Loren(t)z

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Introduction

Jean Van Bladel produced many oustanding contributions in electromagnetics, for which he is here remembered.

We wish here to highlight a contribution which can seem minor but which indeed equals the others, not only a scientific or technical contribution but a cultural one.

He was the first, to the best of the author's knowledge, nearly thirty years ago, to point out, in a dedicated article, the rightful attribution to **L.V. Lorenz** of the gauge, and, indeed, of the very idea of retarded potential itself.

These ideas were usually, and sometimes are still, credited to **H.A. Lorentz.**

Jean Van Bladel
(July 24, 1922 – 2018)

Hendrik Antoon Lorentz

Hendrik Antoon Lorentz attended the "Hogere Burger School" with exemplary results: he excelled in physical sciences and mathematics, but also in English, French, and German.

Lorentz studied physics and mathematics at the University of Leiden where he earned a bachelor's degree in physics in 1871.

In 1875 Lorentz earned a doctoral degree under Pieter Rijke on a thesis entitled "*Over de theorie der terugkaatsing en breking van het licht*" (*On the theory of reflection and refraction of light*), in which he refined the electromagnetic theory of James Clerk Maxwell

Hendrik Antoon Lorentz
18 July 1853 Arnhem, Netherlands
4 February 1928 Haarlem, Netherlands

Hendrik Antoon Lorentz

On 17 November 1877, only 24 years of age, Hendrik Antoon Lorentz was appointed to the newly established chair in theoretical physics at the University of Leiden. In 1881, he became member of the Royal Netherlands Academy of Arts and Sciences.

During the first twenty years in Leiden, Lorentz was primarily interested in the electromagnetic theory of electricity, magnetism, and light. After that, he extended his research to a much wider area while still focusing on theoretical physics.

His most important contributions were in the area of electromagnetism, the electron theory, and relativity.

Hendrik Antoon Lorentz

Lorentz theorized that atoms might consist of charged particles and suggested that the oscillations of these charged particles were the source of light.

Pieter Zeeman, colleague and former student of Lorentz's, discovered the Zeeman effect in 1896.

The experimental and theoretical work of both was honored with the Nobel prize in physics in 1902.

Hendrik Antoon Lorentz

Lorentz's name is now associated with

- the Lorentz-Lorenz formula,
- **the Lorentz force**,
- the Lorentzian (Cauchy) distribution,
- the Lorentz transformation.

$$\frac{n^2-1}{n^2+2}=\frac{4\pi}{3}N\alpha_m$$

$$\mathbf{f}=\boldsymbol{e}+q\mathbf{v}\times\mathbf{b}$$

$$f(x;x_0,\gamma)=\frac{1}{\pi\gamma\left[1+\left(\frac{x-x_0}{\gamma}\right)^2\right]}$$

$$t'=\gamma\left(t-\frac{\mathbf{r}_{\parallel}\cdot\mathbf{v}}{c^2}\right)$$
$$\mathbf{r}'_{\parallel}=\gamma(\mathbf{r}_{\parallel}-\mathbf{v}t)$$
$$\mathbf{r}'_{\perp}=\mathbf{r}_{\perp}$$

Hendrik Antoon Lorentz

and, in Electromagnetics, besides

- the Lorentz force,

$$\mathbf{f} = \boldsymbol{e} + q\mathbf{v} \times \mathbf{b}$$

There is also

- the Lorentz Gauge

$$\nabla \cdot \mathbf{A} + \frac{1}{c^2}\frac{\partial \phi}{\partial t} = 0$$

- the Lorentz potential.

$$\phi(\mathbf{x}, t) = \frac{1}{4\pi\varepsilon_0}\int \frac{\rho\left(\mathbf{x}_0, t - \frac{|\mathbf{x}-\mathbf{x}_0|}{c}\right)}{|\mathbf{x}-\mathbf{x}_0|} dV$$

$$\mathbf{A}(\mathbf{x}, t) = \frac{1}{4\pi\varepsilon_0 c^2}\int \frac{\mathbf{J}\left(\mathbf{x}_0, t - \frac{|\mathbf{x}-\mathbf{x}_0|}{c}\right)}{|\mathbf{x}-\mathbf{x}_0|} dV$$

