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RE-APPRAISAL OF COULOMB'S LAW

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Abstract

The origin for the electric potential and hence Coulomb's law has been investigated for the first time employing propagation of the electric field by self-excitation mechanism associated with strings in a compact form of liquid with the help of "stick-slip" process. It is found that the electric potential is an exponential function of $\frac{1}{r}$ where r is the distance between the charge particle and the point under consideration. Obviously this view provides a theoretical support for Coulomb's law. Nuclear forces have an exponential fall and the present view helps in understanding the unification of forces only on the basis of the presence of vibrating strings. This aspect has already explained successfully for conservation of the charge of the electron. Moreover, the magnitude of the vacuum permittivity is explained on the basis of resistance originated in the medium. This, novel approach also helps to estimate the velocity of light for the first time on the basis of universal fundamental constants, namely Planck's length, Planck's force and Planck's time.

Keywords and phrases: Coulomb's law, self-excitation of strings, vacuum permittivity, strings as a compact liquid.

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1. Introduction

It is well established that the force of attraction or repulsion between two charges is inversely proportional to the square of the distance between them. The intensity of the electric field is given by [1]

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}, \tag{1}$$

where q is the charge under consideration and ε_0 is the vacuum permittivity. This means that the potential energy, U, originated from the charge is

$$E = -\text{grad}\, U, \tag{2}$$

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}. \tag{3}$$

This is an accepted fact both theoretically and experimentally. This inevitably suggests that the product of potential energy and the distance is constant. This relation is originated comparing with gravitational force and experimentally confirmed by several methods and technologically verified. Vacuum permittivity is the inverse of resistivity of the vacuum, indicating that the vacuum has some elements which resist the flow of electricity. The constant of proportionality

$$\frac{1}{4\pi\varepsilon_0} = 10^{-7}c^2 = 9\times 10^9$$

is given as a definition [1] and its origin has never been discussed. The magnitude of $\frac{1}{4\pi\varepsilon_0}$ is confirmed only by experimental methods and it is found to be 9×10^9. It is worth to point out that the basic cause for this important constant is never addressed. It is just taken for granted [1].

Vibrating strings are considered as a compact form of a liquid and any kind of motion, in this case, the flow of the electric field has some form of drag or opposition. It is proportional to the tension and the length of the string which provides the resistance. Therefore, the constant is the product of Planck's length $(1.6 \times 10^{-35} \text{meters})$ and Planck's force which creates the tension in the string $(1.2 \times 10^{44} \text{Newton})$; and the product is approximately 2×10^{9}, very close to the experimentally observed value.

It is clear that the resistance of the medium for the flow of the electric field is very high and electron emits energy continuously without losing its charge and mass. The conservation of the electron's charge is explained on the basis of vortex induced vibrations in a compact form strings with the help of fluid dynamics by Joshi [2]. The feedback energy to maintain the charge is provided by Resonance Energy Transfer process. The flow of electric field through the medium of high resistance with a low power source like electron directly suggests that the medium should be also active and have a self-excitable system which maintains the process of flow of energy. This is done with self-excited vibrational mechanism.

2. Self-Excited Vibrations

Recently the proposed theory [3] strongly indicates that the electric field is propagated by self-excited vibrations induced in the strings in the form of compact liquid. This view has given a new dimension to the nature and propagation of electric field and it explains several basic principles of electro magnetism like Maxwell's equations [4], electrostatic attraction or repulsion [5], Lorenz force [6], Faraday's law [7] in a consistent manner. Self-excitation is induced by stick-slip process [3] according to which an excited string is attached and slides over the next string inducing excitation in it. Friction-induced self-sustained vibrations play a crucial role not only in macro mechanical systems but also in atomic and nano-scale processes [8, 9, 10].

Induced sustained vibrations are originated by two mechanisms. The predominant is a Stick-slip excitation and the other is quasi harmonic oscillations [10]. In fact, both processes are based on the presence of vibrational units. The stick-slip vibrational process is characterized by a displacement-time evolution which is clearly defined stick and slip phases in which the two surfaces in contact stick and then slide over the other. In a stick phase a static frictional force plays a role in exciting the next string meanwhile in the slip phase a velocity dependent kinetic friction acts to excite. The “stick mechanism” is due to the higher static friction between the surfaces, and the “slip” due to the lower kinetic friction during the slip itself [9].

