

Extended Use of Coulomb's Law in Relation to Established Laws within Electromagnetism

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Abstract-The competence of the basically electrostatic Coulomb's Law has historically been assumed to be restricted to pure electrostatics. As soon as electric charges were studied in motion, new sets of laws were introduced to explain the electromagnetic forces that are impelled by the motion. Among these new laws are Neumann's law of induction, Grassmann's force law, Lorentz' force law, and Ampère's force law. Furthermore, the difficulties in explaining the nature of light have given rise to the so-called wave-particle paradox. 1997 was the first year of the public circulation of research results that succeeded in showing that the basic force behind cases involving electricity or, more precisely, electromagnetism, can be derived from electrostatics. The aim of this article is to unify the results of existing theoretical research that discusses problems inherent within the prevailing standpoint on electromagnetism. In this paper, the conflict between the Lorentz Force Law and Ampère's Law is explored. Simultaneously, an alternative based strictly on electrostatics is closely examined. The very limited interest in this field of research, however, makes the amount of existing papers rather limited. The present study's new intervention is as follows: The so-called Ampère forces between collinear currents, as in Ampère's bridge and in exploding wires, have been explained to be due to electrostatics, provided that the propagation delay dependant on the motion of charges is correctly taken into account. The Lorentz Force Law fails in this case. Additionally, electromagnetic induction can be explained by applying electrostatics, whereas the induction law fails. Light on the orbit electrons in the atoms involved in excitation and de-excitation of states can be explained using Coulomb's law (this has been widely disputed within science). The appearance of light at an atom hit by electromagnetic radiation can be shown to constitute a case of electromagnetic induction. The present study's conclusion is therefore that Coulomb's law is the only necessary force law within electromagnetism.

Keywords- *Coulomb's Law; Ampere's Law; Ampere's Bridge; Grassmann's Law; Lorentz' Force Law; Neumann's Law; Lenz' Law; Electromagnetic Radiation; Graneau's Exploding Wires; Propagation Delay; Sagnac Effect; Special Relativity Theory*

I. INTRODUCTION

Based on current research, it is not evident that Coulomb's law should be able to account for more than pure electrostatic problems. Ampère already made great efforts in deriving a mathematical formula aimed at predicting the force between two electric currents [1]. He was not alone in doing so. Grassmann, basing himself on Ampère's law, derived a force law [2], though he simultaneously made serious mathematical errors [3]. His result was basically the first version of Lorentz' force law, which is, in turn, a part of the Maxwell system summing up electromagnetism [4]. Since Coulomb's law is very well corroborated with respect to stationary charges [5, 6], it follows naturally to examine whether it would be possible to derive other effects of electric charges using the same law. In more recent work, it has been possible to derive the force between electric currents [7], the induction law [8-10], and the basic planetary atom model with respect to the excitation of electromagnetic radiation [11-14]. It has also been possible to falsify the Lorentz Force Law, whereas Coulomb's law succeeds in giving credit to the electromagnetic force, provided the effects of propagation delay are correctly taken into account [7].

II. THEORY

A. *The Electromagnetic Force between Electric Currents*

When it comes to electromagnetic forces between electric currents, it has generally been assumed that Coulomb's law is not applicable. Instead, a Lorentz force term has been added to Coulomb's law [15]. However, in 1997 an expression for the electromagnetic force based solely on Coulomb's law was derived. This was able to account for the force between electric currents [7]. The extension of the usability of Coulomb's law resulted out of the discovery that it is the inhomogeneous propagation delay of the electric force field (i.e. Coulomb's law) that gives rise to the force between electric currents in conducting devices. This new theory was first corroborated by comparing it with experimental results on Ampère's bridge, performed in the 1980's.

Interestingly, this interpretation of retardation subsequently led to the discovery that the traditional derivation of the retarded Liénard-Wiechert potentials appeared to be fallacious [16]. The fallacy is illustrated in the derivation by Feynman, where he assumes the time to be constant at each charge element, instead of being a continuous function of the distance between the sending point and the field point [17]. This new approach also allows explains the repulsive force between collinear currents, as in Ampère's bridge.

