intense light from time to time arise in those portions of the tail that were furthest from the nucleus. Sometimes instantaneous, and appearing upon a small extension of the extremity of the tail, which then became more visible, the fugitive gleams receded before the passing light of the aurora borealis. At other times they were less fleeting, and their propagation in rapid succession could be followed for some seconds in the direction of the nucleus near the extremity of the tail. These appearances then resembled the progressive undulations of the aurora borealis; but even in this case they were only visible in the last third of the length of the tail. The gleams in question were similar to those that I remember to have seen in the tail of the great comet of 1843, and which were observed by very many astronomers. 1

The American observers of Donati’s comet in 1868 described a number of brighter bands “like auroral streamers” crossing the tail and diverging from a point between the nucleus and the sun.

This point is one well worthy of subsequent inquiry. I have brought together evidence to show that in the aurora one of the chief factors in the production of the spectrum is meteoric dust. If this be conceded, we have meteoric dust in all probability very close to the sun through our atmosphere at a height at which its pressure is very low, the luminosity both of the dust and the atmosphere being produced by electricity. Whether the electricity is produced by the movement is a matter on which we are quite ignorant, but it has been shown that all aurora follow well-recognized star-shows a certain amount of plausibility will be accorded to the notion.

However this may be, we must in the case of the aurora regard the permanent gases in the air as a constant, and the dust as the variable. But if we wish to assimilate these displays with comets’ tails, we must in the latter case consider meteors in space as the constant, and the permanent gases repelled from the comet as the variable.

Prof. Tait, assuming that the head of a comet is a swarm of meteors or stones, varying in size from a marble to boulders 20 or 30 feet in diameter, has shown that all the various cometary phenomena may be explained. His researches have not yet been printed in extenso, but the following general statement gives a summary of the results of his calculations which appeared in his book. 2

Firstly, with regard to the masses of the comets. The total mass of a comet cannot be very great, for, as we have seen, no measurable disturbance of planetary orbits has been known to be produced, and this small mass is just as likely to be due to scattered solid masses as to one continuous gaseous mass, and indeed it is not likely that this is so. In the case of comets of small masses, the component meteors would be small and far apart.

Then, with regard to the transparency of the comet, it is calculated that a meteoric 25 feet in diameter at a distance of half a million miles from us could not totally eclipse a star of the same size as our sun, even if it were at such a distance as to be barely visible to the naked eye. Again, if some of the meteors were large enough to eclipse the stars behind the comet, the eclipse would be of very brief duration, and we should see the star as if nothing had happened. In order for the comet to reduce the light of a star seen through it by one-tenth, it would require to be 300 miles thick, suppose the stones to be 1 inch cube and 20 feet apart.

The force which builds up the comet is coursing round the sun as a whole, the individual members will themselves gravitate towards each other; and if we suppose the whole mass to be 1/1000 that of the earth, and the meteors to be uniformly distributed in a sphere 20,000 miles in diameter, those coming from the outside to the centre of the group would have a velocity of about 300 feet per second. The stones colliding will generate heat, and some gas will be evolved; some members of the mass will be quickened, while other constituents of the mass will be retarded in their motion, and in this way we have a probably sufficient explanation of the various forms which the telescope has revealed to us. And then finally Prof. Tait goes on to show that the result of these collisions would be such a smashing up of the constituent parts of the swarm that much finely attenuated material would be left behind, sufficient to reflect sunlight, and to give rise to the phenomena of the tail.


1 Translated and communicated by Dr. Oliver Lodge.

THE FORCES OF ELECTRIC OSCILLATIONS TREATED ACCORDING TO MAXWELL’S THEORY. BY DR. H. HERZ.

1.

Note by the Translator.

The early part of the following paper is no doubt familiar to the more important persons in this country, and therefore need perhaps hardly have been translated. Nevertheless, as these experiments of Hertz form a sort of apotheosis of Maxwell’s theory, it is natural to reproduce this portion, as well as the rest; and part would be about 176 feet. The swarm would reflect about half as much sunlight as a slab of the same material in the same place, but would probably be too opaque to transmit starlight. By making the stones larger, and thus increasing the distances between them, the luminosity would be retained, while at the same time the swarm would be sufficiently transparent. It thus seems to suit the hypothesis better if we regard the separate stones to be greater than 10 inches cube.

J. NORMAN LOCKEY.

The results of the experiments on quick electric oscillation which I have carried out appear to me to lend to Maxwell’s theory of electrodynamics an ascendency over all others. At first I interpreted these experiments in terms of older notions, seeking to explain the phenomena in part by means of the cooperation of electrostatic and electro-magnetic forces. To Maxwell’s theory in its pure development such a distinction is foreign. I wish, therefore, now to show that the phenomena can also be explained in terms of Maxwell’s theory without any such distinction. If this attempt succeeds, questions about special propagation of electrostatic force, being meaningless in Maxwell’s theory, are at once settled. And besides this special aim, a closer insight into the play of forces concerned in rectilinear oscillations is not without interest.

The Formulae.

In what follows we have only to concern ourselves with forces in free ether. Let , , be the components of electric force acting on the points , , ; let , , be the corresponding components of magnetic force; let be the time, and let A stand for . Then, according to Maxwell, the time-rate of change of the forces is dependent on their distribution in space in the following way:

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and if we put \( Q = \frac{\partial \Pi}{\partial r} \), the following is a possible solution of our equations: 
\[
Z = \frac{1}{r} \frac{\partial Q}{\partial r}, \\
R = -\frac{1}{r} \frac{\partial Q}{\partial \phi}, \\
P = \frac{A}{r} \frac{\partial Q}{\partial \phi}, \\
N = 0.
\]

To prove this assertion we observe that 
\[
X = R \frac{dr}{dx} = -\frac{d^2 \Pi}{d\phi^2}, \\
Y = R \frac{dr}{dy} = -\frac{d^2 \Pi}{d\phi^2}, \\
Z = 1 \frac{d}{\frac{\partial}{\partial \phi} \frac{\partial^2}{\partial \phi^2}}, \\
L = P \frac{dr}{dx} = A \frac{\partial^2 \Pi}{d\phi^2}, \\
M = -P \frac{dr}{dy} = -A \frac{d^2 \Pi}{d\phi^2}, \\
N = 0.
\]

One has only to insert these expressions into equations (1), (2), (3), to find equations (2) and (3) identically satisfied, and (1) also if we have regard to the differential equation for \( \Pi \).

It may be mentioned that also inversely, neglecting certain practically unimportant limitations, every possible distribution of electric force which is symmetrical to the axis of \( z \) can be represented in the above form, but it is not necessary for the sequel to substantiate this assertion.

The function \( Q \) is of importance. The lines in which the surface of rotation \( Q = \) const. cut the meridian planes are the lines of electric force; the construction of the same for one meridian plane furnishes at every instant an immediate presentation of the force distribution.

If we cut the shell between \( Q \) and \( Q + \partial Q \) by a surface of rotation round the axis of \( z \), the product of electric force and surface which Maxwell calls the "induction" is for every such surface the same. If we arrange the system of surfaces \( Q = \) const. in such a way that \( Q \) increases in arithmetical progression, the same statement remains true when we compare the sections of the different shells with one another.

In the plane diagram which consists of sections of the meridian plane with the equidistant surfaces \( Q = \) const., the electric force is inversely proportional to the normal distance of consecutive lines \( Q = \) const. only for the case when points compared lie at the same distance from the axis of \( z \). In general the rule is that the force is inversely proportional to the product of this distance and the co-ordinate \( r \) of the point considered.

If we introduce polar co-ordinates \( \rho \) and \( \phi \) they will be like this.

The figure represents an electric oscillator at origin of co-ordinates as intended to be understood by Hertz.

The Forces concerned in a Rectilinear Oscillation.

Let \( E \) denote a quantity of electricity, and \( l \) a length; let \( m = \frac{\pi}{l} \) be a reciprocal length, and \( n = \frac{\pi}{T} \) a reciprocal time; and let us put 
\[
\Pi = E \int_{\phi}^{\phi} \sin (\mu \phi - n\phi) d\phi.
\]
This value satisfies the equation
\[ \frac{\partial^2 \Pi}{\partial \tau^2} = \nabla \Pi, \]
so soon as we settle that,
\[ \frac{m}{n} = \frac{T}{\lambda} = \Gamma, \]
and \( \frac{\lambda}{\Gamma} \) will be the velocity of light. And, indeed, the introduced equation is satisfied everywhere, except at the origin.