Hendrik Antoon Lorentz

and, in Electromagnetics, besides

- the Lorentz force,

WAIT

There is also

- the Lorentz Gauge
- the Lorentz potential.

$$\nabla \cdot \mathbf{A} + \frac{1}{c^2}\frac{\partial \phi}{\partial t} = 0$$

$$\phi(\mathbf{x}, t) = \frac{1}{4\pi\varepsilon_0}\int \frac{\rho\left(\mathbf{x}_0, t - \frac{|\mathbf{x}-\mathbf{x}_0|}{c}\right)}{|\mathbf{x}-\mathbf{x}_0|} dV$$

$$\mathbf{A}(\mathbf{x}, t) = \frac{1}{4\pi\varepsilon_0 c^2}\int \frac{\mathbf{J}\left(\mathbf{x}_0, t - \frac{|\mathbf{x}-\mathbf{x}_0|}{c}\right)}{|\mathbf{x}-\mathbf{x}_0|} dV$$

These are not Lorentz's but Lorenz's!

Ludvig Valentin Lorenz

Ludvig Valentin Lorenz Ludvig Lorenz is far less known than Hendrik Lorentz.

He was born in Helsingør, known worldwide for being the city were Shakespeare's Hamlet takes place, and studied at the Technical University in Copenhagen. He became professor at the Military Academy of that same city in 1876.

He investigated the mathematical description for light propagation through a single homogeneous medium and described the passage of light between different media.

Ludvig Valentin Lorenz
18 January 1829 Helsingør, Denmark
9 June 1891 Frederiksberg, Denmark

Ludvig Valentin Lorenz

And indeed It has something of a Shakespearian tragedy, to be born in Helsingør and to be mistaken with another scientist.

Yet retarded potentials in electromagnetics and the Lorenz gauge condition were published by him, even if often they are credited to A.H. Lorentz

Indeed his work was almost contemporary to Maxwell's Dynamical Theory, but he did not use Maxwell theory, too complex and new, and based his work on older approaches, as Kirchhoff's.

Helsingør, Castle

Ludvig Valentin Lorenz

In[1] he writes the electric field components u, v, w, following Kirchhoff, as

$$\left.\begin{aligned} u &= -2k\left(\frac{d\Omega}{dx} + \frac{4}{c^2}\frac{dU}{dt}\right), \\ v &= -2k\left(\frac{d\Omega}{dy} + \frac{4}{c^2}\frac{dV}{dt}\right), \\ w &= -2k\left(\frac{d\Omega}{dz} + \frac{4}{c^2}\frac{dW}{dt}\right); \end{aligned}\right\} \quad \ldots\ldots \quad (1)$$

being Ω what we now call ϕ, the scalar potential, and U, V, W the Cartesian component of modern vector potential **A** - vector notation still having to be introduced – and k and c constants.

[1] L.V. Lorenz, “On the identity of the vibrations of light with electrical currents,” Philosoph. Mag., Ser. 4, 34, 230, pp. 287-301, 1867.

Ludvig Valentin Lorenz

but then he introduces a new **retarded** potential, taking into account explicitly the speed of light in defining the potential value at a distance from the source:

$$\bar{\Omega} = \iiint \frac{dx'\,dy'\,dz'}{r}\,\epsilon'\left(t-\frac{r}{a}\right) + \int \frac{ds'}{r}\,e'\left(t-\frac{r}{a}\right)$$

In this latter equation ε' and e' are the volumetric and surface charge densities, respectively, which we now call ρ and ρ_s.

He then defines a similar structure for a retarded vector potential..

