Unification of Gravitation and Electrostatics

Misheck Kirimi

Moi University, Eldoret, Kenya

Email: misheck.kirimi@students.mu.ac.ke; Tel: +254-724-368-005

Abstract

Unification of Newton's law of universal gravitation and Coulomb's law of electrostatics is explored. The similarities and the differences in these laws have remained unexplained since 1784 when Coulomb published the latter law. It is noted here that no past research has paid attention to the fact that 'gravitational mass' (M_1M_2) and 'electric charge' (Q_1Q_2) are the only physical parameters that Newton's and Coulomb's laws do not share. The observation reduces 'unification of gravity and electricity' to 'unification of mass and electric charge'. Despite the simplicity of this observation, physics literature is silent about the relation of mass to electric charge. Little effort has been devoted to this subject because the meaning of charge is ambiguous – charge has never been explained in terms of known physical parameters. An intelligible explanation of charge is suggested here. Based on the explanation, it is demonstrated that mass and charge are different aspects of the electron. Consequently, it is shown that gravitation and electrostatics are different facets of a common phenomenon. It is concluded that positron and negatron are the ultimate elementary units of matter, i.e. matter is nothing but equal positive and negative grains of electricity. The results solve a major problem in physics, namely the

unification of gravitation and electrostatics, and also provide a theoretical foundation for attempts to manipulate gravity.

Keywords: electric charge, electrostatics, inertial mass, gravitation, gravity, mass, gravitational mass, unification.

French translation

Abstrait

L'unification de la loi de la gravitation universelle de Newton et de la loi électrostatique de Coulomb est explorée. Les similitudes et les différences dans ces lois sont restées inexpliquées depuis 1784 quand Coulomb a publié cette dernière loi. Il est noté ici qu'aucune recherche antérieure n'a fait attention au fait que la «masse gravitationnelle» (M_1M_2) et la «charge électrique» (Q_1Q_2) sont les seuls paramètres physiques que les lois de Newton et de Coulomb ne partagent pas. L'observation réduit «l'unification de la gravité et de l'électricité» à «l'unification de la masse et de la charge électrique». Malgré la simplicité de cette observation, la littérature de physique est muette sur la relation de la masse à la charge électrique. Peu d'efforts ont été consacrés à ce sujet car le sens de la charge est ambigu - la charge n'a jamais été expliquée en termes de paramètres physiques connus. Une explication intelligible de la charge est suggérée ici. Basé sur l'explication, il est démontré que la masse et la charge sont des aspects différents de l'électron. Par conséquent, il est montré que la gravitation et l'électrostatique sont des facettes différentes d'un phénomène commun. Nous concluons que le positron et le negatron sont les unités élémentaires ultimes de la matière, c'est-à-dire que la matière n'est rien d'autre que des grains d'énergie positive et négative égaux. Les résultats résolvent un problème majeur en

physique, à savoir l'unification de la gravitation et de l'électrostatique, et fournissent également une base théorique pour les tentatives de manipulation de la gravité.

The Klein-Gordon relativistic equation connects energy E and momentum p of a free particle of mass m with the speed of light c as

$$E^2 = p^2c^2 + m^2c^4 .$$

In Dirac's equation 'mass m' is the 'electron mass m_e', such that

$$E^2 = p^2c^2 + m_e{}^2c^4 .$$

Therefore,

$$m_e{}^2 = \frac{E^2 - p^2c^2}{c^4} .$$

Hence,

$$m_e = \pm\sqrt{\frac{E^2 - p^2c^2}{c^4}} \qquad (1).$$

Dirac, in equation (1), showed that electron mass (m_e), like electron energy (E), is either positive or negative. Schrodinger was the first physicist to note that Dirac's equation suggests that negative (as well as positive) electron mass exists[1]. However, the negative mass solution was dismissed as non-physical[2] because mass of any known particle, including the positron and the negatron, is implicitly defined as always positive[3]- [4] - [5]. Restricted by the definition physicists conclude that Dirac's negative mass solution makes mathematical sense but lacks physical

meaning[6]. But the definition is completely arbitrary. No one has ever demonstrated that ordinary mass is positive – or even negative. Bondi hypothesised the existence of negative mass[7] with properties that contrasts those of ordinary mass, and which would justify the notion that ordinary mass is positive. But Bondi's negative mass has never been found[8]. Even the recently reported 'negative mass effect'[9] did not show that Bondi's negative mass exists. The researchers were categorical that they had observed 'negative mass effect' and not the negative counterpart of ordinary mass. All observations made to date show that ordinary mass has, invariably, uniform gravitational and inertial properties. Therefore, the notion that known mass is always positive lacks scientific support.