In order to find out what electrical processes are set up by the distribution of forces specified by \( \Pi \), we investigate its immediate surroundings.

We put \( \rho \) vanishing in comparison with \( \lambda \), and neglect \( mp \) in comparison with \( nt \).

Then:
\[ \Pi = \frac{E}{\rho} \sin nt. \]

Since, now:
\[ \left( \frac{d^2}{dx^2} + \frac{d^2}{dy^2} \right) \varphi = - \frac{d}{dx} \left( \frac{E}{\rho} \right), \]
we have:
\[ X = - \frac{d^2 \Pi}{dxdx}, \quad Y = - \frac{d^2 \Pi}{dydy}, \quad Z = - \frac{d^3 \Pi}{dxdy}. \]

So the electric forces appear as the derivative of a potential—
\[ \phi = \frac{d^2 \Pi}{d\tau^2} = \frac{E}{\rho} \sin nt - \frac{d}{dx} \left( \frac{E}{\rho} \right); \]
and this expresses an electrical [Doppelpunkt, by which I suppose is meant either an involution or a spherical function] whose axis coincides with the \( z \) axis, and whose moment oscillates between the extreme values \( EL \) and \( -EL \) with the period \( T \).

Our force distribution, therefore, represents the action of a rectilinear oscillator which has the very small length \( l \), and on whose poles at the maximum the quantities of electricity \( \pm E \) are free.

The magnetic force perpendicular to the direction of the oscillator is, in the immediate neighbourhood,
\[ P = - \frac{\pi AE \sin nt \sin \theta}{\rho^2}. \]

According to the Biot-Savart law, this is the force of a current element in the direction of the axis of \( g \), of length \( l \), whose intensity, magnetically measured, oscillates between the extreme values \( \pm \pi AE \). In fact the motion of the electricity \( E \) corresponds to a current of that magnitude.

From \( \Pi \) we get:
\[ Q = \frac{E}{\rho} \left( \cos \left( \frac{mp - nt}{\rho} \right) - \sin \left( \frac{mp - nt}{\rho} \right) \right) \sin^2 \theta, \]
and from this the forces \( Z, R, P \) follow by differentiation.

The formulas are too complicated for it to be possible to obtain immediately from them in their general form a representation of the distribution of the forces. For some special cases the results are meanwhile proportionately simple. We get these at once—

(1) The immediate neighbourhood of the oscillator we have already treated.
(2) In the \( z \) axis, i.e. in the direction of swing, we have
\[ dr = pdo, \quad dz = d\theta, \quad \theta = 0; \] so then—
\[ R = 0, \quad P = 0, \]
\[ L = \frac{\pi AE}{\rho} \left\{ \cos \left( \frac{mp - nt}{\rho} \right) - \sin \left( \frac{mp - nt}{\rho} \right) \right\}. \]

The electric force acts always in the direction of the oscillator; it diminishes for small distances as the inverse cube, for greater distances as the inverse square, of the distance.

(3) In the \( xy \) plane, or \( z = 0 \), we have
\[ dx = -pdo, \quad dp = d\theta, \quad d\theta = 0, \quad \theta = 90, \quad \rho = \frac{E}{\rho^2} \]
\[ R = 0, \quad P = \frac{\pi AE}{\rho} \left\{ \cos \left( \frac{mr - nt}{\rho} \right) + \sin \left( \frac{mr - nt}{\rho} \right) \right\}, \]
\[ Z = \frac{\pi AE}{\rho} \left\{ - \cos \left( \frac{mr - nt}{\rho} \right) - \sin \left( \frac{mr - nt}{\rho} \right) + \sin \left( \frac{mr - nt}{\rho} \right) \right\}. \]

The electric force of the electric force perpendicular to the oscillator plane through the oscillator is parallel to the oscillator, its amplitude being
\[ \frac{E}{\rho} \sqrt{1 - m^2 r^2 + m^2 r^2}. \]

The force decreases with distance, at first quickly as the inverse cube, later only slowly, and inversely as the distance itself. At great distances the action of the oscillator can only be noticed in the equatorial plane, not in the axis itself.

(4) At very great distances we can neglect higher powers of \( 1/\rho \), compared with lower ones. So we get at such distances—
\[ Q = \frac{E}{\rho} \cos \left( \frac{mp - nt}{\rho} \sin \theta \right), \]
\[ P = \frac{\pi AE}{\rho} \sin \left( \frac{mp - nt}{\rho} \sin \theta \right), \]
\[ Z = \frac{\pi AE}{\rho} \sin \left( \frac{mp - nt}{\rho} \sin \theta \right), \]
\[ R = \frac{\pi AE}{\rho} \sin \left( \frac{mp - nt}{\rho} \sin \theta \right). \]

Thence follows—
\[ Z \cos \vartheta + R \sin \vartheta = \rho. \]

The direction of the force is therefore at great distances everywhere normal to the radius vector from the origin of force; the spreading out occurs in pure transverse waves. The magnitude of the force is equal to \( \frac{\pi AE}{\rho} \sin \left( \frac{mp - nt}{\rho} \sin \theta \right) \) and decreases at a constant distance from the origin towards either axis, being proportional to the distance from this latter.

(To be continued.)
M. Rolland, a French naturalist, charged with an official mission to Madagascar, has sent in his Report to the Minister of Public Instruction. M. Rolland sums up his girandole of geographical conjectures by remarking that, notwithstanding its apparently simple contour, the topography of Madagascar is exceedingly complex. Behind the line of lagoons which border the coast, and which, except that the water is salt, remind one of the lagoons of Langedoc, the hills begin to rise, and increase in height towards the interior. Behind these, again, the mountains rise by stages to a height of over 6500 feet. The surface is cut up by impenetrable ravines, at the bottom of which are torrents, which rush on their way towards the Indian Ocean. This chain forms the backbone of the island, and consists mainly of Primary and crystalline rocks. When it is crossed, the Mozambique Channel is reached. The two slopes, east and west, are very unequal in extent. The former, which M. Rolland has explored to a considerable extent, occupies more than one-third of the total area of Madagascar. A broad valley, that of the Mangoro, runs north and south, parallel to the great central chain. Unfortunately the Mangoro is navigable, even for canoes. The two other most important rivers are the Manangoro and the Mangataeka; and these three rivers, with innumerable streams, render this part of the island one of the best-watered regions on the globe. The climate varies considerably from one zone to another. On the east coast the temperature oscillates between 13° and 30° C.; on the west coast, it never descends below 17°; in Insulinde province it ranges from 5° to 25°. M. Rolland refers in some detail to the well-known characteristics of the fauna of Madagascar, and to the abundance of mineral treasures, especially iron, copper, and lead; but, he states, the natives carefully conceal the localities of the beds.

Lieut. Vans Agnew has undertaken a journey to the Upper Salween and South-Eastern Tibet, with the object of attempting the solution of the problem of the cause of the Lu River—whether to the Iravadi or the Salween—proposed by General J. T. Walker in his paper read to the Royal Geographical Society on August 25, 1889. The Council of the Society has sanctioned a contribution of £100 towards the expenses of the expedition. Lieut Vans Agnew leaves India for the Salween in the course of the present month.

At the February meeting of the Berlin Geographical Society Dr. A. Schenck read a report on his recent journey in Nama Land and Herero Land, South-West Africa. He showed that the whole country between Walvis Bay and the Orange River is—in consequence of the purely mechanical decomposition of the prevailing granite rock, which is taking place under the great daily variations of temperature, causing in many places the disintegrated surfaces to be eaten away in the form of a crust—covered over with a sea of sand and granitic shingle, from which the highest elevations stand out like islands. The country is not suitable for agricultural colonies. The coast and the interior stand in contrast with regard to the season of rainfall. While on the coast the rain falls mostly in winter, the rainfall in the interior occurs only in summer, and nearly always in the form of thunder-showers, which, as Dr. Schenck believes, are caused by the condensation of the moisture-laden air, which is brought to this part by the warm, humid, north-east winds blowing from the coast to the interior. As to the configuration of Great Nama Land, Dr. Schenck gives the following notes. After the hilly coast-region between Angra Pequena and Aos is passed, a broad valley-like depression in the bed of the river is reached, which, with drift-sand, forms the boundary of the country and the south side of the Aos river. The valley is at first very narrow, then it widens out, and the flat sandforms a connected mountain system composed of ancient rocks, granite, and gneiss, which has been buried by the sand from which the higher parts stand out. Beyond Aos the traveller enters upon the steppe region, which is divided into detached plateau districts. Beyond Aos and the river-bed of the Goalgib, on which the station of Bethanien is situated, the Hub district stretches away to the north, and is followed by the Khuaas, and to the south to a point a few miles north of the Orange. A long series of table-mountain, resembling in form truncated cones, marks the western escarpment of this plateau; the former are composed of granite and gneiss, and are covered with limestone and sandstone, horizontally laid down. East of Bethanien, and corresponding with the line of a long geological fault, is the escarpment of another plateau; it is about 5000 feet in height. It descends to the Great Fish River on the east; on the other side of the river, the plateau character of the country is continued to the Karas Plateau, which extends into the brush steppe of the Karabari. Further details concerning this interesting region will be found in the March number of the Proceedings of the Royal Geographical Society.

