Electromagnetism and Optics – Historical Chronology

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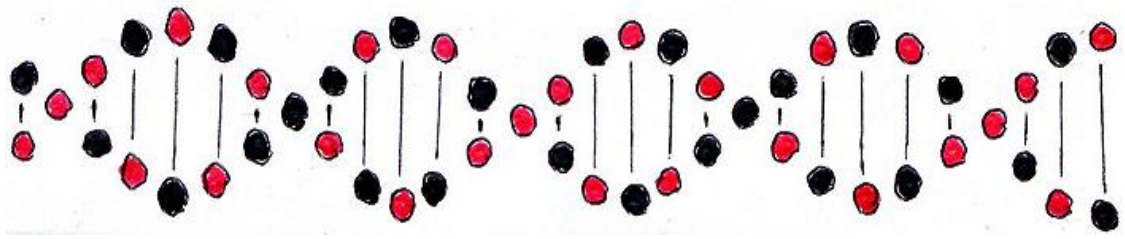
Abstract. **A chronology of the main events in the history of the unity of optics and electromagnetism.**



1855. German physicists Wilhelm Eduard Weber and Rudolf Hermann Arndt Kohlrausch performed an experiment to compare the effects of a closed galvanic circuit with the effects of the discharge-current of a collection of free electricity. From this experiment they obtained the ratio between electrostatic and electrodynamic units of charge, **[1]**.

1857. German physicist Gustav Robert Kirchhoff noticed that the Weber-Kohlrausch ratio, when divided by the square root of two, is very nearly equal to the optically measured speed of light, **[2]**. Had Weber and Kohlrausch used electromagnetic units instead of electrodynamic units, the speed of light would have shown up immediately, and the natural inference would therefore have been, that electric current flows in a conductor at a speed close to the speed of light, and as such, electric current must be something more fundamental than merely the relatively slow flow of charged particles in a conducting wire. But this inference was missed by Weber and Kohlrausch, because, not only having themselves failed to notice the connection between their ratio and the speed of light, they had already bought into Fechner's hypothesis, according to which electric current consists of positive electricity moving in one direction, combined with an equal and opposite current of negative electricity moving in the opposite direction, **[3]**, as though that was the main event. Meanwhile, Kirchhoff also bought into Fechner's hypothesis, and so none of the three of them seemed to perceive of electric current as being a uni-directional flow at a deeper level.

1861-1862. ***(a)*** In Parts **I** and **II** of his 1861 paper, ***"On Physical Lines of Force"***, **[4]**, Scottish physicist James Clerk Maxwell explained magnetic force and electromagnetic induction hydrodynamically in the context of an all-

pervading sea of tiny aether vortices in which electric particles circulate around the edge of the vortices. These vortices bond together by aligning along their mutual rotation axes to form solenoidal vortex rings which constitute the prevailing magnetic lines of force. Stability is established on the basis of a balance between tension acting along the lines of force and centrifugal pressure acting sideways from them. Equation (77) in Part **II** is an electromotive force equation, written here in modern vector format as,

$$\mathbf{E} = \mu_o \mathbf{v} \times \mathbf{H} + \partial \mathbf{A}/\partial t - \nabla \psi \qquad \textbf{(1)}$$

where the first and third terms on the right-hand side of equation **(1)** are the pressure and tension respectively. The centrifugal force, $\mu_o \mathbf{v} \times \mathbf{H}$, presses outwards in the equatorial plane of the tiny vortices as they strive to dilate, **[5]**, **[6]**, where **v** is the circumferential speed of an individual vortex and **H** is its vorticity, that being the basis of the concept of magnetic intensity, while μ_o is a measure of the density of the vortex sea. This force acts sideways on wire that is carrying electric current in a magnetic field, and it is also the convective component in electromagnetic induction. The $-\nabla\psi$ term is the electrostatic force, where ψ is the scalar potential, while the $\partial \mathbf{A}/\partial t$ term in the middle is the force that is involved in time-varying electromagnetic induction, that being the time derivative of the *electromagnetic momentum*, **A**, where **A** is nowadays known as the *magnetic vector potential*. The vector **A** actually represents the momentum density of the *electric fluid, or aether*, and it would appear to represent electric current at the most fundamental level. In modern textbooks, equation **(1)** appears in an alternative format referred to as *the Lorentz force law*, after the Dutch physicist Hendrik Antoon Lorentz.

