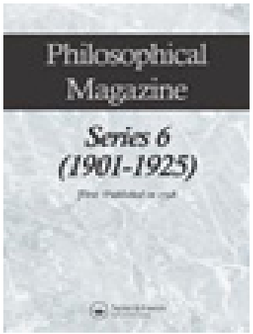

Taylor & Francis
Taylor & Francis Group

Philosophical Magazine Series 6

ISSN: 1941-5982 (Print) 1941-5990 (Online) Journal homepage: http://www.tandfonline.com/loi/tphm17

LXIX. On the ascertained absence of effects of motion through the Æther, in relation to the constitution of matter, and on the FitzGerald-Lorentz hypothesis

Prof. J. Larmor Sec.R.S.

To cite this article: Prof. J. Larmor Sec.R.S. (1904) LXIX. On the ascertained absence of effects of motion through the Æther, in relation to the constitution of matter, and on the FitzGerald-Lorentz hypothesis , Philosophical Magazine Series 6, 7:42, 621-625, DOI: 10.1080/14786440409463156

To link to this article: http://dx.doi.org/10.1080/14786440409463156

LXIX. *On the ascertained Absence of Effects of Motion through the Æther, in relation to the Constitution of Matter, and on the FitzGerald-Lorentz Hypothesis.* *By* Prof. J. LARMOR, *Sec.R.S.**

IN a recent paper by Prof. D. B. Brace (Phil. Mag. April 1904, p. 318) the author removes by very refined experimenting all trace of doubt from Lord Rayleigh's conclusion that motion of transparent solids through the æther does not induce any double refraction, even to the second order of the ratio of the velocity of the translation to that of radiation; but he infers from this the non-existence of the second-order deformation of the solid due to its translation, suggested by FitzGerald and by H. A. Lorentz to account for Michelson's earlier demonstrated absence of effect on optical interferences over long paths in free æther. As he remarks, it had previously been suggested by Lord Rayleigh that such an inference might possibly follow from this result. The object of this note is to explain that the inference in question is the opposite to that which I still hold to be the natural result of the theory of the motion of molecular aggregates through æther, as hitherto developed †.

The argument of Prof. Brace proceeds on the basis that the *whole* effect of the convection through the æther is to *introduce new forces* between the molecules, causing the shrinkage aforesaid along the direction of convection; and it can be readily granted that if this were all, double refraction must result. But both the line of argument suggested as probable by Lorentz ‡, and the molecular analysis offered by me some years later §, proceed by comparing a system shrunk in the FitzGerald-Lorentz manner and convected through the æther, with the *same system* unshrunk and at rest, and finding a complete correspondence between them as regards the states and activities of the individual molecules. As the argument is somewhat complex and has been misunderstood, a brief re-statement of the result may prove useful.

We are to compare the field of physical activity of a system of molecules at rest, with the field of the identically same configuration of molecules in uniform translatory motion through æther. If small quantities of the order of the square of the ratio of the velocity of convection to that of radiation (v/c) are neglected, the Maxwellian physical equations for the

* Communicated by the Physical Society: read May 27, 1904.

† 'Æther and Matter,' Camb. Univ. Press, 1900, chapter xi.

‡ '*Versuch einer Theorie*,' 1895, §§ 91–2, translated in part in 'Æther and Matter,' p. 186.

§ *Loc. cit.*

second system, referred of course to axes of co-ordinates moving along with it, can be reduced to the form belonging to the same system at rest, by the transformation first developed by Lorentz: namely, each point in space is to have its own origin from which time is measured, its "local time" in Lorentz's phraseology, and then the values of the electric and magnetic vectors

$$(f,\ g,\ h) \text{ and } (a,\ b,\ c),$$

at all points in the æther between the molecules in the system at rest, are the same as those of the vectors

$$\left(f,\ g-\frac{v}{4\pi c^2}a,\ h+\frac{v}{4\pi c^2}b\right) \text{ and } (a,\ b+4\pi vh,\ c-4\pi vg)$$