THE FORCES OF ELECTRIC OSCILLATIONS TREATED ACCORDING TO MAXWELL'S THEORY. BY DR. H. HERTZ.

II. Note by the Translator.

IT is to be noted that Hertz follows the French system of wave-lengths and periods. I had noticed this before the diagrams went to the engraver, I would have altered it, and interpreted his T as $\frac{1}{\lambda}$, &c., throughout. As it is, I have left them everywhere as in the original. My elaborate effort to evade a literal translation of *Doppelpunkt* was quite unnecessary. Prof. Karl Pearson has sent me a reference to Maxwell's definition of "double-point" in vol. i. Art. 129, first edition of "Electricity and Magnetism."—O. J. L.

In order now to ascertain the distribution of force for the remaining parts of space we may use graphic representation, constructing for definite times the lines of electric force, viz. the curves Q = const., for equi-distant values of t.

Since $Q$ itself is the product of two factors, of which one depends only on $r$, the other only on $\theta$, the construction of these curves presents no great difficulty.

We decompose every value of $Q$ for which we want the curve into two factors in different ways; we determine the angle $\theta$ for which sin $\theta$ is equal to the one factor, and by means of an auxiliary curve that value of $\rho$ for which the function of $\rho$ contained in $Q$ is equal to the other factor; we thus get as many points as we please of the curve. When one attempts to carry out some piece of hard work, one perceives, however, a multiplicity of processes which it would be prolix to detail here. We will content ourselves with examining the results of such construction, as exhibited in Figs. 1, 2, 3, 4.

These figures represent the distribution of force at the times $t = 0, \sqrt{t}, \sqrt{t}, \sqrt{t}$; and also, by suitable inversion of the arrows, for all future times which are similar multiples of $\sqrt{t}$. At the origin is shown, in the correct aspect and about of the right proportional size, the arrangement by which in our earlier experiments the oscillations were excited.

The lines of force are not indicated right up to the picture because our formulae regard the oscillators as infinitely short, so in the neighbourhood of a finite oscillator they are insufficient. Let us begin a study of the figures with Fig. 1. Here, when $t = 0$ the radiation is in the condition of its strongest development, but the poles of the straight oscillator are not electrically charged—no lines of force start thence. Such lines of force begin, however, now from the time $t = 0$ to start out from the poles; they are inclosed in a sphere which expresses the value $Q = 0$. In Fig. 1 this sphere is indeed still vanishingly small, but it enlarges itself quickly, and by the time $t = 1$ it fills already the space $R_1$. The distribution inside the sphere is approximately of the same kind as correspond to a static electric charge on the pole. The speed with which the spherical surface $Q = 0$ spreads out from the origin is at first much greater than $\frac{1}{\sqrt{t}}$; in fact, the latter velocity would only correspond to $A$.

1 Translated and communicated by Dr. Oliver Lodge. Continued from P. 464.
the distance given in the figure as $\frac{1}{2}A$ for the time $\frac{1}{2}T$. At infinite distance from the origin the velocity of outspreading is indeed infinite.

This phenomenon it is which we represented in the old mode of expression by saying that along with the inductive action travelling with the velocity of light there was superposed an electrostatic force travelling with infinite speed.

We properly express this phenomenon in terms of our present theory when we remark that fundamentally the self-forming waves do not arise solely from processes occurring at the origin, but are influenced by the condition of the whole surrounding medium, which latter, according to Maxwell’s theory, is the true seat of the energy. However this may be, the surface $Q = 0$ expands with a velocity which gradually reduces to $\frac{1}{A}$, and by the time $t = \frac{1}{2}T$, it fills the space $R_4$ (Fig. 3). By this time the electrostatic charging of the pole is at its greatest development; the number of lines of force which start thence attains its maximum value.

With further increase of time no fresh lines of force protrude from the poles; rather, those already produced begin to withdraw back into the conductor, there to vanish as lines of electric force, their energy, however, being converted into magnetic energy.

Hence occurs a singular behaviour which in Fig. 4 ($t = \frac{3}{2}T$) is plainly to be recognized, at least in its beginning. The lines which have furthest removed themselves from the origin get drawn together by the stress with a lateral inflexion; this inflexion approaches nearer and nearer to the axis of $z$; and then a self-closed portion detaches itself from each of the outer lines of force, which automatically spread out into space, while the residue sink back into the conductor.

The number of receding lines is just as great as the number of originally expanding lines; their energy, however, is necessarily diminished by the energy of the detached portion. This loss of energy corresponds to the radiation into space. In consequence of it the oscillation must soon come to rest unless some impressed forces restore the energy lost to the source. Meanwhile we have regarded the oscillations as undamped, and thus implicitly understood the existence of such forces.

In Fig. 1, to which we can now return for the time $t = T$, since we can imagine the arrows inverted, the detached portions of the lines of force fill the space $R_4$, while the lines starting from the poles have completely vanished. But new lines of force break out from the pole, and compress the lines whose early history we have followed into the space $R_4$ (Fig. 2).

It needs no further explanation now to follow these lines into the spaces $R_6, R_6$, and $R_6$. More and more they transform themselves into a pure transverse wave motion, and lose themselves as such in the distance. One would get the best picture of the play of force if one made a series of drawings for still smaller time-intervals, and examined them with a stroboscopic disk.
A closer consideration of the figures shows that the direction of the force changes from instant to instant for such points as lie either in the axis of \( z \) or in the plane \( xy \). If we represent the force at a point, therefore, in the customary way by a line, the end point of this line oscillates, not indeed in a straight line, but in an ellipse. In order to see whether there are any points for which this ellipse approximates to a circle, in which, therefore, the forces go through all the directions of a windrose without important change of magnitude, let us superpose two of the representations expressing times which differ by \( \frac{T}{4} \); for instance, Figs. 1 and 3, or 2 and 4.

For the points we seek, the lines of the one set must plainly cut those of the other system orthogonally, and the distances of the lines of the one figure must be equal to those of the other. The small quadrangles formed by the superposition of the two systems must therefore be squares for the sought points.

There may be now remarked, in actual fact, a region of the kind sought: it is represented in Figs. 1 and 2 by circular arrows, whose directions give at once the direction of the rotation of the force. The dotted lines are inserted for convenience; they belong to the line system of Figs. 3 and 4.

One finds, moreover, that the force exhibits the behaviour here described, not only at the specified points, but also in the whole strip-formed region which, spreading out from those points, forms the neighbourhood of the \( s \) axis. Nevertheless, the magnitude of the force decreases so quickly in these directions, that only when the points above-mentioned can its singular behaviour be important.

The system of forces now described and required by theory can be quite well recognized in an incomplete observation, not hitherto indicated by theory, which I formerly described (Phil. Trans. xxxiv. p. 155, 1868). One cannot, indeed, explain everything about those experiments, but one can get the main points correctly.

By both experiment and theory the distribution of force in the neighbourhood of the oscillator is chiefly an electrostatic distribution. By both experiment and theory the forces spread out chiefly in the equatorial plane and decrease in that plane at first quickly, afterwards slowly, without being zero at a mean distance.

By both experiment and theory the forces in the equatorial plane, in the axis, and at great distances, is of constant direction and varying magnitude, while at intermediate points it changes its magnitude but little and its direction much. The correspondence between theory and those experiments only breaks down in this, that at great distances, according to theory, the forces remains always normal to the straight line through the source, while by experiment it appears to be parallel to the oscillator. For the neighbourhood of the equatorial plane where the forces are strongest this follows from the equations too, but not for directions which lie between the equatorial plane and the axis. I believe that the error is on the side of experiment. In these experiments the direction of the oscillator was parallel to both the main walls of the laboratory, and the component of the force which was parallel to the oscillator might be thereby strengthened in proportion to the normal components.

