ELEMENTS OF THE ELECTROMAGNETIC THEORY OF LIGHT

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PREFACE.

THIS little volume, whose object is to present the essentials of the electromagnetic theory of light, was rewritten, at the instance of Messrs. Adam Hilger, Limited, from my Polish treatise on Electricity and Magnetism (3 vols., Warsaw, 1908-1913, published by the kind help of the Mianowski Institution). It consists principally of an English version of chapter viii., vol. ii., of that work with some slight omissions and modifications. In order to make the subject accessible to a larger circle of readers Section 3 was added. The language adopted is mainly vectorial. This is the chief reason of the compactness of the book which, it is hoped, notwithstanding its small number of pages, will be found to contain an easy and complete presentation of the fundamental part of Maxwell's theory of light.

I gladly take the opportunity of expressing my best thanks to Messrs. Hilger for enabling me to submit a portion of my treatise to the English reader.

L. S.

LONDON, *May*, 1918.

CONTENTS.

1. The Origin of the Electromagnetic Theory.

The electromagnetic theory of light, now for many years in universal acceptance, was proposed and developed by James Clerk Maxwell about the year 1865.* By elimination, from his classical differential equations, of the electric current Maxwell has obtained, for the "vector potential" $\mathfrak{A}$,† a differential equation of the second order which in the case of a non-conducting isotropic medium has assumed the form

$$K\mu\frac{\partial^2\mathfrak{A}}{\partial t^2} = \nabla^2\mathfrak{A} \quad . \quad . \quad . \quad . \quad [M]$$

where ∇^2 is the Laplacian (Maxwell's $-\nabla^2$, borrowed from Hamilton's calculus of quaternions). Maxwell's coefficients, the "specific inductive capacity" K, and the magnetic "permeability" μ, are not pure numbers. Let c be the ratio of the electromagnetic unit of electric charge to the electrostatic unit of charge. Then Maxwell's coefficients are such that, for air (or vacuum),

$$K = 1,\ \mu = \frac{1}{c^2},\ \text{in the electrostatic system,}$$

$$K = \frac{1}{c^2},\ \mu = 1,\ \text{in the electromagnetic system.}$$

* *Phil. Trans.*, 1865, p. 459 *et seq.*, reprinted in *Scientific Papers.* See also *Treatise on Electricity and Magnetism*, vol. ii., chap. xx.

† Which, in absence of a purely electrostatic potential, gives the electric force by its negative time derivative, *i.e.* in the notation to be adopted throughout this volume, $\mathbf{E} = -\partial\mathfrak{A}/\partial t$.

Thus, in either system, $K\mu = 1/c^2$, for air. Now, from his above equation which in the case of plane waves, for instance, reduces to

$$K\mu \frac{\partial^2 \mathfrak{X}}{\partial t^2} = \frac{\partial^2 \mathfrak{X}}{\partial x^2},$$

Maxwell concluded at once that the velocity of propagation of electromagnetic disturbances should be

$$v = \frac{1}{\sqrt{K\mu}}$$

in any medium, and therefore, in air, $v = c$.

Thus Maxwell has arrived at the capital conclusion that "*the velocity of propagation in air* [*or in vacuo*] *is numerically equal to the number of electrostatic units contained in an electromagnetic unit of electric charge*". The dimensions of this "number" c, or ratio of units, are obviously those of a *velocity*. For, by what has just been said, we have the dimensional equation

$$[c^2 t^2] = [x^2]$$

where x is a length and t a time.

Now, the experimental measurements of Kohlrausch and Weber,* famous in those times, have given for the ratio of the two units of charge the value

$$c = 310740 \text{ km. sec.}^{-1} = 3{\cdot}107 \,.\, 10^{10} \text{ cm. sec.}^{-1},$$

or rather, after account has been taken of W. Voigt's corrections (*Ann. d. Phys.*, vol. ii.), $3{\cdot}111 \,.\, 10^{10}$ cm. sec.$^{-1}$. Maxwell quotes also the value obtained from a comparison of the units of electromotive force † by William Thomson (1860),

* Kohlrausch and Weber, *Elektrodyn. Maassbestimmungen, etc.*; W. Weber, *Elektrodyn. Maassbestimmungen, insbesondere Widerstandmessungen.*

† An electromagnetic unit of electromotive force contains $1/c$ electrostatic units.