The Commonality between Light and Electric Current

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Abstract. **In the year 1855, German physicists Wilhelm Eduard Weber and Rudolf Hermann Arndt Kohlrausch performed an experiment involving the discharge of a Leyden jar and they established the ratio between electrostatic and electrodynamic units of charge. This ratio, which became known as Weber's constant, was measured numerically to be $c\sqrt{2}$, where c was very close to the speed of light. Since this experiment had nothing to do with optics, the question then arises as to whether they had perhaps actually measured the speed of electric current, which just happens to be close to the speed of light for the reason that the speed of light is in turn determined by the speed of electric current within the context of the medium for the propagation of light.**

We must establish the physical commonality between light and electric current.

The Speed of Light

I. In the year1855, German physicists Wilhelm Eduard Weber and Rudolf Hermann Arndt Kohlrausch performed what was perhaps the most historically significant of all experiments in the fields of optics and electromagnetism, **[1]**, **[2]**, **[3]**, because it connected the optically measured speed of light to purely electric and magnetic effects that ostensibly had no connection to optics. The theory behind the experiment centred on the force law,

$$F = kq_1q_2/r^2[1 - \dot{r}^2/C_w^2 + 2r\ddot{r}/C_w^2] \qquad \textbf{(1)}$$

which Weber had already proposed a number of years earlier in the year 1846. This force law contained a constant, C_w, known as Weber's constant, and the purpose behind the experiment was to establish a numerical value for C_w.

The experiment involved transferring a quantity of electricity from a charged Leyden jar over to a 13-inch ball that was coated with tin foil, and then discharging the remainder through a conducting channel. The electrostatic force generated by the charged ball was measured using a torsion balance while the magnetic force induced by the current, due to the discharge of the Leyden jar, was measured by the deflection of the compass needle in a galvanometer. The idea behind the experiment was that since the electrostatic force was measured using electrostatic units of charge, while the magnetic force was measured using electrodynamic units of charge, then the numerical ratio between the two forces would yield the value of C_w.

The only term of major interest in equation **(1)** is the middle term on the right-hand-side. This term, $\dot{r}^2/C_w^2$, is the convective term, where $\dot{r} = V_w$. It's a magnetic force which is a kind of centrifugal force, **[4]**, because it opposes an electrostatic force of attraction. Weber considered V_w to be the mutual speed between two charged particles, q_1, and q_2, distance r apart, and he saw C_w as a reducing speed such that when $V_w = C_w$, then the electrostatic force would be completely cancelled.

Because the experiment begins with two unknowns, V_w, and C_w, it follows therefore that there will be a corollary to the discovery of the numerical value of C_w. This corollary was never noticed though, perhaps due to the conviction that electric current consisted in the equal and opposite flow of charged particles. But while that may well be the case, especially when a current is flowing through an electrolyte, equation **(1)** above tells us that when the electrostatic and magnetic forces are equal, then V_w must be equal to C_w, and so something must be travelling in the discharge wire at speed C_w.

In 1857, German physicist Gustav Robert Kirchhoff, while studying the motion of electricity in conducting wires, identified, in German miles, what appeared to be the speed of light, c, in the relationship $C_w = c\sqrt{2}$, and through the telegrapher's equation which he derived in that same year, **[5]**, Kirchhoff linked this to the speed of electric signals in the wire. Had Weber and Kohlrausch used electromagnetic units of charge for the magnetic force, instead of electrodynamics units, they would have concluded that the reducing speed was in fact very close to the speed of light. Instead, they thought that the reducing speed was significantly greater than the speed of light.

Wave Mechanics or Hydrodynamics?

II. Kirchhoff's telegrapher's equation applied to all the electromagnetic functions, and it was intended to represent the propagation of any changes in the electric current along a conducting wire. The speed, c, was not therefore intended to represent the actual speed of flow of electric current. But was Kirchhoff correct in this regard?

While we all know that the electric particles that are involved in an electric current travel at nowhere remotely near to the speed of light, the implication of the Weber-Kohlrausch experiment is nevertheless that something much more subtle must be the fundamental basis of electric current, and that even if changes in electric current propagate in a wave-like form along a conducting wire at the speed of light, that this is only because they are carried by the movement of a fluid which is itself flowing at that same speed. As to what exactly this fluid is, we should look to the electrostatic field that surrounds charged particles and consider that the inflowing or outflowing aethereal electric fluid, that is the physical basis of this field, is the prime candidate.