I have therefore repeated the experiment with a different arrangement of the primary oscillator, and found that with certain arrangements the result corresponds with theory. I did not attain an exact result, but found that at great distances, and in regions of small intensity of force, disturbances due to the boundary of the space available were already too considerable to permit a safe verdict.

While the oscillator is at work, the energy vibrates in and out of the spherical surfaces surrounding the origin. More energy goes out, however, through any spherical surface during an oscillation than comes back; and indeed the same excess quantity goes through all spherical surfaces. This extra quantity represents the loss of energy during the period of swing due to radiation. We can easily calculate its value for a spherical surface whose radius, \( r \), is so great that it is permissible to attempt a simplified formula. Thus the energy going out of the spherical zone between \( \theta \) and \( \theta + d\theta \) in the time \( dt \) will be—

\[
2\pi r^2 \sin \theta \cdot d\theta \cdot \frac{P}{4\pi} (Z \sin \theta - R \cos \theta).
\]

Putting into this the values of \( Z \), \( P \), and \( R \), which are proper for great distances, and integrating from \( \theta = 0 \) to \( \pi \), and from \( t = 0 \) to \( T \), we get, as the energy going out through the whole sphere during every half complete swing,

\[
\frac{1}{2} P_0 \frac{m}{r} T^2 = \frac{\pi T^2 R^2}{3k^2}.
\]

Let us try to obtain an approximate estimate of the amount of this corresponding to our actual experiments. In those we charged two spheres of 15 centimetres radius in opposite senses up to a spark length of 1 centimetre about. We may estimate the difference of potential between these spheres as 120 C.C.S. electrostatic units, so each sphere was charged to half this potential, and its charge was therefore \( F = 900 \) C.C.S. units.

The total store of energy which the oscillator originally possessed amounted to \( 60 \times 900 = 54,000 \) ergs, or 55 centimetre-grams. The length of the oscillators, moreover, was 1 metre approximately, and the wave-length was about 480 centimetres.

So the loss of energy in half a swing comes out about 2400 ergs. It seems, therefore, that after eleven half-swings one-half of the energy must have gone in radiation. The quick damping which the experiments made manifest was therefore necessitated by radiation, and could not be prevented even if the resistance of conductor and spark were negligible.

A loss of energy of 2400 ergs in 1\(^{1/100}\)000,000,000 of a second means a performance of one horse-power to 22 horse-power. The primary oscillator must be supplied with energy at at least this rate if the oscillation is to be permanently maintained at constant intensity in spite of the radiation. During the first few oscillations the intensity of the radiation at about 12 metres distant from the vibrator corresponds with the intensity of solar radiation at the surface of the earth.

(To be continued.)

**GENERAL EQUATIONS OF FLUID MOTION.**

The general equations of the motion of a fluid can all be comprehended in a single form, which seems to be deserving of special notice.

Taking the ordinary notation, \( u, v, w \), for the velocity-components at any point, \( P \), of the fluid at any instant, and denoting the components of vortical spin at the point by \( \omega_1, \omega_2, \omega_3 \), the usual Cartesian equations can be at once put into the form—

\[
\frac{dv}{dt} + \frac{d}{dx} \left( \frac{v^2}{2} + \frac{dp}{\rho} \right) + 2(\omega_1 v - \omega_2 w) = X,
\]

and two analogues, \( q \) being the resultant velocity. If through the point \( P \) we draw any curve whatever, the direction-equis of whose tangent are \( t, m, n \), and multiply the above and its two analogues, respectively, by \( t, m, n \), we obtain by addition the equation—

\[
\frac{dt}{dt} + \frac{dU}{dt} + t \omega s = S \cdots \cdots \cdots (a)
\]

in which \( J \) stands for the component of velocity along the tangent to the curve, \( U = \frac{dy^2}{dt} + \int P \), \( S \) component of external force-intensity along the tangent, and \( \Delta \) is the volume of the tetrahedron formed by the vector drawn to \( P \) to represent \( q \), the resultant velocity, the vector drawn to represent \( t \), the resultant vortical spin, and the vector representing a unit length along the tangent to the curve at \( P \). (Strictly speaking, the notation \( \omega \) is not a good one, but it is the best that presents itself.)

This equation (a) is that which I propose, as typical of all fluid motion, and as including all the special Cartesian equations in current use.

Some simple results follow at once for the case of steady motion. Thus, if we integrate (a) between any two points, \( A, B \), of the curve,

\[
U_B - U_A + 12 \int \Delta s = 12Sds \cdots \cdots \cdots (1)
\]

where \( U_B \) and \( U_A \) are the values of \( U \) at \( B \) and \( A \).

Now, in particular, if the curve drawn at \( P \) is a stream-line, \( \Delta = 0 \) at every point of it; also, if the curve is a vortex-line, \( \Delta = 0 \) at every point, and we have the simple result,

\[
U_B - U_A = 12Sds \cdots \cdots \cdots (2)
\]
THE FORCES OF ELECTRIC OSCILLATIONS TREATED ACCORDING TO MAXWELL’S THEORY. BY DR. H. HERZ.

III.

The Interference Experiments.

In order to ascertain the velocity of propagation of electric force in the equatorial plane, we brought it into interference with another wave advancing with corresponding constant velocity in a wire. The result was, that the successive interferences did not occur at equal distances, but followed more rapidly in the neighbourhood of the oscillator than at greater distances.

This behaviour was explained by the supposition that the total force could be decomposed into two parts, of which the one, the electrodynamic, travelled with the velocity of light, while the other, the electrostatic, travelled with a greater, perhaps an infinite, velocity.

According to our theory now, however, the force in question in the equatorial plane is

$$Z = E \sin \left( \frac{m \varphi - n \varphi}{m \varphi} \right) - \cos \left( \frac{m \varphi - n \varphi}{m \varphi} \right) + \sin \left( \frac{m \varphi - n \varphi}{m \varphi} \right),$$

and this expression in no way splits up into two simple waves travelling with different velocities. If, then, the present theory is correct, the earlier explanation can only be an approximation to the truth.

We will investigate whether the present theory leads to a general explanation of the phenomenon. First, we can write $Z = B \sin \left( \frac{m \varphi - n \varphi}{m \varphi} \right)$, where the amplitude

$$B = \frac{E}{\lambda},$$

and the phase $\delta$ is determined by the equation

$$\sin \frac{m \varphi - n \varphi}{m \varphi} + \cos \frac{m \varphi - n \varphi}{m \varphi} - \sin \frac{m \varphi - n \varphi}{m \varphi} = 0,$$

$$\tan \delta = \frac{\cos \frac{m \varphi - n \varphi}{m \varphi} - \sin \frac{m \varphi - n \varphi}{m \varphi}}{1 - \sin \frac{m \varphi - n \varphi}{m \varphi}},$$

which, after transformation, gives

$$\delta = \frac{m \varphi - \tan^{-1} \frac{m \varphi}{1 - m \varphi}}{m \varphi}.$$

In Fig. 5, the quantity $\delta$ is represented as a function of $\varphi$ by the curve labelled $\delta$. The length $ab$ corresponds in the

(Wied. Ann., xxix, p. 609, 1888), $\lambda$ was equal to 4-8 metres, and thus the scale-length of a metre is determined. The zero of the scale is, however, not at the oscillator, but at a distance of 0-45 metre from it; for in this way the scale corresponds to the actual division of the base-line on which the position of the interferences was determined. One sees from the figure that the phase does not in general spread from the source, but its course is such that the waves arise at a distance of about $\lambda$ from it, and give off thence a part to the conductor and a part out into space. At great distances, the phase is smaller by the value $\pi$ than it would be if the waves had spread out with constant velocity from the source: the waves therefore behave, at great distances, as if they had traversed the first half wave-length with infinite speed.

The action, $\varpi$, of the wire-waves at a definite position of the secondary conductor can now in any case be represented by the form $\varpi = C \sin \left( \varphi - \delta \right)$, wherein the abbreviation

$$\delta = \lambda \varphi + \varpi = \frac{2\pi}{\lambda} \varpi,$$

is used. $\lambda$ denotes the half wave-length of the waves in the wire, which in our experiment was 2-8 metres; $\varpi$ is the phase of its action at the point $\varphi = 0$, which we can arbitrarily change by adjustment of the length of the wire.