(b) In Part **III** of the same paper, **[4]**, Maxwell considered his sea of aether vortices to be a dielectric solid and to serve as the medium for the propagation of light, which he referred to as the luminiferous medium. Through the ratio established in the 1855 Weber-Kohlrausch experiment mentioned above, Maxwell connected the elasticity of this luminiferous medium to the speed of light, hence concluding that light is a wave in the same medium that is the cause of electric and magnetic phenomena.

1864. Maxwell conceived of displacement current in Part **III** of his 1861 paper in connection with dielectric polarization and the electrostatic force, but later, in his 1865 paper, ***"A Dynamical Theory of the Electromagnetic Field"***, **[7]**, he extended the concept to time-varying electromagnetic induction, and he derived a wave equation in the magnetic field, **H**. The involvement of the electromagnetic momentum, **A**, in the displacement mechanism, flowing at the same speed as electric current as established by the 1855 Weber-Kohlrausch experiment, indicates that electromagnetic waves must be interwoven with an

aethereal electric current, swirling from vortex to vortex. Maxwell, however, seems to have missed this important observation.

1867. Danish physicist Ludvig Valentin Lorenz, not to be confused with the already mentioned Dutch physicist Hendrik Lorentz, with a 't', proposed a theory in which light was considered to take the form of propagated electric oscillations, **[8]**. We might suppose Lorenz was implying that light is a relay of half-cycle oscillations of fine-grained electric current through a physical medium, satisfying the simple harmonic equation,

$$\mathbf{A} = -\varepsilon_o \partial^2 \mathbf{A}/\partial t^2 = \varepsilon_o \partial \mathbf{E}/\partial t \qquad \textbf{(2)}$$

where ε_o is the reciprocal of the elasticity constant, and where $\varepsilon_o \partial \mathbf{E}/\partial t$ is Maxwell's displacement current.

In the same paper, Lorenz invented *the Lorenz Gauge*,

$$\nabla \cdot \mathbf{A} + (1/c^2)\partial \psi/\partial t = 0 \qquad \textbf{(3)}$$

which, many years later, was involved in the Lorentz transformation of electric and magnetic fields in motion. But as regards applying the Lorenz gauge to electromagnetic waves, if we use Maxwell's version of the luminiferous medium, then the electric current, **A**, will be perpendicular to the radial direction within each vortex, meaning that we would expect the divergence of **A** to be zero, and at any rate, the electromagnetic wave equations cannot be derived unless the divergence of **A** is zero. It seems therefore that Lorenz repeated the mistake that Maxwell made in his 1861 paper, but which Maxwell corrected in his 1865 paper, that mistake being the association of displacement current in wireless radiation with the electrostatic force.

The Lorenz gauge seems to have been a premature proposal invented in the wrong, but closely related context, and which would eventually, years later, find its correct context in the study of electric and magnetic fields in motion, **[9]**.

1884. The Poynting Vector, $\mathbf{S} = \mathbf{E} \times \mathbf{H}$, is the electric power density in wireless electromagnetic radiation. The formula was discovered by Sir Henry Poynting, **[10]**, and independently by Oliver Heaviside in the same year, **[11]**. This formula is derived in connection with the equation of continuity of electromagnetic energy, but we cannot derive it if the electrostatic field, $\mathbf{E_S} = -\nabla\psi$, is the singular component in the electric field term, whereas we can derive it using the time-varying electromagnetic induction component, $\mathbf{E_K} = -\partial \mathbf{A}/\partial t$, all on its own, **[12]**. The essential involvement of the electromagnetic momentum, **A**, testifies to the presence of a flow of electric fluid interwoven with the electromagnetic wave.

1889-1908. This was a period of intense research aimed at establishing the inter-relationships which arise due to matter and fields in motion through the luminiferous medium. It started out as an investigation by Oliver Heaviside into the effects of an aether wind on an electrostatic field, and how Maxwell's equations would be accordingly modified. The main research, carried out by Heaviside, **[13]**, George Francis Fitzgerald, **[14]**, Sir Joseph Larmor, **[15]**, Hendrik Lorentz, **[16]**, and Henri Poincaré, **[17]**, was not centrally coordinated, although ideas were often exchanged between these leading pioneers.

The most significant result emerging from this period of research was the *Lorentz transformation*, which, in 1908, was put into the mathematical form,

$$s^2 = x^2 + y^2 + z^2 - c^2t^2 \qquad \textbf{(4)}$$

by Hermann Minkowski. With the benefit of hindsight, it could be argued that the mathematical perfection inherent in equation **(4)** is evidence in itself of the validity of the Lorentz transformation, and that it only ever remained for experimental evidence to emerge that would point us to the physical contexts in which this interesting mathematical relationship would apply. Now, it's most important to understand, that although this equation has the superficial appearance of a four-dimensional application of Pythagoras's theorem, it is in fact merely a case of successive applications of the standard 3-D Pythagoras's theorem. There can be no equivalent of Pythagoras's theorem in 4-D space, as is explained in ***"Pythagoras's Theorem in Seven Dimensions"***, **[18]**.

