Fundamental Journals
International Journal of Fundamental Physical Sciences (IJFPS)

Original Research Papers
Open Access Journals
ISSN: 2231-8186

IJFPS, Vol 14, No 1, pp 7-13, March, 2024
https://doi.org/10.14331/ijfps.2024.330163

New Classical Relativistic Theory of a Charged Particle in an Electric Field

Grigori.G. Karapetyan

Independent Scientist, Yerevan, Armenia

grigori.g.karapetyan@gmail.com

Received Feb 2024
Received in revised: Feb 2024
Published: March 2024

ABSTRACT

A new relativistic theory of the classical motion of a charged particle in an electric field has been developed. The resulting equations characterize the kinematic and dynamic features of particle motion, demonstrating peculiar behavior in areas with high attractive potentials. This changes the existing paradigm for the interaction of charge with an electric field, entailing profound consequences. The new theory converges with the conventional theory of electricity under conditions of low potentials and nonrelativistic particle velocities. The possibility of experimental verification of the new theory is discussed.

Keywords: Electric interaction, Coulomb potential, Negative Lorentz factor, Dynamic and static electric forces, Kinetic and potential energies

INTRODUCTION

The specific equations and interactions Dirac envisioned were not explicitly stated in this quote, and they could have pertained to his broader quest for a more fundamental theory in physics.
In this context, the new theory of electric interactions presented in our manuscript, which overcomes some problems in conventional electricity theory can be considered an example that we believe aligns with the spirit of such explorations.
We develop a new classical relativistic theory of electric interactions (NTE), to describe the motion of charged particles in an electric field. The theory is grounded in the equations of a scalar theory of gravity, explored in (Andersen & von Baeyer, 1971; Bergmann, 1956).
Subsequent investigations (Bragança & Lemos, 2018; Dowker, 1965; Lindén, 1972; Sexl, 1967; Shapiro & Teukolsky, 1993; Wellner & Sandri, 1964) have delved into the modification and analysis of the properties of scalar theories. However, scalar theories have not emerged as a viable alternative to the general theory of relativity due to its inability to account for space-time curvature. In this regard, we explore the applicability of the equations of the scalar theory of gravity in the realm of electricity theory, where space-time curvature is not taken into account.
NTE must solve the problems faced by the conventional theory of electricity, which arise when describing the behavior of

relativistic charged particle in regions with high potentials exceeding mc^2/e (= 0.51 MV for electron).

One of the problems is that under such a high attractive potential the traditional equations permit the kinetic energy of a particle to surpass its total energy, resulting in inconsistencies with the law of energy conservation. This problem becomes apparent in scenario such as the "electron falling onto a nucleus at $Z > 137$" problem. (Pomeranchuk & Smorodinsky, 1945; Rafelski, Fulcher, & Klein, 1978; Zeldovich & Popov, 1972).

At the atomic scale, this problem is somehow solved by the many-particle concept, which involves the creation of particle-antiparticle pairs in the strong electric field of the nucleus. However, it remains unresolved at the macroscales, where the electric field of charged bodies (which plays the role of nuclei) is many orders of magnitude smaller than the field required for pair production.

Indeed, let us consider the radial motion of a particle with a negative charge e toward a positively charged sphere having charge q. Initially, the particle is at a distance r from the center of the sphere, having potential energy $-eq/r$, kinetic energy K, and total energy (including rest energy mc^2) equal to $E = K - eq/r + mc^2$.

When approaching the sphere, the kinetic energy increases, and the potential energy decreases so that their sum – the total energy of the particle-remains constant. At a distance $r = eq/mc^2$, where the potential energy is $-mc^2$ and the electric field is mc^2/qr, the kinetic energy is equal to the total energy and then exceeds it at closer distances. This field mc^2/qr is negligibly smaller than the field $mc^2/q\lambda_c$ required for pair production (Schwinger, 1951) (λ_c is the Compton wavelength); therefore, a many-particle model of pair production is not applicable here.

Another example involves a particle penetrating a region characterized by a high repulsive potential, referred to as a potential barrier, where its potential energy significantly exceeds its initial total energy ($e\Phi \gg E$).

This scenario represents a quantum mechanical process where the particle's kinetic energy and momentum assume imaginary values, rendering classical motion within the barrier region impossible. However, the conventional relationship between total energy and momentum (Equation 4) allows for such classical motion (as it yields a real value for the particle's momentum at $e\Phi \gg E$), thus leading to a contradiction with the law of energy conservation.