By this means we can change the amplitude, $C$, and give such a magnitude that the action of the wave in the wire was approximately equal to that of the direct action. The phase of the interference depends, then, only on the difference of the phases $\delta_1$ and $\delta_2$. With the particular adjustment of the secondary circle to which our expression for $\varpi$ refers, both actions correspond (the interference has the sign $+$ if $\delta_1 - \delta_2$ is equal to zero, or a whole multiple of $2\pi$; the actions disagree (the interference has the sign $-$) if $\delta_1 - \delta_2$ is equal to $\pi$ or any whole multiple of $\pi$). No interference occurs (the interference has the sign $0$) if $\delta_1 - \delta_2$ is a whole multiple of $\pi$.

We will now so determine $\delta$ that at the zero of the metre-divisions the phase of the interference has a definite value, $\delta_0$, so that $\delta_1 = \delta_2 = \delta_0$.

The straight line 1 of our figure shall then represent the values of $\delta_1$ and $\delta_2$ as a function of the distance. The line is specially drawn with such a slant that for an increase of abscissa by $\lambda_1 = 2-8$ metres the ordinate increases by the value $\pi$, and is so arranged that it cuts the curve $\delta_1$ in a point whose abscissa is the zero of the metre-divisions.

The lines 2, 3, 4, &c., represent further the course of the values $\delta_1 + \delta_2 - \frac{\lambda}{\pi}, \delta_2 + \delta_2 - \pi, \delta_2 + \delta_2 + \pi, \&c.$ These lines are parallel to the line 1, and so drawn that they cut one and the same ordinate at distances of $\pi$, and one and the same abscissa at distances of 4 metres.

Project now the section of these straight lines with the curve $\delta_1$ on the axis of abscissa below, and one gets immediately those distances for which $\delta_1 = \delta_2 + \delta_2 + \pi, \delta_2 + \delta_2 + 2\pi, \&c.$, for which, therefore, the phase of the interference increases from the origin by $\pi$, $3\pi$, $5\pi$, &c.,

One obtains immediately from the figures the following:—

If the interference at the zero of the base-line possesses the sign $+(-)$, it vanishes for the first time at a distance of about 1 metre; it attains the sign $- (+)$ at about 3-2 metres, vanishes again at 4-5 metres, and reverts back to the sign $+$ ($-$) at about 7-0 metres; it is again 0 at 14 metres, and thence onward the signs recur at fairly regular intervals. If at the zero of the base-line the interference was zero, it will be zero again at about 2-3, 7-6, and 14 metres, while it has a prominently positive or negative character at about 1 metre, 4-8 metres, 11 metres distance from the zero. For mean phases finite values serve.

If one compares with this result the theory of the result of experiments, especially those interferences which occurred with arrangements of 100, 250, 400, 550 centimetres of wire (Wied. Ann., xxvii, p. 553), one will find a correspondence as complete as can be at all expected.

I do not succeed quite so well in calculating back to the interferences of the second kind (i.e., p. 553). To get these we used an arrangement of secondary circle by which the integral force of induction through the closed circuit cannot prominently into account. If we regard the dimensions of the latter as vanishingly small, the integral is proportional to the rate of change of the magnetic field normal to the plane of the circle, and hence to the expression

$$\frac{d\varpi}{dt} = \Lambda E \sin \left( \frac{m \varphi - n \varphi}{m \varphi} \right) + \sin \left( \frac{m \varphi - n \varphi}{m \varphi} \right),$$

Translated and communicated by Dr. Oliver Lodge. Continued from p. 453.
Hence we get for the phase $\delta$, this expression—
\[
\tan \delta = -\frac{\cos mr - \sin mr}{\sin mr + \cos mr} \frac{mr}{m^2\pi^2}
\]
or, after transformation—
\[
\delta = mr - \tan^{-1} mr.
\]

The line $\delta$ of our Fig. 5 represents this function. One sees that for this action the phase steadily increases direct from the origin. Those phenomena, therefore, which indicate a finite velocity of propagation must make themselves apparent by interferences even close to the vibrator. So it shows itself in these experiments, and just herein consists the advantage which we derived from this kind of interference experiment. But the apparent velocity comes out greater in the neighbourhood of the vibrator than at a distance, and it is not to be denied that the phase of the interference must theoretically change less, but notably more quickly than was experimentally the case.

It appears to me probable that a more complete theory, one which does not consider both conductors as vanishingly small—perhaps, also, another estimate of the value of $a$—would here afford a better correspondence.

It is of importance that even on Maxwell's theory the experiments cannot be explained without assuming a marked difference between the velocity of waves along wire and their velocity in free space. (To be continued.)

**Note on the Use of Geissler's Tubes for Detecting Electrical Oscillations.**

At the suggestion of Prof. Lodge, I undertook to repeat in the Physical Laboratory of the University College, Liverpool, Hertz's celebrated experiments on electrical oscillations. In performing these experiments, I was searching for means to make the effect of the electrical oscillations more easily observable, and I was induced to use for this purpose (1) Geissler's tubes, in order to strengthen the visible effect; and (2) the chemical action of the oscillating currents (paper soaked in solution of iodide of potash), in order to obtain a permanent trace of them.

For the present I will describe briefly the results of the use of Geissler's tubes.

In order to produce the electrical oscillations, I used a conductor consisting of two zinc plates, about 41.5 centimetres square, suspended in the same plane 55 centimetres apart; so each plate was fastened a No. 6 copper wire, which was finished off with a small brass knob. The two brass knobs were about 5 millimetres apart, and formed the sparking gap, as we shall call it. As receiver of the oscillations, I used, like Hertz, circles of No. 14 wire, 35 centimetres in radius.

After the example of Mr. F. T. Trouton (Nature, February 21, p. 391), I will call the first conductor a vibrator, and the wire, circles, or other receivers, resonators.

The vibrator was connected with a small coil, 20 centimetres long, supplied with an ordinary spring interrupter, and excited by four secondary cells.

If we connect one electrode of a convenient Geissler's tube with either side of the sparking gap of the resonator, currents pass through or into the tube, which lights up and so makes the effect of the electrical oscillations on the resonator visible even at a great distance.

Of the Geissler's tube, which were at my disposal, I found that the most convenient for this purpose was a small one with electrodes 8.5 centimetres apart, and filled with highly rarefied air. But spectral tubes 20 centimetres long and filled with hydrogen, oxygen, or nitrogen also gave good results.

With the first mentioned tube I perceived a visible effect, when the resonator was held horizontally in the plane containing the wires of the vibrator, and with the sparking gap turned towards it, at a distance of 4 metres from the vibrator. By this arrangement all the phenomena described by Hertz (Wiedemann's Ann., xxxvi. p. 160, 1888) about the direction of the electrical lines of force can easily be shown.

A very instructive experiment is to show the directions of these lines by suspending a fine wire in a horizontal position in front of the vibrator. For this purpose I suggest the following apparatus:—

On a wooden frame mounted so as to be able to revolve on a vertical axis standing under the sparking gap of the vibrator are fastened several resonators, with their planes vertical and parallel respectively to the directions of the lines of force and the sparking gaps at the highest point. These resonators are supplied with Geissler's tubes. In this position of the resonators all the tubes will lighten up when the vibrator is working. But if we move the frame with the resonators moves round the vertical axis, the light of the tubes will become weaker, and, when the frame is turned 90°, the tubes will become quite dark; the planes of all the vibrators in this position being perpendicular to the directions of the lines of force. This change will occur inversely by turning the frame from 90° to 180°.

If, instead of one resonator, two are fastened to each point of the frame, one perpendicularly to the other, both being vertical, the changes in either of these will be contrary—that is to say, when the light in one set of the tubes becomes brighter it becomes weaker in the set perpendicular to it and vice versa. Thus the strength of the light is, so to say, proportional to the magnitude of the components of the lines of force in the direction of the tubes.

If a disconnected Geissler's tube is held near the vibrator, it begins in a short time to light up, owing to oscillatory currents passing through it. The same effect is obtained if instead of holding the tube by the hand it is placed in an insulating body. This lighting occurs at all points near the vibrator, except about the sparking gap. The tube becomes quite dark if the hand or a conductor is interposed between it and the vibrator; on the contrary, the interposing of an insulating body causes no change in the tube. The tube becomes more sensitive if a portion of it is surrounded with tinfoil.