On the contrary, Dirac's equation is explicit that positron and negatron masses are fundamentally opposite. Given that the equation has stood the test of time as the correct description of the electron[10], its most profound claim – that electron mass is either positive or negative – was rejected on the basis of a weak hypothesis. Moreover, experimental evidence validates the equation's claim. If force (F) in Newton's second law of motion (F = ma) were held constant, two particles with equal masses of opposite signs (m^+ and m^-) would experience acceleration (a) in opposite directions[11]. But Anderson[12], and others after him, observed that under identical force positron and negatron accelerate in opposite directions – in agreement with the predicted behaviour of particles with reversed masses. Other than mass, opposite electrons have no known physical parameters that would explain the opposite accelerations. However, the prevailing opinion is that charge, not mass, is what positron and negatron have in opposite. But it is not known what charge really means[13]. Taken as a physical reality, Dirac's positive-negative electron masses are the physical realties that differentiate positron and negatron. Thus the

equation explains charge, at least partially, in terms of an intelligible physical parameter – the electron mass.

In addition to mass, however, the electron has another definite physical component – the electrostatic field[14]. Electrostatic field "occupies space, contains energy, and its presence precludes a classical 'true vacuum'"[15]. Further, evidence shows that electrostatic field, like electron energy and electron mass, exists in either positive or negative forms. Placed alternately in the fields of opposite charges a test charge deflects in opposite directions[16]. This is interpreted to mean that field lines in opposite charges face opposite directions – radially outward in positive charge and radially inward in negative charge[17]**.** The bottom-line is, however, that electrostatic fields around opposite charges are also opposite.

Combined, Dirac's equation and the test charge experiment amount to firm theoretical and experimental evidence, respectively, that 'electron mass' and 'electrostatic field' exist in either positive or negative forms. Thus whether an electron is positive or negative is the description of its two physical constituents (fig.1).

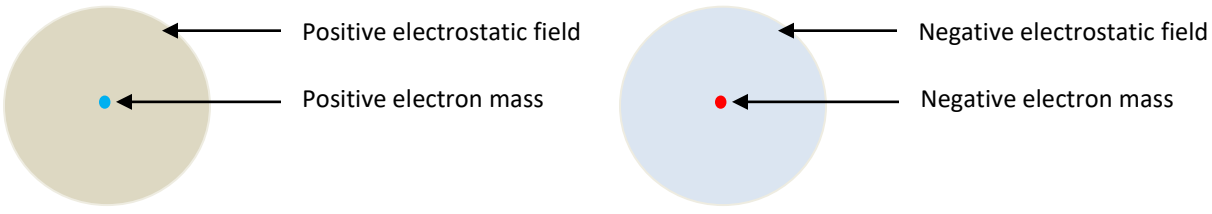

Fig. 1| Physical constituents of the positron (L) and the negatron (R)

Unit charge (e) and an electron have been viewed as different phenomena. Charge is generally considered a fundamental natural quantity at par with length, time and mass. This depicts charge as an independent, albeit mysterious, physical entity. The difficulty with this view is that charge has never been isolated as an independent entity; it is always associated with mass. Charge can be explained intelligibly, provided it is recognized that the electron is not an ordinary particle. An ordinary particle comprises 'gravitational mass' and 'gravitational field' around the mass; but an electron comprises 'electron mass' and 'electrostatic field' around the mass (fig. 3). Thus an electron and a gravitational particle are different. The distinction arises because 'electron mass' and 'electrostatic field' are either positive or negative but 'gravitational mass' and 'gravitational field' do not exhibit similar positive-negative characteristics.