It is unsatisfactory also that in conventional theory the relativistic Lagrangian L, unlike to non-relativistic case is not expressed as difference of kinetic K and potential W energies. It is represented as $L = -(mc^2)/\gamma - W$ (Landau, 2013) (γ is Lorentz factor), which by adding constant term mc^2 becomes $L = K/\gamma - W$. Thus, instead of the kinetic energy K, there is an incomprehensible term K/γ, which does not correspond the meaning of the Lagrange formalism.

Looking ahead, it should be noted that NTE effectively solves these problems. The contradiction in the first example is resolved by the fact that the kinetic energy of a particle in the NTE according to (19) has a maximum possible value equal to half the total energy.

Consequently, it is impossible for the kinetic energy to surpass the total energy in any circumstance. Regarding the second example, the absence of contradiction is attributed to relation (3), affirming that at $e\Phi \gg E$, the particle momentum assumes imaginary values. This excludes the possibility of classical motion of a particle in the barrier region. Regarding the Lagrange formalism: in NTE the usual equation $L = K - W$ is valid in both the non-relativistic and relativistic cases.

Naturally, along with NTE, a new theory of magnetic interactions (NTM) must be developed; together they will form a general new theory of electromagnetic interactions (NTEM).

The foundations of this general theory were laid and studied by V. Mekhitarian in pioneering works (V. J. J. o. C. P. Mekhitarian, 2012, 2018; V. J. Q. M. L. I. Mekhitarian, 2020), where electric and magnetic interactions were considered using both classical and quantum descriptions. However, at present, NTEM is still in its infancy and requires intensive development. In this manuscript, we develop NTE. This requires the formulation of appropriate modifications and additions to the existing equations describing the electric field and its interaction with charged particles.

The foundational hypothesis of the NTEM, introduced in (V. J. J. o. C. P. Mekhitarian, 2018; V. J. Q. M. L. I. Mekhitarian, 2020) posits that the electromagnetic scalar and vector potentials acting a moving particle are Lorentz transformations of the potentials acting on a motionless particle at the same location. The exploration of this hypothesis for electric potential leads to equations, coinciding with those of scalar theory of gravity (Andersen & von Baeyer, 1971; Bergmann, 1956).

These equations describe the interaction of a charged particle with an electric field, noticeably different from the usual interaction. NTE differs from conventional theory at high potentials, comparable to or exceeding mc^2/e. At low potentials and non-relativistic velocities, NTE seamlessly transitions into conventional theory. This article delves into the detailed examination of the NTE.

GENERAL EQUATIONS

The total energy E and generalized momentum **P** of a charged particle in an electromagnetic field in the traditional theory of electromagnetism are determined by the expressions,

$$E = mc^2\gamma + e\Phi \qquad P = mc\gamma\beta + \frac{e}{c}A \tag{1}$$

Here the symbols Φ and **A** denote, respectively, the electric scalar and magnetic vector potentials acting on the particle; m and e are the mass and charge of the particle, $\boldsymbol{\beta} = v/c$, $\gamma = 1/(1-\beta^2)^{1/2}$ is Lorentz factor.

As can be seen from these equations, the action of potentials on a particle does not depend on whether the particle is moving or at rest. However, according to the NTEM, it is presumed that this action depends on the particle speed (V. J. J. o. C. P. Mekhitarian, 2012, 2018; V. J. Q. M. L. I. Mekhitarian, 2020) so that instead of ϕ and $\boldsymbol{A}$ in equations (1), it is necessary to use their Lorentz transformations Φ' and **A**', given by the well-known formulas

$$\Phi' = \gamma(\Phi + \beta A) \qquad A' = \gamma(A_{\parallel} + \beta\Phi) + A_{\perp} \tag{2}$$

where $\mathbf{A}_{\parallel}$ and $\mathbf{A}_{\perp}$ are respectively parallel and perpendicular to the velocity components of the vector potential.

As a result, the NTE equations for the total energy and generalized momentum of a particle in an electrostatic scalar potential ϕ have the form (Andersen & von Baeyer, 1971; Bergmann, 1956; Pomeranchuk & Smorodinsky, 1945; Rafelski et al., 1978; Zeldovich & Popov, 1972).

$$E = mc^2\gamma + e\Phi\gamma \qquad P = \frac{\beta}{c}E \tag{3}$$

Equations (2) determine the components of the electron 4-momentum $P^i = (E/c, \boldsymbol{P})$, the squared modulus of which is

$$\left|P^i\right|^2 = \left(\frac{E}{c}\right)^2 - P^2 = \left(mc + \frac{e\Phi}{c}\right)^2 \tag{4}$$

This equation describes the relationship between energy and momentum in the NTE. It significantly differs from the corresponding well-known conventional relationship (V. J. Q. M. L. I. Mekhitarian, 2020).