Ludvig Valentin Lorenz

Most important, in

$$\bar{\Omega} = \iiint \frac{dx'\,dy'\,dz'}{r}\,\epsilon'\left(t-\frac{r}{a}\right) + \int \frac{ds'}{r}\,e'\left(t-\frac{r}{a}\right)$$

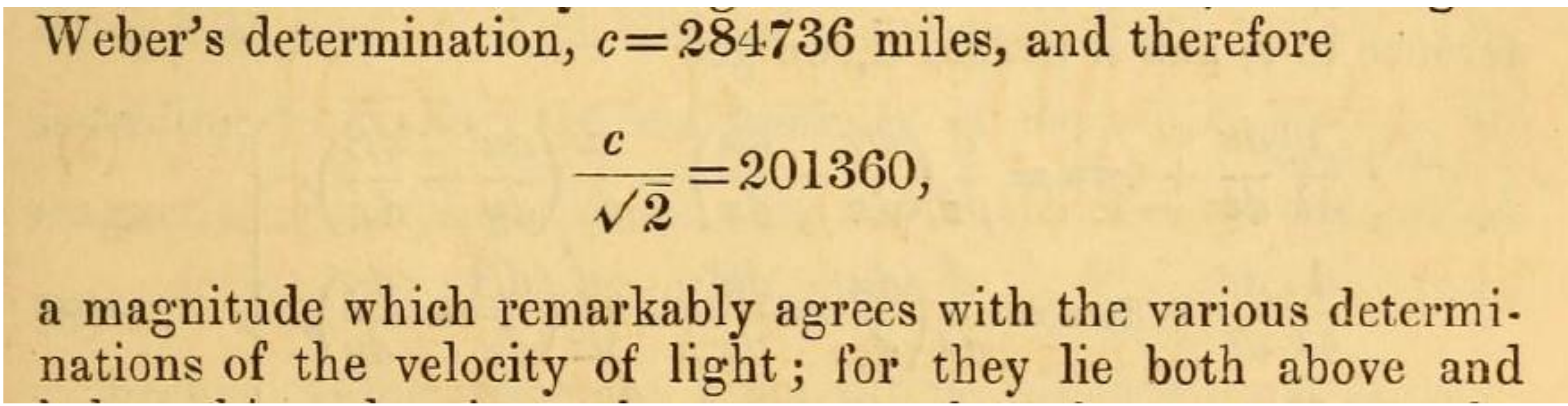
a is the speed of the electrical perturbation in the ether.

Since he derives in his paper that Kirchhoff constant c and his arbitrary velocity a must be in the relation

$$c = \sqrt{2}a$$

Ludvig Valentin Lorenz

He correctly infers that the electrical perturbations he developed moves at a speed which is remarkably similar to the speed of light as it was known at the time



Weber's determination, $c=284736$ miles, and therefore

$$\frac{c}{\sqrt{2}}=201360,$$

a magnitude which remarkably agrees with the various determinations of the velocity of light; for they lie both above and

Ludvig Valentin Lorenz

Lastly, he proves that

by partial integration and introduction of the designations α, β, γ we obtain

$$\frac{d\bar{\Omega}}{dt} = -2\left(\frac{d\alpha}{dx} + \frac{d\beta}{dy} + \frac{d\gamma}{dz}\right).$$

Which, in modern notation is

$$\nabla \cdot \mathbf{A} + \frac{1}{c^2}\frac{\partial \phi}{\partial t} = 0$$

Being α, β and γ proportional to U, V and W with proportionality constant $1/a^2$ or either $2/c^2$

Who did what?

$$f(x; x_0, \gamma) = \frac{1}{\pi\gamma\left[1 + \left(\frac{x - x_0}{\gamma}\right)^2\right]}$$

$$\nabla \cdot \mathbf{A} + \frac{1}{c^2}\frac{\partial \phi}{\partial t} = 0$$

$$\mathbf{f} = \boldsymbol{e} + q\mathbf{v} \times \mathbf{b}$$

$$\frac{n^2 - 1}{n^2 + 2} = \frac{4\pi}{3} N\alpha_m$$

$$t' = \gamma\left(t - \frac{\mathbf{r}_\parallel \cdot \mathbf{v}}{c^2}\right)$$
$$\mathbf{r}'_\parallel = \gamma(\mathbf{r}_\parallel - \mathbf{v}t)$$
$$\mathbf{r}'_\perp = \mathbf{r}_\perp$$

$$\phi(\mathbf{x}, t) = \frac{1}{4\pi\varepsilon_0}\int \frac{\rho\left(\mathbf{x}_0, t - \frac{|\mathbf{x} - \mathbf{x}_0|}{c}\right)}{|\mathbf{x} - \mathbf{x}_0|} dV$$

$$\mathbf{A}(\mathbf{x}, t) = \frac{1}{4\pi\varepsilon_0 c^2}\int \frac{\mathbf{J}\left(\mathbf{x}_0, t - \frac{|\mathbf{x} - \mathbf{x}_0|}{c}\right)}{|\mathbf{x} - \mathbf{x}_0|} dV$$

Jean Van Bladel 1991 paper

As already stated in the introduction, **Jean Van Bladel** produced a very acute contribution in 1991[1], only a column and a half, but very learned.

