

The 1856 Weber-Kohlrausch Experiment

(The Speed of Light)

*Frederick David Tombe,
Northern Ireland, United Kingdom,
sirius184@hotmail.com
18th October 2015*

Abstract. Nineteenth century physicists Wilhelm Eduard Weber, Gustav Kirchhoff, and James Clerk-Maxwell are all credited with connecting electricity to the speed of light. Weber's breakthrough in 1856, in conjunction with Rudolf Kohlrausch, revealed the speed of light in the context of a ratio as between two different units of electric charge. In 1857 Kirchhoff connected this ratio to the speed of an electric signal travelling along a wire. Later, in 1862, Maxwell connected this ratio to the elasticity in the all-pervading luminiferous medium that serves as the carrier of light waves. This paper sets out to establish the fundamental cause of the speed of light.

Introduction

I. The 1856 Weber-Kohlrausch experiment established a ratio between two different units of electric charge. The experiment involved discharging a Leyden jar (a capacitor) that had been storing a known amount of charge in *electrostatic units*, and then seeing how long it took for a unit of electric current, as measured in *electrodynamic units*, to produce the same deflection in a galvanometer. This resulted in a ratio C , known as Weber's constant, and we know today that it is equal to $c\sqrt{2}$ where c is the directly measured speed of light. Weber interpreted this ratio in connection with the convectively induced force that he had identified and formulated in 1846 as between two charged particles in relative motion. He believed C to be the speed that would produce an exact counterbalancing force to the electrostatic force. In this respect, C was like a kind of escape velocity, with the convective force behaving like a centrifugal force. In 1862, Maxwell isolated the speed of light, c , from Weber's constant and he attempted an alternative physical interpretation. The centrifugal force equations of Weber and Maxwell will be reconciled in section **IV** below.

Electric Permittivity

II. Electric permittivity, ϵ , is an elasticity constant associated with dielectrics through Maxwell's fifth equation $\mathbf{D} = -\epsilon\mathbf{E}$, a form of Hooke's Law, where \mathbf{D} is the electric displacement vector and \mathbf{E} is an externally applied electric force. We can measure the electric permittivity experimentally using an electric circuit that

involves discharging a capacitor. Electric current is measured, and the electric permittivity is then established using known quantities in the standard textbook equations. *See the appendix after the reference section at the end.*

Electric permittivity is also a disguised value for the speed of light through the equation,

$$\mu\varepsilon = 1/c^2 \tag{1}$$

Unlike electric permittivity, magnetic permeability, μ , has always been a defined quantity. Even though Maxwell attributed the physical significance of μ to the density of the sea of molecular vortices which he believed constituted the luminiferous medium, he had no way of knowing its absolute value. This however didn't matter for his purpose since he was only working with ratios, and in electrodynamic units, μ is unity.

The origins of this equation can be traced back to the year 1856 to an experiment carried out by Wilhelm Weber and Rudolf Kohlrausch [1]. Weber and Kohlrausch had no concept of electric permittivity. They discharged a capacitor (Leyden jar) and noted the galvanometer reading, first with a known amount of charge measured in electrostatic units, and secondly with a known electric current measured in electrodynamic units. From these readings it was discovered that the ratio of the two systems of units is equal to what became known as Weber's constant C .

In order to make sense out of this result, Weber looked to the convective term \dot{r}^2/C^2 (v^2/C^2) in the force equation that he had proposed ten years earlier in 1846. This equation takes the form,

$$F = kq_1q_2/r^2[1 - \dot{r}^2/C^2 + 2r\ddot{r}/C^2] \tag{2}$$

remembering with the benefit of hindsight that C is equal to $c\sqrt{2}$, where c is the speed of light. Weber interpreted C as being a kind of reducing velocity which undermines the electrostatic force. The convective term in Weber's equation therefore takes on the form of a centrifugal force [2] written as a proportion of the value of the electrostatic force that it is undermining.