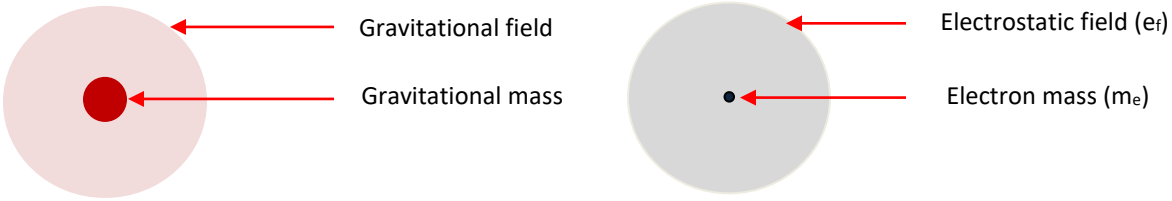

Fig. 3| Contrasting physical constituents of a gravitational particle (L) and an electron (R)

Clearly, electrons are not gravitational particles and do not interact in accordance with Newton's law of gravity. Instead, electrons are electrostatic particles and interact in accordance with Coulomb's law of electrostatics. The electrons' unusual (positive-negative) constituents explain their unusual interactive behaviors that characterize charges. Hence the electron does not 'carry' charge has it has always been stated[18]. Rather, the electron is the charge. Put differently, charge

(e) is not a single physical entity but the sum of electron's unusual constituents – electron mass (m_e) and electrostatic-field (e_f). Conceptually,

$$e = m_e + e_f \tag{2}.$$

Since charge (e) is either positive (e^+) or negative (e^-) equation (2) is expressible in two ways:

$$e^+ = m_e{}^+ + e_f{}^+ \tag{3}.$$

Or,

$$e^- = m_e{}^- + e_f{}^- \tag{4}.$$

Equation (3) and equation (4) unify Dirac's positive-negative electron masses ($m_e{}^+$ and $m_e{}^-$) with positive-negative electric charges (e^+ and e^-). But it is known that positive-negative electron pair annihilates into energy[19] and positive-negative charge pair neutralizes into non-electrical matter. This creates the impression that electron and unit charge are different entities. If unit charge is always an electron as depicted in equation (2), then unit charge is an electron at rest and an electron is unit charge in motion. Put differently, 'free' or 'dynamic' grains of electricity are perceived as electrons but 'bound' or 'static' ones as unit charges. Thus a pair of free opposite electrons annihilates into energy but a pair of bound opposite electrons (charges) neutralizes into non-electrical matter. Neutralization, therefore, results in the coexistence of a static positive charge (e^+) and a static negative charge (e^-) as a static neutral charge ($2e^0$). This can be illustrated by combining equation (3) and equation (4):

$$e^{+} = m_e^{+} + e_f^{+}$$

$$+ \quad \underline{e^{-} = m_e^{-} + e_f^{-}}$$

$$2e^{0} = 2m_e^{0} + 2e_f^{0} \qquad (5).$$

The previous three equations lead to two critical inferences. One, existing independent of its opposite partner a static electron manifests electrostatic properties and it is observed as positive or negative charge. Two, coexisting positron-negatron pair ($2e^0$), or its whole number multiple, manifests mechanical properties and it is observed as a gravitational mass particle. Thus equation (5) unified mass, electric charge and the associated fields. It shows how inter-conversion of electrical and non-electrical matter occurs. The import of equation (5) becomes evident once the information is tabulated (table 1).

Table 1| Natural relation of mass, electric charge and the associated fields

Unit **positive** charge (e^+)	=	Unit **positive** mass (m_e^+)	+	Unit **positive** field (e_f^+)
+		+		+
Unit **negative** charge (e^-)	=	Unit **negative** mass (m_e^-)	+	Unit **negative** field (e_f^-)
II		II		II
Unit **neutral** charge ($2e^0$) or unit gravitational mass	=	Unit **neutral** mass ($2m_e^0$) or unit inertial mass	+	Unit **neutral** field ($2e_f^0$) or unit gravitational field

The natural place of unit neutral charge ($2e^0$) becomes obvious after examining the simplest atom, hydrogen-one. Treating unit charge as an electron shows that the atom has two familiar electrons – nucleus positron (e^+) and orbital negatron (e^-). The positron is attached to the

electrically neutral proton mass (m_p^0) where it is observed as unit positive charge. Positive beta decay, in which a positron in ejected from the proton, proves that the proton's unit positive charge is indeed a positron. Thus nucleus positron (e^+) and orbital negatron (e^-) coexist as unit natural charge ($2e^0$) or gravitational mass unit in the 'outer' part of the atom (Fig. 1).