In this way the existence of electrical oscillations in space can be ascertained, and also the transparency of insulating bodies and the opacity of conductors for electrical oscillations can be demonstrated.

When the two electrodes of a Geissler's tube are connected with two different points of a resonator, the effect in the tube is produced by the difference of potential at the two points. If now we connect one point of the vibrator or the resonator with one electrode of the tube, the other electrode hanging free in the air or being earthed, we have an alternative current through the tube whenever the potential of the point connected with the electrode becomes different from zero, and thus the tube lights up. The effect is strengthened if one portion of the tube is surrounded by tinfoil. This is a very convenient arrangement for observing the form of the electrical oscillation in conductors.

If we investigate in this manner our circular resonator held vertically before the vibrator, with its plane parallel to it and the sparking gap upwards, we find that a tube hanging at the lower end of the vertical diameter of the circle, opposite to the sparking gap, and lights quite darkly on the right or to the left of this point. The light becomes brighter till the horizontal diameter is reached; further on the light begins to grow weaker till the sparking gap is attained, where the tube, however, continues to lighten. The light becomes weaker when the sparking gap is narrowed, and ceases when it is quite closed. Thus we see that the circular resonator possesses one at its lowest point, two ventral segments at equal distances from the node and the sparking gap, and two minima of oscillation one on each side of the sparking gap.

That a node is situated at the point opposite to the sparking gap is also ascertained by observing that by touching this point with the finger or by hanging from it a piece of wire or by connecting it to earth, the tube ceases to be illuminated. These manipulations, if applied to another point of the resonator, diminish the spark.

If the resonator is formed by a closed circle of wire, we find a node at each end of the vertical diameter, and well defined patches of light on the horizontal, diameter of the circle. The distance between the two nodes being here 110 centimetres, the wave-length is 220 centimetres, while the length of the primary wave is about 880 centimetres. Thus the wave-length in the resonator corresponds to the second high octave of the fundamental oscillation.

If, instead of circular, we use linear resonators placed parallel to the vibrator, we must be very careful to distinguish between the direct produced directly from the vibrator in the linear tube and the effect caused by the oscillations of the resonator. In the case of the circular resonators, placed in the position above described, one need not trouble much about the direct effect of the vibrator, this being very small in the neighbourhood of the vibrator's sparking gap.
only terminate with the life of the unfortunate subject. This power of growing aresh so complex and specialized an organ as an eye, by no means certain at first sight, is not a little astonishing, but it appears to be capable of a very simple explanation: the cells terminating the cut stumps of the tentacle are the ancestors of those which were removed; a fresh series of descendants are derived in the same manner as by the ancestral cells and their predecessors which they replace; the first generation of descendants become in turn ancestors to a second generation, similarly related to them as were the second tier of extirpated cells; and this process of descent being repeated, the complete organ will at length be rebuilt. The possibility of this arises from the fact that in the snail the embryological course of development is capable of being repeated by the adult structure. In higher organisms this possibility does not as a rule exist, and maturation is not followed by regeneration; but even in their case the ancestral cells remain, and when the embryological development is repeated their representatives in the embryo are present to give rise to descendants of the normal type in the normal fashion. It follows from this view, which leaves pan-
genesis out of account, that mutilations cannot possibly be inherited, and this for the reason that the cells forming the organism at each stage of its development must be regarded as the ancestors of those of the next stage; thus finally we are brought round to something which looks very like Weismannism.

W. J. Sollas.

Trinity College, Dublin, March 15.

P.S.—The foregoing completely accounts for the non-inheritance so often referred to of the character produced by circumcision. In the case of a snail it might be presumed that circumcision could not produce any persistent result; in the human subject what is remarkable is not the reappearance of the prepuce in the descendant, but that no regrowth beyond healing takes place in the subject.

Mr. Marcus M. Hartog’s letter of March 6 inserted in last week’s number (p. 452), is a very valuable contribution to the growing evidence that acquired characters may be inherited. I have long held the view that such is often the case, and that I have myself observed several instances of the, at least I may say, apparent fact.

Many years ago there was a very fine male of the Cepaea nemoralis in the gardens of the Zoological Society. To restrain this animal from jumping over the fence of the inclosure in which he was confined, a long and heavy chain was attached to a collar round his neck. He was constantly in the habit of taking this chain up by his horns and moving it from one side to another over his back; in doing this he threw his head very much back. His horns being placed in a line with the back: the habit had become quite chronic with him, and was very tiresome to look at. I was very much astonished to observe that his offspring inherited the habit, although it was not necessary to attach a chain to their necks. I have often seen a young male throwing his horns over his back and shifting from side to side an imaginary chain. The action was exactly the same as that of his ancestor. The case of the kid of this goat appears to me to be parallel to that of child and parent given by Mr. Hartog. I think at the time I made this observation I informed the late Mr. Darwin of the fact by letter, and he did not accuse me of “flat Lamarckism.”

J. Jenner-Weir.

Chibbury, Beckenham, Kent, March 16.

The celluloid Slide-Rule.

In Dr. Oliver Lodge’s valuable communication to Nature of the 21st ult. (p. 423), giving Hertz’s equations for the field of a rectilinear vibrator, may I suggest the omission of a slight change, in order to bring the formulae into complete accord with those of the Maxwellian theory.

Hertz has, with \( A^2 = \mu k \),

\[
A \frac{dL}{dt} = \frac{dy}{dt} \quad A \frac{dM}{dy} = \frac{dx}{dt} - \frac{d\mathbf{N}}{dt},
\]

\[
A \frac{dX}{dy} = \frac{dx}{dy} - \frac{d\mathbf{N}}{dy},
\]

\[
A \frac{dY}{dx} = \frac{dy}{dx} - \frac{d\mathbf{N}}{dx},
\]

\[
A \frac{dZ}{dx} = \frac{dy}{dx} - \frac{d\mathbf{N}}{dx} &c.,
\]

whence he obtains the suitable solutions

\[
X = - \frac{d\mathbf{N}}{dx} \quad Y = - \frac{d\mathbf{N}}{dy} \quad Z = \mathbf{v} \frac{d\mathbf{N}}{dx} - \mathbf{v} \frac{d\mathbf{N}}{dy},
\]

\[
L = A \frac{dY}{dy} \quad M = - A \frac{dX}{dx} \quad N = 0,
\]

where \( \mathbf{v} \) satisfies the equation

\[
\mathbf{v}^2 = \frac{A^2}{\mu^2} t^2.
\]

The corresponding Maxwellian equations would be

\[
\frac{dL}{dt} = \frac{dy}{dt} \quad \frac{dM}{dy} = \frac{dx}{dt} - \frac{dN}{dt}, \quad \frac{dN}{dt} = \frac{dx}{dy} \quad \frac{dX}{dx} = \frac{dy}{dx} \quad \frac{dY}{dx} = \frac{dy}{dx} \quad \frac{dZ}{dx} = \frac{dy}{dx} &c.,
\]

with the solutions, \( X, Y, Z, \) as before, and

\[
L = A^2 \frac{dY}{dy} \quad M = - A^2 \frac{dX}{dx} \quad N = 0.
\]

The more general solutions of the field equations would be

\[
X = \frac{d}{dx} (\mu \frac{d\mathbf{N}}{dx} - \lambda \frac{d\mathbf{N}}{dy}) \quad Y = \frac{d}{dy} (\mu \frac{d\mathbf{N}}{dx} - \lambda \frac{d\mathbf{N}}{dy}) \quad Z = \mathbf{v} \frac{d\mathbf{N}}{dx} - \mathbf{v} \frac{d\mathbf{N}}{dy},
\]

with corresponding expressions, mutatis mutandis, for \( Y, Z, \) \( M, N \); where \( \lambda, \mu, \mathbf{v} \) are arbitrary constants, coinciding with Hertz’s results when \( \lambda = 0, \mu = 0, \mathbf{v} = -1 \).

H. W. Watson.

Alternative Path Leyden Jar Experiments.

In your issue of Feb. 14 (p. 360) there is an “Electrical Note” which is very misleading, and I will perhaps allow me to say, therefore, that Mr. Acheson’s photographs show no evidence of oscillation whatever; that his experiments are aimed at a particular question, connected with lightning protectors, and confidantly stated to be made in such a way as to have much importance; that Mr. Acheson is not expounding a new theory by calling self-induction “extra currents”; and finally, that the author of the note, in speaking about “the errors due to charging which vitiated Prof. Lodge’s early experiments,” is talking about something which has no existence.

Oliver J. Lodge.