It's not clear when exactly Weber and Kohlrausch first noticed the connection between C and c , but in 1857, Gustav Kirchhoff, using Weber's constant in the known equations of electromagnetism [3], concluded that electric signals propagate along a conducting wire at the speed of light.

Maxwell on the other hand was convinced that Weber's constant meant that light is an electromagnetic wave in an elastic solid which pervades all of space. He developed a model for the luminiferous medium based on the idea that space is filled with tiny aethereal vortices that press against each other with centrifugal force while striving to dilate [4], [5], [6]. He derived an equation for convectively induced electromotive force $\mathbf{E} = \mu\mathbf{v}\times\mathbf{H}$ (nowadays wrongly

credited to Lorentz), which is equivalent in all important respects to the convective term in Weber's force equation. See section **IV** below.

As regards the speed of light, Maxwell's objective was to link the Weber-Kohlrausch numerical ratio to the transverse elasticity of his sea of tiny vortices, and then apply it to Newton's equation for the speed of a wave in an elastic solid. The full derivation is found in Part III of the 1861 paper "*On Physical Lines of Force*" [4] where he begins by demonstrating the linkage between dielectric constant and transverse elasticity. Equations (132) to (135) in this paper should leave nobody in any doubt that Newton's equation is the equivalent of both $E = mc^2$ and $c^2 = 1/\mu\epsilon$, which are in effect the same equation.

In Part III, Maxwell does not resort to the specifics of the sea of molecular vortices that he postulated in Part I of the same paper. Had he done so; he could have linked c directly to the circumferential speed in his vortices. See "*Radiation Pressure and $E = mc^2$* " and section 2 in "*The Speed of Light*" [7]. Nevertheless, he still establishes that light is a transverse wave in the same medium that is the cause of electric and magnetic phenomena.

Electric Current

III. Maxwell and Kirchhoff both used broadly the same equations of electromagnetism in connection with the Weber-Kohlrausch numerical ratio, but they came to different conclusions. In 1857, Kirchhoff concluded that an electric signal travels along a conducting wire at the speed of light whereas Maxwell in 1862 concluded that the speed of light is the speed of an electromagnetic wave through space, which he believed to be densely packed with tiny aethereal vortices. One wonders whether Kirchhoff applied the correct theory to the wrong context, but it is nevertheless generally believed that electric signals do travel along wires at speeds in the order of the speed of light. The only way that these two seemingly contradictory positions could be reconciled is if Maxwell's aethereal vortices constitute tiny electric circulations in which the circumferential speed is the speed of light. See the paragraph below equation (5) in the next section. The drift velocities of charged particles in an electric current are nowhere near the order of the speed of light, but the electric force field that drives them will have an associated aethereal velocity field which will be.

Centrifugal Force

IV. Maxwell's convective electromotive force is a centrifugal force of the form,

$$\mathbf{E} = \mu \mathbf{v} \times \mathbf{H} = \mathbf{F}/q \quad (3)$$

It is a centrifugal force by virtue of its origins in a sea of tiny aethereal vortices which are pressing against each other while striving to dilate, as like the water presses on the walls of Newton's rotating bucket. The magnetic intensity \mathbf{H} is a measure of the vorticity or angular momentum of the vortices. Electric particles at the edge of the vortices have an angular momentum $\mathbf{H} = \mathbf{D} \times \mathbf{v}$ where \mathbf{D} is the displacement of these particles from the polar origin in the centre, and where \mathbf{v} is their circumferential speed. The elasticity in the sea of vortices due to centrifugal pressure is expressed by Maxwell's fifth equation (Hooke's Law) $\mathbf{D} = -\epsilon \mathbf{E}$. Substituting this into $\mathbf{H} = \mathbf{D} \times \mathbf{v}$ leads to,

$$\mathbf{H} = \epsilon \mathbf{v} \times \mathbf{E} \quad (4)$$

If we then substitute (4) into (3) we obtain,

$$\mathbf{E} = \epsilon \mu \mathbf{v} \times (\mathbf{v} \times \mathbf{E}) \quad (5)$$

Since $\epsilon \mu$ is equal to $1/c^2$ and since \mathbf{H} , \mathbf{v} , and \mathbf{E} are mutually perpendicular, then it follows that the circumferential speed of Maxwell's tiny vortices is what determines the speed of light.