$$\left(\frac{E-e\Phi}{c}\right)^2 - P^2 = (mc)^2 \tag{5}$$

Equation (3), together with the expression of momentum in (2), leads to the following equation for the particle velocity in NTE:

$$\beta^2 = \frac{1}{E^2}\left[E^2 - (mc^2 + e\Phi)^2\right] \tag{6}$$

From here the general equation for the one-dimensional motion of a particle in an electrostatic scalar potential ϕ is written as:

$$t(r) = \pm\frac{E}{c}\int\frac{dr}{\sqrt{E^2-(mc^2+e\Phi)^2}} + const \tag{7}$$

RADIAL MOTION IN THE COULOMB ATTRACTING POTENTIAL

To clarify the consequences of the new equations, consider the one-dimensional radial motion of a negatively charged particle in the Coulomb attractive potential $\phi(r) = -q/r$, where $q > 0$ is the positive charge of the center. A brief analysis of this problem is presented in (Karapetyan, 2022).
Substituting the potential $\phi(r) = -q/r$ into (6), we obtain the following equation relating the radial distance r with time t.

$$t(r) = \pm\frac{\varepsilon}{c}\int_{r_0}^{r}\frac{dr}{\sqrt{\varepsilon^2 - \left(1 - \frac{r_c}{r}\right)^2}} \tag{8}$$

Here, $\varepsilon = E/mc^2$, $r_c = |e|q/mc^2$, e is the charge of the particle, and r_0 is the initial distance of the particle from the center at $t = 0$. The parameter r_c plays an important role in the NTE and is called the critical radius. The roots of the denominator in (7) determine the boundaries of accessible intervals of electron motion, where radical is real. There are two roots, r_{min} and r_{max} for $\varepsilon < 1$,, and one root, r_{min} for $\varepsilon > 1$, which are determined by the formulas.

$$r\,\frac{r_c}{1+\varepsilon} \qquad \frac{r_c}{1-\varepsilon}{}_{max}{}_{min} \tag{9}$$

For $\varepsilon < 1$, the electron moves in the interval $r_{min} < r < r_{max}$, and for $\varepsilon > 1$, in the interval $r > r_{min}$. It is convenient to calculate the integral in (7) assuming that initially, the electron is at a minimum distance from the center, i.e. $r_0 = r_{min}$. Then, a positive sign is taken in (7), and the result is the following equation for the radial motion,

$$t(r) = \frac{r_c\varepsilon}{c(1-\varepsilon^2)}\left[\sqrt{\left(\frac{\varepsilon r}{r_c}\right)^2 - \left(1 - \frac{r}{r_c}\right)^2} - \frac{1}{\sqrt{1-\varepsilon^2}}arccos\frac{1-(1-\varepsilon^2)r/r_c}{\varepsilon}\right] \tag{10}$$

For $\varepsilon < 1$, this equation describes the motion as follows (see Fig. 1): The particle, moving toward the center, crosses the critical radius r_c and begins to slow down. At the distance r_{min} it stops and starts moving in the opposite direction.
At a distance r_{max}, it stops again and moves back toward the center. Thus, for $\varepsilon < 1$, the particle performs radial oscillations, which at small energies ($\varepsilon \ll 1$) are close to sinusoidal oscillations (green curve). As ε approaches unity, the amplitude of oscillations increases, and the particle approaches closer to the center (as indicated by the blue curve).
At $\varepsilon > 1$, the particle is not confined within a finite interval and moves to infinity under any initial conditions.
For example, if a particle with $\varepsilon > 1$ moves toward the center, then it slows down when crossing the critical radius, bounces back, reaching the distance r_{min}, and finally goes to infinity (red curve). The larger the energy, the closer the particle approaches the center and then goes to infinity. However, at no energy can the particle reach the center.
This indicates the absence of a physical singularity for a point charge, despite the mathematical singularity of its potential $1/r$.

