The Hypothesis of a New Fundamental Physical Constant (the Electric Potential Limit Constant) and the Outline of Its Theoretical Exploration

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Abstract

This article reviews the preprints of the author's two papers: The Theory of Electrodynamic Space-Time Relativity[1] and Discussion on the Covariant Relationship between the Theory of Electric Potential Relativity and Maxwell's Equations[2].

Numerous experimental observations indicate that fundamental charges are quantized. Therefore, the point charge model is widely used in fundamental physical theories such as electromagnetism and quantum field theory and has succeeded dramatically. However, electromagnetic theory calculations indicate that the energy of point charges diverges, a phenomenon considered a long-standing fundamental challenge in physics.

The author proposes the hypothesis of a new fundamental physical constant - the electric potential limit constant. If this assumption holds, the authors discuss the basis for solving the problem of point charge electric field energy divergence. In addition, the paper also proposes that the electric potential limit constant may be a fundamental physical constant as important as the speed of light and Planck's constant and may extend Maxwell's equations and modern space-time theory. The authors performed theoretical derivation, including the derivation of the new Maxwell equations. Within the framework of this new electromagnetism, the problem of infinite energy of point charges was thoroughly solved, and new physical effects were predicted for experimental verification.

1. The Energy of a Point Charge is Divergent

According to electromagnetic theory calculations, the electric field energy of a point charge is infinite. There are further difficulties without using the point charge model. This is a difficulty that electromagnetism itself cannot overcome.

Classical electromagnetism (potential limit is infinity)

- Point charge potential equation:

$\phi = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$, $r \to 0$, $\phi \to \infty$

- Electric field strength equation for point charge:

$E = -\frac{d\phi}{dr} = \frac{q}{4\varepsilon_0 r^2}$, $r \to 0, E \to \infty$

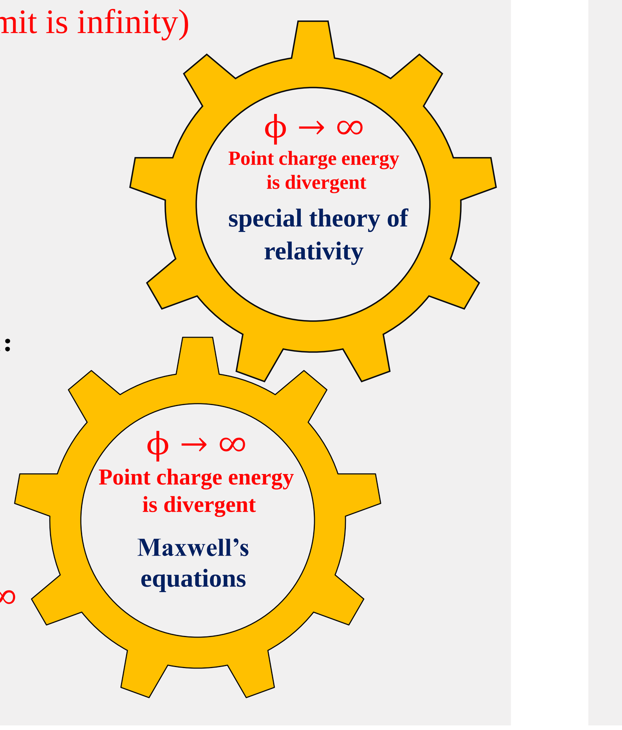
- Electric field energy density equation:

$w_e = \frac{1}{2}\varepsilon_0 E^2$, $r \to 0, w_e \to \infty$

- The point charge energy:

$E_e = \iiint_0^\infty \frac{1}{2}\varepsilon_0 E^2\, dv$

$= \int_0^\infty \frac{q^2}{8\pi\varepsilon_0 r^2} dr = \left[-\frac{q^2}{8\pi\varepsilon_0 r}\right]_0^\infty \to \infty$



2. Hypothesis of the Electric Potential Limit Constant

The point electric charge energy divergence is a fundamental challenge in electromagnetism. To address this, the author proposes the hypothesis of a potential limit constant. This hypothesis explains how the existence of a potential limit constant can resolve the issue of point charge energy divergence. However, this requires the development of Maxwell's equations and the special theory of relativity.

