

## The 1856 Weber-Kohlrausch Experiment (The Speed of Light)

*Frederick David Tombe,  
Northern Ireland, United Kingdom,  
sirius184@hotmail.com  
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**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 along a wire. Finally 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 [1] compared two systems of electrical units. The principle was to discharge a Leyden jar (a capacitor) that had been storing a known amount of electric charge in *electrostatic units*, and then to see how long it took for a unit of electric current, as measured in *electromagnetic units*, to produce the same deflection in a galvanometer. The ratio turned out to be very close to the measured speed of light. Weber interpreted this ratio in connection with the convectively induced force that he believed to exist between two charged particles in relative motion. He believed it to be the speed that would produce an exact counterbalancing force to the electrostatic force. In this respect, the speed of light becomes like a kind of escape velocity, with the convective force being like a centrifugal force [2]. Maxwell in 1862 however interpreted the result differently.

### Electric Permittivity

II. Electric permittivity,  $\epsilon$ , is associated with dielectrics, yet it is also a disguised value for the speed of light through the equation,

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

Magnetic permeability,  $\mu$ , has always been a defined quantity. Even though Maxwell attributed the physical significance of  $\mu$  to the density of the sea of molecular vortices [3] 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 electromagnetic units  $\mu$  is unity. We can however measure the electric permittivity  $\epsilon$  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 standard equations. The known quantities nowadays are the applied voltage that charges the capacitor in the first place and the frequency of a vibrating reed switch that is involved in the discharging process†.

The situation was different however in 1856 for Weber and Kohlrausch. They 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 electromagnetic units. They found the ratio of these two systems of units to be equal to the speed of light.

In order to make sense out of this amazing result, Weber looked to the convective term in the force equation that he had derived in 1846,

$$F = (v^2/2c^2)(q_1q_2/r^2) \tag{2}$$

In Weber's original works, he uses a constant  $C$  that was actually 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. Weber's equation takes on the form of a centrifugal force written as a proportion of the value of the electrostatic force that it is undermining for a particular radius.

In 1857, Kirchhoff, using Weber's result in the known equations of electromagnetism [4], purported to derive the telegraphy equation and he concluded that electric signals propagate along a wire at the speed of light. Kirchhoff did not give any consideration to what is going on in the space beyond the wire.

Maxwell on the other hand was convinced that Weber's result 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 [3], [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 Weber's convective force equation for the special case of a radius of magnitude 2.81 femtometres as between two fermions. *See section V below.* Maxwell could have applied  $c^2$  to the centrifugal force in his molecular vortices and hence directly established the linkage between the speed of light and the dielectric

constant in the luminiferous medium, as is done in section 2 of *“The Speed of Light”* [7], but that’s not the way that he did do it. Maxwell considered  $c$  to be the speed of a wave in an elastic solid. Using Newton’s equation for the speed of a wave in an elastic solid, he substitutes  $c$ . The result in effect is  $E = mc^2$  as can be ascertained from equations (132) to (135) in his 1861 paper *“On Physical Lines of Force”* [3]. From this Maxwell establishes a dielectric constant for the luminiferous medium. We can then see that the equation  $E = mc^2$  becomes equivalent to the equation  $c^2 = 1/\mu\epsilon$ .

The full derivation is found in Part III of the 1861 paper beginning at equation (105), although it should be noted that Maxwell works backwards from the end result. He starts with the displacement equation (105) containing the dielectric constant and seeks to link that constant to the transverse elasticity of an elastic solid. He then introduces the Weber/Kohlrausch result and substitutes it all into Newton’s equation. In Part III he does not resort to the specifics of the sea of molecular vortices that he postulated in Part I of the same paper, but it would have been better if he had done so. Nevertheless he still establishes that light is a transverse wave in the same medium that is the cause of electric and magnetic phenomena.

† (There has been a tendency in recent years to play down the experimental determination of electric permittivity  $\epsilon$  in the literature. This follows from the tautological fact that in 1983, the speed of light became a defined quantity by virtue of the fact that the metre became defined in terms of the speed of light. The end result is that we have the absurd situation whereby equation (I) becomes an equation linking three defined quantities and hence loses all its physical significance. Under this inferior new way of thinking, the 1856 Weber-Kohlrausch experiment becomes redundant.)

## Electric Current

**III.** In 1857, Kirchhoff using Weber’s ratio, concluded that electric signals propagate along a wire at the speed of light. This however seems to conflict with Maxwell’s analysis of the situation, unless the tiny vortices which Maxwell believed to occupy all of space, constitute tiny electric currents circulating at the speed of light and therefore also account for the speed of electromagnetic waves in which these tiny electric circulations angularly accelerate. The drift velocities of charged particles in a laboratory electric circuit are nowhere near the speed of light, but this is not a problem if we consider the existence of a more fundamental aether flow which constitutes the velocity field of the electric field, with the flow of the charged particles being merely a secondary effect.