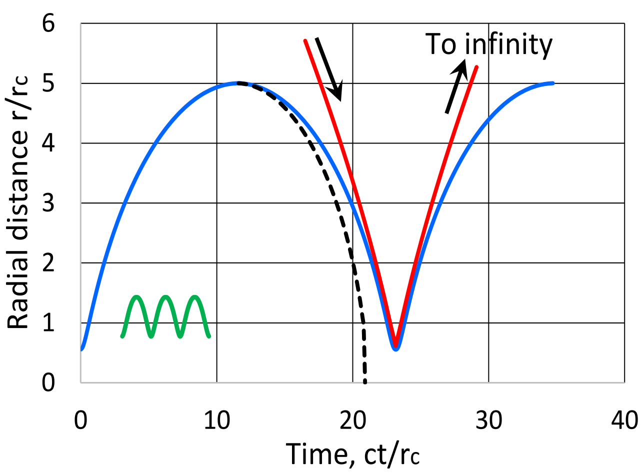

Fig. 1 Trajectories of radial oscillations of a particle at different energies. $\varepsilon = 0.8$ (blue curve), $\varepsilon = 0.3$ (green curve) and $\varepsilon = 1.1$ (red curve). The dashed black curve was computed by the equations of conventional theory. It shows the trajectory of a particle, initially at rest at $t = 0$, which begins to move towards the center from a distance of $5r_c$. The timeline is arbitrarily adjusted for easy viewing.

From eq (7) it is seen that the denominator in the integrand equals ε on the critical radius (at $r = r_c$), which leads to particle velocity $v = dr/dt$ to equal speed of light c, on the critical radius r_c and consequently to the divergence of Lorentz factor γ there. This problem arises from the presentation of a particle as a point charge. However, this divergence is not essential, and it eliminates when considering a small size of a particle.

Then the denominator in (7) becomes somewhat less than ε at the critical radius, which leads to a value of the velocity less than c and a finite value of the Lorentz factor at the critical radius. The smaller the assumed size of the particle, the closer the particle speed to c at the critical radius and the greater the Lorentz factor there. However, it does not lead to any contradictions with the observable characteristic of the particle-its kinetic energy.

As will be shown below, the kinetic energy of a particle is a finite continuous function of coordinate, having the value $E/2$ at the critical radius, regardless of the assumed negligible small size of the particle.

The critical radius defines the boundary separating two regions: the region where $mc^2 + e\Phi < 0$, which we call the anomalous region, and the region where $mc^2 + e\Phi > 0$, called the normal region. For the Coulomb central field, these regions are $r < r_c$ and $r > r_c$, respectively, and the boundary separating them is the sphere $r = r_c$.

When a particle crosses this boundary, the quantity $mc^2 + e\Phi$ changes sign. Since the total energy of the particle (equation 2) is conserved throughout the motion, it follows that the Lorentz factor must also change sign when crossing the boundary. Consequently, the Lorentz factor in the NTE is defined as

$$\gamma = \begin{cases} \dfrac{1}{\sqrt{1-\beta^2}} & \text{in the normal region (where } mc^2 + e\Phi > 0) \\ -\dfrac{1}{\sqrt{1-\beta^2}} & \text{in anomalous region (where } mc^2 + e\Phi < 0) \end{cases} \qquad (11)$$

and the total energy is always positive. The cause of radial oscillations is the repulsive force acting on the particle in the anomalous region (at $r < r_c$). Differentiating equation (3) with respect to time and using (2), we obtain the following expression for the force $f(r)$ acting on a moving particle

$$f(r) = \left(\frac{dP}{dt}\right) = -\left(\frac{mc^2}{E}\right)\frac{d}{dr}\left[e\Phi + \frac{(e\Phi)^2}{2mc^2}\right] = \frac{1}{\varepsilon}\left(-\frac{eq}{r^2} + \frac{eqr_c}{r^3}\right) \qquad (12)$$

From this equation, it is seen that the force (11) consists of two components, which depend differently on the distance to the center and are directed differently.

The first force is inversely proportional to the square of the distance; it is negative, i.e., attractive. The second force is inversely proportional to the cube of the distance and, being positive, is repulsive.

These two forces have similar magnitudes near the critical radius and balance each other at the critical radius (at $r = r_c$). In total, the force $f(r)$ is negative, i.e., attractive, in the normal region ($r > r_c$) and positive, i.e., repulsive, in the anomalous region ($r < r_c$). As a result, unusual dynamics of particle motion appear in and around the anomalous region. Note the formal similarity of (11) with the force of interatomic interaction in diatomic molecules (Kratzer, 1920; Macke, 1959).

We call the force $f(r)$ the “dynamic force” because it acts on a moving particle. Like the potential acting on a moving particle, the dynamic force also depends on the particle speed, although this dependence is not clearly visible in equation (11). Indeed, for a given energy ε, there is a single value of velocity for each r in equation (11), indicating that the dynamic force $f(r) = f(r(\beta))$ is a single-valued function of velocity.

The dynamic force should be distinguished from the static force $F(r)$ acting on a motionless particle.