at the corresponding points in the convected system at the same local times. This correspondence can, in fact, be shown to locate the electrons at corresponding points in the two systems, and to make them equal; if, then, they are held in rigid connexion, or more generally if their states of orbital motion in the molecules are conserved, the effect of translatory motion of the system with velocity v is to transform the æthereal field around them and between them as here specified. The fields of æthereal activity are *not identical*, but where one vanishes at any point so does the other at the same point. This conclusion was reached by Lorentz, who pointed out that it carried with it a null result for all recognizable optical tests of convection in the system, up to the first order, with the one exception of the Doppler effect which is involved in the "local" time measurements, and which is only a partial exception because it refers to radiation coming from outside the system.

Does, however, the system of electrons need to be constrained in order to prevent change of configuration when being convected? The force acting on an individual electron e is thereby changed from

$$4\pi c^2 e\left(f,\ g-\frac{v}{4\pi c^2}c,\ h+\frac{v}{4\pi c^2}b\right) \text{ to } 4\pi c^2 e(f,\ g,\ h).$$

If there is a magnetic field (a, b, c) there will thus be alteration: if there is no sensible average magnetic field, even among the molecules, we may perhaps fairly assume, with Lorentz, that no constraint is needed in order to prevent change in molecular configuration in the system due to convection. Anyhow, the absence of recognizable optical result to the first order is certain, as the physical constants of the system in bulk must be unaltered to that order.

But the brilliant experimenting of Michelson and Morley

had already led to the recognition of absence of optical result up to the second order of the ratio of the velocities. Thus the question was suggested whether the above correspondence between the resting and convected systems can be effectively extended up to the second order. It is, in fact, found that the Maxwellian circuital equations of æthereal activity, in the ambient æther, referred to axes moving along with the uniform velocity of convection v, can be reduced to the same form as for axes at rest, up to and including $(v/c)^2$, but not $(v/c)^3$, by adopting a local time $\epsilon^{-\frac{1}{2}}(t-vx/c^2)$ as before, but with a new unit $\epsilon^{-\frac{1}{2}}$, and also a reduced unit of length parallel to x equal to $\epsilon^{-\frac{1}{2}}$, where here and in what follows ϵ represents $1+v^2/c^2$, the units of length along y and z remaining unaltered. It is found that for two æther-fields, one referred to fixed axes and the other to moving axes, standing in this mutual correlation, the electrons, or poles, in approaching which the æthereal electric vector becomes infinite as er^{-1}, are situated at corresponding points and are of equal values: the relation, exact to the second order, is now that

$$(f, g, h) \text{ and } (a, b, c)$$

in the field belonging to the fixed system of poles correspond to

$$\epsilon^{\frac{1}{2}}\left(\epsilon^{-\frac{1}{2}}f,\ g-\frac{v}{4\pi c^2}c,\ h+\frac{v}{4\pi c^2}b\right)$$

and

$$\epsilon^{\frac{1}{2}}(\epsilon^{-\frac{1}{2}}a,\ b+4\pi vh,\ c-4\pi vg)$$

for the field belonging to the convected system; where ϵ is $1+v^2/c^2$, as above, the factor $\epsilon^{\frac{1}{2}}$ being needed to make corresponding poles equal in value instead of merely proportional.

If each pole or electron is connected with a molecule possessing extraneous mass, and it may be having an extraneous field of gravitational and other force of its own, and thereby interacting with other molecules, we shall want to know the forces exerted on that molecule by the surrounding æther, in order to form its own equations of motion, which must be combined with those of the æther-field around it in order to constitute a complete system. But if such other forces are molecularly insignificant, or better, if the electron is a mere passive pole—nucleus of beknottedness in some way—in the æther, conditioned and controlled entirely by the æther around it, just as a vortex ring is conditioned by the fluid in which it subsists and is also carried along thereby, then, as in the familiar hydrodynamics of vortices, the motion of the æther determines the motion of the entirely passive

electrons, and the idea of force acting between them and the æther is dispensed with.