New electromagnetism (there is electric potential limit constant Φ_0):

- Point charge potential equation:

$\phi = f(r)$, $r \to 0$, $\phi \to \Phi_0$

- Electric field strength equation for a point charge:

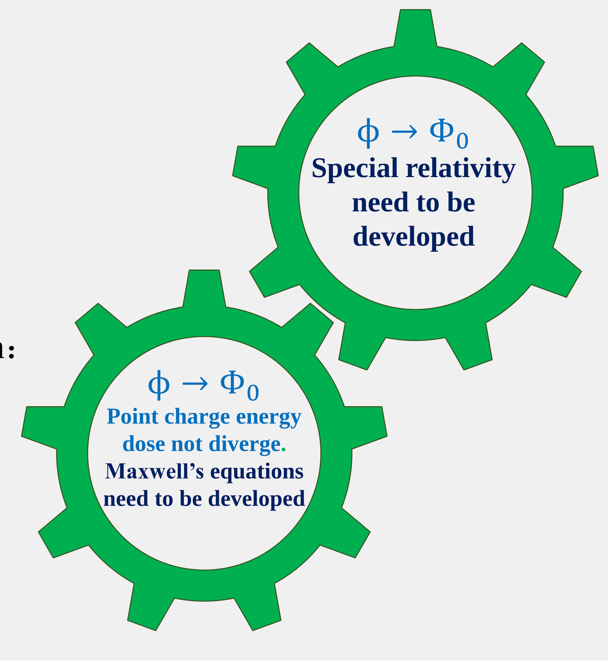
$E = -\frac{df(r)}{dr}$, $r \to 0, E \to 0$

- Electric field energy density equation:

$w_e = \frac{1}{2}\varepsilon_0 E^2$, $r \to 0, w_e \to 0$

- The point charge energy:

$E_e = \iiint_0^\infty \frac{1}{2}\varepsilon_0 E^2\, dv = constant$



Two basic assumptions of special relativity:

(1)Principle of relativity of motion: The laws of physics have the same form in any inertial system.

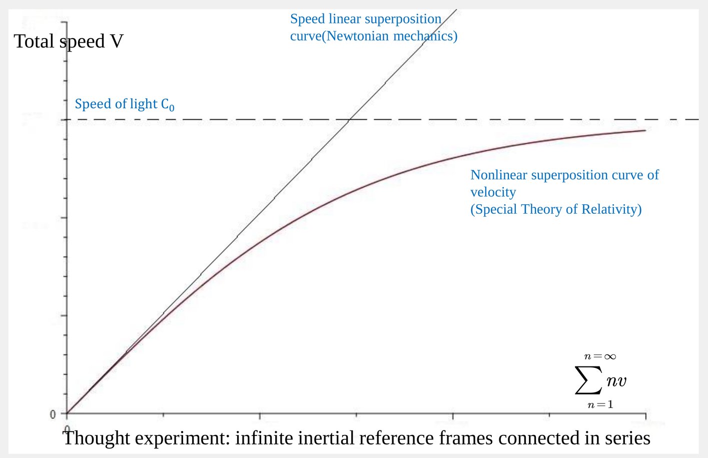
(2) Assumption of constant speed of light: In any inertial system, the speed of light in a vacuum is constant.

