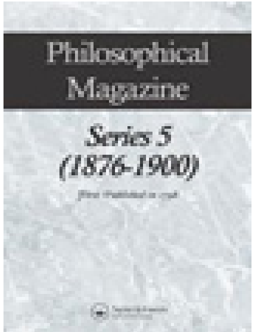

Philosophical Magazine Series 5

ISSN: 1941-5982 (Print) 1941-5990 (Online) Journal homepage: http://www.tandfonline.com/loi/tphm16

III. Experiments on the motion of the æther in an electromagnetic field

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To cite this article: W. Craig Henderson M.A. B.Sc. & J. Henry M.A. B.E. (1897) III. Experiments on the motion of the æther in an electromagnetic field , Philosophical Magazine Series 5, 44:266, 20-26, DOI: 10.1080/14786449708621024

To link to this article: http://dx.doi.org/10.1080/14786449708621024

Published online: 08 May 2009.

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water, becomes more conductive and its freezing-point falls. The *increase of conductivity* is proportional to *the amount of water* added. This law holds from 1 to 6 % of water. Similar *proportionality* appears between the *freezing-point* and *conductivity* and between the *freezing-point* and *concentration* measured in *per cents.*

The *specific conductivity* of anhydrous formic acid freezing at $8^{\circ}{\cdot}52$ is $1{\cdot}5 \,.\, 10^{-9}$ in terms of mercury at $8^{\circ}{\cdot}52$, which value agrees very well with the observations of Saposchnikoff.

The molecular conductivity of anhydrous formic acid freezing at $8^{\circ}{\cdot}52$ is $32 \,.\, 10^{-9}$ in terms of mercury at $8^{\circ}{\cdot}52$.

The temperature-coefficient, or the change of the conductivity in per cents. for 1°, is 0·020, and it is practically the same for all solutions of water in formic acid up to 6 %.

The relations can be written :—

Specific conductivity at the temperature of freezing
$$= 6{\cdot}10 + 10{\cdot}546 \text{ (per cents. of water).}$$
$$= 64{\cdot}77 - 6{\cdot}937 \text{ (freezing-point).}$$
$$\text{Freezing-point} = 8{\cdot}52 - 1{\cdot}537 \text{ (per cents. of water),}$$
using the limits from above.

My best thanks are due to Prof. J. J. Thomson who supported me with his kind advice, and to Mr. W. C. D. Whetham, who followed this work with the greatest interest.

Cambridge, Cavendish Laboratory,
1896–97.

III. *Experiments on the Motion of the Æther in an Electromagnetic Field.* *By* W. Craig Henderson, *M.A., B.Sc., and* J. Henry, *M.A., B.E.,* 1851 *Exhibition Science Scholars* *.

An electric wave when it passes through the æther produces a displacement current and a magnetic force at right angles to this current; there will thus be a mechanical force acting on the æther in a direction at right angles both to the displacement current and to the magnetic force, which will therefore at some distance from the radiator be at right angles to the front of the wave. If the oscillations are not damped this force will be periodic and its mean value zero; it will, however, have a finite value if the oscillations are rapidly damped. The following experiments were undertaken at the suggestion of Professor J. J. Thomson to see whether this force would set the æther in motion.

* Communicated by Prof. J. J. Thomson, F.R.S.

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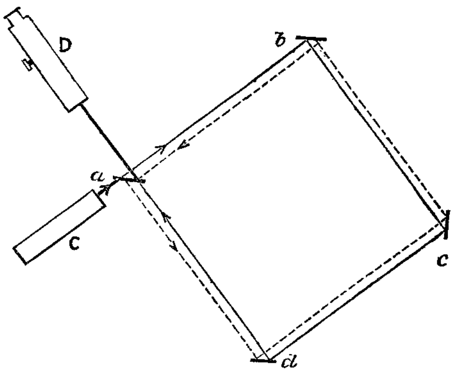
The method adopted for the detection and measurement of this motion was similar to that used by Professor Oliver Lodge*. Three small plane mirrors are placed vertically at three corners of a square marked out on a rigid table. These mirrors were mounted in such a way that, by the pressure of screws behind, a slight rotation round a vertical or round a horizontal axis could be given to each. The mirrors were placed with their planes perpendicular to the diagonals of the square. At the fourth corner and with its plane in the diagonal there was placed a fourth mirror, vertical as the others, but "silvered" only to such an extent that a beam of light incident at 45° is divided into two beams of approximately equal intensity, one transmitted, the other reflected.

Fig. 1.



A beam of parallel light from the collimator C (fig. 1) falls on this mirror (a) at the required angle of 45°. The transmitted beam passes along the side ab, while the reflected beam goes at right angles to this along ad. By adjustments of the mirrors b, c, d these two beams are made to pass round the square to a again, where they are partly transmitted and partly reflected, so that both now travel in the same direction along aD.