Hermann Minkowski did however propose the concept of ***4-D space-time***, as opposed to simply 4-D space. In 1905, Poincaré invented the mathematical tool known as four-vector algebra, distinct from quaternion algebra, and this tool was perfect for the analysis of equation **(4)**. Minkowski developed four-vector algebra further, but before one gets carried away by sensational terminologies like ***4-D space-time***, we first need to find out what the *x*, *y*, *z*, and *t*, variables, as well as *c*, mean in the physical contexts in which we can actually apply equation **(4)**.

We do know in the field of optics that equation **(4)** suggests a transverse Doppler effect, but it can also be shown to be involved in the classical analysis of the return-path longitudinal Doppler effect, **[19]**. The Lorentz transformation, however, is something that is normally applied to matter and fields in motion, and so if the Doppler effect can be extended into matter and fields in motion, then the commonality needs to be physically explained. For example, we would need to identify how the concept of frequency becomes relevant in the case of matter in motion. In the case of atomic clocks, we might therefore be looking at the angular frequency of the caesium atoms, and as such we will consider the atoms and molecules of ponderable matter to constitute complex vortices in the all-pervading electric fluid aether. Meanwhile, in the case of magnetic fields in motion, we would be looking at the angular frequency of the tiny rotating

electron-positron vortices from which a magnetic field is constructed out of the luminiferous medium.

As such, when matter is in translational motion, the to-and-fro, but net forward motion of the aether circulation within the constituent vortices, would bear at least some similarity in principle to the situation with respect to a wave reflected from a moving target. We might expect an actual contraction in length along the direction of motion, corresponding to the Doppler shift in wavelength in the case of a wave being reflected from a target that is moving towards the source, and in all cases, this would be accompanied by an increase in density. But there still remains the issue of how to connect such length contraction and mass increase to the speed of light, unless of course we are dealing with circumferential speeds in the atoms or molecules that are in that order of magnitude. It was roughly along these lines that Sir Joseph Larmor was working, **[20]**. And so, it is here proposed that a Lorentz transformation only makes physical sense if we treat the space variables as relating to the circumferential length of an atom, molecule, or vortex, while treating the time variable as being the associated angular period.

As mentioned above, Maxwell proposed the presence of an all-pervading sea of tiny aether vortices that makes up the luminiferous medium, and this was such as to explain Ampère's circuital law by virtue of the mutually aligned rotation axes of these vortices forming vortex rings around a source electric current. These vortex rings constitute solenoidal magnetic lines of force in the form of a centrifugal force field, and the associated vortices definitely do have a circulation speed in the order of the speed of light, **[21]**. If we consider the special case of one of these tiny molecular vortices in translational motion relative to the wider sea of such tiny vortices, and then apply the Lorentz transformation, with *c* referring to the speed of the circumferential flow of the electric fluid in the vortices, this tends to predict a precession. See ***"The Lorentz Aether Theory"***, **[22]**.

It is therefore proposed that when a force acts on a charged object so as to accelerate it translationally relative to the luminiferous medium, the surrounding vortices precess to form a disc-like solenoidal alignment of their mutual rotation axes. This constitutes a magnetic field perpendicular to the direction of motion. Meanwhile, the asymptotic factor, known as *the Lorentz factor*, predicts that the input energy is increasingly absorbed into this emerging magnetic field, and no doubt adding to the mass of the source charge itself, as opposed to being used to increase its speed. As the source charge approaches the speed *c*, the radially symmetric electrostatic field is being subjected to a flattening effect along the direction of motion, as it morphs into a disc-like magnetic field.

As to the extent that length contraction can be applied to ponderable matter in motion, Lorentz proposed that this is what explains the famous Michelson-Morley experiment of 1887. He suggested that contraction of the longitudinal arm of a Michelson interferometer, undergoing motion through the luminiferous

medium, would result in a reduction of the optical path length in the direction of motion, hence explaining the null result. But that would only be so if we could definitely extend a *speed of light* equivalent to the circumferential momentum of the constituent atoms or molecules of the material from which the arms of the Michelson interferometer are made. The Michelson-Morley null result might perhaps be more credibly explained by the entrainment of the luminiferous medium in the vicinity of the Earth, by the Earth's magnetic field, or failing that, by the Earth's gravitational field, **[23]**.