The static force acts on the particle at the boundaries of the interval of radial oscillations r_{min} and r_{max}, where the speed of the particle is zero; therefore, $F(r_{min}) = f(r_{min})$ and $F(r_{max}) = f(r_{max})$. Taking this circumstance into account, the general equation for the static force $F(r)$ is derived from eqs (11), and (8) and has the form

$$F(r) = \begin{cases} -\dfrac{eq}{r^2} & \text{if} \quad r > \dfrac{eq}{mc^2} \\ \dfrac{eq}{r^2} & \text{if} \quad r < \dfrac{eq}{mc^2} \end{cases} \qquad (13)$$

The obtained formula describes the force, acting on a motionless particle in the attractive central Coulomb potential. The magnitude of the force (12) everywhere coincides with the Coulomb force, but in the anomalous region $r < r_c$ the force (12) acts in the opposite direction. At point r_c, the static force (12) is undefined, having a discontinuity of the first kind.

This occurs because the particle is represented as a point charge. For an assumed small particle size δ, the values of the force $F(r)$ are equal to $-eq/r^2$ for $r = r_c + \delta$ and eq/r^2 for $r = r_c - \delta$.

By combining these values, we can represent the force $F(r)$ as a continuous function, varying in the vicinity of r_c from $F(r) = -eq/r^2$ at $r = r_c + \delta$ to $F(r) = eq/r^2$ at $r = r_c - \delta$. Figure 2 shows graphs of the dynamic and static forces plotted using equations (11) and (12).

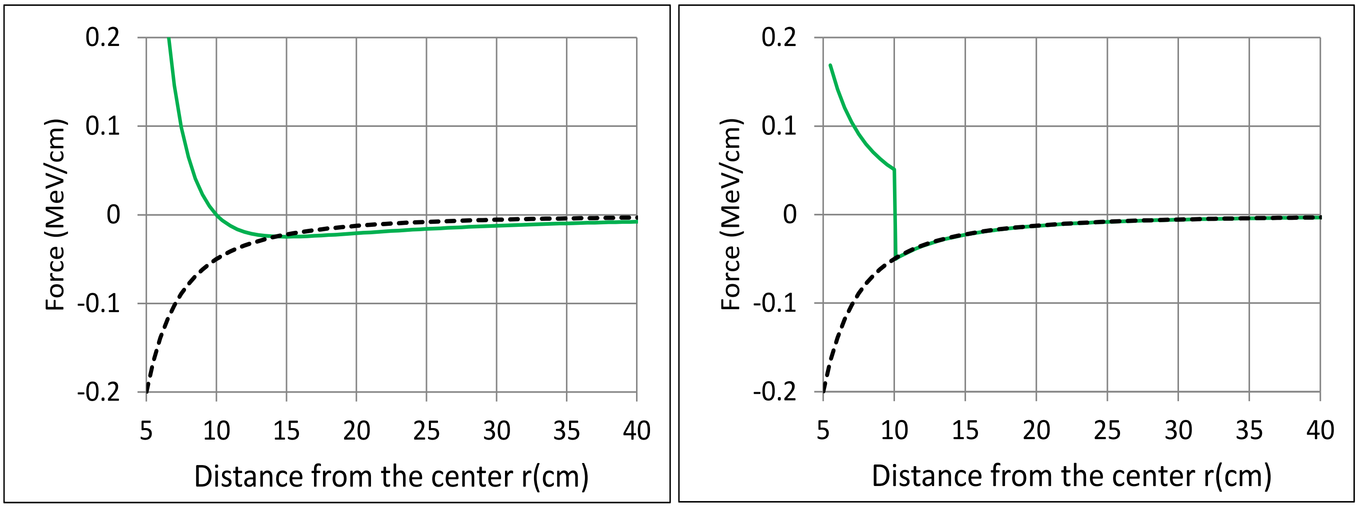

Fig. 2. The left panel shows the dynamic force f(r), and the right panel shows the static force F(r), calculated using formulas (11) and (12). Both forces are attractive (negative) at $r > r_c$, and repulsive (positive) at $r < r_c$. The dashed lines show the Coulomb force $-eq/r^2$. $\varepsilon = 0.3$, $r_c = 10\ cm$.

Let us now consider the energetic characteristics. The potential energy of a motionless particle, denoted as $W(r)$, can be determined by taking into account that at the boundaries of the motion interval r_{min} and r_{max} the particle velocity is zero. Therefore, the potential energy at these points is equal to the total energy minus the rest energy. Using the formula $\varepsilon = r_c/r_{min} - 1$ from (8), we obtain the following equation for the potential energy of a motionless particle in the anomalous region $r < r_c$:

$$W(r) = mc^2\frac{r_c}{r} = \frac{eq}{r} \qquad \text{at } r < r_c \tag{14}$$

This formula can also be obtained by integrating the static force (12) over the coordinate.