If we now consider \mathbf{H} in equation (3) to be a vector field in the vicinity of an electromagnet, we can substitute a form of the Biot-Savart law such that \mathbf{v} becomes the mutual velocity as between an element of electric current in the wire, to which will be ascribed a charge q_1 , and a charged particle with charge q_2 that is moving in the magnetic field. If, based on the Biot-Savart Law, we take \mathbf{H} to be,

$$\mathbf{H} = q_1 \mathbf{v} \times \hat{\mathbf{r}} / 4\pi r^2 \quad (6)$$

then in the special case where \mathbf{v} is perpendicular to $\hat{\mathbf{r}}$, multiplying top and bottom by ϵ , equation (3) becomes,

$$\mathbf{F} = q_1 q_2 \epsilon \mu v^2 \hat{\mathbf{r}} / 4\pi \epsilon r^2 \quad (7)$$

And since $\epsilon \mu$ is equal to $1/c^2$ we get as close as possible to reconciling Maxwell with Weber in the form,

$$\mathbf{F} = v^2/c^2(q_1q_2/4\pi\epsilon r^2)\hat{\mathbf{r}} \quad (8)$$

There is a discrepancy of ½ as compared with Weber’s equation (2). It must be remembered however that Weber first postulated his equation in 1846 not knowing the numerical value of C. Just because the 1856 Weber-Kohlrausch experiment used electrodynamic units of charge as opposed to electromagnetic units of charge, which are related to each other through a factor of $\sqrt{2}$, doesn’t mean that the speed of light, c, wasn’t the correct constant for Weber’s equation.

In the 2006 article entitled *“The Double Helix Theory of the Magnetic Field”* [8], it was argued that the electric particles that surround Maxwell’s tiny vortices are in fact just a single positron and a single electron. In the equatorial plane, the escape velocity relative to the electrostatic force has been exceeded and they are hemmed into their circular orbits by centrifugal force pressing inwards from the surrounding vortices. This centrifugal pressure must be counterbalanced by electrostatic tension in the axial direction channelled along the double helix.

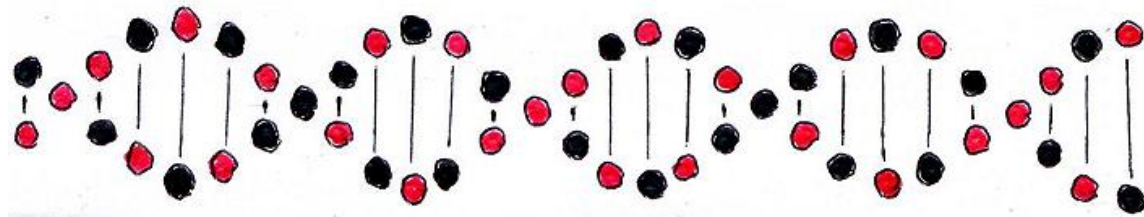


Figure 1. A close-up view of a single magnetic tube of force. Attraction along the tube is caused by electrostatic attraction between the electrons and positrons. Repulsion laterally between adjacent magnetic tubes of force is caused by centrifugal force. Within each rotating electron-positron pair, the orbital speed is what determines the speed of light.