By carefully adjusting the mirror a these two beams are superposed so as to produce interference-fringes, which are observed through the telescope D. In actual experiment we found that the two beams produced by the semitransparent mirror were of unequal brilliancy, the reflected beam being the more intense; and in order to obtain the best effect we found it necessary to move that mirror in the direction of the transmitted beam so as to decrease the angle of incidence, thereby

* Phil. Trans. vol. clxxxiv. (1893).

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decreasing the amount of reflected light and increasing that of transmitted light. By this means we obtained in the field of the telescope perfectly defined interference-bands, the slightest motion of which could be at once detected.

If now the æther can be made to move in the direction of the transmitted beam, the increase thus caused in the velocity of light in that direction and the corresponding diminution of the velocity of light in the contrary direction should alter the difference of phase between the beams on arrival at the mirror *a*, and so produce a displacement of the bands.

To endeavour to produce this motion of the æther our apparatus was arranged as follows:—Two condensers, consisting each of two plates of sheet tin (56 centim. × 39 centim.) separated by a glass plate (3 millim. in thickness), were laid horizontally side by side on paraffin blocks on a table. The bottom plates were connected to the terminals of the secondary of a Ruhmkorff coil. The upper plates were joined through a circuit containing two spark-gaps—one placed at the slit of the collimator so as to be the source of light, while the other was situated at a distance of 4 centim. from the edge of the mirror *c* and in the plane of the mirror.

The primary plates of the condenser were also connected through a spark-gap. When these plates are raised to a high potential by the coil they suddenly discharge themselves through the spark-gap, thus causing the secondary plates to discharge themselves through their connecting circuit with its spark-gaps.

The equation for the discharge of a condenser of capacity C through a circuit of self-induction L and resistance R is

$$L\frac{d^2Q}{dt^2}+R\frac{dQ}{dt}+\frac{Q}{C}=0,$$

whence

$$Q=A\epsilon^{\left(-\frac{R}{2L}\pm\frac{\sqrt{R^2-\frac{4L}{C}}}{2L}\right)t+\alpha},$$

where Q is charge in condenser at time *t* after beginning of discharge.

If $R^2<\frac{4L}{C}$, the discharge is oscillatory, and

$$Q=A\epsilon^{-\frac{R}{2L}t}.\cos\left[\sqrt{\frac{1}{LC}-\frac{R^2}{4L^2}}.t+\alpha\right].$$

The amplitude of the oscillation is

$$A\epsilon^{-\frac{R}{2L}.t},$$

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and the period is

$$T=\frac{2\pi}{\sqrt{\frac{1}{LC}-\frac{R^2}{4L^2}}}.$$

In order to compare the magnitudes of successive oscillations, we have

(i.) $t=0$, amplitude $= A$.

(ii.) $t=T$, amplitude $= A\epsilon^{-\frac{R}{2L}\cdot\frac{2\pi}{\sqrt{\frac{1}{LC}-\frac{R^2}{4L^2}}}}$.

As R is increased, since $R^2<\frac{4L}{C}$, both factors in the index of ϵ in (ii.) increase, and therefore the amplitude diminishes.

By introducing a resistance, therefore, into the circuit the effects of second and succeeding oscillations may be rendered negligible. In the secondary circuit of our condensers we accordingly introduced a resistance which experiment showed to be sufficient to fulfil this object.

The object of the spark near *c* is to produce electric waves in the direction *cb*, those in the direction *cd* being screened off by a copper plate. If, then, these electric waves are accompanied by an actual motion of the æther in the direction of propagation, it should be at once apparent by the displacement of the interference-bands. In actual experiment this spark-gap was at first short-circuited; then one of us observed the bands produced by the spark at the collimator, and watched if he could detect any displacement when the short circuit was suddenly removed. In repeated experiments, however, no motion whatever was discernible, although a displacement for one fifth of the breadth of a band—a displacement which would be produced by an alteration of the difference of phase by one tenth of a period—would have been visible to the eye.

In our next experiment the spark-gap at *c* was removed, and the wires of the secondary circuit were led to earth after passing round the three sides *ab*, *bc*, *cd* of the square—parallel to the beams and so as to include the beams between them. The same damping was kept in this circuit. The wires were insulated on paraffin blocks and strips of tinfoil hung over them to a depth of 3 centim. throughout their length, thus giving sides to the electric waves (fig. 2).

When the secondary plates discharge, a positive current runs down the one wire and a negative current down the

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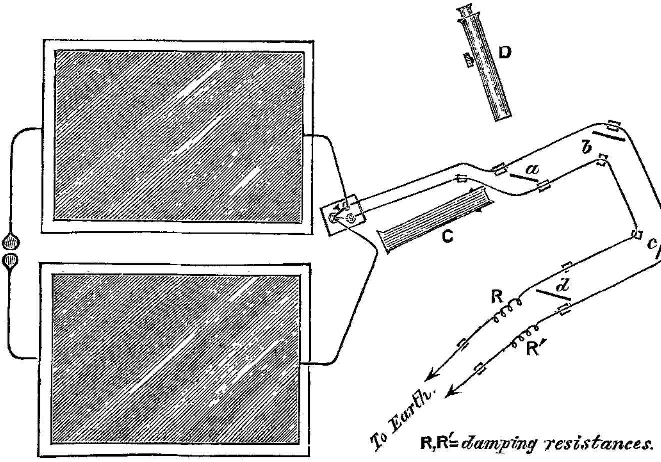
other. We may therefore consider the space between the strips to be filled with tubes of forces stretching horizontally across perpendicular to the beams of light and moving along in the direction of the transmitted beam. If these tubes of

Fig. 2.



force drag the æther with them, a displacement as already described should be observed in the interference-bands, when, after being short-circuited, these parallel wires are suddenly introduced into the circuit.

