the H-atom, provide an excellent example and support for the reciprocal nature of these arguments: During absorption, an electron in the lower energy (say ground) state assimilates an appropriate energy photon and literally ascends to a higher energy level. But during emission, the higher potential energy electron descends to a permitted lower energy orbital by handing over the excess energy to the **ambient vacuum**, which converts it into a photon.

### **Intrinsic Charge, Elementary Charge, Charge Interaction, and Alpha ( $\alpha$ ) – the Electromagnetic Force Coupling Constant**

*In short, the “Neutral, Zero Energy State of the Vacuum” - in which the energy rich bubbles / balloons are encapsulated, transported, and delivered – is impacted by its contents and transformed into the so called “Polarized Electromagnetic Entity” – hereby denominated ‘Energetic Capsules’ of EMR (and leptons). And just like the Internal and Surface Potential ( $Q/R$ ) of a spherical conductor and its potential energy ( $E_{pot} = Q^2/2R$ ) [10], these ‘Energetic Capsules’ also have their respective intrinsic potential energy ( $E = \hbar c/r$ ;  $E_0 = \hbar c/2r$ ) and the surface potential,  $(\hbar c)^{1/2}/r$ . This surface potential will determine their ‘Close Contact’ Strong Force interactions, while the long distance interactions will be governed by the EM properties of the intervening medium. In vacuum, this interaction corresponds to:  $e^2 = \hbar c \alpha = 23.1 \times 10^{-20} \text{ erg} \times \text{cm}$ . Thus, this “Energetic State above the normal Vacuum” corresponds to the “Inner Medium” of photons, leptons, and other composite particles, such as, protons, neutrons, mesons, and hadrons, etc. and reflects their dynamic contents.*

Fortunately, the codified contents of these “Energetic Capsules” are governed by the interrelated “Conservation Laws” and guaranteed by the super fidelity of the universal vacuum. Thanks to the scientific revolution provoked by the ‘energy quanta’ of Max Planck and the

subsequent progress of the Quantum Theory, the dynamic parameters of photons and leptons can be deciphered by the quantum interrelations already discussed in the previous pages and especially tabulated on page 6 of this study. Thus,  $\hbar c/r = E$  (photons) and  $\hbar c/2r$  (leptons), faithfully express the respective energy content of photons and leptons. This energy is 137 times larger than that calculated from the elementary charge interaction ( $e^2/r = E$ ;  $e^2/2r = E_0$ ), as already demonstrated in an earlier section. But this comparison is unfair and invalid, because it compares two different parameters: The Intrinsic or “Intra Particle” energy of photons or leptons with their potential energy in the “Inter Particle” interactions.

However, in a legitimate comparison, the inter-particle elementary electromagnetic charge interaction in free space or vacuum ( $e^2 = 23.1 \times 10^{-20}$  erg x cm) is again 137 times weaker than the so called **Strong Force Interactions** *between the nucleons (protons & neutrons) and also between their constituent quarks*, as described earlier referring to the Hyper Physics link [8]. Therefore, this persistent (-constant) difference has deserved the special denomination “**Alpha**” ( $\alpha$ ) – “**The Electromagnetic Force Coupling Constant**”... As a matter of fact, this constant factor was first observed/ detected by Arnold Sommerfeld, in 1916, during the description of the fine splitting of the H-atom spectra, which explains its alternative designation as “**The Fine Structure Constant**”. Since that time, the mystery of the ‘ $\alpha$ ’ constant has captivated and puzzled the minds of the subsequent generations of physicists, without revealing its real nature. Consequently, there is a huge volume of scientific literature about ‘ $\alpha$ ’, concerning its diverse explanations, derivations, definitions, and experimental determinations. But, in the cgs system this constant is simply:  $\alpha = e^2/\hbar c$ , which corresponds to the already discussed ratio of the elementary charge interaction, in vacuum, to the intrinsic and also the strong force charge interactions [1, 8, and 13].