3. Stick-Slip Mechanism

A detailed investigation has been carried out on macroscopic and nano-scale stick-skip process [8]. From earlier investigation, it is found that the properties of strings can be well understood on the basis of “strings in the form of a compact liquid” and this explains several properties of electric and magnetic fields [3-7]. Therefore, the earlier established “stick-slip” theory for nano-scale can be extended to vibrating strings. It shows that the energy excitation from one unit (at atomic or molecular level) to another is mainly due to the vibrational energy [8, 9]. The “Stick and Slip” process confirms this aspect. The amplitude of the slip, or the sliding velocity depends upon the stiffness of the vibrating unit, in the present case string. Dynamical analysis reveals that the sliding becomes unstable when the potential energy of string varies in an accelerated form, then the string stiffness is altered and the energy transfer or excitation becomes unavoidable. This view is consistent with the analysis of strongly coupled harmonic oscillators according to which when the force constant is altered, the potential energy of each oscillator changes [11]. This consequently changes the vibrational frequency giving rise to energy transfer and self excitation efficiently.

The strength of the excitation depends upon the intensity of the vibrational mode of the exciting string. If U is the energy of the exciting string then only the part of it, $\delta U,$ is used to excite the string located at the next layer. δU is directly proportional to the value of U at that moment. It is worth to mention that exponential functions are uniquely characterized by the fact that the decay (or growth) rate is directly proportional to the value of the function at that instant and this aspect is being examined here.

Let f be the small fraction of the energy used for excitation purpose. This means that the energy used for the excitation of the next string has the same proportion of the total potential energy at that time. This potential energy is associated with the quantum harmonic oscillators of strings. In the stick process, the mechanical instability in the contact of two strings increases which causes energy dissipation and this helps the self-excitation process [9]. Obviously, as higher number of strings, n, gets excited, the available energy for excitation δU decreases.

$$\frac{fKU}{n} = \delta U. \tag{4}$$

Here K is a constant depending upon the sticking coefficient between the exciting string and the mass of the string which is being excited. As the parameters of strings and the details of conversion of storage energy are not available, it is not possible to estimate the value of K.

Equation (4) becomes

$$\frac{\delta U}{U} = \frac{fK}{n}, \tag{5}$$

$$U = \exp\left(\frac{fK}{n}\right) + \text{Constant}. \tag{6}$$

The distance, r, of the excited string from the source can be given by $r = nL,$ here L is the dimension of the string $(1.6 \times 10^{-35}\,\text{meters})$ which is equal to Planck's length. The solution of the differential equation is

$$U = \exp\left(\frac{fKL}{r}\right) + \text{Constant}. \tag{7}$$

After expanding U in series, adjusting the constant of integration for $r = \infty$, potential, U, is 0, and neglecting the higher order terms of the expansion $\exp\left(\frac{fKL}{r}\right)$, the equation becomes

$$U = fKL\frac{1}{r}. \tag{8}$$

Thus, only on the basis of the presence of vibrating strings and the propagation through self-excitation process with the help of stick-slip process, the variation of the potential energy of the electric field as function of $\frac{1}{r}$ is a direct consequence. So the inverse square law of repulsion or attraction between charges can be understood with the presence of strings as discussed earlier by Joshi [5] without considering the "force at a distance. In fact the concept "force at a distance" is never justified and not explained vigorously, particularly in the present context. The force of attraction or repulsion between two charges is not only related with the distance between two charges but it involves the consideration of the surrounding space. This aspect has been discussed earlier by considering the potential energy of strings and also in the open course on "Charge and Coulombs law" published by MIT. Videos which appear in the open course clearly show the stresses in the medium originated as a consequence of the motion of the charge particle [12]. These aspects support the view that strings in a compact form of liquid play a crucial role in electro-magnetic fields as the stresses in the liquid are originated from non-uniform forces applied in different directions. The concept of stress, as observed directly in the electric field, is difficult to understand in an empty space.