The philosophical Transactions.

Your correspondent “S.” seems to be unaware that what he asks for has been already done. The abridgment of the Philosophical Transactions, which was brought down to the year 1800 by Charles Hutton, George Shaw, and Richard Pearse, was continued in octavo form, by order of the President and Council of the Royal Society, under the title of "Abstracts of the Papers printed in the Philosophical Transactions of the Royal Society of London." This series extended to six volumes, bringing the abridgment down to the year 1854. At the seventh volume the title was changed to "Abstracts of the Royal Society of London," a publication which still exists, and which contains abstracts of all the papers in the Philosophical Transactions and a good deal besides.

H. R.
ably on account of absorption in the cloud regions of our atmosphere, which, as Langley has shown, takes up with great avidity the violet and ultra-violet rays.

May it not be that in clouds we have conditions especially favourable to the production of the Hertz effect? If so, the discharge from one cloud to another would be accompanied by an earth current in the opposite direction, as in the theory proposed by Prof. Stokes, in which a decrease of resistance is produced by an increase of heat from the sun.

Hertz found his effect (Wied. Ann., xxxi. p. 993) much more marked in a medium under diminished pressure.

Under 300 millimeters of mercury, he finds that the ultra-violet radiation will nearly quadruple the length of spark obtained without it, while under ordinary atmospheric pressure it would scarcely double it. But this is the very circumstance which is realized in the case of C.L.U.D.S.

There is also reason to think that solar outbursts are especially rich in these rays of short wave-length which are required to explain the phenomena.

Henry Crew.

Haverford College, U.S.A., March 22.

Hertz’s Equations in the Field of a Rectilinear Vibration.

Returning to Hertz’s equations for the field of the rectilinear vibrator, it appears to me that, while his conclusions are sound as regards the forces at points very distant from the vibrator, they require modification for the rest of the field. In fact, the principles upon which the question is investigated require that the electric motive force in the direction of s should become vanescent close to the vibrator (the axis of z).

The general form of $\Pi$ is either—

$$\frac{M \sin \frac{p}{\lambda}}{p} \cdot \sin nt$$

or$$\frac{M \cos \frac{p}{\lambda}}{p} \cdot \sin nt,$$

where $\lambda$ large, and $\lambda t = \frac{1}{\lambda} t$, or, of course, the sum of the two forms.

In assuming for points near the origin (say the middle point of the vibrator) the approximate expression—

$$\frac{M}{p} \cdot \sin nt,$$

Hertz, in point of fact, takes the second of the above forms for $\Pi$, for this reduces to $\frac{M}{\lambda} \cdot \sin nt$ when $\frac{p}{\lambda}$ is very small.

But this assumption makes both $\Pi$ and $Z$ infinitely great close to the vibrator. Whereas, by assuming the former of the two forms, or—

$$M \sin \frac{\lambda}{p} \cdot \sin nt,$$

i.e. near the origin $\Pi = M \sin nt$, we get, as a general expression for $Z$—

$$Z = M \left(1 - \frac{1}{p^2} + \frac{s^2}{\lambda^2} - \frac{1}{\lambda^2} \right) \sin \frac{p}{\lambda} - M \left(1 - \frac{3s^2}{\lambda^2} - \frac{3s^2}{\lambda^4} \right) \cos \frac{p}{\lambda} \cdot \sin nt,$$

and, as $\rho$ is indefinitely diminished, this reduces to—

$$- \frac{2M}{3\lambda^3} \sin nt$$

as a limiting value.

For distant portions of the field, Hertz’s results as to the laws and amplitudes of the forces electric and magnetic remain unaltered.

Of course, the whole investigation, with such a simple assumption as to the nature of the field, must be regarded as only approximate. For any given form of vibrator—as, for example, a straight wire connecting two spheres—the exact treatment will be very difficult. In the simplest conceivable case of a spherical metal sheet with an induced Q, distribution 1-t to itself, the analysis is intricate (see a paper by Prof. J. J. Thomson to the Mathematical Society of London, January 1884).

Berkswell, March 29.

H. W. Watson.

Early History of Lightning-Conductors.

Can any of your readers refer me to the sources of some of the late Mr. Richard Anderson’s information with regard to the early history of the lightning-conductor? (1) On p. 27 of the third edition (1885) of his book; “Lightning Conductors,” he states that Franklin, in the 1758 issue of “Poor Richard’s Almanack,” gave directions for the erection of lightning-conductors. (2) On p. 23 he refers to Prof. Winthrop, of Boston, having in 1755, defended the lightning-conductor against a person who had attributed a Massachusetts earthquake to the innovation. I should be much obliged for any reference to a library where access of “Poor Richard’s” for 1758 could be found or, again, for any information with regard to Winthrop’s defence of the lightning-conductor.

Prof. Meidinger, of Karlsruhe, who is preparing a second edition of his “History of Lightning-Conductors,” is extremely desirous of verifying these details of their early history, and I should be glad if any of your readers could supply me with information for him on these points.

Karl Pearson.

University College, April 9.

The Satellite of Procyon.

Mr. J. M. Barrie’s suggestion (NATURE, March 28, p. 510), as to the use of photography to ascertain whether there is any close companion or satellite to Procyon, would be considered a very desirable one by astronomers, in order to set at rest the question whether a companion can actually be the observed place of the hypothetical one, of which the elements were given by Dr. Auwers in 1864, from investigations of the irregularity in the proper motion of Procyon observed by Bessel in 1844, and by Madler in 1851. The orbit was computed on the assumption of a circular motion in a plane perpendicular to the line of sight round a point about 1" away, having a period of about 40 years, the position angle for 1873 being about 90°, so the present angle would be about 234°, or about 9° per annum.

I fear, however, serious instrumental difficulties would arise in observing such a brilliant object as Procyon in a large telescope by a seer, so as to get the impress on a plate of a probably faint companion at the extremely close distance of two to three seconds of arc.

This difficulty, no doubt, must have presented itself to the minds of the astronomers at the Lick Observatory, California, or they would have tried the sensitive plate with the 36-inch photo lens of the great refactor, instead of examining Procyon visually with the 36-inch glass, as was done by Mr. S. W. Burnham on the early morning of November 18 last, with the following result: “Procyon—Carefully examined with all powers up to 3000 on the 36-inch under favourable conditions. Large star single, and no near companion.”

If this means that no companion was seen within 10° or 12° radius, it makes the matter very perplexing, as Otto Straube measured a supposed new companion in 1873 with the 26-inch refractor at Pulkowa—the mean of several measures for March 28 being P. angle 90° 24', and distance 12° 49', and for 1874 P. angle 90° 50', and distance 11° 67'. This companion was looked for at Washington with the 26-inch refractor on several occasions from November 1873 till January 1876, and by the three Clark’s (father and two sons) with the McCormick 26-inch refractor, then completed at Cambridgeport, Massachusetts, but Straube’s companion could not be seen with either instrument, and I am not aware that it has since been seen at all by Straube himself with the new Russian 30-inch refractor. The Washington observers at that time, however, gave estimated places for three new companions, supposed to be seen by them as follows:—

No. 1. Position angle, about 10°, and distance about 6°.
2. ... 2. ... 36° 8' ... 8° 8'
3. ... 50° ... 10°

These appear (if they have an existence at all) to have been missed with the 36-inch glass at the Lick Observatory, as above referred to.

It is a singular coincidence that the position-angles of the companion supposed to have been seen by Otto Straube in 1873 and 1874 agreed with the identical places computed by Dr. Auwers, but its distance involved the assumption of an enormous mass to Procyon for the parallax assigned to the principal star.

Isaac W. Ward.

Belfast, April 1.
of balls in single file, the sloping faces all showing the spheres in triangular order.

Suppose a bag, impermeable to water, is filled with liquid soap, placed in an hydraulic press, and subjected to great pressure. The lead spheres will be flattened against each other in regular cell structure into a solid mass, each sphere being changed into a cylindrical decahedron; and in this manner the form of the cell of the bee has been considered as arising in a natural manner by Mrs. Bryant, D.Sc., in a paper read before the London Mathematical Society, vol. xvi. "On the Ideal Geometrical Form of Natural Cell-Structure. The plane surfaces of separation form a geometrical arrangement of the films of a soap-bubble; but the instability of the owners where six edges meet modifies the soap bubble arrangement to the form investigated by Sir W. Thomson in the Acta Mathematica, April 27.

A. G. GREENHILL.

Name for Unit of Self-Induction.