It is worth mentioning that Wesley also criticized the Liénard-Wiechert potential, having found a mathematical error [18].

B. *Special Case: Parallel Electric Currents*

The traditional reason for supporting the Lorentz Force Law is its ability to predict the force between moving charges [19]. This result is further generalized to continuously distributed charges in the shape of currents, and a famous application is the case of two parallel currents carrying wires [20].

Application of the Special Relativity Theory on Coulomb's law has been able to account for the attractive forces in a recent paper [21]. Hence, one of the key reasons for adhering to the Lorentz Force Law has been abolished, and Coulomb's law can thus account for a broader spectre of experiments than the Lorentz Force Law.

As previously established, Coulomb's law is very well corroborated [5-6], especially since it is based on the most fundamental electromagnetic interaction, electrostatics. Comparatively, Lorentz' Force Law is defined separately in order to estimate forces between moving charges or in the shape of electric currents, without any connection to Coulomb's law [19, 20]. The state of movement appears in the velocity term, either explicitly (as in the case of discrete charges) or implicitly (in the shape of current terms). Coulomb's law is not inherited with any velocity term, hence the qualitative difference of art between Coulomb's and Lorentz' laws.

C. *The Inadequacy of the Lorentz Force Law with Respect to Collinear Currents*

Maxwell mentions the problem that the Lorentz force (talking thereby about the 'Grassmann force' [4]) cannot predict the repulsive force between collinear currents [22]. However, Maxwell immediately makes a compromise by saying that for closed circuits they give the same result. Regrettably, he does not support this statement with any mathematical proof.

Graneau, in analyzing exploding wires, assumes a longitudinal force acting simultaneously with the Lorentz force, predominantly mentioning this as Ampère's Law [23-25]. Jonson, on the other hand, makes the Lorentz force unnecessary, simultaneously explaining the Ampere force [7]. Graneau explains the recoil mechanism in railgun accelerators [24] and explosions in currents carrying liquids the same way [26]. However, Aspden questions the explanation for the explosions in metals and instead proposes induced electromotive force and the ohmic potential during an explosive current surge [27]. Wesley discusses these results and proposes a solution based solely on Ampère's law [28]. Phipps, in turn, has corroborated Wesley's theory in experiments showing Ampère forces when passing an AC current through Mercury cells [29].

In another paper, Wesley discusses the results by Hering on the so-called Hering's pump [30]. Hering [31, 32] succeeded in demonstrating that mercury in a wedge-shaped trough rises to a higher level on the wider end. Furthermore, Hering demonstrated that a wedge-shaped piece of copper, the "Graneau-Hering submarine", moves towards the wider end when placed in a trough filled with mercury. Graneau repeated the latter experiment [33]. Hering was unable to explain the results, but Wesley clarifies that Ampère's law could be used to that extent. In a subsequent paper, Wesley shows that the Lorentz force cannot account for the maximum height of mercury in Hering's pump, while simultaneously demonstrating that Ampère's law will give a better accordance with measurement results [34]. Interestingly, two other scientists, Assis and Bueno, have made efforts to show that the Grassmann Force (predecessor to the Lorentz Force) equals the Ampère force, at least in the case of a closed circuit [35, 36]. However, Jonson has successfully refuted this claim by Assis and Bueno [3].

The debate concerning the alleged accordance between the Biôt-Savart force and the Ampère force has interestingly old roots. Cleveland criticizes Maxwell's choice of the Biôt-Savart Law as defining the electromagnetic force between currents, since it does not make action and reaction equal and opposite for elements of a circuit and the remaining circuit. For that, it requires continuous radiation for an electron rotating about a positive nucleus. Maxwell claims that the Ampère Force fulfills the requirements, offering an agreeable result for the forces in a rectangular circuit, one side of which is mechanically separable from the other three [37].