The constant K is proportional to the force associated with string. Therefore, $K = \alpha F$ where the value of α depends upon the medium in which the energy is excited and its frequency. The magnitude of the force associated with the string, F, used for excitation does not change significantly in the process. Equation (8) can be written as

$$U = f\alpha FL\frac{1}{r}. \tag{9}$$

F, L are the parameters of string namely force and length and are related with the universal constants namely Planck's force $(1.2 \times 10^{44}\,\text{Newton})$ and Planck's length $(1.6 \times 10^{-35}\,\text{meters})$. Therefore, FL is $2.9 \times 10^{9}\,\text{Newton-meter}$. So the equation becomes

$$U = f\alpha\frac{1}{4\pi\varepsilon_0}\frac{1}{r}. \tag{10}$$

The parameters f and α depend on the medium, particularly sticking coefficient and varies considerably from material to material. The fraction f of the potential used for excitation also depends upon, humidity, temperature and other parameters of the medium. Further investigation in this direction is needed.

The magnitude of vacuum resistance to the propagation of electric energy is really high suggesting that there is some element in the vacuum which opposes the propagation and it has vibrational nature or features of harmonic oscillator.

4. Application to Short Range Forces

The other significant aspect of the potential obtained in the present investigation is that it is an exponential function and it is a characteristic of short range forces which are observed within the nucleus. Beyond $0.9\,\text{fm}$, the force drops exponentially and at about $2.1\,\text{fm}$, it is negligibly small and cannot be detected. For example, Yukawa potential (also called a screened Coulomb potential) has a potential of the form [13]

$$U(r)_{\text{Yukawa}} = -g^2 \frac{1}{r} e^{-\mu r}, \tag{11}$$

where g is the magnitude of the scaling constant and μ depends upon the mass, spin and other properties of the particle. The potential energy of electric field and the potential associated with other nuclear forces have exponential nature; the former one with $\frac{1}{r}$, meanwhile the later one is with $-r$.

In the present work, it is pointed out that a potential associated with long range and short range forces, both have exponential nature. This has been explained directly assuming only the presence of vibrating strings in a compact form of liquid. The short range forces (related with elementary particles like quark, etc.) are observed in a confined region of nucleus where elementary particles and their fields interact with each other strongly. Obviously, there is no spherical symmetry and the space is not free to propagate the field like electric or magnetic in the space. In such situation, the damping becomes an important parameter and therefore, Van der Pol nonlinear differential equation [14] plays a crucial role.

In a dynamical system, it is frequently used for non conservative oscillators with non linear damping. It evolves in time according to the second-order differential equation:

$$\frac{d^2x}{dt^2} + \zeta(1 - x^2)\frac{dx}{dt} + \eta x = 0. \tag{12}$$

Here ζ is the damping coefficient and η is a constant of the resort of the vibrating string.

The solution of this equation is given by

$$x = e^{-\zeta t}[b \sin(\omega t + \alpha)]. \tag{13}$$

The values of b and α depend upon the initial conditions. The frequency is controlled by the constant η. Details have been discussed earlier by Akabari et al. [15]. It is clear that the solution is highly sensitive to the relative values of the damping coefficient, ζ, force constant η and initial conditions. The parameter b is related to the amplitude of vibration of the harmonic oscillator at the start. A slight increase in the damping coefficient reduces the range considerably. The form and the rang of the force is strongly influenced by these strongly interrelated parameters and therefore this simple equation give rise to forces of different ranges and their nature observed in the nucleus.

With the present view not only the exponential nature and their sharp variation in short range forces observed in the nucleus are explained, but also non Abelin fields which do not fan out all over space, but remain confined to a narrow cylindrical region and help the confinement process [16]. A satisfactory explanation has not been provided by quantum chromodynamics, however the above presented method does. In stick slip process, in a confined region, torsional stress is originated giving rise to strong directional dependence. Therefore, the field does not spread in three dimensional space giving rise to non Abelin field.