A name for the unit efficient of self-induction is much wanted. No one is satisfied with secomhon, and yet it seems unsuitable. We have, by reason of Ayton and Perry's ingenious commuting arrangement for helping to measure, its being named in the past. The name quad, which I formerly suggested, is on further consideration still less satisfactory for permanent use, because it emphasizes unduly the word "quad" that in electro-magnetic measures self-induction happens to be a length. One looks forward to the time when all distinction between electrostatic and electro-magnetic measures shall vanish by both ceasing to be; and at that not far distant time names emphasizing the present arbitrary state of things will be anachronisms, as well as not being blocks to beginners. I beg to suggest that a milli-seconhon shall be called a vo. It is a short and hairless unmeaning syllable not yet appropriated. It should be its plural. The unit of conductivity is already a mo; and \( S \) vo will look well alongside \( S \) mo. "Volometer" is short and satisfactory. A unit of magnetic induction will then be the vo-ampere; and this, being of a size convenient for dynamo makers, may be hoped to replace their abominable mongrel unit "Kapp-lines." The vo in electro-magnetic measure is 10 kilomètres, and hence a vo ampère per square decimètre is a magnetic field of a thousand C.G.S. units, and might be called a "Gauss." For lightning-conductor work the natural unit of self-induction will be a milli-vo, or 10 metres of electro-magnetic measure.

Grasmere, April 16.

OLIVER J. LODGE.

Hertz's Equations.

PERMIT me to add a line of explanation of my letter on this subject, printed in Nature, v. xcv., p. 358. I intended no criticism of Hertz's general result, but merely to draw attention to the necessity of rejecting all solutions of the equation in \( n \) which make the fore (1) infinite for points on the vibrator. Berkswell, April 24.

H. W. WATSON.

A NEW PEST OF FARM CROPS.

During the past three or four years, in the examination of plants attacked by various injurious worms and Arthropods, and of the soils in which such plants grew, I have from time to time been led to suspect that certain small species of Oligochaeta were concerned in damaging, if not ultimately destroying, several species of cultivated plants. With a view to converting suspicion into fact, experiments on isolated growing pots-plants have been carried on.

Within the past few weeks I have received, through the kindness of Miss E. A. Ormerod, additional evidence of a striking character, which induces me to place the main facts on record.

In the spring of 1888, Miss Ormerod forwarded to me for inspection two small white Oligochaeta, 1½ inch long, received by her in soils from the roots of plants. In reporting on them I replied that it did not seem very probable that they could seriously injure the plants.

In April 1888, an inquiry reached me as to the nature and means of prevention of a serious attack of "small white worms" destructive to pot and green-house plants. On being placed in communication with the observer, the Rev. William Lockett, rector of Loddon, Norfolk, I received from him a box of soil taken from his afflicted flower-pots, and much valuable information in answer to a series of questions put by me. The soil itself contained some hundreds of the white worms described; and the detailed information all pointed to these worms as the cause of many serious losses which had been sustained. I received the worms in soil which was alternately wetted and dried at regular intervals. They all kept alive and vigorous; when wet to complete immersion they were most active; when dry they remained quiescent, apparently dried up, and difficult to discover.

After two months, the sunflower drooped and bent over, and examination showed the roots and rootlets dead and the stem rotting. Within the decaying stem some of the Enchytraeidae were found alive and active. The other two plants are still living; but it will be shown that the number of worms supplied them was too small. Mr. Lockett lost spirals, vegetable marrows, fuchsias, gloxinias, and many other plants, and the dead roots often contained in and around them hundreds of worms to each plant. Both in his garden and a neighbouring ash-heap he found an abundance of them.

I was on the point of repeating my experiments this spring with various seedlings, when I received by the kindness of Dr. K. G. R. of Rothamsted (at the suggestion of Miss Ormerod), a quill with two or three specimens of worms of the same genus. Mr. John J. Willis, the superintendent of the field experiments at Rothamsted, in sending them described them as obtained from a field of clover with a good plant except across one portion of the field, where all the plants were dying off, the small worms occurring at the roots of the clover along with larvae of Sitona and wire-worm. There is scarcely a plant that has not one or more of these creatures attacking it." Mr. Willis has been good enough to send me several communications on the subject, and a supply of the worms, living and in spirit. Much of his information is interesting, as that the more decayed the root, the larger the number of worms; that even healthy plants harbour a few specimens; that the worms seem sometimes to enwrap the rootlets with their coiled body. He hears of other fields of clover in a similar condition apparently to those at Rothamsted. I have a quantity of detailed information, but to sumarize it, there appears to be but little room for doubt that these small Oligochaeta are one cause of the decay of the clover at Rothamsted, as they were of the many varieties of garden plants at Littledean.

The Enchytraeidae have not hitherto, so far as I can learn, been accused of causing serious injury to plants. Vjezdovsky, in his "Monographie der Enchytraeiden," says, "Die Enchytraeiden bewohnen trockene und feuchte Erde, sisses und salziges Wasser, Sandes und morsche Holz." In what manner they directly injure the plant remains to be observed—probably by sucking the fine root-hairs. Under observation the pharynx is rapidly everted and withdrawn in the act of feeding. I have so far recognized two species. If, as seems not improbable, the borers of corn are one, they should be for the reason of this mass that we have to add to the list of enemies of the clover plant from which it so mysteriously suffers, these unsuspected Oligochaeta. The discovery, though fraught
But, to work out what is happening in the immediate neighbourhood of a dumb-bell oscillator must be left, I imagine, to the time when some pure mathematician may devote his attention to this particular shape of conductor, if the case appears to him of sufficient interest to present. I have no special reason why it should be so regarded, but of that Mr. Watson is a better judge. I hope he may see fit to attack the problem.

Gmsmere, April 13.

OLIVER J. LODGE.

THE COMPRESSIBILITY OF HYDROGEN.

As stated in the obituary notice that appeared in NATURE (vol. xxxviii., p. 583) at the time of the melancholy accident which caused his death, Wroblewski was engaged in an investigation of the behaviour of hydrogen on compression. The results of this investigation, as far as it had then advanced, have now been made public (Monatshef für Chem., 1888, p. 1069 et seq.). They are of a most important and interesting nature, and form a fitting memorial of the patience and skill of the observer, who most unhappily was not spared to bring this, the last and most complete of a long series of similar investigations, to a close.

Hydrogen has long occupied an exceptional and isolated position among the gases. This is due to the fact that, as Regnault first pointed out, hydrogen forms the sole exception to the law that the product of the pressure into the volume, $pv$, of any gas decreases with increasing pressure, the exact converse being true in the case of hydrogen, this product showing a regular increase. It is true that, as since shown by Amagat and others, this behaviour of hydrogen becomes general for all gases when the pressure is increased beyond a certain limit, but before reaching this limit the product $pv$ invariably decreases until a minimum is reached for all gases with the exception of hydrogen. For hydrogen neither the decrease nor the minimum has yet been observed, the gas as hitherto examined showing an invariable increase of $pv$ with increasing pressure.

The natural inference was, however, that the exception was only apparent, and that the minimum above noted would be found to occur also with hydrogen if the gas were examined at lower pressures than those hitherto investigated—thats is, at pressures below one atmosphere. But a difficulty in the way of this hypothesis arises from the fact that the critical pressures of all gases are found to be below the pressure at which the minimum value for the product of pressure into volume occurs, and therefore on the above hypothesis of hydrogen the pressure would have to be phenomenally low and considerably below one atmosphere.

To gain a further insight into the relation of volume to pressure in the case of hydrogen, Wroblewski decided to investigate this relationship through a wide range of temperatures. For this purpose he selected as temperatures sufficiently apart, the boiling-point of water, 100° C., the melting-point of ice, 0° C., the boiling-point of liquid ethylene, −105° C., and the boiling-point of liquid oxygen, −183° C. The pressures employed varied from one to seventy atmospheres.

The method of experimenting was exceedingly simple. The gas at a known pressure was forced into a bulb of known capacity having a capillary neck, and kept at one of the above four temperatures. A sufficient length of time was allowed for the gas to attain the fixed temperature; it was then transferred to a eudiometer, and its volume measured. And it is needless to add that every precaution was taken both in purifying the gas and in applying the necessary corrections.

The results with the three first of the above temperatures agree with the behaviour of hydrogen already observed, the product of volume into pressure constantly increasing with the minimum having been obtained at the range of pressures under investigation (one to seventy