In his own words, in this paper:

It appears that the various authors of textbooks who sinned against historical accuracy – the undersigned being regretfully one of them – should amend their references in future printings of their books!

[1] J. Van Bladel, "Lorentz or Lorenz?", IEEE Antennas Propagat. Mag., 33, 2, 1991, p. 69.

Lorenz or Lorentz?

The name of the Dutch physicist, Hendrik Antoon Lorentz, is familiar to anybody interested in Electromagnetism. Particularly well-known are his article, "Ueber die Grundgleichungen der Elektrodynamik für bewegter Korper," published in 1890 in the *Annalen der Physik und Chemie*; his extended paper on "La théorie électromagnetique de Maxwell et son application aux corps mouvants," written in 1892 and published in the *Archives neerlandaises des Sciences exactes et naturelles*;" and his book on the *Theory of Electrons*, which came out in 1909 (and has been reprinted by Dover Publications). Lorentz was present at the birth of Relativity, and published his famous transformation formulas, which connect the 4-coordinates in an inertial frame to those in another frame, at the turn of the century. Even more familiar are the "Lorentz retarded potentials," based on the "Lorentz condition." In this instance, however, a case of mistaken paternity seems to have taken place. The undersigned was recently glancing through Whittaker's monumental *History of the Theories of Aether and Electricity*, and read with interest, on p. 268 of Volume 1, that the paternity for the retarded potentials should really be assigned to L. Lorenz, a Danish physicist who introduced them in three articles written in 1867 (Lorentz was 14 years old at the time). One of the articles, entitled "On the Identity of the Vibrations of Light with Electrical Currents," was written in English, and appeared in Volume XXXIV of the *Philosophical Magazine*. It is most interesting. The author first quotes the Kirchoff expression for the electric field, viz.

$$u = -2k\left[\frac{d\Omega}{dx} + \frac{4}{c^2}\frac{d\alpha}{dt}\right],$$
$$v = -2k\left[\frac{d\Omega}{dy} + \frac{4}{c^2}\frac{d\beta}{dt}\right], \quad (1)$$
$$w = -2k\left[\frac{d\Omega}{dz} + \frac{4}{c^2}\frac{d\gamma}{dt}\right].$$

We nowadays use the more compact form

$$\bar{e} = -\mathrm{grad}\,\phi - \frac{\partial \bar{a}}{\partial t}. \quad (2)$$

The quantity c in (1) is a given constant. Lorenz then writes the scalar potential as

$$\Omega = \iiint \frac{dx'dy'dz'}{r}\,\varepsilon'\left(t - \frac{r}{a}\right) + \int \frac{ds'}{r}\,e'\left(t - \frac{r}{a}\right) \quad (3)$$

where ε' and e' stand for the volume and surface charge densities, respectively, and he gives corresponding expressions for the vector potential (α, β, γ). The retardation effect appears clearly in (3), where the symbol a is the velocity of light. Lorenz assumes that c^2 in (1) is $2a^2$, and mentions that the best value of c known at the time was 284736 miles per second. Towards the end of the article, he proves that

$$\frac{d\Omega}{dt} = -2\left[\frac{d\alpha}{dx} + \frac{d\beta}{dy} + \frac{d\gamma}{dz}\right] \quad (4)$$