Similarly, using $\varepsilon = 1 - r_c/r_{max}$ from equation (8), one can obtain the potential energy in the normal region $r > r_c$. Thus, the general formula for the potential energy of a motionless particle is,

$$W(r) = \begin{cases} -\dfrac{eq}{r} & \text{at } r > \dfrac{eq}{mc^2} \\ \dfrac{eq}{r} - 2mc^2 & \text{at } r < \dfrac{eq}{mc^2} \end{cases} \tag{15}$$

This formula significantly differs from the well-known Coulomb potential energy formula

$$W(r) = -\frac{eq}{r} \tag{16}$$

which implies that potential energy can have arbitrarily large negative values at small distances from the attracting center. In contrast, the new formula (14) shows that the minimum potential energy of a motionless particle is $-mc^2$, which is achieved at a distance eq/mc^2 from the attracting center. At smaller distances, the potential energy increases rather than decreases (see Fig. 3).

Let us now calculate the potential energy of a moving particle, denoted $V(r)$. By integrating the dynamic force (11) over the coordinate, we can represent the potential energy of a moving particle as

$$V(r) = \frac{mc^2}{E}\left(e\Phi + \frac{e^2\Phi^2}{2mc^2}\right) + const \tag{17}$$

This unusual expression for the potential energy of a moving particle includes a positive quadratic term, which is significant at high potentials and is responsible for the repulsive force in attractive potentials.

The unknown constant is found from the condition that the potential energy is equal to $E/2$ at the boundary between the normal and anomalous regions (i.e., at $e\Phi = -mc^2$). Taking this into account, the following expression for *const* is obtained as

$$const = \frac{(E - mc^2)^2}{2E} \tag{18}$$

Therefore, the general equation of the potential energy of a moving particle is determined by eqs (16), and (17). In the Coulomb attracting central potential, the potential energy of the particle is

$$V(r) = \frac{mc^2}{E}\left(-\frac{eq}{r} + \frac{e^2q^2}{2mc^2r^2}\right) + \frac{(E - mc^2)^2}{2E} \tag{19}$$

At the critical radius $r = r_c$, the potential energy reaches its minimum value $V(r_c) = E/2 - mc^2$. It is important to note that the potential energy (17) tends to zero at infinity, coinciding with the conventional expression (15) only at energy $E = mc^2$, because only at this energy does the particle achieve zero speed at infinity.

If the particle energy E exceeds mc^2, then the speed of the particle, moving to infinity does not tend to zero. Consequently, its potential energy at infinity, which depends on the speed, also does not tend to zero, which is reflected in (17). Subtracting the potential energy and rest energy from the total energy, we obtain the kinetic energy $K(r)$ as a function of the coordinate

$$K(r) = -\frac{mc^2}{E}\left(-\frac{eq}{r} + \frac{e^2q^2}{2mc^2r^2}\right) + \frac{E^2 - (mc^2)^2}{2E} \tag{20}$$

Kinetic energy, like potential energy, is a continuous finite function that reaches its maximum value $E/2$ at the critical radius $r = r_c$. Using equation (5), we can transform eq (18) and represent the kinetic energy of a particle as a function of its speed

$$K = \frac{E\beta^2}{2} \tag{21}$$

This nice formula shows that the kinetic energy is always less than half the total energy. This important circumstance resolves the paradox of excess of kinetic energy over total energy in conventional theory, as discussed in the Introduction. In the absence of potential, the kinetic energy of a free particle is equal to

$$K = \frac{mc^2\gamma\beta^2}{2} \tag{22}$$

which in ultra-relativistic limit tends to half the total energy (the other half is provided by potential energy).
At $\beta \ll 1$ the kinetic energy tends to the usual non-relativistic expression $\sim mc^2\beta^2/2$. Figure 3 shows graphs of the potential and kinetic energies calculated using equations (17) and (18),