- The Lorentz transformation can be obtained:

$X' = \gamma(X - V_x t)$

$t' = \gamma\left(t - \frac{V_x}{C_0^2}X\right)$

$\gamma = \frac{1}{\sqrt{1-\frac{V_x^2}{C_0^2}}}$

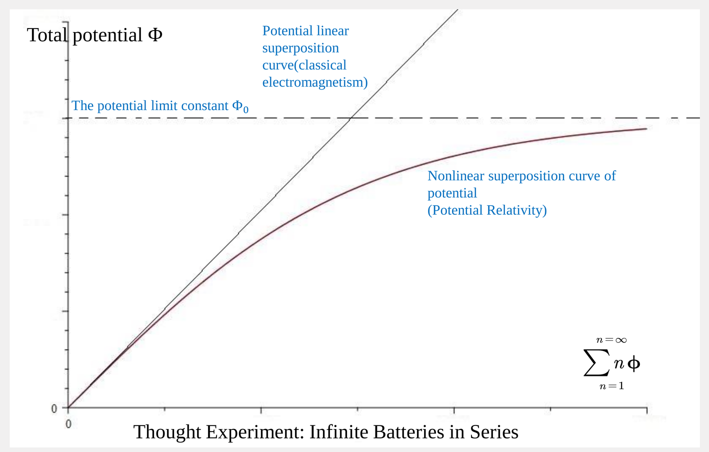


If there is the potential limit constant Φ_0 , the basic assumption of the potential reference system is:

(3) Principle of relative potential: physical laws have the same form in any equipotential reference system;

(4) Assumption of constant potential limit: There is a limit constant for potential, and in any equipotential stationary reference frame in vacuum, this potential limit is a same constant Φ_0;

Comparison found that: The basic assumptions (1) (2) of the inertial reference system and the basic assumptions (3)(4)of the potential reference system are in the same form. At the same time, the shape of the velocity superposition curve is the same as that of the potential superposition curve. There are various indications that there is potential relativity.



3. The Theory of Electrodynamic Space — Time Relativity[1]

3.1 The Theory of Complex Electrodynamic Space-Time Relativity

Therefore, there should be a correspondence between the potential and the imaginary speed. That is, the potential ϕ is equivalent to the imaginary speed $V_\phi i$. The limit potential Φ_0 should also be equivalent to the imaginary speed limit C_0 :

$V_\phi i = K\phi$

$C_0 i = K\Phi_0$

Among them, the imaginary factor $i = \sqrt{-1}$. It can be obtained from the equation:

$K = \frac{C_0}{\Phi_0} i$

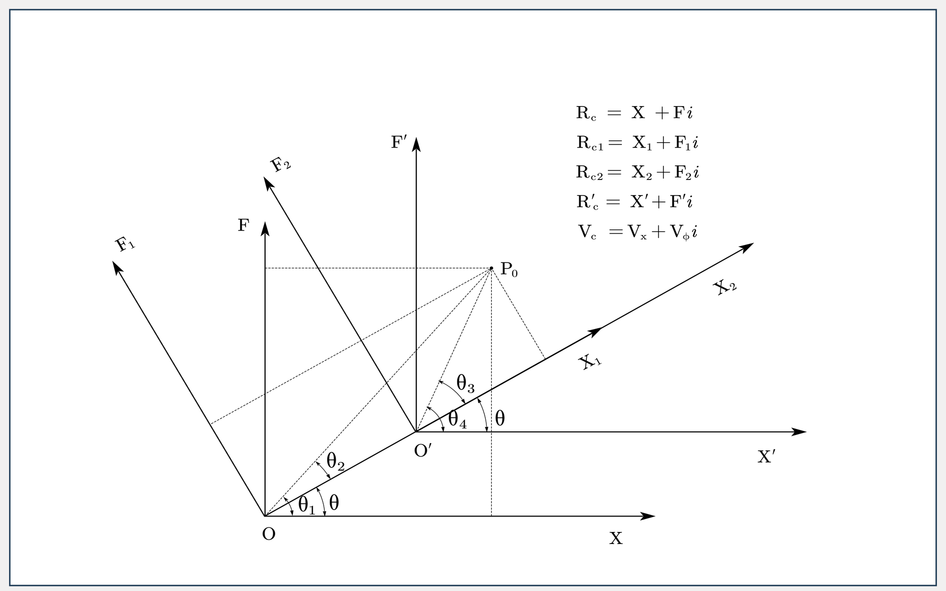
$V_c = V_x + V_\phi i$

Physically, it corresponds to a frame of reference that has both real velocity and potential. It is equivalent to a carriage that is both moving and electrified. Therefore, basic assumptions can be proposed:

(5) Complex electrodynamic space-time relativity principle: the laws of physics have the same form in any complex electrodynamic inertial frame of reference;

(6) The assumption of the spatiotemporal limit of complex electrodynamics: In any complex electrodynamic inertial frame of reference, the limit of the modulus of the complex velocity at any point in the vacuum is a constant C_0, or the limit of the modulus of its complex potential is a constant Φ_0.