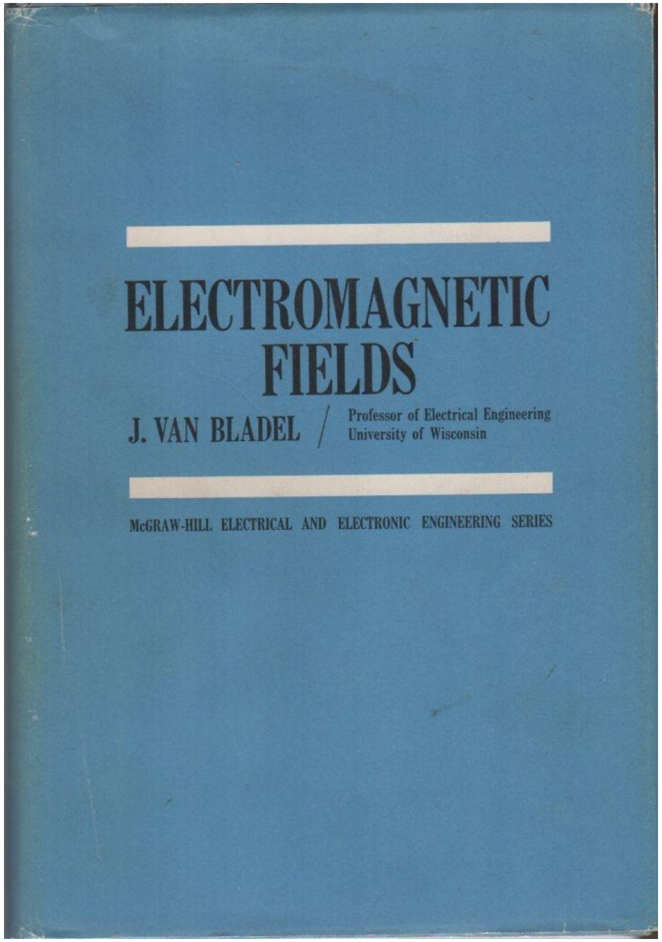
which is the well-known condition

$$\mathrm{div}\,\bar{a} + \frac{1}{a^2}\frac{\partial\phi}{\partial t} = 0. \quad (5)$$

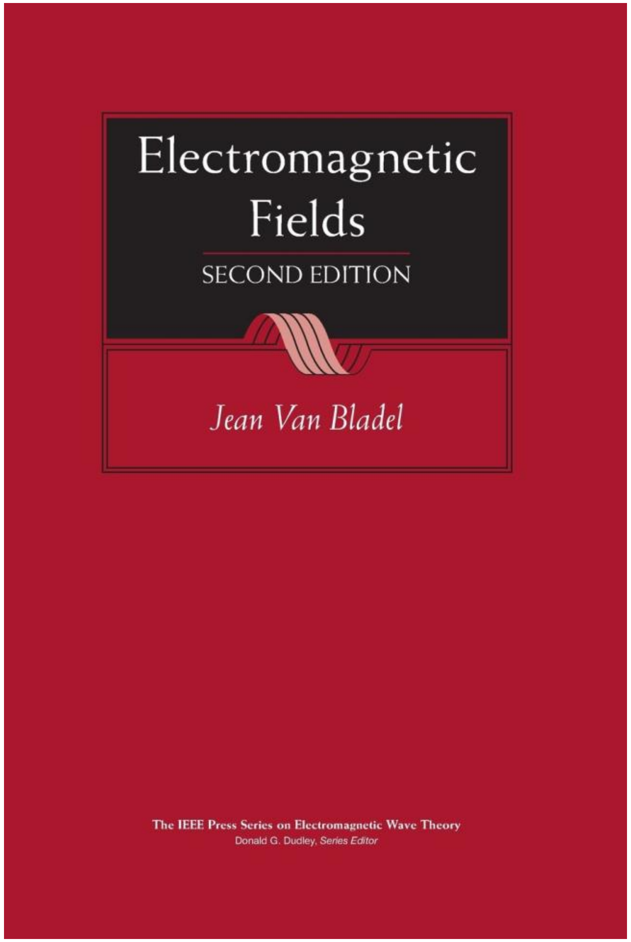
Lorenz' work is remarkable, since it was performed in parallel with that of Maxwell. The reader will probably agree that the paternity suit must be decided in Lorenz' favour. It appears that the various authors of textbooks who sinned against historical accuracy – the undersigned being regretfully one of them – should amend their references in future printings of their books!