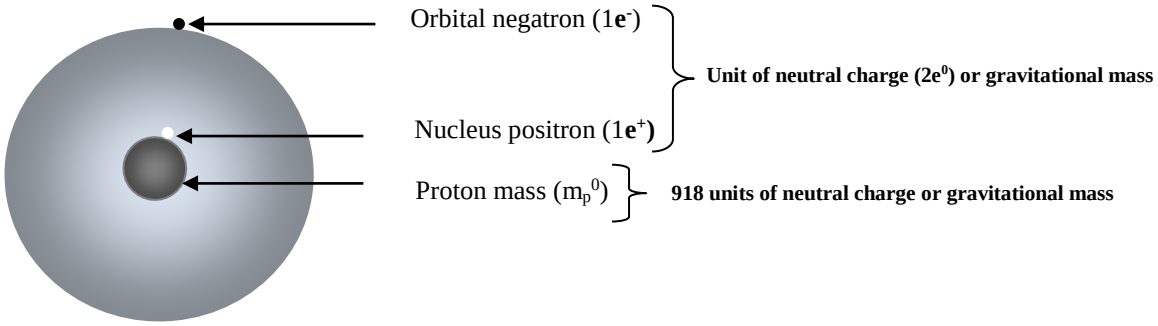

Figure 1 | Positron-negatron constituents of the hydrogen atom

From table 1, 'gravitational mass' and 'neutral charge' ($2e^0$) describe the same thing. Thus nature counts gravitational mass in $2e^0$ units. Consequently, any electrically neutral particle must be a whole number multiple of $2e^0$. For example the proton, which is 1836 times the mass of electron, must comprise 918 $2e^0$ units. Therefore, universally, any electrically neutral particle must comprise an even number of electrons – half positive and half negative. Conversely, any electrically charged particle must comprise an odd number of electrons – with at least one unpaired positron or negatron. This can be demonstrated to be that case if the experimental masses[20] of 'elementary particles' are rounded off to nearest whole number of electron mass units (EMUs). A definite pattern of mass and charge states (table 2) emerges: every particle in a multiplet differs from its next neighbour by three EMUs and charge states (superscripts) alternate

regularly between positive and negative with neutral states in the interludes. A potential decay-construction route in each multiplet can be illustrated with the nucleon multiplet as:

... 1843^{-} => $\mathbf{e^{-}}$ + $\mathbf{2e^{0}}$ + $\mathbf{1840^{0}}$ => $\mathbf{e^{-}}$ + $\mathbf{2e^{0}}$ + $\mathbf{1837^{+}}$ => $\mathbf{e^{+}}$ + $\mathbf{2e^{0}}$ + 1834^{0} => $\mathbf{e^{+}}$ + $\mathbf{2e^{0}}$ + 1831^{-} => $\mathbf{e^{-}}$ + $\mathbf{2e^{0}}$ + 1828^{0} => $\mathbf{e^{-}}$ + $\mathbf{2e^{0}}$ +1825^{+}....

The pattern in table 2 links all known particles (bolded) in a multiplet and predicts others (un-bolded) in terms of their mass and electric charge states. The traditional gamma ray seems like the same thing as the neutral charge or gravitational mass unit ($2e^{0}$) in equation (5). The decisive observation is that all particles with even-number EMUs are electrically neutral while the odd-numbered ones are electrically charged. The pattern demonstrates matter is ultimately made of positrons and negatrons only. Where positive-negative electrons balance out, the particle is observed as an ordinary, non-electrical mass; and where one type of electrons is in excess, the particle exhibits the electric charge phenomenon. Thus conservation of electric charge is not the conservation of negatron-proton pairs but the conservation of negatron-positron pairs.

Table 2 |Electric charge and mass patterns in elementary particle multiplets observed when particle masses are rounded off to the nearest EMUs. The lighter-than-proton particle (1834 EMUs) is probably the particle that is observed in positive beta decay, and which is erroneously named 'neutron.' True neutron has 1840 EMUs.