If electrons and positrons are sources and sinks in a primary aethereal fluid, it is proposed that the rate of inflow and outflow will be proportional to the vorticity. The magnetic intensity \mathbf{H} (angular momentum) will therefore determine the electrostatic charge in the axial direction. As such, we cannot simply use Coulomb’s Law to calculate the spacing between the individual vortices, because Coulomb’s Law assumes that electrons and positrons have a fixed charge. In the bound state within the double helix alignment, their electric charge will not however be fixed. While the magnitude of the spacing remains uncertain, it was estimated in section **IV** of the above article [8] that the vortices are on the picometre scale, each about one thousandth the size of an average atom hence rendering the electron-positron sea about thirty-two times denser than lead.

The presence of this dense sea of electron-positron dipoles throughout all of space not only acts as the medium for the propagation of light but also causes a compound centrifugal force to act upon all bodies in motion [9], [10], and this is what gives rise to the Newton's laws of motion and the inertial path. The inertial forces on the large scale are a product of the inertial path and not, as is wrongly taught in the modern literature, a product of making observations from a rotating frame of reference.

Conclusion

V. The speed of light, which arises in connection with both electromagnetic radiation and electric current, is a product of the velocity field of the electric field. It is the average speed with which the ancient electric fluid flows from positive source particles to negative sink particles. This is so in the case of the electric fluid emerging from one terminal of a battery and flowing back into the other terminal, and it is also the case with electromagnetic radiation in space where the electric fluid flows between neighbouring electrons and positrons. Space is densely packed with tiny dipole pairs like two pin power points, each pair consisting of an electron in mutual orbit with a positron circulating at the speed of light. Angular acceleration of an electron-positron dipole leads to an overflow of electric fluid into the neighbouring dipole at that same average speed [11]. This is the principle behind transverse electromagnetic waves.

The velocity field is more correctly the momentum field \mathbf{A} known as the magnetic vector potential [12]. In the tensile state it is gravity and in the pressurized state it is electric current. In particular it is Maxwell's displacement current. It exists everywhere in space in a state of fine-grained circulation such that $\text{curl } \mathbf{A} = \mathbf{B}$ where \mathbf{B} is the local magnetic flux density. This aether when accelerating, would impart its acceleration to particles but not its velocity. When accelerating it would push positive particles along with it, while negative particles would eat their way towards the source. The motion of charged particles in an electric current is merely secondary to a more fundamental flow of aether at average speeds in the order of the speed of light. The idea of such an electric fluid is not new but it gave way to the belief that electric current is in fact a flow of charged particles. The two ideas are not however mutually exclusive.

References

[1] Weber, W., and Kohlrausch, R., "*Elektrodynamische Maassbestimmungen insbesondere Zurueckfuehrung der Stroemintaetsmessungen auf mechanisches Maass*", Treatises of the Royal Saxon Scientific Society, Volume 5, Leipzig, S. Hirzel, (1856)

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](https://www.ifi.unicamp.br/~assis/Weber-Kohlrausch(2003).pdf)

[2] Assis, A.K.T., “***Centrifugal Electrical Force***”, Communications in Theoretical Physics, 18, pp. 475-478 (1992)

[http://www.ifi.unicamp.br/~assis/Commun-Theor-Phys-V18-p475-478\(1992\).pdf](http://www.ifi.unicamp.br/~assis/Commun-Theor-Phys-V18-p475-478(1992).pdf)

[3] Kirchhoff, G., “***On the Motion of Electricity in Conductors***”, Annalen der Physik, Volume 102, p.529 (1857)

[http://freenrg.info/Scientific Books/Kirchhoff on the Motion of Electricity in Conductors .pdf](http://freenrg.info/Scientific_Books/Kirchhoff_on_the_Motion_of_Electricity_in_Conductors.pdf)

[4] Clerk-Maxwell, J., “***On Physical Lines of Force***”, Philosophical Magazine, Volume XXI, Fourth Series, London, (1861)

http://vacuum-physics.com/Maxwell/maxwell_oplf.pdf

[5] Whittaker, E.T., “***A History of the Theories of Aether and Electricity***”, Chapter 4, pages 100-102, (1910)

“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.”