The Electric Fluid

III. Consider the radial electrostatic field lines that surround a charged particle. It is proposed that this field, $\mathbf{E_S}$, has an associated momentum field, **A**, which involves a fundamental electric fluid flowing into or out of the particle, according to whether the particle is negative or positive. This electric fluid undercurrent is the primary essence of electric current. It is the aether and the stuff of all matter, **[6]**. It is further proposed that space is densely packed with rotating electron-positron dipoles with circumferential speeds which determine the speed of light, **[7]**, **[8]**. When these dipoles are induced to angularly accelerate (or precess), electric current overflows to the immediate neighbour, at this same speed, causing the neighbour to angularly accelerate too. Electric current in a conducting wire, flows at roughly this same speed, for the simple reason that this speed is governed by the flow of aether from positive particles to negative particles. This is an average speed which determines the order of the speed associated with both electric current and of wireless electromagnetic waves. Positively charged particles are pushed along in the flow while negatively charged particles eat their way in the opposite direction, but due to ohmic resistance, they are never accelerated to anywhere near the speed of the more fundamental aethereal undercurrent.

Displacement Current

IV. It is proposed that electric current is hemmed into conducting channels by the all-pervading sea of rotating electron-positron dipoles, which is equivalent to a sea of dipolar aether vortices, **[9]**. The phenomenon of *displacement current* occurs when electric fluid leaks from a conductor into this all-pervading dielectric sea during the transient state, prior to the leak being halted by a back-EMF. The back-EMF can be electrostatic in nature, such as in connection with a charging capacitor or in connection with dielectric polarization. The elasticity involved in this kind of back-EMF is similar in nature to that which is observed in a mechanical spring. It causes a recoil, and it is associated with the dielectric nature of the electron-positron sea.

The back-EMF can also be magnetization-based due to the electric field that is caused by time-varying electromagnetic induction, and the elasticity involved in this kind of back-EMF is more akin to that observed in the inertial behaviour of a flywheel. It resists, but it doesn't induce a recoil. Rather, it induces a forward kick when the applied EMF is removed, and so it is involved in the propagation of waves through the sea of tiny vortices.

Wireless Electromagnetic Radiation

V. The general picture of the electromagnetic wave propagation mechanism seems to have already been known by the 1930s. This quote, in relation to the speed of light, appeared in the 1937 Encyclopaedia Britannica, in the article entitled, ***"Ether (in physics)"***, **[10]**,

"The most probable surmise or guess at present is that the ether is a perfectly incompressible continuous fluid, in a state of fine-grained vortex motion, circulating with that same enormous speed. For it has been partly, though as yet incompletely, shown that such a vortex fluid would transmit waves of the same general nature as light waves— i.e., periodic disturbances across the line of propagation—and would transmit them at a rate of the same order of magnitude as the vortex or circulation speed"

The bit where it mentions incompressibility, however, probably applies more to the sea of vortices itself rather than to the aethereal electric fluid of which the vortices are comprised. This picture is fully compatible with the sea of aethereal vortices which Scottish physicist James Clerk Maxwell proposed in Part **I** of his 1861 paper, ***"On Physical Lines of Force"***, **[11]**, in order to account for magnetic force. He then extended the application to electromagnetic induction in Part **II** of the same paper.

In Part **III**, Maxwell, using Weber's constant, set out to link the elasticity of such a sea of aethereal vortices to the speed of light. Maxwell converted the electrodynamic units of charge inherent in Weber's constant into electromagnetic units and he was able to link this to the dielectric constant, which he had in turn purported to link to the transverse elasticity at equation (108), although it is uncertain as from where Maxwell obtained the 6 to 5 ratio of transverse to cubic elasticity. In order to definitively link the elasticity to the speed of light, Maxwell should have invoked the circumferential speed of his vortices, but he didn't.

Such an analysis has however been done in the article entitled, ***"Radiation Pressure and $E = mc^2$"***, **[12]**. In this article, the elasticity constant is connected to the circumferential speed in a rotating electron-positron dipole, and instead of using Weber's constant, the speed of light is introduced into the analysis through the phenomenon of electron-positron pair production and annihilation.

Although Maxwell never explicitly invoked the circumferential speed of his vortices in the elasticity of the luminiferous medium, he did however transfer this elasticity into a magnetization-based displacement current in his 1865 paper, ***"A Dynamical Theory of the Electromagnetic Field"***, **[13]**, and this enabled him to derive a wave equation in the magnetic field. Maxwell first conceived of displacement current in the preamble of Part **III** in his 1861 paper, in connection with dielectric polarization and the electrostatic force, but in order

to obtain a wave equation, a forward propagation mechanism is needed, and Maxwell found that he had to switch to a magnetization-based version of displacement current, **[13]**, in order to derive a wave equation. But because he never highlighted this switch, the physical interpretation of magnetization-based displacement current is never investigated, since the textbooks always associate displacement current with capacitance or dielectric polarization. This has had the effect of throwing researchers off the trail when it comes to trying to establish the physical meaning of the displacement current in wireless phenomena such as starlight in space.