MULTIPLET NAME	PATTERN OF ELECTRON MASS AND ELECTRIC CHARGE STATES(SUPERSCRIPT)
Nucleon	...1825^{+}...1828^{0}...1831^{-}…1834^{0}...**1837^{+}**…**1840^{0}**...1843^{-}…
Pion	... **264^{0}** … 267^{-} … 270^{0} … **273^{+}**...
Kaon	... **965^{+}** … **968^{0}** … 971^{-} … **974^{0}**...
Eta	…1071^{-}... **1074^{0}** … **1077^{+}**...1080^{0}…
Lambda	... **2153^{+}**… 2156^{0}… 2159^{-}… 2162^{0} … 2165^{+} … 2168^{0}… 2171^{-} … 2174^{0} … 2177^{+}… 2180^{0} … **2183^{-}**...
Sigma	... **2328^{0}** … 2331^{-} … 2334^{0}… 2337^{+}… 2340^{0}… **2343^{-}**...
Xi	... **2573^{-}** … 2576^{0}… **2579^{+}**...

Clearly, equal numbers of positrons and negatrons, occurring in $2e^{0}$ units, are condensed within and constitute the atom. The units are arranged in outer and in the inner compaction zones. In terms of mass, the units in the outer zone are observed as Dirac's positive and negative electron masses (m_e^{+} and m_e^{-}) and in the inner zone as half positive and half negative proton masses ($½m_p^{+}$ and $½m_p^{-}$). This means that the atom's physical content is internally polarized and quantized. Hence ordinary mass is neither positive nor negative but neutral (M^{0}) – a composite of half positive ($½M^{+}$) and half negative ($½M^{-}$) fundamental types of masses:

(6).

$$M^0 = \tfrac{1}{2}M^+ + \tfrac{1}{2}M^-$$

It is known that 'unlike' charges as well as 'unlike' magnetic poles attract. Equation (6) implies that the principle extends to mass, such that 'unlike' halves of 'like' gravitational masses M_1 and M_2 attract:

$$\tfrac{1}{2}M_1^+ \times \tfrac{1}{2}M_2^- = \tfrac{1}{4}M_1M_2^-$$

.

Evidently, what Bondi termed 'passive' and 'active' gravitational masses[21] are the positive and negative internal components of an externally neutral gravitational mass (fig.2). This provides logical explanation for the observation that gravitationally attracting masses experience equal but opposite forces even when their magnitudes are unequal.

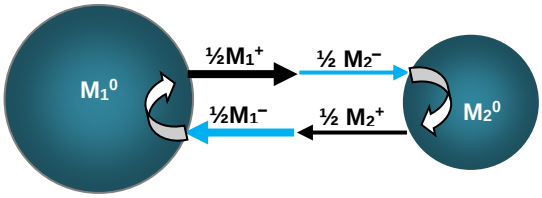

Figure 2 |Gravitation attraction involves 'unlike' components of 'like' masses M_1 and M_2.

In addition to being polarized, hydrogen atom (fig.1) shows that gravitational mass is quantized into two distinct particles – proton mass (m_p^0) and the mass of neutral charge ($2m_e^0$). The two

quanta comprise the same physical stuff ($2m_e^0$) existing in differing only densities. Therefore, Newton's mass (M_1M_2) is a whole number multiple of $m_p^0 2m_e^0$:

$$M_1M_2 = xm_p^{\ 0}\, 2m_e^{\ 0} \tag{7}.$$

Polarizing equation (7):

$$¼ M_1M_2 = x ½ m_p m_e \tag{8}.$$

Clearly, $¼M_1M_2^-$ is a whole number multiple of $½m_pm_e^-$. Thus gravitational attraction is due to opposite halves of neutral charges while electrostatic attraction is due to opposite, externally polarized charges. Hence $¼M_1M_2^-$ in gravitation corresponds with $Q_1Q_2^-$ in electrostatics and $½m_pm_e^-$ with e^{2-}. Substituting $½m_pm_e^-$ with one (unit) in equation (8):

$$¼ M_1M_2 = x\,.$$

Substituting x with $¼M_1M_2^-$ in equation (8):

$$¼ M_1M_2^{\ -} = ¼ M_1M_2^{\ -} \times ½ m_p m_e^{\ -} = ⅛ M_1M_2 m_p m_e \tag{9}.$$