Among them, C_0 is the speed of light in the Vacuum with zero potential, C_0 =299,792,458meters/second. The value of the limit Φ_0 of the mode of the complex potential will be finally determined by experiments.



Obtained through the rotation and translation transformation of the coordinate system:

3.1.1 The fundamental equation of The Theory of Complex Electrodynamic Space-Time Relativity expressed in system times t_c and t_c' is as simple as the equation of Galileo transformation:

$R_c' = R_c - V_c t_c$

$t_c' = t_c$

Where, $t_c = (1-\frac{1}{\gamma})\frac{C_0^2}{|V_c|^2}(t+t')$

3.1.2 The fundamental equation of The Theory of Complex Electrodynamic Space-Time Relativity expressed in reference frame times t and t' is:

$R_c' = R_c - \frac{V_c}{|V_c|}((1-\gamma)X_1 + |V_c|\gamma t)$

$t' = \gamma\left(t - \frac{|V_c|}{C_0^2}X_1\right)$

Where, $\gamma = \frac{1}{\sqrt{1-\frac{|V_c|^2}{C_0^2}}}$

$X_1 = \frac{1}{|V_c|}(XV_x + FV_\phi)$

3.1.3 Let $V_\phi = 0$, and $V_x > 0$, then there is the special theory of relativity:

$X' = \gamma(X - V_x t)$

$F' = F$

$t' = \gamma\left(t - \frac{V_x}{C_0^2}X\right)$

$\gamma = \frac{1}{\sqrt{1-\frac{V_x^2}{C_0^2}}}$

3.1.4 Let $V_x = 0$, and $V_\phi > 0$, then there is a form that is symmetrical with the special theory of relativity, that is, the potential relativity theory:

$F'i = \gamma\left(Fi - \frac{C_0}{\Phi_0}\phi i t\right)$

$X' = X$

$t' = \gamma\left(t - \frac{\phi}{\Phi_0 C_0}F\right)$

$\gamma = \frac{1}{\sqrt{1-\frac{\phi^2}{\Phi_0^2}}}$

3.2 The special the Theory of Biquaternion Electrodynamic Space-Time Relativity

In mathematics, it is a special form of biquaternion. Physically it is a five-dimensional space-time (4 dimensions of space + 1 dimension of time). Extend the concepts of complex velocity and complex distance to the concept of biquaternion velocity and biquaternion displacement. Establish the inertial reference frame of the biquaternion. Further establish the basic assumptions of the quaternion reference system. And derive the basic assumptions of quaternion electrodynamic space-time relativity.

$R_q = Fi + \mathbf{r} = Fi + X\mathbf{i} + Y\mathbf{j} + Z\mathbf{k}$

$R'_q = F'i + \mathbf{r}' = F'i + X'\mathbf{i} + Y'\mathbf{j} + Z'\mathbf{k}$

$V_q = V_\phi i + \mathbf{V_r} = V_\phi i + V_x\mathbf{i} + V_y\mathbf{j} + V_z\mathbf{k}$