## Centrifugal Force

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

$$\mathbf{E} = \mu\mathbf{v}\times\mathbf{H} \quad (1A)$$

It is a centrifugal force by virtue of its origins in a sea of tiny aethereal vortices which are pressing against each other with centrifugal force while striving to dilate, with  $\mathbf{H}$  being a measure of the vorticity. Weber of course never had the benefit of this clarification since he didn't advocate a sea of tiny aethereal vortices, and that's why it's harder to visualize Weber's convective force as a centrifugal force. The modern equivalent of Maxwell's convective force is,

$$\mathbf{F} = q\mu\mathbf{v}\times\mathbf{H} \quad (2A)$$

The significant difference with the modern case is that  $\mathbf{H}$  is yielded by the Biot-Savart law and has lost its overt connection with vorticity. When we substitute  $\mathbf{H}$  using the Biot-Savart law, we get,

$$F = v^2\mu q_1q_2/4\pi r^2 \quad (3A)$$

Multiply the top and bottom lines by electric permittivity  $\epsilon$  and we get,

$$F = v^2\mu\epsilon q_1q_2/4\pi\epsilon r^2 \quad (4A)$$

Working backwards from Maxwell to Weber-Kohlrausch and substituting,

$$\mu\epsilon = 1/c^2 \quad (5A)$$

we get,

$$F = (v^2/c^2)(q_1q_2/4\pi\epsilon r^2) \quad (6A)$$

This equation is the same as Weber's convective equation but without the factor of  $1/2$ . It means that if the velocity is equal to  $c$ , the convective force cancels an attractive electrostatic force. (*Weber's constant  $C$  was therefore more like an escape velocity than a reducing velocity.*) Hence the convective electromotive force has all the hallmarks of a centrifugal force for a particular radius  $R$ . Let's say that,

$$mc^2/R = q_1q_2/4\pi\epsilon R^2 \quad (7A)$$

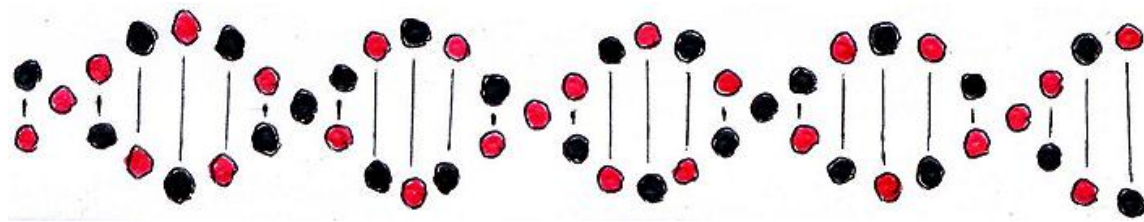
It follows that,

$$c^2 = q_1q_2/4\pi\epsilon mR \quad (8A)$$

Substituting equation (8A) into equation (6A), the convective electromotive force then reduces to the overtly centrifugal force form,

$$F = mv^2/R \tag{9A}$$

where R is equal to 2.81 femtometres in the case of two interacting fermions. This confirms Maxwell’s view that the convective electromotive force is generated by a sea of tiny vortices. While it was established in *“The Double Helix Theory of the Magnetic Field”* [8] that the diameter of these vortices must be in the order of picometres, the separation distance between neighbouring vortices is a thousand times smaller. This is necessary, because the electrostatic force that attracts neighbouring vortices along the axis of the double helices must balance with the centrifugal force which causes the vortices to repel each other in their equatorial planes. In the case of the vortices themselves however, the individual orbiting electric particles have vastly exceeded their escape velocity with respect to the electrostatic force that attracts them together and so the internal diameter of the rotating dipoles is expanded to the picometre scale.



**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 electron-positron pair, the orbital speed is equal to the speed of light.

The presence of this dense sea of electron-positron dipoles throughout all 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 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. Hence this is so both in the case of the electric fluid emerging from one terminal of a battery and flowing back into the other terminal, and also in the case of electromagnetic radiation in space where the electric fluid flows between electrons and positrons, space being densely packed with electron-positron pairs, each pair consisting of a mutual orbit 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 speed [11].

The 1856 Weber/Kohrausch experiment established a linkage between electromagnetism and the speed of light through a ratio between two systems of units. Weber himself saw significance in this through the convective component in the force law that he had derived ten years earlier. The speed of light in this sense became a reducing velocity whereby the magnetic force would overcome the electrostatic force, hence rendering the magnetic force into a kind of analogy with centrifugal force, and the speed of light into a kind of escape velocity. The following year in 1857, Kirchhoff used Weber's result in order to establish that the speed of an electrical signal along a wire is equal to the speed of light. There is a problem though, in that nowadays we know that the drift velocity of electrons in a wire is many orders of magnitude less than the speed of light. This discrepancy will now be explained.

In 1862 James Clerk-Maxwell showed how the speed of light, as established by Weber and Kohlrausch electromagnetically, could be linked to Newton's equation for the speed of a wave in an elastic solid. The speed of a wave in an elastic solid is governed by the kinetic energy of the constituent particles of the solid and the forces acting between them. One way that Weber, Kirchhoff, and Maxwell could all be right is if electric current is a fluid flow that emerges from sources (positively charged particles) and drains out into sinks (negatively charged particles) at an average speed in the order of the speed of light, providing that space is densely packed with tiny electric circulations each comprising of a source and a sink. In that respect, electromagnetic radiation in space would simply be the electric fluid swirling from one tiny circulation to its neighbour during angular acceleration [11]. We must look to the velocity field that exists in conjunction with Gauss's law, and which can be connected to escape velocity. It is proposed that electric current is primarily a flow of pressurized aether while gravity is a flow of tensile aether, the aether being the stuff which binds all matter. Hence the clouds are capacitors and lightning is stored gravity being released under pressure. This aether, when accelerating, would impart its acceleration to particles. It would not however impart its velocity to embedded particles, since particles need to be free to move relative to the aether. The aether when accelerating would push positive particles along with it, while negative particles would eat their way towards the source. As such, the motion of charged particles in an electric current circulation would only be secondary to a more fundamental flow of aether at

average speeds in the order of the speed of light. This electric fluid/aether that was still believed to exist in the nineteenth century gave way to a new concept that electric current is primarily a flow of charged particles. The transition can be seen in the work of Weber and Fechner, whereas Maxwell seemed to work with both concepts. It is essential that the electric fluid is once more restored to the education curriculum.

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