In our experiments, however, we again failed to detect any motion. At this point we may find what minimum velocity of the æther would have been detected by this method.

Let u = velocity of the æther,
v = " " light,
d = path of light in moving æther,
λ = wave-length of light used.

Then $v+u$ = velocity of one beam,
$v-u$ = velocity of other beam ;

$\therefore \quad \dfrac{d}{v+u}$ = time taken by first beam to travel distance d,

and $\dfrac{d}{v-u}$ = " " second " " "

$\therefore \quad \dfrac{2ud}{v^2-u^2}$ = difference of time occupied by the two beams in passing round the square.

Denote this time by τ.

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Let $\tau = n\mathrm{T}$, where T is the period of vibration of the light used. There will therefore be a displacement of the fringes through $2n$ bands. Taking one fifth of the breadth of a band as the minimum displacement which the eye could have detected—and such a displacement could certainly have been observed—we have

$$n = \frac{1}{10},$$

$$\therefore \quad \frac{2ud}{v^2 - u^2} = \frac{1}{10} \cdot \mathrm{T}.$$

Neglecting u^2, for a first approximation we have

$$u = \frac{1}{20} \cdot \frac{v^2 \mathrm{T}}{d},$$

$$= \frac{1}{20} \cdot \frac{v\lambda}{d},$$

For

$$v = 3 \times 10^{10} \text{ centim. per second,}$$

$$\lambda = 0{\cdot}00059 \text{ millim.,}$$

$$d = 77 \text{ centim.,}$$

we have

$$u \doteqdot 11{\cdot}5 \text{ metres per second.}$$

So that any velocity of the æther exceeding 11·5 metres per second would have been detected ; and the experiment therefore shows that if the æther does move at all, its velocity does not attain to even this small magnitude.

In our first experiment, as $d = 27$ centim., a velocity of the æther of at least $\frac{77}{27} \times 11{\cdot}5$ metres per second would have been detected.

In our third experiment we dispensed with the condensers and circuit round the mirrors, and interposed in the path of the light along the side *bc* of the square (fig. 1) an electrolytic cell (breadth 45 millim., length 61 millim., height 42 millim.) with bottom and sides of plate glass and ends of brass. These brass plates formed the electrodes of the cell, so that when connected to storage-cells there was a uniform current through the electrolyte (acidulated water). The cell rested on one pole of an electromagnet with the other pole vertically over it, and was so placed that the beams of light traversed it at right angles to the current. We therefore had a vertical magnetic field, a horizontal electric current, and the beams of light at right angles to both. The interference-fringes were now obtained by a sodium-flame at the slit of the collimator,

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and were much brighter than those obtained from the electric spark; but assuming as before one fifth of a band's breadth as the minimum displacement which would be visible to the eye, we have, since $d=45$ millim.,

$$u \doteq 200 \text{ metres per second}$$

as minimum velocity of the æther in the cell which would be detected. The strength of the magnetic field was 300 C.G.S. units.

In our final experiment, while retaining the electromagnet in position, we removed the electrolytic cell and set up in its place a horizontal electrostatic field by means of a condenser, consisting of two tin plates $4\frac{1}{2}$ centim. apart. These plates measured 17 centim. × 12 centim., but one of them was cut at the middle of its length so as to pass between the pole-pieces of the electromagnet. The position of the apparatus was therefore this:—The plates of the condenser were in vertical planes parallel to the direction of the beams of light. Between these plates were the poles of the electromagnet, the one vertically above the other. The plates were connected with the poles of a Wimshurst machine, and also with the terminals of a Kelvin electrostatic voltmeter. The negative pole of the machine was connected further with the case of the voltmeter and led to earth. The positive plate of the condenser was insulated on glass plates.

The strength of the magnetic field was the same as before, 300 C.G.S. units; and between the plates of the condenser the difference of potential was varied, the maximum being 6600 volts. During each set of observations the potential was kept constant; but in none of the observations was any motion of the interference-bands discerned.

Cavendish Laboratory,
Cambridge, 1897.

IV. *A Nickel Stress Telephone.* *By* T. A. Garrett, *M.A.*, *and* William Lucas, *M.A.**

It is well known that, if a magnetized nickel wire be subjected to longitudinal stress, variations of this stress produce variations in the magnetization of the wire. If the stress be a pressure, an increase in the pressure produces an increase in the magnetization, and a decrease in the pressure a decrease in the magnetization.

Suppose then that a magnetized piece of nickel wire,

* Communicated by the Physical Society: read April 9, 1897.