*In summary, with respect to the **energy-rich environment** of the EMR and the fundamental particles during their ‘**Close Contact Embrace**’, their long range interactions through free space or vacuum are 137 times weaker, which resolves the century-old puzzle of the Coupling Constant Alpha ( $\alpha$ ) – an experimentally observed ratio between the strengths of the Electromagnetic Force and the so called Strong Force:  $\alpha = e^2/\hbar c = 1/137$ .*

Thus, for the convenience of comparison among the strengths of different forces, ‘The Strong Force Coupling Constant’ ( $\alpha_s$ ) has been allotted the unit reference value, while the other Force Constants follow a decreasing scale [8]:  $\alpha_s = 1$ ;  $\alpha = 1/137$ ;  $\alpha_w = 10^{-6}$ ;  $\alpha_g = 10^{-39}$ , as already listed in a previous section. But due to several other scales in use to describe the EM parameters of diverse dielectric media and materials, the relative values of the EM parameters of the energy-rich Strong Force medium and those of the normal vacuum will depend on the reference standard and the scale chosen for their comparison. For instance, the Coulomb Force

Constant for vacuum has the fixed value of unity in the cgs system,  $k_0 = 1$ . Therefore, the relative values of the EM parameters of the energy-rich Strong Force medium would be:

$$\text{Coulomb Force Constant (cgs units), } k_s = 137; \quad \epsilon_s = 1/4\pi 137; \quad \mu_s = 1/\epsilon_s c^2 = 4\pi 137/c^2.$$

### Charges and the Charge Interactions

Well, the preceding fairly elaborate discussions and explanations have demonstrated that the Intrinsic Charge Interactions ( $i e^2$ ) as well as the Strong Force Interactions are both expressed by  $\hbar c = mc^2 \times r$ . In essence, the compound constant  $\hbar c$  represents the cross product of the potential energy ( $E_{\text{pot}}$ ) and the lever arm or the radial distance between the interacting particles. In the 'Close Contact' scenario, this distance ( $d$ ) corresponds to the sum of the reduced wavelengths ( $r_1$  and  $r_2$ ) of the interacting partners:  $d = r_1 + r_2$  and  $E_{\text{pot}} = hc / (r_1 + r_2)$ . Hence, I have employed this very powerful property of the 'Close Contact Interactions' to forge quarks and muons into protons in my recent publications [6, 7].

Similarly, the Elementary Charge Interaction is determined by a compound constant:  $e^2 = \hbar c \alpha$ . But, we may recall that the discoverer of  $\alpha$ , A. Sommerfeld, also offered its first explanation, as the ratio  $v_1/c$ , where  $v_1$  is the electron's velocity in the 1<sup>st</sup> Bohr orbit of the H-atom. This value reduces  $\hbar c \alpha$  to  $\hbar v_1$ , which I have listed, with the due explanations, as  $\hbar c \alpha = \hbar v_e = mv_e^2 \times r_e$  in the Tabulation on page 6. In fact, this value may be generalized to include all the energy levels of the H-atom:  $e^2 = \hbar v_e = n \hbar v_n = n \hbar v_e/n = \hbar v_e$ . But, it should be remembered that the velocity of electron ( $v_e$ ) in the H-atom is not the cause, but a result of alpha ( $\alpha$ ), which reflects the EM properties of vacuum.

### Charge Conservation

Consequently, in view of the constant values of the intrinsic charge interaction ( $i e^2 = \hbar c$ ) and the elementary charge interaction ( $e^2 = \hbar c \alpha$ ), the values of the individual charges are also constant:  $i e = (\hbar c)^{1/2}$  and  $e = (\hbar c \alpha)^{1/2}$ . Needless to add that the conservation of  $\hbar$  ( $mc \times r$ ) and  $\hbar c$  ( $mc^2 \times r$ ) guaranties the charge conservation. Further, we know experimentally that the charges and charge interactions of electrons (simple fermions) and protons (composite fermions) are equal in magnitude and independent of the rest mass energy of the interacting particles. Therefore, the mechanism which assures the resultant spin of the proton ( $\hbar/2$ ), also assures its charge and charge interaction. And, as stated earlier (p. 5), the oppositely directed angular momentum, spin, and the associated potential torque of the particles and antiparticles impact (polarize) their ambient space in an opposite manner, resulting in the oppositely directed central forces, which are perceived, interpreted, and named by us, as the plus (+) and the minus (-) charges.