Thus, polarized and quantized Newton's mass (M_1M_2) becomes $^1/_8M_1M_2m_pm_e$. If Coulomb's charge (Q_1Q_2) is also polarized and quantized, the two phenomena should become equivalent. This can be done by recalling Millikan's experiment[22], which demonstrated that quantity Q of

electric charge is a whole number multiple of the elementary charge (e). If x_1 and x_2 are positive integers,

$$Q_1 = x_1 e \text{ and } Q_2 = x_2 e .$$

Hence:

$$Q_1 Q_2 = x_1 x_2 e^2 .$$

Representing $x_1 x_2$ with y:

$$Q_1 Q_2 = y e^2 \quad (9).$$

Equation (9) shows that any $Q_1 Q_2$ equals y whole number e^2 units. Just as Q is quantized into e units, $Q_1 Q_2$ is quantized into e^2 units. Since e equals one elementary unit of charge, e^2 equals one unit of elementary charge squared. Thus e^2 in equation (9) can be replaced with one, such that:

$$Q_1 Q_2 = y .$$

Consequently, y in equation (9) can be substituted with $Q_1 Q_2$, such that:

$$Q_1 Q_2 = Q_1 Q_2 e^2 \quad (10)$$

Hence $Q_1Q_2e^2$ represents the number of e^2 (constant) units that make Q_1Q_2 (variable). Put differently, quantized Q_1Q_2 is $Q_1Q_2e^2$. If Dirac's equation has been correctly interpreted so far, then polarized and quantized Newton mass ($^1/_8M_1M_2m_pm_e$) and Coulomb charge ($Q_1Q_2e^2$) are equivalent and have equivalent interactive effect. Making gravitational constant (G) and electrostatic constant (K) subjects of respective equations:

$$G = \frac{Fr^2}{M_1M_2} \quad (11).$$

And,

$$K = \frac{Fr^2}{Q_1Q_2} \quad (12).$$

Equation (11) and equation (12) show that Newton mass (M_1M_2) and Coulomb charge (Q_1Q_2) are the only physical parameters that differentiate gravitation and electrostatics. Force (F) and distance (r) remain the same. But if Newton mass and Coulomb charge polarized and quantized constants G and K change to new constants T_1 and T_2 respectively:

$$T_1 = \frac{Fr^2}{8M_1M_2m_pm_e} \quad (13).$$

And,

$$T_2 = \frac{Fr^2}{Q_1 Q_2 e^2} \quad (14).$$

Substituting Fr^2/M_1M_2 with constant G in equation (13):

$$T_1 = \frac{8G}{m_p m_e} \quad (15).$$

Substituting Fr^2/Q_1Q_2 with constant K in equation (14):

(16).

$$T_2 = \frac{K}{e^2}$$

Calculations based on CODATA values of physical constants[23]give a value of 3.506 x $10^{47}NM^2/Kg^4$ for T_1 and 3.506 x $10^{47}NM^2/C^4$ for T_2. This amazing agreement proves that gravitational mass and electric charge are equivalent phenomena. Equating T_1 to T_2 leads to equation (17), which links gravitation-mass constants with electrostatic-charge constants and effectively unifies Newton's and Coulomb's laws.

$$\frac{8G}{m_p m_e} = \frac{K}{e^2} \quad (17).$$

Evidence has been mounting, albeit slowly, that gravitation and electrostatics are related interactions. Greulich observed that gravity can be rewritten completely as electrostatics, "provided one assigns to matter a very small gravitational charge density"[24]. However, he did not

demonstrate the natural significance of 'gravitational charge density.' Similarly, Spears concluded that "gravity is almost certainly an electrostatic phenomenon" while Haug demonstrated that, for Planck masses, Coulomb's formula is mathematically exactly the same as Newton's formula[25]. Another researcher, Aspden, concluded that gravitation is mutual electrostatic action between material particles that are uncharged[26]. He termed such uncharged particles 'neutral dipoles', a description that fits the neutral charge ($2e^0$) particle in equation (5). In related study Assis showed that gravity is the statistical residual force between groups of 'neutral charges'[27]. Unification of gravitation and electrostatics in equation (17), as a consequence of unified mass and electric charge, is the culmination of the previous partial findings.

The findings presented above lead to the overall conclusion that matter is ultimately made of positive and negative grains (quanta) of electricity. In their 'free' state the grains of electricity manifest as electrons but in their 'bound' state as unit charges. It has been demonstrated that an electron comprises electron mass and electrostatic field only. These features determine whether the electron is positive or negative. Consequently, it has emerged that electrons are electrostatic and not gravitational particles. Further, it is concluded that coexisting pairs of positive-negative charges manifest as gravitational mass. With mass and electric charge thus unified, the laws of gravitation and electrostatics have been unified: two particles of matter (gravitational masses or electric charges) interacting across space experience force F that is directly proportional to the product of their natural quanta ($^1/_8M_1M_2m_pm_e$ or $Q_1Q_2e^2$) and inversely proposal to the square of their distance (r^{-2}) apart.