Recent evidence in connection with the GPS system, does however indicate that the motion of atomic clocks through the luminiferous medium affects the angular frequency of the constituent caesium atoms in line with that predicted by a Lorentz transformation, **[24]**. Perhaps, though, these clocks aren't massive enough for their gravitational fields to entrain a pocket of the luminiferous medium as they orbit the Earth.

By failing to grasp the importance of Maxwell's sea of molecular vortices, as regards providing the basis for a frequency when applying the Lorentz transformation to electromagnetic fields in motion, Lorentz, and later Einstein too, **[25]**, wrongly interpreted the time term. Instead of treating it as a reciprocal angular frequency term in connection with the all-pervading aether vortices, Lorentz talked about a vaguely defined, *"local time"*, while Einstein stupidly treated it as referring to the actual passage of time itself, **[26]**, and likewise, they both treated the space terms as being on the terrestrial scale rather than using the circumference of the vortices as a yardstick. Contrary, however, to what is inferred from the Lorentz transformation, there is no question of any such thing as time dilation on the astronomical scale. When the Earth completes an orbit around the Sun, relative to the background stars, one year will have passed by for everybody in the universe.

Einstein made matters even worse by claiming that the luminiferous medium is not needed at all, despite its central role in establishing a physical rationale for the Lorentz transformation. In doing so, he introduced a symmetry paradox, known as the *clock paradox*, which reduced the Lorentz transformation to absurdity. In fact, even when treated within its correct physical context, it would be true to say that the Lorentz transformation is not a coordinate frame transformation at all, but rather it amounts to the analysis of the precession of a dipolar vortex that is being subjected to linear acceleration through the luminiferous medium.

1915. Einstein's general theory of relativity is essentially just the Lorentz transformation with the escape velocity of the prevailing gravitational field, substituted into the speed, *v* term, all complete with a four-vector analysis.

While electromagnetism is understood in the context of a sea of tiny aether vortices, gravity on the other hand is tied up with a much larger radial flow of the same aether. A gravitational field amounts to a prevailing aether flow

superimposed upon a sea of tiny local whirlpools; therefore, Einstein's general theory of relativity is simply the Lorentz transformation applied to the gravitational inflow.

The orbital speed of a GPS satellite is measured relative to the entrained region of the luminiferous medium which forms the Earth-centred inertial frame of reference, while the shear interaction between the luminiferous medium and the caesium atoms in the onboard atomic clocks, causes these atoms to precess, resulting in a change of both their angular frequency and their energy state. Meanwhile, like pivoted gyroscopes in a gravitational field, these caesium atoms are also caused to precess about the gravitational lines of force, to a degree based on the speed that the pure aether itself flows downwards through the static sea of tiny aether vortices, and into the Earth, **[24]**. Both motion and gravitational field strength therefore affect the rate at which the GPS caesium clocks tick.

The large-scale gravitational aether inflow also causes the all-pervading tiny aether vortices to precess about the field lines, hence accounting for the centrifugal pressure in planetary orbits that emanates at right-angles from the field lines. This centrifugal pressure, at the interface between two gravitational fields increases due to the shear interaction that is caused by the mutual transverse motion between two gravitational fields, **[27]**.

Conclusion. In his 1861 paper, ***"On Physical Lines of Force"***, **[4]**, Maxwell proposed the existence of an all-pervading dielectric sea of molecular vortices. When Maxwell incorporated the speed of light into the elasticity of this luminiferous medium, using the results of the 1855 Weber-Kohlrausch experiment, **[1]**, he should have concluded that light is not just simply a wave in this medium, but that it is a wave which must be intertwined with a flow of electric current. Maxwell should have arrived at this conclusion because the Weber-Kohlrausch experiment was not an optical experiment. It was a purely electric experiment which measured the speed of electric current. Maxwell, unfortunately, did not draw this conclusion. And although he did connect the displacement mechanism in electromagnetic waves with the electromagnetic momentum, **A**, while deriving the first electromagnetic wave equation in his 1865 paper, **[7]**, there was never any direct identification of his famous displacement current with the vector **A** itself in the dynamic state, when the electric fluid is swirling from vortex to vortex. Maxwell missed out on that too.