$||V_q|| = \sqrt{V_\phi^2 + V_r^2} = \sqrt{V_\phi^2 + V_x^2 + V_y^2 + V_z^2}$

3.2.1 The fundamental equations of the special TBESTR are described by system times t_q and t_q' can be obtained:

$R_q' = R_q - V_q t_q$

$t_q' = t_q$

$t_q = (1-\frac{1}{\gamma})\frac{C_0^2}{||V_q||^2}(t+t')$

3.2.2 The fundamental equations of the special TBESTR are described by reference frames t and t' can be obtained:

$R_q' = R_q - \frac{V_q}{||V_q||}((1-\gamma)r_1 + ||V_q||\gamma t)$

$t' = \gamma\left(t - \frac{||V_q||}{C_0^2}r_1\right)$

$r_1 = \frac{1}{||V_q||}(FV_\phi + XV_X + YV_Y + ZV_Z)$

where: $\gamma = \frac{1}{\sqrt{1-\frac{||V_q||^2}{C_0^2}}}$

3.2.3 When $V_\phi = 0$, then $||V_q|| = |\mathbf{V_r}|$, $R_q = \mathbf{r}$, $R_q' = \mathbf{r}'$, $V_q = \mathbf{V_r}$:

$r_1 = \frac{\mathbf{r}\cdot\mathbf{V_r}}{|\mathbf{V_r}|}$

The special theory of relativity in any direction $\mathbf{r}(x, y, z)$ in three-dimensional space can be obtained :

$\mathbf{r}' = \mathbf{r} - \frac{\mathbf{V_r}}{|\mathbf{V_r}|}\left((1-\gamma)\frac{\mathbf{r}\cdot\mathbf{V_r}}{|\mathbf{V_r}|} + |\mathbf{V_r}|\gamma t\right)$

$t' = \gamma\left(t - \frac{\mathbf{r}\cdot\mathbf{V_r}}{C_0^2}\right)$

where, $\gamma = \frac{1}{\sqrt{1-\frac{|\mathbf{V_r}|^2}{C_0^2}}}$

3.2.4 When $\mathbf{V_r} = 0$, there is Potential time dilation effect:

$\Delta t' = \frac{1}{\sqrt{1-\frac{\phi^2}{\Phi_0^2}}}\Delta t$

The potential limit constant:

$\Phi_0 = \frac{\phi}{\sqrt{1-\frac{\Delta t^2}{\Delta t'^2}}}$

3.3 The Complete the Theory of Biquaternion Electrodynamic Space-Time Relativity

Fundamental postulates of The Theory of Biquaternion Electrodynamic Space-Time Relativity:

(7) The principle of relativity in biquaternion electrodynamic space-time: physical laws have the same form in any biquaternion electrodynamic inertial reference system.

(8) The postulate of biquaternion electrodynamic space-time limit: in any biquaternion electrodynamic inertial reference system, the limit of biquaternion velocity state's norm-modulus of any point in the vacuum is the same constant C_0; or the limit of biquaternion electric potential state's norm-modulus of any point is the same constant Φ_0.

Where C_0 is the speed of light in a vacuum with zero electric potential, equaling 299,792,458 m/sec. Φ_0 can only be determined by experiment.

$R_Q = (F_1 + F_2 i) + (X_1 + X_2 i)\mathbf{i} + (Y_1 + Y_2 i)\mathbf{j} + (Z_1 + Z_2 i)\mathbf{k}$

$R'_Q = (F'_1 + F'_2 i) + (X'_1 + X'_2 i)\mathbf{i} + (Y'_1 + Y'_2 i)\mathbf{j} + (Z'_1 + Z'_2 i)\mathbf{k}$

$V_Q = (V_{\phi1} + V_{\phi2} i) + (V_{x1} + V_{x2} i)\mathbf{i} + (V_{y1} + V_{y2} i)\mathbf{j} + (V_{z1} + V_{z2} i)\mathbf{k}$

$||V_Q|| = \sqrt{V_\phi^2 + V_r^2} = \sqrt{V_{\phi1}^2 + V_{\phi2}^2 + V_{x1}^2 + V_{x2}^2 + V_{y1}^2 + V_{y2}^2 + V_{z1}^2 + V_{z2}^2}$