References

1. Winterberg, F. The Planck Aether Hypothesis, Gauss Press, Reno, Nevada, Z. f. Naturforsch 58a, 231 (2003).
2. Stephen, G. B. & Ariel, S. The Making of Twentieth Century Science, How Theories Became Knowledge, P. 271, Oxford University Press (2015).
3. Pollard, D. & Dunning, J. A Consideration of the Possibility of Negative Mass, Il Nuovo Cimento Vol.110 B, N. 7 (1995).
4. Bonnor, W. B. Negative Mass in General Relativity, Gen Relat Gravit, 21:1143 (1989)
5. Robert, L. F. Negative matter propulsion, Journal of Propulsion and Power, Vol. 6, No. 1, pp. 28-37 (1990).
6. Golden, G. N. Avoiding Negative Probabilities in Quantum Mechanics, Journal of Modern Physics, 4, 1066-1074 (2013).
7. Bondi, H. "Negative Mass in General Relativity," Reviews of Modern Physics, Vol. 29, No.3, pp. 423-428 (1957).
8. Weber, J. General Relativity and Gravitational Waves, Dover Publications, Inc., Mineola, New York (2004), pg. 5.
9. Khamehchi, M.A. et al, Negative-Mass Hydrodynamics in a Spin-Orbit–Coupled Bose-Einstein Condensate, Phys. Rev. Lett. 118, 155301 (2017).
10. Bergstrom, L. Goobar, A. Cosmology and Particle Astrophysics, Second Edition, Springer, p.310 (2006).
11. Tajmar, M & Assis A. K. T. Particles with Negative Mass: Production, Properties and Applications for Nuclear Fusion and Self-Acceleration, Journal of Advanced Physics, Vol. 4, pp. 77-82 (2015).

12. Carl, D. A. The Positive Electron, Phys. Rev. 43, 491 (1933).
13. Mahad, J.N. “On the nature of electric charge” IJPS, Vol. 9(4): 54-60, (2014).
14. Einstein, A. Podolsky, R. Can Quantum-Mechanical Description of Physical Reality Be Considered Complete? Physical Review 47, 15 (1935).
15. Wheeler, J. A. Black Holes, and Quantum Foam: A Life in Physics p. 163, London (1998).
16. Purcell, E.M. & Morin D. J. Electricity and Magnetism (3rd Ed.) Harvard University, Cambridge University Press, New York pp. 5-7 (2013).
17. Frank, W. The Electric Field – Chapter 23 of Frank Wolfs's Lectures at University of Rochester (2013).
18. Simak, C.D. (ed.) From Atom to Infinity, Readings in Modern Science, Minneapolis Star and Tribune Company, p.282 (1964).
19. Sodickson, L. et al. “Single-Quantum Annihilation of Positrons" Physical Review. 124: 1851 (1970)
20. Parker, S.P. (ed.): McGraw-Hill Encyclopaedia of Science and Technology,' Fifth Edition, Vol. 5, McGraw-Hill Book Co., New York (1982).
21. Bondi, H. "Negative Mass in General Relativity," Reviews of Modern Physics, Vol. 29, No.3, pp. 423-428 (1957).
22. Millikan, R. A. "On the Elementary Electric Charge and the Avogadro Constant," Phys. Rev. 2 (2): 109–143 (1913).
23. Mohr, P.J. et al. CODATA Recommended Values of the Fundamental Physical Constants, Rev. Mod. Phys, 84 1527-1605 (2012).

24. Greulich, K. O. A Surprising Close Relationship Between Gravitation and Electrostatic Interaction, University of Jena, Lecture (2011).
25. Haug, E. G. Unification of Gravity and Electromagnetism, GravityElectroMagnetism – A Probability Interpretation of Gravity, Norwegian University of Life Science (2016)
26. Aspden, H. Research Papers No. 3: Can Gravity Be an Electrostatic Force? (2005).
27. Assis, A.K.T. Advanced Electromagnetism – Foundations, Theory and Application, World Scientific, Singapore, pp. 314-331 (1995).

Competing financial interests

The author declares that he has no competing financial interests.