J. Van Bladel
University of Ghent
St.-Pietersnieuwstraat 41
B-9000 Gent, Belgium

The Books, by than Bladel



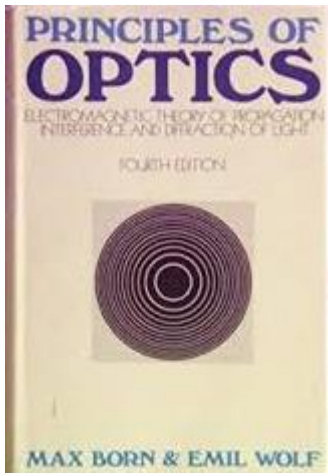
1964, 1st edition
(Lorentz)

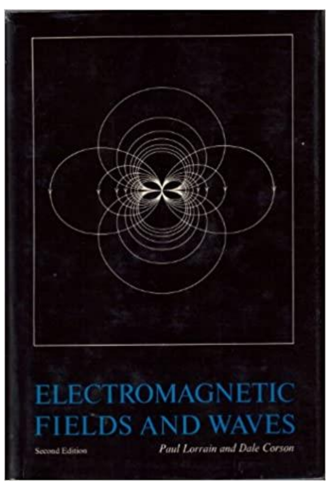


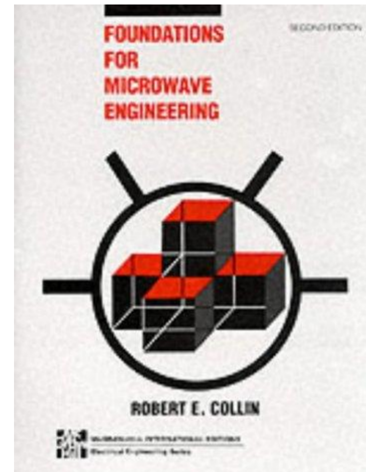
2007, 2nd edition
(Lorenz)

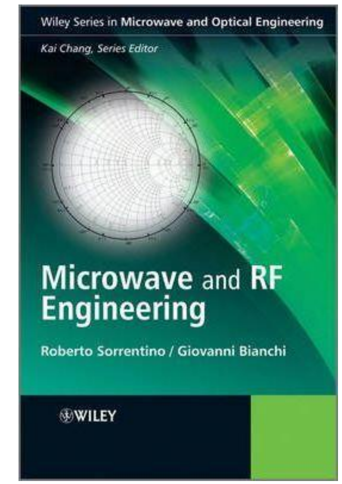
The Books… not crediting Lorenz!

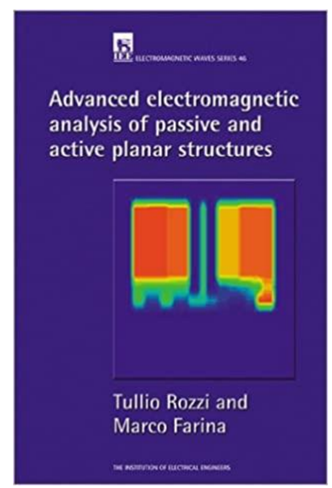
1991

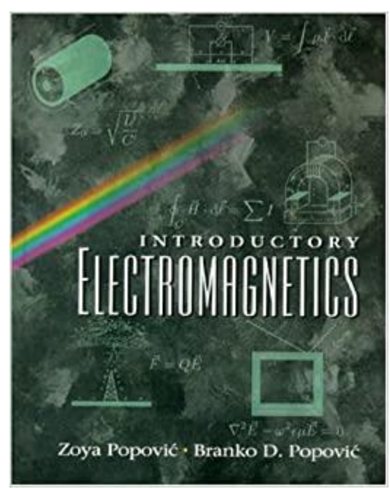


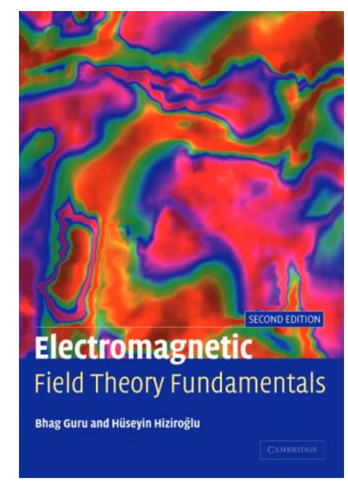












Some more Lorenz

Ludvig Valentin Lorenz contributed more that his Gauge and the retarded potentials to electromagnetics.