[6] O’Neill, John J., “***PRODIGAL GENIUS, Biography of Nikola Tesla***”, Long Island, New York, 15th July 1944, quoting Tesla from his 1907 paper “Man’s Greatest Achievement” which was published in 1930 in the Milwaukee Sentinel,

“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”.

<http://www.rastko.rs/istorija/tesla/oniell-tesla.html>

<http://www.ascension-research.org/tesla.html>

[7] Tombe, F.D., “***Radiation Pressure and $E = mc^2$*** ” (2018)

<http://www.gsjournal.net/Science-Journals/Research%20Papers-Mathematical%20Physics/Download/7324>

and Tombe, F.D., “***The Speed of Light***” (2014)

<http://gsjournal.net/Science-Journals/Research%20Papers-Mechanics%20/%20Electrodynamics/Download/5373>

[8] Tombe, F.D., “***The Double Helix Theory of the Magnetic Field***” (2006)

Galilean Electrodynamics, Volume 24, Number 2, p.34, (March/April 2013)

<http://gsjournal.net/Science-Journals/Research%20Papers-Mathematical%20Physics/Download/6371>

[9] Tombe, F.D., “*The Coriolis Force in Maxwell’s Equations*” (2010)
Galilean Electrodynamics, Volume 25, Number 2, p.22, (March/April 2014)
<http://gsjournal.net/Science-Journals/Research%20Papers-Astrophysics/Download/3161>
and Tombe, F.D., “*Pythagoras’s Theorem and Special Relativity*” (2018)
https://www.researchgate.net/publication/322559041_Pythagoras's_Theorem_and_Special_Relativity

[10] Tombe, F.D., “*Magnetic Repulsion and the Gyroscopic Force*” (2015)
<http://gsjournal.net/Science-Journals/Essays-Mechanics%20/%20Electrodynamics/Download/5887>

[11] Lodge, Sir Oliver, “*Ether (in physics)*”, Encyclopaedia Britannica, Fourteenth Edition, Volume 8, Pages 751-755, (1937)
<http://gsjournal.net/Science-Journals/Historical%20PapersMechanics%20/%20Electrodynamics/Download/4105>

[12] Tombe, F.D., “*An Interpretation of Faraday’s Lines of Force*” (2019)
https://www.researchgate.net/publication/332249473_An_Interpretation_of_Faraday's_Lines_of_Force

Appendix

The Experimental Determination of Electric Permittivity

A capacitor is discharged using a vibrating switch unit at a frequency f . The discharge current I is measured using a sensitive galvanometer. The capacitance equations are $C = \epsilon A/d$ and $Q = CV$, where ϵ is electric permittivity, C is capacitance, A is the area of the capacitor plates, d is the separation distance between the plates, Q is charge, and V is the applied voltage. Since $Q = I/f$, we can combine these equations into $\epsilon = Id/fVA$, and since V is known, we can numerically evaluate ϵ , which in SI units comes out to be 8.85×10^{-12} farad metre⁻¹.

There has been a tendency since 1983 for the textbooks to avoid treating the experimental determination of electric permittivity ϵ . In that year, BIPM decided to define the metre in terms of the speed of light resulting in the fact that the speed of light itself has now become a defined quantity. This tautology has resulted in the absurd situation whereby equation (1) becomes an equation linking three defined quantities and hence loses all its physical significance. It is not widely known that the speed of light only enters Maxwell’s equations through the 1856 Weber-Kohlrausch experiment. In fact, it is a common error to believe the complete opposite, which is that equation (1) is a consequence of Maxwell’s equations. In modern textbooks, the significance of the speed of light has been shifted away from the Weber-Kohlrausch experiment and placed within the realm of Einstein’s theories of relativity instead. The decision of BIPM to make the speed of light a defined quantity might possibly be interpreted as a decision to consolidate Einstein’s theories of relativity within the established system of units.