If, then, matter is for physical purposes a purely æthereal system, if it is constituted of simple polar singularities or electrons, positive and negative, in the Maxwellian æther, the nuclei of which may be either practically points or else small regions of æther with internal connexions of pure constraint, the propositions above stated for the first order are extended to the second order of v/c, with the single addition of the FitzGerald-Lorentz shrinkage in the scale of space, and an equal one in the scale of time, which, being isotropic, is unrecognizable.

On such a theory as this the criticism presents itself, and was in fact at once made, that one hypothesis is needed to annul optical effects to the first order ; that when these were found to be actually null to the second order another hypothesis had to be added ; and that another hypothesis would be required for the third order, while in fact there was no reason to believe that they were not exactly null to all orders. Such a train of remarks indicates that the nature of the hypotheses has been overlooked. And if indeed it could be proved that the optical effect is null up to the third order, that circumstance would not demolish the theory, but would rather point to some finer adjustments than it provides for : needless to say the attempt would indefinitely transcend existing experimental possibilities.

As, then, the theory contains no further power of immediate adaptation, what are the hypotheses on which it rests, and how far are they gratuitous hypotheses introduced for this purpose alone ? Up to the first order the electron hypothesis, that electricity is atomic, suffices by itself, as Lorentz was the first to show. Yet, even if the nature of the particles of the cathode discharge had never been made out, and the Zeeman effect had never been discovered, the facts known to Ampère and Faraday were sufficient to *demonstrate* that no other conception of electricity than the atomic one is logically self-consistent *.

Up to the second order the hypothesis that matter is constituted electrically—of electrons—is required in addition. For this there is no independent evidence except perhaps the general simplicity of the correlations of physical law. The circumstance that positive electrons have not yet been isolated naturally counts considerably on the other side ; yet the theory puts no limit to the size and inertia and complexity of an electron, it only prescribes that it must be a collocation of æther poles connected together by some sort of pure constraint, but with no extraneous activities.

* *Cf.* 'Æther and Matter,' p. 337.

Any rival theory must on the threshold give an account of the Michelson null optical result, of Trouton's null electric result for convection of a charged condenser *, and of Rayleigh's absence of double refraction now rendered thoroughly secure by Brace †.

As electrons are already held to be a reality on various grounds, theoretical and experimental, it would appear therefore that there is much to be said for a benevolent attitude to the proposition that all the interactions of matter, so far as the laws of physics and chemistry extend, are to be described as phenomena occurring in and through the æther, and thus differentiated from the more recondite world of vital growth and change which they make manifest to our senses. This principle does not yet, so far as one can see, stand in the way of any other branch of physical science, while it accounts for the very remarkable absence of influence of the earth's motion through space on the most sensitive phenomena, and is almost led up to thereby.

It is pertinent to the present subject to refer to Mr. Sutherland's recent remarks (Phil. Mag. April, p. 406) on the magnetic effect of electric convection, in relation to the mysterious action of a dielectric varnish that has been announced by Crémieu and Pender. The discrepancy in the conservation of energy, there described, applied to the domain of electric polarization, is too startling to have been overlooked by the current theory ‡; and accordingly closer consideration gets rid of the difficulty. When an electron e is transferred in an electric field from a place where the potential is V_1 to a place where it is V_2, the force acting on it, being e multiplied by the gradient of V, does work equal to $e(V_1-V_2)$. When, however, the electron is embedded in a piece of dielectric matter which is so transferred, the force acting on the electron itself is diminished by the presence of the surrounding polarized matter, and so the work done on the electron is less than before: but now the electric polarization induced by the electron in this surrounding matter is also acted on by the electric field, and if we add the work done on it during the movement, we shall get the same total work as before for the system that is moved, and there will be no discrepancy to be otherwise explained.

Cambridge, April 7, 1904.

---

* Phil. Trans. 1903.

† The null influence on optical rotation, observed by Rayleigh, counts here as a first-order effect.

‡ *Cf.* Phil. Trans, 1897 A, p. 248, and 'Æther and Matter,' 1900, Appendix A.