He was one of the **four** scientists to independently found a relation linking the refractive index of a medium to its density [1,2]. The other three were A.H. Lorentz, O.F. Mossotti and R. Clausius.

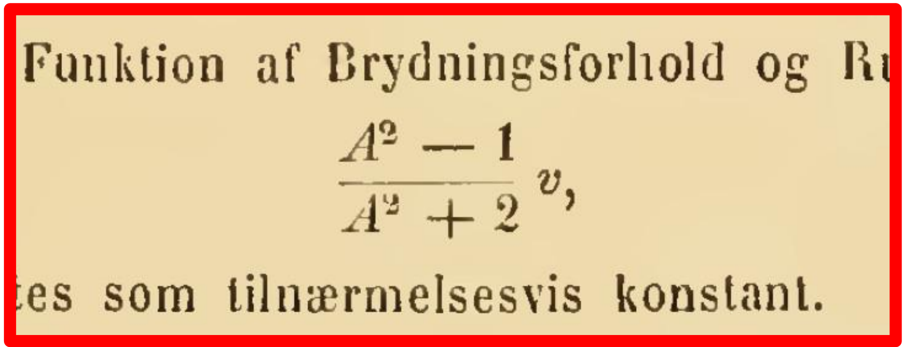
The formula is either the Lorenz-Lorentz formula or the Clausius-Mossotti formula, depending on the Physics field considered.

[1] A. Sihvola, “Lorenz-Lorentz or Lorentz-Lorenz?” IEEE Antennas and Propagation Magazine, Vol. 33, no. 4, p. 56, 1991.

[2] S. Selleri, “The Clausius-Mossotti and Lorentz-Lorenz Relations” URSI Radio Science Bullettin, *to appear*.

O.F. Mossotti

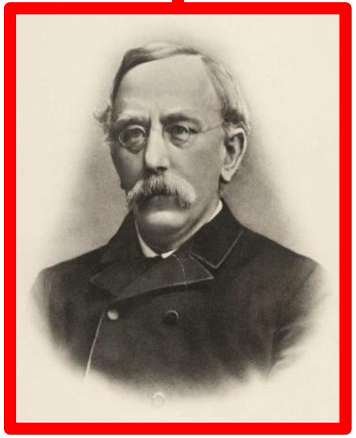
R. Clausius



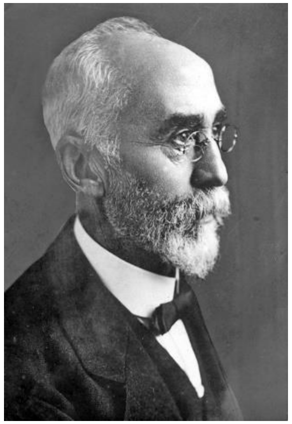
Funktion af Brydningsforhold og R

$$\frac{A^2-1}{A^2+2}v,$$

es som tilnærmelsesvis konstant.