D. *Application of Ampère's Law*

Wesley has made extensive efforts to explain the repulsive force within Ampère's bridge by applying Ampère's law [38, 39]. We must clarify that Wesley uses the term 'Ampère's law' for the expression of the force that Ampère derives in his original paper [38], whereas Jackson uses this term to resemble the Lorentz force [40]. This might cause some initial confusion. Wesley claims that Ampere's law is often usurped with force laws that are not compatible with Ampere's original law (i.e. Biôt-Savart's law). However, Ampère's law has been criticized for the lack of description of its original derivation [41]. Maxwell therefore discusses Ampère's expression. Nonetheless, Maxwell states that without presenting supporting evidence, in an integral sense Ampere's law equals Grassmann's law [22]. Grassmann tries to prove that his law (predecessor to the Lorentz force [4]) can be derived by using Ampère's law [2], but regrettably, he commits a severe mathematical error [3].

E. *Incorrect Interpretation of Special Relativity Theory*

In one particular paper [21], the Special Relativity Theory is used to analyze the electromagnetic forces within Ampère's bridge, thereby incorporating the concept of time dilatation.

This had already been applied in a paper dealing with the Sagnac effect [42]. However, the Sagnac effect refers to a case where the field being studied (in that case, light) is distributed along a rotating disc. Time dilatation, on the other hand, implies

that an observer in the not-moving inertial system would observe time passing with a different rate depending on the direction where the field is sent out. Sending out the field simultaneously along and against the direction of rotation gives rise to a meeting point asymmetrical with respect to the sender.

In the case where electromagnetic forces between wires are immobile with respect to each other, or there are no moving parts in the forces within a circuit (i.e., as in Ampère's bridge), no time dilatation is to be observed.

In a recent paper dealing with the forces between parallel electric currents [21], discussion includes the fallacious idea, whereas another recent paper [43] dealing with Ampère's bridge has avoided the mistake.

III. APPLICATION OF COULOMB'S LAW ON SEVERAL ELECTROMAGNETIC PHENOMENA

A. Ampère's Bridge

Ampère's bridge consists of a closed circuit cut-off at two perpendicular points. In the simplest case, the circuit's shape is rectangular. In a case study, Pappas and Moysides describe the circuit along an experiment they performed [44]. They observed a repulsive force between the two parts, dependent on the thickness of the wire. If we assume the Lorentz force is responsible for the force between electric currents, this result would not be possible [7].

Coulomb's law, in turn, cannot be applied straightforwardly as in the electrostatic case. An analysis of the retardation of the field is necessary. This has also been done [7]. It is the spatially inhomogeneous propagation delay of the electrostatic force field, i.e. the Coulomb field, which gives rise to a difference in the forces between charges of different combinations of sign, even though they are at the same observational points.

A recent paper [43] has shown that the application of the Special Relativity theory does not contradict these results.

B. Ampère's Law and Ampère's Bridge

Wesley, in turn, describes a different model for the force between electric currents. He does not apply either Coulomb's Law or Lorentz' Force Law. Instead, he applies Ampère's law in order to estimate the electromagnetic force between the two parts of Ampère's bridge, presenting the results in two papers [38, 39]. Wesley achieves some numerical success, but (as mentioned earlier), problems remain in conciliating Ampère's law with the need for epistemological coherence with other laws. This becomes apparent in complaints by Maxwell [41]. However, even if a full understanding of its origin has not been achieved, a law can be used anyway, provided it has been empirically corroborated. For instance, neither the electron nor the Special Relativity Theory was known in Ampère's time.

C. Neumann's Induction Law

Maxwell claims that Neumann has completed the mathematical treatment of induced currents [45], discovered most famously by Faraday. (It is not this paper's intention to discuss which scientist was the first to experimentally demonstrate induction). This applies primarily to the fundamental case of having a transformer circuit, where an AC current flowing through a primary circuit will induce another AC circuit with the same frequency in a secondary circuit. This effect is transmitted without any galvanic contact between the two circuits.