In fact,some properties of the nucleus and certain types of forces were explained on the basis of the earlier model "liquid drop model" according to which the nucleus was considered as "incompressible fluid". It was proposed by Gammow and then developed by Bhor and Heisenberg [13]. The main difference between the present model and the earlier is that in the present investigation, the liquid has vibrational energy in an organized form which can be converted into kinetic and potential energies. The most important aspect is that it is self-excitable. As a fluid it supports stress and follows dynamics as mentioned earlier. The main advantage of the above point of view is that string theory helps to the unification of forces (short range and long range) in a simple way. In the present context extra dimensions, the presence of D-branes etc. are not required. It is only considered that the space is filled with vibrating units (strings).

5. Velocity of Light

The other advantage of the proposed approach is that it explains the velocity of light in a lucid manner on the basis of universal constants. As mentioned earlier self-excitation is originated from a static frictional force and interfacial damping which is directly related with the force which is applied in "stick process". The slip process is a kinetic friction and is the momentum of the oscillating system. Obviously, higher the kinetic friction, the time required for excitation is reduced or time of activation for the next string is inversely proportional to it [8]. The damping at atomic or nano-scale has been examined earlier and arrived to the same conclusion, namely the frictional force is inversely proportional to the slip time or in the present situation, the time required to excite the next string. Kinetic friction F_k is the rate of change of momentum, P, and in the present context the momentum of the quantum harmonic oscillator. In stick-slip process, external force acting on a system is the rate of the change of momentum and it is proportional to F_k.

Therefore, the kinetic friction F_k is proportional to the Force applied and hence

$$F_k = e_k \text{ Force}. \tag{14}$$

Here e_k is coefficient of the kinetic friction.

The time required to excite one string to another is inversely proportional to the kinetic friction which opposes the momentum dP

originated from the flow of the vibrational energy, therefore, is inversely proportional to dp. Consequently

$$t_{\text{exc}} = 1/e_k \text{ Force}, \tag{15}$$

where t_{exc} is the time required for exciting the string in the slip process.

As the dimension of the string is very small (Planck's length), the time to excite with the slip process is expected to be very small and this can be understood with a high magnitude of the force associated with strings. The change in the momentum used in the excitation process is small compared with the static force. In the harmonic oscillator related with the string it is not possible to separate contribution from potential, kinetic and stored energies. The change in the momentum, dP is used to dissipate the energy to excite the harmonic oscillator at a higher level and its magnitude is very small compared with Planck's force. As the detail mechanism of "slip-stick" process is not known for strings in the form of a compact liquid, it is not possible to estimate the value of e_k. Moreover, earlier investigations provide information about the magnitude of e_k for conventional coefficient of kinetic friction but does not throw light on the situation where the dissipation of energy is originated from vibrational energy. However, the momentum associated with the lateral force varies from 10% to 20%. Therefore, in the present work we assume that the value of $e_k = 0.2$.

It is known that strings are very heavy and have Planck's force 1.2×10^{44} Newton. Therefore, according to equation [15], the time to excite the next string for $e_k = 0.2$ is 4.16×10^{-44} sec. This shows that in 1 second, a chain of 2.4×10^{43} strings are excited. The dimension of the string is of the order of Planck's length 1.6×10^{-35} meters. Therefore in one second 3.8×10^{8} meters of strings are activated and this is the velocity of light. The rough estimation is in very close agreement

$(2.9 \times 10^8 \text{meters})$ in spite of the non-precise values of constants related with strings (Planck's force, dimension of string etc.) and value assumed for e_k. However, it is worth to mention that the value obtained for the time to excite one string is very close to Planck's time constant 5×10^{-44} sec. It is worth to mention that the value of e_k depends upon the medium and hence velocity of light varies with the medium. The important aspect of the present work is to point out that the universal constant, the velocity of light c, is related with other three fundamental constants namely Planck's length, Planck's force and Planck's time.

6. Conclusion

The origin for the electric potential and Coulomb's law has been explained on the basis of self-excitation of strings with the help of "stick-slip" process. It is found that the potential varies exponentially with $\frac{1}{r}$ and it has significant consequences. The present approach has helped to evaluate the permittivity of vacuum and the velocity of light in terms of universal constants in a simple manner.

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