$R_Q \cdot_{ar} V_Q = F_1 V_{\phi1} + F_2 V_{\phi2} + X_1 V_{X1} + X_2 V_{X2} + Y_1 V_{y1} + Y_2 V_{y2} + Z_1 V_{Z1} + Z_2 V_{Z2}$

The fundamental equations of the complete TBESTR described by the system times t_Q and t_Q':

$R_Q' = R_Q - V_Q t_Q$

$t_Q' = t_Q$

$t_Q = (1-\frac{1}{\gamma})\frac{C_0^2}{||V_Q||^2}(t+t')$

The fundamental equations of the complete TBESTR described reference frames time t and t':

$R_Q' = R_Q - \frac{V_Q}{||V_Q||}\left((1-\gamma)\frac{R_Q \cdot_{ar} V_Q}{||V_Q||} + ||V_Q||\gamma t\right)$

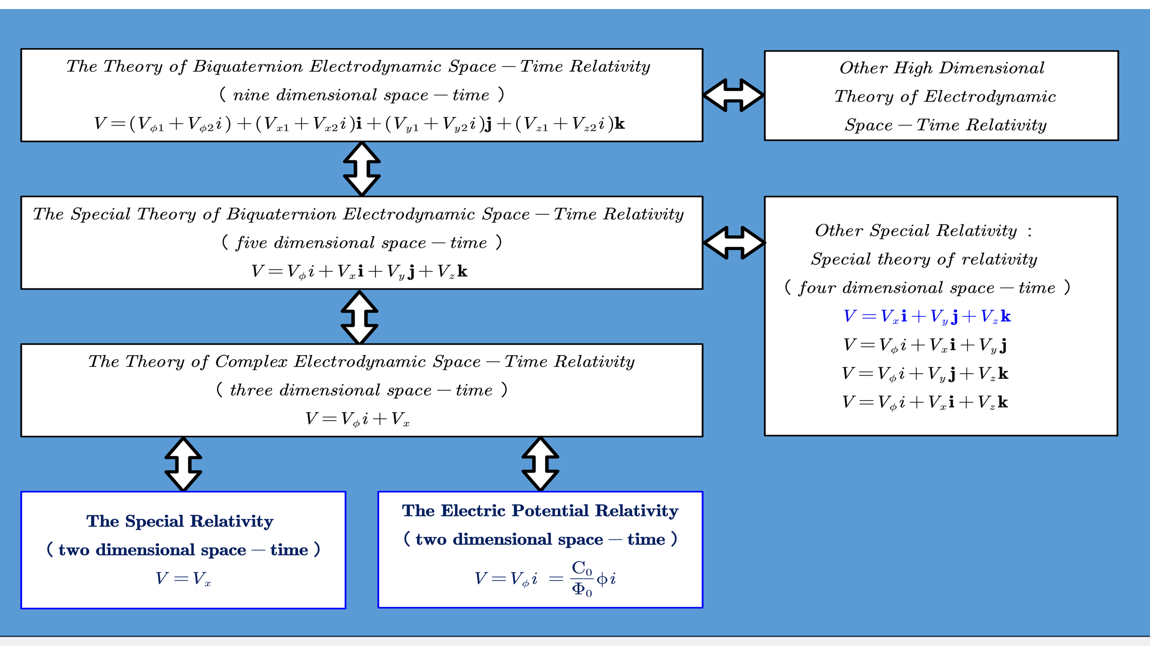
$t' = \gamma\left(t - \frac{R_Q \cdot_{ar} V_Q}{C_0^2}\right)$

$\gamma = \frac{1}{\sqrt{1-\frac{||V_Q||^2}{C_0^2}}}$

Verification of the theory

$F_1'^2 + F_2'^2 + X_1'^2 + X_2'^2 + Y_1'^2 + Y_2'^2 + Z_1'^2 + Z_2'^2 - C_0^2 t'^2$
$= F_1^2 + F_2^2 + X_1^2 + X_2^2 + Y_1^2 + Y_2^2 + Z_1^2 + Z_2^2 - C_0^2 t^2$

- The conclusion is that the equation is established above (the detailed proof process in Appendix A of the paper[1]). That is, the theory of electrodynamic space-time relativity is theoretically self-consistent.