However, a rigorous mathematical analysis of the general method, with which measurements of the voltage at the secondary circuit is done, reveals that there is an implicitly embedded computational phase error of order 90 degrees [8]. Hence, the traditional treatment above is fallacious.

An alternate model has been proposed, based on the law of the Continuity Equation for Electric Charge Density and Current Density, thereby applying the above mentioned results concerning Coulomb's law [1] that exclude the usage of magnetic fields. This proposed model appears to be very successful [10].

Furthermore, concerning Neumann's work on electric induction, it has been satisfactorily shown elsewhere that he has performed several fallacious calculations [46]. Among those is the effort to prove that the mathematical treatment of electromagnetic induction is consistent with Ampère's Law.

D. Lenz' Law

Lenz's law only describes the direction the induced current has in respect to the inducing current [47]. It consists of a definition, exclusively done by Lenz, without justifying it with reference to any preceding law.

E. The Origin of Electromagnetic Radiation

The issue of reconciling the fact that atoms are stable with the fact that Maxwell's electromagnetic theory predicts a spiralling collapsing movement of an orbiting electron has led to the formulation of the so-called 'wave-particle paradox'. Bohr is famous for this due to his formulation of the solution [48-51]. Compton, on the contrary, simply states that electrons are orbiting in stable planetary orbits around the nucleus [52]. These contradictions have recently been resolved by applying

Coulomb's law as well as the discoveries concerning induction [11-14]. In order to solve the problem, it was fundamental to analyse the Coulomb field that arises from an electrically neutral atom during the de-excitation of an orbit electron, therefore using the concept of retarded action (as explained above).

F. Proposed Explanation to Gravity

In this paper, we propose an explanation to gravity based on Coulomb's law. The widespread premise has been that the movement of the even neutral matter is built as small moving charges, known as 'quarks' [53, 54]. Applying the effects of retarded actions, as defined earlier [7], makes it possible to explain why a neutral sum of charges may give rise to a Coulomb force. In this paper, this was the case with the force between current-carrying conductors.

IV. CONCLUSIONS

All the cases described above point to a general observation: that the use of Coulomb's law can be extended to cover electrostatics and electromagnetic radiation. As we found, Coulomb's law may be regarded as the fundamental natural law with respect to electric charges, independent of whether they are moving or not. Therefore, when it is possible to derive expressions using Coulomb's law in connection with related basic physics laws (like the continuity equation) in order to explain different phenomena, earlier laws invented with the same intention must be rejected. Several scientists have been struggling with the inherent contradictions between the Biot-Savart Force (i.e. the Lorentz Force) and the Ampère Force, as demonstrated by experiments. However, there is a reluctance to resort to Coulomb's Law; the present author offers a corrective to this. Speaking about possible restrictions, the restrictions prescribed by the Standard Model, especially the Strong Interaction, have not been mentioned, but this is beyond the scope of this article. The present paper's focus is primarily on traditional experimental situations on a macro-scale. The origin of light might be regarded as an exception, but since it was possible to find an explanation to the dual nature of light using Coulomb's law, it was done. It was possible thanks to a very rigorous mathematical treatment. This might raise the question whether also the Strong and Weak Interactions might be explained in the same way (this has not been tested yet). However, the preliminary results concerning gravity make this discussion interesting, even if as of yet fruitless due to the lack of known efforts.

Concerning established laws that have thus been discarded, there are in many cases severe mathematical deficiencies in the analyses, or obvious calculation flaws. This points to the potential of many additional discoveries, if fundamental papers on each subject are thoroughly investigated.

Objections might be made that the claims of the article are too far-reaching and do not connect well with the body of knowledge. However, this paper is concerned with a very narrow discipline and, in relation to this, supporting evidence is substantial. Further, most references are so-called self-references. A self-critical approach is of course key. Firstly, the claims made in this paper are not as radical as they initially appear. In fact, they all give credit to the founders of electricity, Cavendish and Coulomb. Secondly, the disproportionately large part with self-references is due to fact that research within this field has been quite sparse. Finally, it is unavoidable that if finding at least some few credible experiments that refute established knowledge, it is necessary to find a new theory that offers a plausible explanation. Several efforts have been made, but none based on Coulomb's Law.