Meanwhile, in his 1873 Treatise, **[14]**, Maxwell derived the electromagnetic wave equation again, this time for the *magnetic vector potential*, **A**, which he called the *electromagnetic momentum*. If we treat this momentum as the circumferential momentum density of the tiny aethereal vortices, then, since $\nabla\times\mathbf{A} = \mathbf{B}$, and $\mathbf{E_K} = -\partial\mathbf{A}/\partial t$ in the case of time-varying electromagnetic induction, it follows that the wave equation in **A** corresponds exactly to the picture described above in the 1937 Encyclopaedia Britannica. If **A** is a momentum density, then **B** must be a vorticity density, while $\mathbf{E_K}$ must be the circumferential force that drives the wave propagation mechanism within each vortex. The significance of involving time-varying electromagnetic induction in the derivation, through the associated magnetization-based displacement current, is, that unlike in the case of conduction current, which is a pure flow, wireless electromagnetic waves involve a relay of electric current between adjacent vortices, in a wave-like manner, by analogy with the transfer of energy between the two windings of an AC transformer.

Kirchhoff and the Telegrapher's Equations

VI. Maxwell's use of magnetization-based displacement current in the derivation of the electromagnetic wave equation in the magnetic field, means that electromagnetic waves represent an application of Faraday's law of induction acting between miniature electric circuits that pervade all of space. However, since Kirchhoff used capacitance and back-EMF while deriving his telegrapher's equations in the context of a single electric circuit, it's not altogether clear as to whether the derivation was entirely legitimate. It's not clear how the capacitive back-EMF can be equated with the EMF of self-induction, as is necessary in Kirchhoff's derivation. It appears that liberties have been taken in the derivation of the telegrapher's equations, both then and since, but that these liberties have been camouflaged by the fact that the electric current in the wire is already flowing at near to the speed of light anyway.

Conclusion

VII. The speed of electric current is what determines the speed of light, because light itself is a relay of electric current, propagating as fine-grained vortex circulations through a dense all-pervading sea of tiny rotating dipoles. The 1855 Weber-Kohlrausch experiment was actually measuring the speed of the electric current in the conducting channel of the discharging Leyden jar, so the question then remains as to what determines the speed of electric current.

It is proposed that the radial electrostatic field that surrounds a charged particle has an associated momentum field in connection with the fundamental aethereal medium with which all matter is comprised. Electric current will therefore consist in a flow of aether from positive source particles to negative sink particles, and the average speed will be in the order of the speed of light. In the case of light itself, the tiny aethereal vortices that fill all of space will constitute rotating electron-positron dipoles, while electromagnetic radiation consists in the overflow of aether between the positron of one dipole and the electron of the immediately neighbouring dipole which occurs when the first dipole is induced to angularly accelerate. The overflow in turn causes the second dipole to angularly accelerate and the cycle repeats through the sea of dipolar vortices in a wave-like manner.

Electromagnetic radiation is Faraday's law of electromagnetic induction operating in miniature. The vortices that fill all of space are like tiny electric circuits. It can be shown that the elasticity constant in the EM wave equation derives from the circulation speed in a vortex, **[10], [12].**

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See chapters 5, 6, and 7 in this link,
https://www.ifi.unicamp.br/~assis/Weber-in-English-Vol-3.pdf
Prof. A.K.T Assis has written an excellent summary of this work in an article entitled ***"On the First Electromagnetic Measurement of the Velocity of Light by Wilhelm Weber and Rudolf Kohlrausch"***.
https://www.ifi.unicamp.br/~assis/Weber-Kohlrausch(2003).pdf
Weber and Kohlrausch wrote a short precis of their paper, and this can be found in Poggendorf's Annalen, vol. XCIX, pp. 10-25. An English translation of this precis is presented in the appendix at the end of Prof. Assis's paper.

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"Long ago he (mankind) recognized that all perceptible matter comes from a primary substance, of a tenuity beyond conception and filling all space - the Akasha or luminiferous ether - which is acted upon by the life-giving Prana or creative force, calling into existence, in never ending cycles, all things and phenomena. The primary substance, thrown into infinitesimal whirls of prodigious velocity, becomes gross matter; the force subsiding, the motion ceases and matter disappears, reverting to the primary substance".
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"All space, according to the younger Bernoulli, is permeated by a fluid aether, containing an immense number of excessively small whirlpools. The elasticity which the aether appears to possess, and in virtue of which it is able to transmit vibrations, is really due to the presence of these whirlpools; for, owing to centrifugal force, each whirlpool is continually striving to dilate, and so presses against the neighbouring whirlpools."

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The derivation of the electromagnetic wave equation in the magnetic field begins on page 497. Note how the electrostatic component of the displacement current is eliminated after equation (68), hence leaving the elastic displacement mechanism in the wave as an effect that is connected exclusively with time-varying electromagnetic induction. Maxwell originally conceived the idea of displacement current in connection with dielectric polarization, and hence with electrostatics, but in this derivation, it is no longer applicable to polarization, but instead applies to magnetization. This swap has never been highlighted, and as such, Maxwell's displacement current transferred into the early twentieth century literation as a concept related to capacitors and transmission lines, but in order to derive the electromagnetic wave equations, we need to use the inductive form that is compatible with Faraday's law.
VIII. A dynamical theory of the electromagnetic field (royalsocietypublishing.org)

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