With the benefit of hindsight, Maxwell's dielectric molecular vortices could now safely be said to have referred to rotating electron-positron dipoles, mutually aligned with their immediate neighbours, so that their rotation axes trace out the prevailing magnetic field, with each individual magnetic line of force constituting a double helix vortex ring of electron sinks and positron sources, **[28]**, **[29]**. The tiny vortices would align around matter in motion, like smoke rings, so as to form a centrifugal force field, similar in principle to a

magnetic field, [27]. While being capable of flowing through the interstitial spaces between the atoms and molecules of ponderable matter, more easily than water flowing through the holes in a basket, a magnetic field, or a strong enough gravitational field, can entrain an extended region of the luminiferous medium along with the translational motion of the field's source object. No such entrainment can however be expected where rotational motion is concerned. As regards the question of the luminiferous medium presenting friction to inertial motion, this would simply manifest itself in the form of the inertial forces, along with the speed of light being a terminal speed predicted by the Lorentz transformation.

Interestingly, although there is no record of Maxwell's sea of vortices ever having been overtly returned to the curriculum in the twentieth century, there is the interesting fact, that by the time of publication of the 1937 Encyclopaedia Britannica, the broad picture of the electromagnetic wave propagation mechanism had been quite well identified.

This quote, from the article ***"Ether (in physics)"***, is in relation to the speed of light, [30],

"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"

Despite what it says though, regarding incompressibility, the sea of aether vortices is nevertheless visibly compressed when two magnetic fields are pushed together, and the corresponding stretchability is observed when two attracting magnets are pulled apart, so the quote is wrong in that particular respect, [31]. The associated compression and rarefaction waves will be dry longitudinal waves, not involving any accompanying net flow of the electric fluid aether, and they will involve restoring forces which are the first and third terms, $\mu_o \mathbf{v} \times \mathbf{H}$ and $-\nabla\psi$, on the right-hand-side of equation **(1)** above.

Electromagnetic waves on the other hand are associated with time-varying electromagnetic induction, as per the middle term, $\partial \mathbf{A}/\partial t$, on the right-hand-side of equation **(1)** above. The fact that the divergence of **A** is zero while its vorticity is $\mu_o \mathbf{H}$, paints a picture of wet vortex waves, intertwined with an electric current of pure aether fluid, swirling in and out of the sinks (electrons) and sources (positrons) that make up the dielectric sea of molecular aethereal vortices that pervades all of space. These wireless waves, which are emitted perpendicularly from a tangential electric current source, will in effect, amount to the propagation of fine-grained precession through a dense sea of tiny fluid

gyroscopes, with the electric current maintaining a straight path on the large scale, but while being constantly being deflected by the gyroscopic force into the axial direction with respect to the precessing gyroscopes/vortices themselves. Hence the electric fluid momentum, **A**, propagates in a wave-like manner through the luminiferous medium, swirling from positron source to electron sink, and when it strikes the conducting wire of a receiving antenna at right-angles, the gyroscopic force from the precessing vortices deflects the electric current at right-angles along the conducting wire, **[32]**.

Electric current in general, at the deepest level, is electric fluid aether, flowing at a speed in the same order as the speed of light, light itself being a particular kind of electric current. Charged particles are involved too, and in a conductor, they move with the current, but they are not the main action, neither do they move at speeds that are anywhere near the speed of the electric fluid itself. In a conductor, positively charged particles get accelerated along with an accelerating flow of electric fluid, while negative particles, being sinks, eat their way in the opposite direction. Wireless electromagnetic radiation is a more complex kind of electric current whereby the electric fluid flows through the dielectric luminiferous medium, in and out of the constituent electron sinks and positron sources. The luminiferous medium is an all-pervading elastic solid comprised of electrons and positrons, bonded together into rotating dipoles on the picoscopic scale. These dipoles exhibit the characteristics of tiny electric circuits, dipolar vortices, fluid gyroscopes, and two-pin power points.

In the case of a DC current source, the emitted electromagnetic radiation forms a near magnetic field, which is in effect a centrifugal force field which hems in any further radiation emission since the vortices in this near magnetic field will be pushing inwards against the current source with centrifugal force in their equatorial planes. This near field unwinds when the power is disconnected, resulting in the electric fluid pouring back into the wire again, still in the original direction.

Man's Greatest Achievement

"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".
Nikola Tesla, 1907, published on 6th July 1930 in the New York American, on 13th July 1930 in the Milwaukee Sentinel, and again on 20th July 1930 in the San Antonio Sunday Light.

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For an English translation by Professor A.K.T. Assis, see chapters 6 and 7 in this link, and especially page 179 regarding mentions about the speed of light.
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Prof. A.K.T Assis has also 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"***,
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Weber and Kohlrausch further 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.
See also, Tombe, F.D., ***"The Commonality between Light and Electric Current"***, (2022)
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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.
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