APPENDIX

A. Laws That Appear in the Paper

1) Coulomb's Law [55]

$$\vec{F} = kq_1q_2 \cdot \frac{(\vec{x}_1 - \vec{x}_2)}{|\vec{x}_1 - \vec{x}_2|^3} \quad (1)$$

\vec{F} denotes the force on a point charge q_1 located at \vec{x}_1 , due to another point charge q_2 , located at \vec{x}_2 and k is a constant of proportionality that depends on the system of units used.

2) Lorentz' Force Law [19]

$$\vec{F} = q(\vec{E} + \frac{\vec{v}}{c} \times \vec{B}) \quad (2)$$

\vec{F} denotes the force acting on a point charge q in the presence of electromagnetic fields, where \vec{E} is the electric field and \vec{B} is the magnetic flux density. \vec{v} is the velocity of the point charge, and c is the speed of light. Gaussian units have been assumed.

3) Grassmann's Force Law [2, 3]

$$\text{Force} = \left(\frac{ab_l}{r^2}\right) \cdot \sin \alpha \quad (3)$$

a denotes the infinitesimal element of a current element, b_l is the cosine component of the b element on the perpendicular, r is the distance between any two points of two respective electric currents, and α is the angle formed by the element a with the line drawn between the two mid-points.

4) Bi- α -Savart's Law [56]

$$d\vec{B} = kI \cdot \frac{(d\vec{l} \times \vec{x})}{|\vec{x}|^3} \quad (4)$$

$d\vec{B}$ denotes the elemental magnetic flux density at the point P , the constant of proportionality k depends on the system of units used, I is the current carried by a filament wire, $d\vec{l}$ is an element of length pointing in the direction of current flow, and \vec{x} is the coordinate vector from the element of length to an observation point P .

5) Ampère's Law [38]

$$c^2 \vec{F}_A = I_2 I_1 \vec{r} \cdot (-2d\vec{s}_2 \bullet d\vec{s}_1 / r^3 + 3(d\vec{s}_2 \bullet \vec{r})(d\vec{s}_1 \bullet \vec{r}) / r^5) \quad (5)$$

c is speed of light, \vec{F}_A is the force on a current element $I_2 d\vec{s}_2$, due to a current element $I_1 d\vec{s}_1$ at \vec{r}_1 separated by the distance $\vec{r} = \vec{r}_2 - \vec{r}_1$, $d\vec{s}_1$ and $d\vec{s}_2$ are the elements of length pointing in the direction of current flow I_1 and I_2 respectively. Gaussian units have been assumed.

6) Neumann's Induction Law [46, 57]

$$E \cdot Ds = -\varepsilon \nu C \cdot Ds \quad (6)$$

E denotes the induced electromotive force (emf) per unit length, Ds is the infinitesimal element of the secondary circuit, ε is a constant factor and C is the force that the inducing circuit exerts on the conductor carrying the induced current, dependent on the direction.

7) Li énard-Wiechert Potentials [58]

$$\Phi(\vec{x}, t) = \left(\frac{e}{(1 - \vec{\beta} \bullet \vec{n})R}\right)_{ret} \quad (7)$$

$$\vec{A}(\vec{x}, t) = \left(\frac{e\vec{\beta}}{(1 - \vec{\beta} \bullet \vec{n})R}\right)_{ret} \quad (8)$$

$$\vec{\beta} = \frac{\vec{v}(\tau)}{c} \quad (9)$$

$\Phi(\vec{x}, t)$ and $\vec{A}(\vec{x}, t)$ denote the Li énard-Wiechert potentials, where e is a point charge in motion [59], $\vec{v}(\tau)$ is the velocity at the retarded time τ , \vec{n} is a unit vector in the direction of $\vec{x} - \vec{r}(\tau)$. The subscript 'ret' means that the quantity in the parentheses is to be evaluated at the retarded time.

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