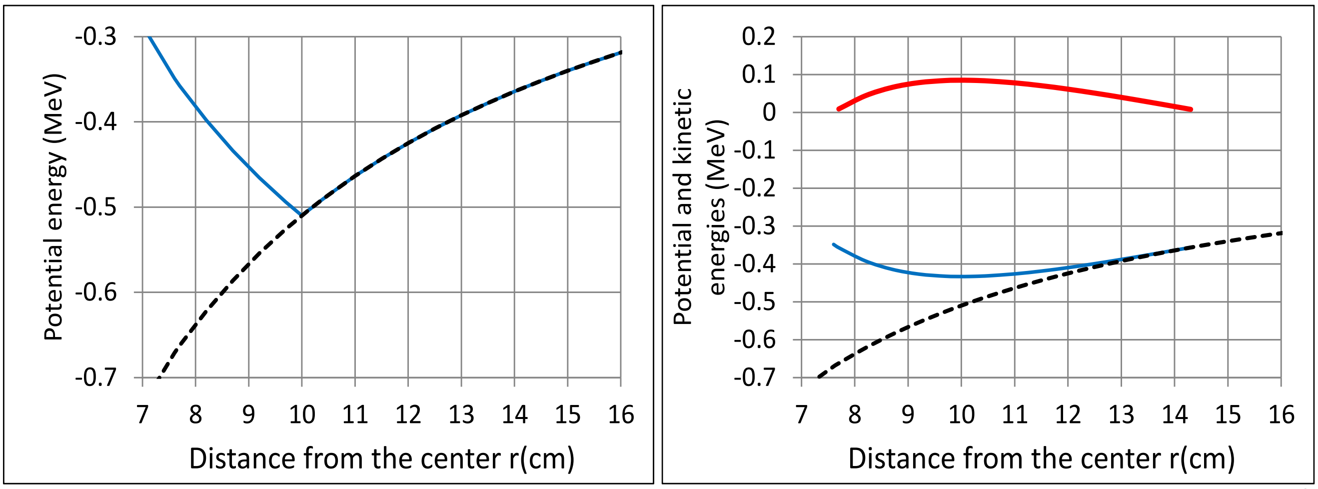

Fig. 3. Left panel: potential energy of a motionless particle W, calculated using formula (14). Minimum value of W is $-mc^2 = -0.51\ MeV$. Right panel: potential energy V (blue curve) and kinetic energy K (red curve) of a moving particle, calculated using the formulas (17) and (18). Minimum value of V is $E/2 - mc^2 - 0.43\ MeV$, maximum value of kinetic energy is $E/2 = 0.75\ MeV$. The dotted lines show the Coulomb potential energy (15). E/mc^2 = 0.3, $r_c = 10\ cm$.

CONCLUSIONS

In this paper, we have introduced a new relativistic theory aimed at describing the behavior of charged particles in electric fields. By presenting novel equations governing particle kinematics and dynamics, we have provided insights into particle behavior in regions characterized by high potentials. The results obtained challenge and extend our current understanding of electrical interactions.
The resolution of certain difficulties encountered in conventional theory, as discussed in the Introduction, suggests the potential validity of our theory. However, the ultimate determination of the correctness of the NTE can only be achieved through experimentation. Laboratory experiments involving electrons pose no fundamental obstacles and can be conducted on a macroscopic scale at potentials of approximately megavolts. For instance, considering a conducting sphere with radius R and potential U, the critical radius $r_c = eUR/mc^2$ is $r_c/R = U/0.51$ (with U measured in MV).
Thus, the anomalous region (and the associated repulsive force) around the sphere arises when the sphere's potential exceeds 0.51 MV. Conversely, when the potential drops below 0.51 MV, the critical radius r_c becomes smaller than the sphere's radius R, and the anomalous region and repulsive force disappear.
Hence, at $U > 0.51MV$, a beam of electrons directed towards a positively charged sphere may repel and deflect without reaching the sphere (see Fig.4). The observation of such behavior would validate the existence of the repulsive force and the correctness of the NTE.

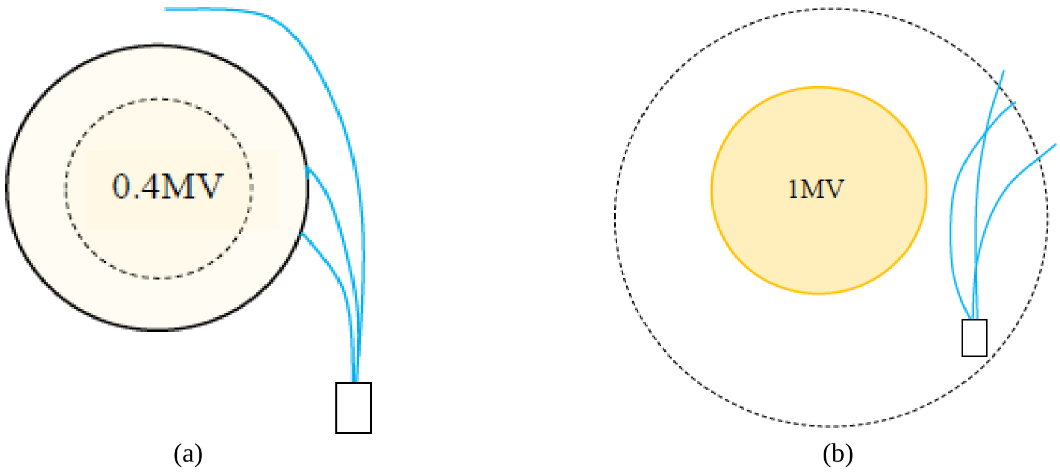

Fig.4. Sketch of an experimental setup for detecting repulsive force.