L.V. Lorenz



A.H. Lorentz

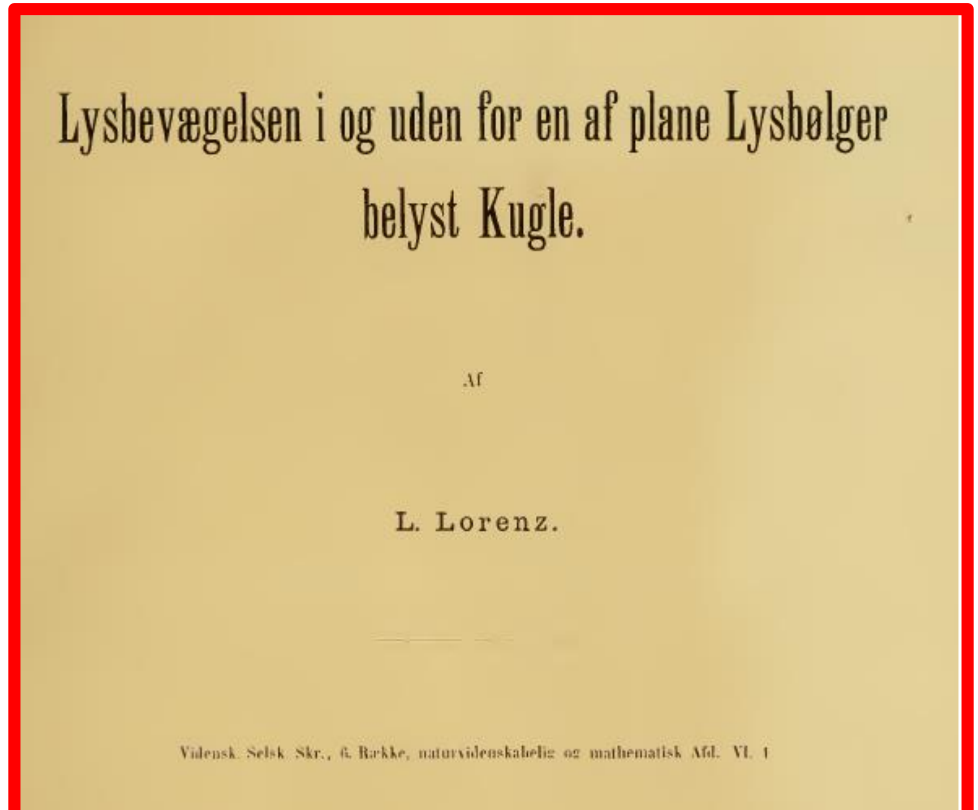
Some more Lorenz

In 1863 A. Clebsch wrote a paper on light scattering by a completely reflecting sphere. This passed unnoticed except by Lorenz, who started working on dielectric spheres in 1885 and published his exact solution in 1890.

Sadly, he published in Danish, and also his paper was unnoticed, even if translated in French in 1896.

Indeed this solution is credited to Gustav Mie, for his 1908 paper where, apparently, he was not aware of Lorenz 1890 paper, but was aware of Lorenz work, since he cites his 1880 Paper[1]…

[1] O. Keller, "Optical works of L.V. Lorenz" in E. Wolf (ed.), Progress in Optics, Vol. 43, Elsevier, Amsterdam, NL, 2002 pp. 195-294.

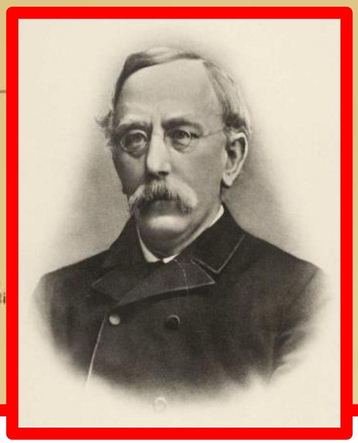

Lysbevægelsen i og uden for en af plane Lysbølger belyst Kugle.

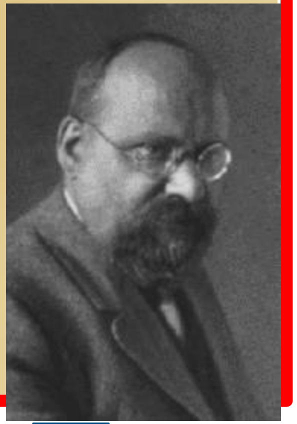
Af

L. Lorenz.

Vidensk. Selsk. Skr., 6. Række, naturvidenskabelig og mathematisk Afd. VI. 1


A. Clebsch


L.V. Lorenz


G. Mie

Conclusions

It is understandable that a Nobel Prize active in electromagnetics might overshadow the contribution of a scientist with (almost) the same family name whose publications were mostly in Danish and translated only in French with large delay.

This explains why this incorrect attribution is so widespread, especially in older textbooks.

Van Bladel was the first, to the best of the author's knowledge, nearly thirty years ago, to point out, in a dedicated article, the rightful attribution to Lorenz of the gauge, and, indeed, of the very idea of retarded potential itself.

This paper by Van Bladel, even if just one page long is, in the authors' opinion a remarkable contribution by him which ought to be celebrated in this special session.

Questions?

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