4. New Maxwell's Equations[2]

The theory of electrodynamic space-time relativity predicts the existence of a symmetrical theory to special relativity: the theory of electric potential relativity. this section discusses the covariant relationship between the theory of electric potential relativity and Maxwell's equations. The author derived the modified Maxwell's equations.

The new Maxwell Equations contains the electric potential limit constant. The functional relationship between the electric potential limit constant and physical quantities was also obtained.

New Maxwell's Equations also predicts many new physical effects, such as electric potential lensing and electric potential redshift effects. They provide a theoretical basis for experimentally testing new theories.

Calculate the electric field energy of the point charge according to the modified Maxwell equation and conclude that the point charge energy is a finite value instead of infinity.

New Maxwell Equations

$$\begin{cases} \nabla'\cdot\boldsymbol{E}' = \left(1-\frac{\phi^2}{\Phi_0^2}\right)\frac{\rho}{\varepsilon_0} = \frac{\rho'}{\varepsilon_0} \\ \nabla'\times\boldsymbol{E}' = -\left(1-\frac{\phi^2}{\Phi_0^2}\right)\frac{\partial\boldsymbol{B}}{\partial t} = -\frac{\partial\boldsymbol{B}'}{\partial t'} \\ \nabla'\cdot\boldsymbol{B}' = 0 \\ \nabla'\times\boldsymbol{B}' = \left(1-\frac{\phi^2}{\Phi_0^2}\right)^{\frac{1}{2}}\left(\mu_0\boldsymbol{J} + \mu_0\varepsilon_0\frac{\partial\boldsymbol{E}}{\partial t}\right) = \mu_0'\boldsymbol{J}' + \mu_0'\varepsilon_0'\frac{\partial\boldsymbol{E}'}{\partial t'} \end{cases}$$

Maxwell Equations

$\frac{\phi}{\Phi_0} \to 0$

$$\begin{cases} \nabla\cdot\boldsymbol{E} = \frac{\rho}{\varepsilon_0} \\ \nabla\times\boldsymbol{E} = -\frac{\partial\boldsymbol{B}}{\partial t} \\ \nabla\cdot\boldsymbol{B} = 0 \\ \nabla\times\boldsymbol{B} = \mu_0\boldsymbol{J} + \mu_0\varepsilon_0\frac{\partial\boldsymbol{E}}{\partial t} \end{cases}$$

Result of calculating the electric field energy of a point charge using the modified electromagnetism (with the existence of the electric potential limit constant):

- Equation for the potential of a point charge

$\phi = \Phi_0 \tanh^2\left(\frac{q}{4\pi\varepsilon_0\Phi_0 r}\right)$, $r \to 0$, $\phi \to \Phi_0$

- Equation for the Electric Field Strength Distribution of a Point Charge

$E' = \frac{q}{4\pi\varepsilon_0 r^2}\left(1-\tanh^2\left(\frac{q}{4\pi\varepsilon_0\Phi_0 r}\right)\right)$, $r \to 0, E' \to 0$

- Equation for the Electric Field Energy Density of a Point Charge

$w_e' = \frac{1}{2}\varepsilon_0' E'^2$, $r \to 0, w_e' \to 0$

- Calculation of the Energy of a Point Charge

$E_e = \iiint_0^\infty \frac{1}{2}\varepsilon_0' E'^2 dv'$

$= \frac{q^2}{8\pi\varepsilon_0}\int_0^\infty \frac{1}{r^2}\left(1-\tanh^2\left(\frac{q}{4\pi\varepsilon_0\Phi_0 r}\right)\right)dr$

$= -\frac{1}{2}q\Phi_0 \tanh\left(\frac{q}{4\pi\varepsilon_0\Phi_0 r}\right)\Big|_{r=0}^{r=\infty} = \frac{1}{2}q\Phi_0$ (constant)

1. Potential light speed effect:

The speed of light in four-dimensional space-time is related to the electric potential:

$C_0' = C_0\sqrt{(1-\frac{\phi^2}{\Phi_0^2})}$

1.2 The speed of light in five-dimensional spacetime remains constant, and the principle of invariant light speed holds. This is entirely consistent with the fundamental assumptions of the Electrodynamic Spacetime Relativity.