Solid circles represent a conducting sphere, charged to potential 0.4 MV in the left panel and to potential 1 MV in the right panel, dotted lines show a spherical surface with a radius equal to critical radius r_c. The electrons are emitted by an electron gun (shown by solid rectangle).

Blue lines show electron trajectories. In the left panel (a) the critical radius is less than the radius of the sphere and so has no any physical meaning. The electrons experience attracting force and fall towards the sphere. In the right panel (b) the critical radius is greater than the radius of the sphere. It defines a spherical surface $(r = r_c)$, which is the boundary between the normal $(r > r_c)$ and anomalous $(r < r_c)$ regions. The electrons experience a repulsing force in anomalous region and are deflected away from the sphere. It is important to note that, like the traditional theory of electricity, our theory does not account for particle spin. Therefore, the NTE assumes spinless particles and cannot formally be applied to electrons. However, the issue of the applicability of the NTE to electrons cannot be definitively resolved a priori and necessitates experimental validation. Consequently, experimental studies are essential to confirm the NTE's validity for both spinless particles and electrons. In the event that experiments with electrons do not corroborate the NTE, subsequent experiments involving spinless particles, such as alpha particles, will be required. Conducting macroscopic experiments of this nature presents significant challenges, as the critical radii when using alpha particles will be approximately 7200 times (which is the ratio of alpha particle and electron rest masses) smaller than when using electrons.

REFERENCES

Andersen, C., & von Baeyer, H. C. J. A. o. P. (1971). On classical scalar field theories and the relativistic Kepler problem. *62*(1), 120-134.

Bergmann, O. J. A. J. o. P. (1956). Scalar field theory as a theory of gravitation. I. *24*(1), 38-42.

Bragança, D. P., & Lemos, J. P. J. T. E. P. J. C. (2018). Stratified scalar field theories of gravitation with self-energy term and effective particle Lagrangian. *78*, 1-11.

Dowker, J. J. P. o. t. P. S. (1965). A scalar theory of gravitation. *85*(3), 595.

Karapetyan, G. G. J. O. P. (2022). Radial oscillations of an electron in a Coulomb attracting field. *20*(1), 1213-1215.

Kratzer, A. J. Z. f. P. (1920). Die ultraroten rotationsspektren der halogenwasserstoffe. *3*, 289-307.

Landau, L. D. (2013). *The classical theory of fields* (Vol. 2): Elsevier.

Lindén, T. J. I. J. o. T. P. (1972). A scalar field theory of gravitation. *5*, 359-368.

Macke, W. J. Z. A. M. u. M. (1959). LD Landau and EM Lifshitz, Quantum Mechanics, Non-Relativistic Theory. Volume 3 of a Course of Theoretical Physics. Authorized Translation from the Russian by JB Sykes and JS Bell. XII+ 515 S. m. 51 Abb. London-Paris 1958. Pergamon Press. Preis geb. 80,—s. *39*(5-6), 250-250.

Mekhitarian, V. J. J. o. C. P. (2012). The invariant representation of generalized momentum. *47*, 249-256.

Mekhitarian, V. J. J. o. C. P. (2018). Equations of relativistic and quantum mechanics and exact solutions of some problems. *53*, 1-21.

Mekhitarian, V. J. Q. M. L. I. (2020). Equations of relativistic and quantum mechanics (without spin). 107-137.

Pomeranchuk, I., & Smorodinsky, Y. J. J. P. U. (1945). On the energy levels of systems with Z> 137. *9*(2), 97-100.

Rafelski, J., Fulcher, L. P., & Klein, A. J. P. R. (1978). Fermions and bosons interacting with arbitrarily strong external fields. *38*(5), 227-361.

Schwinger, J. J. P. R. (1951). On gauge invariance and vacuum polarization. *82*(5), 664.

Sexl, R. U. J. F. d. P. (1967). Theories of gravitation. *15*(4), 269-307.

Shapiro, S. L., & Teukolsky, S. A. J. P. R. D. (1993). Scalar gravitation: A laboratory for numerical relativity. *47*(4), 1529.

Wellner, M., & Sandri, G. J. A. J. o. P. (1964). Scalar gravitation. *32*(1), 36-39.

Zeldovich, Y. B., & Popov, V. S. J. S. P. U. (1972). Electronic structure of superheavy atoms. *14*(6), 673.