## Electric (E) and Magnetic Fields (B)

Moreover, as these dynamic parameters are incessantly impinging on their environment, this continuous disturbance of space is detected by other charges as the **Electric Field (E)**. Further, apart from this intrinsic impact, the secondary movements of the charged particles would produce the secondary effects, denominated as the **Magnetic Field (B)**.

## Standing Waves and their Reference Medium

Now returning to the pending question of 'What and How' maintains the coherence and the integrity of the ever-pulsating EM frames of the fleeting EMR and that of the "Standing Waves" of the leptons, we discover some unsuspected, extraordinary, possibly controversial, and an exotic relation between the throbbing 'Energy Capsules' and their *Zero-Energy Reference Medium*. For instance, as pointed out earlier, the angular momentum / spin of the photons and leptons requires the presence of a pivot or fulcrum, and an axis to provide the necessary central force. This aspect, rather mute or balanced in EMR – as explained earlier (pages 5, 6), comes into a sharp focus in the 'Standing Wave' description of the leptons, because their spin ( $\hbar/2 = m_0c \times r$ ) indicates that their pulsating EM frame behaves like a particle of mass  $m_0$ , revolving in a uniform circular motion, having the radial distance 'r'. Well, to perform a circular (or elliptical) cycle, the particle needs the centripetal force ( $m_0c^2 / r$ ) provided by an agent embedded in its frame. Consequently, this force is being supplied by the zero-energy reference medium of the 'Energy Capsules' of leptons – and by extension that of the photons. Further, the magnitude of this central force ( $m_0c^2 / r$ ) indicates that the said zero-energy medium is serving as a private "Black Hole", which sustains the coherence and maintains the identity of each and every photon, lepton, and by extension that of the composite particles: mesons, nucleons, and other hadrons.

Furthermore, in a sharp contrast to the Free Space, which is crisscrossed by all sorts of EMR coming from whole of the Universe – and according to certain theories even serves as the stage for the "appearance-disappearance" act or trick of the Virtual Particles –, the Internal Medium of the Fundamental Particles and possibly that of the high-energy EMR is devoid of such activity. This sort of activity would just destroy them. Because to get into their interior, the intruder has to possess much higher energy and much smaller EM dimensions than that of the host or victim. Moreover, in contrast to the fleeting EM frames of EMR, which may crisscross each other, the "standing wave" structure of the elementary particles grants them strong shield against EMR intrusions. Just check yourself that the electron protects its integrity during the Compton scattering of x-rays which have energy equal to or even superior to that of the

electron. In fact, the photon loses some of its energy, which it imparts to the recoiling electron [14].

On the other hand, the low energy EM waves are known to modulate or even crisscross each other, in many cases without much suffering or loss of integrity, which indicates the presence of a cohesive force within their EM frame. However, they may undergo either constructive or destructive interference, or suffer jamming, jumbling, and serious effects of “noise” due to the inseparable cousins... [1].

Now, bringing the present study to a close, I would like to mention that presently there are several other descriptions and explanations for the EMR, the matter particles, and the charges. I cite just two of such approaches, which have attracted my attention. For instance, D. J. Pons and collaborators have developed an altogether novel description of Physics, based on their “Cordus Model” [15]. While, V. A. Induchoodan Menon has described the “Standing EM Wave” structure for electron to explain its mass, spin, and charge [16].

**In Conclusion**, there is a great satisfaction to record that an ab initio search into the nature of the Title Topics has revealed the essence of charges and their interactions, and also helped to resolve the century-old riddle of the enigmatic Coupling Constant Alpha ( $\alpha$ ) – the ratio between the Elementary Charge and the Strong Force interactions:  $\alpha = e^2/\hbar c = 1/137$ . I now offer it to the scientific community for its review and evaluation.

Finally, in the light of the preceding explanations – and with the due apologies, respects and regards, owed to the scholars and the laureates of the Standard Model and the Quantum Chromo Dynamics (QCD), I would like to confess that I have not found any fractional charges, nor seen any colors, much less tasted a flavor!