$C_0'^2 + V_\phi^2 = C_0^2$

$V_\phi = C_0\frac{\phi}{\Phi_0}$

There is no contradiction between them and the Special Theory of Relativity.

$\phi = 0$, $C_0' = C_0$

2. Electric Potential Lens Effect

Due to the change in the speed of light in three-dimensional space caused by the electric potential, it can be proven, according to Fermat's principle, that the law of refraction still holds. The refractive index is related to the electric potential:

$n_1 = \frac{C_0}{C_1'} = \frac{1}{\sqrt{(1-\frac{\phi_1^2}{\Phi_0^2})}}$

$n_2 = \frac{C_0}{C_2'} = \frac{1}{\sqrt{(1-\frac{\phi_2^2}{\Phi_0^2})}}$

Law of Refraction:

$n_1\sin\theta_1 = n_2\sin\theta_2$

Therefore, when light passes near a charged sphere, the path of the light will curve towards the center of the sphere. This phenomenon is called the Electric Potential Lens Effect, It similar with the gravitational lensing effect caused by mass.

3. The Relationship Between Resistance, Capacitance, and Inductance with the Potential of the Reference Frame

Resistance, $R' = R(1-\frac{\phi^2}{\Phi_0^2})^{\frac{1}{2}}$

Capacitance, $C' = C\left(1-\frac{\phi^2}{\Phi_0^2}\right)^{-1}$

Inductance, $L' = L$

LC Circuit, Deriving the Potential Redshift Effect

$v' = v\sqrt{1-\frac{\phi^2}{\Phi_0^2}}$

The above equation is suitable for electromagnetic waves, naturally including light.

From the RC Circuit, Deriving the Potential Time Effect:

$\tau' = \tau(1-\frac{\phi^2}{\Phi_0^2})^{-\frac{1}{2}}$

This conclusion is entirely consistent with the conclusions of the Potential Theory of Relativity.

4. The Relationship Between the Potential of the Reference Frame and Other Physical Quantities

The Relationship Between Potential and Energy

$E_\phi' = E_0\left(1-\frac{\phi^2}{\Phi_0^2}\right)$

The Relationship Between Potential and the Planck Constant

$h' = h\left(1-\frac{\phi^2}{\Phi_0^2}\right)^{\frac{1}{2}}$

The Relationship Between Potential and Mass

$m_0' = m_0$

The Relationship Between Potential and Charge

$q' = q$

The Relationship Between Potential and Potential Difference

$\frac{U'}{U} = 1 - \frac{\phi^2}{\Phi_0^2}$

Based on the modified Maxwell's equations, more relationships between physical quantities and potential can be derived.

Internal Consistency Check of the Theory. By calculating the relationship between different forms of energy and the potential of the reference frame, they must be consistent:

$\frac{m_0' C_0'^2}{m_0 C_0^2} = \frac{v'h'}{vh} = \frac{q'U'}{qU} = \left(1-\frac{\phi^2}{\Phi_0^2}\right)$ (Pass the Test)

5. References

[1] Yingtao Yang, The Theory of Electrodynamic Space-Time Relativity (Revision 5) ---An attempt to inherit and develop the special theory of relativity, April 2024, https://www.academia.edu/117776771

[2] Yingtao Yang, Discussion on the covariance between the theory of electric potential relativity and Maxwell's equations (Revision 5) — An attempt to inherit and develop Maxwell's equations, April 2024, https://www.academia.edu/118129195

[3] Yingtao Yang The hypothesis of a new fundamental physical constant (the electric potential limit constant) and outline of its theoretical exploration May 2024, https://www.academia.edu/119806618

[1] [2] [3]

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