However, based on my very limited knowledge of the 3D geometry, I can visualize the eight discrete sections of a sphere, located in its upper and lower parts, which can be allotted eight distinct combinations of the  $\pm x$ ,  $\pm y$ , and  $\pm z$  coordinates... But to what extent the torque, spin, and  $(E \times r)$  interactions would differ in these distinct locations is beyond the scope of the present study.

## References and Notes

1. The topics discussed in this study are very familiar to the professional physicists. The non-experts can visit Google and especially the Wikipedia links, which provide useful information on almost all the topics discussed and often **highlighted** in this study. Similarly, the new ideas, novel concepts, and important conclusions are also highlighted



or shown in *italics* to draw readers' attention. Additional references are pinpointed only in special cases demanding such a care.

2. Pair Production: [www.princeton.edu/~achaney/tmve/.../docs/Pair\\_production.html](http://www.princeton.edu/~achaney/tmve/.../docs/Pair_production.html)
3. Wikipedia: Angular momentum – Angular momentum in classical mechanics. Definition, page 2.
4. Unless stated otherwise, this study employs cgs units, rounding the values to 2-4 decimal places depending on their importance for the argument. Some of the values used in this enquiry are:  $h = 6.6262 \times 10^{-27}$  erg s;  $2\pi = 6.28$ ;  $\hbar = h/2\pi = 1.055 \times 10^{-27}$  erg s;  $c = 3 \times 10^{10}$  cm/s; electron's rest mass,  $m_0 = 0.911 \times 10^{-27}$  g; Elementary charge  $e = 4.806 \times 10^{-10}$  Stat C; electron's reduced wavelength,  $r = \hbar/2m_0c = 0.193 \times 10^{-10}$  cm, as deduced and employed in my previous studies [6, 7, 12].
5. The cross product relation in  $\hbar = mcr = mc \times r$  and  $\hbar c = mc^2 r = mc^2 \times r$  is not always written out, but is understood to be present.
6. Mahajan, J. R., "The Cosmic Forging of Protons by the Electromagnetic Compression of Quarks", [vixra.org/abs/pdf/1207.0086](https://vixra.org/abs/pdf/1207.0086).
7. Mahajan, Jaswant Rai, "Probable Synthesis of Protons from Muons", [vixra.org/abs/pdf/1309.0085](https://vixra.org/abs/pdf/1309.0085).
8. Hyper Physics: [hyperphysics.phy-astr.gsu.edu/hbase/forces/couple.html](http://hyperphysics.phy-astr.gsu.edu/hbase/forces/couple.html).  
*The highlighting of the text is mine to call attention.*
9. Mahajan, Jaswant Rai, Reference 7, note 5.
10. Properties of a Spherical Conductor: Radius =  $r$  cm; charge =  $q$  Stat C; Internal and Surface Potential,  $V = q/r$  Stat volt (erg/Stat C); Stored Potential Energy,  $E_{\text{pot}} = qV/2 = q^2/2r$  erg; Capacitance,  $C = q/V = q r/q = r$  cm (Stat C/Stat volt = Stat C<sup>2</sup>/erg).
11. For an atomic analogy, just recall the potential, kinetic, and the binding energies of the electron in the  $S_1$  and  $S_2$  orbitals of H-atom. In the case of EMR, we are dealing with its diffuse, fluctuating, and periodic EM field structure, which is flying at speed  $c$ , along with its other attributes:  $mc$ ,  $mcr$ ,  $mc^2$ , and  $mc^2 r$ .
12. Mahajan, Jaswant Rai, "Inquiries into the Nature of Mass, Charge and the Related Concepts", *unpublished study*, with limited circulation, Feb., 2006.
13. The NIST Reference on Constants, Units, and Uncertainty. Fundamental Physical Constants: [physics.nist.gov/cuu/Constants/introduction.html](http://physics.nist.gov/cuu/Constants/introduction.html)
14. Wikipedia: Compton scattering.
15. Pons, D. J., "Contrasting Internal Structures: Photon and Electron", [vixra.org/abs/pdf/1109.0045](https://vixra.org/abs/pdf/1109.0045) and references cited therein.
16. Induchoodan Menon, V. A., "Standing (Electromagnetic) Wave Structure of the Electron – III. Creation of the Electric Charge", [vixra.org/abs/pdf/1001.0008](https://vixra.org/abs/pdf/1001.0008).