ASTRONOMISCHE NACHRICHTEN.

MA HZ.

Band 212.

Nr. 5079.

New Theory of the Aether. By T. J. J. See.

(Third Paper.) (With 3 Plates.)

I. Two Remarkable Theorems on the Physical Constitution of the Aether.

In the year 1910 Professor *E. T. Whittaker* published, under the auspices of the Dublin University Press, a valuable »History of the Theories of Aether and Electricity« from the age of *Descartes* to the close of the 19th century. The title of this useful treatise and the general usage of science recognizes that there is some connection between aether and electricity, yet in spite of the great learning shown in *Whittaker*'s work, the nature of that connection remains profoundly obscure, and the modern investigator therefore labors in vain to obtain any clear light upon the subject.

If we could prove, for example, that an electric current is nothing but a series of waves of a certain type propagated in the aether along and from the wire which bears the current, and also connect these waves with magnetism and light, by an extension of the reasoning thus laid down, it would add so much to our understanding of the processes underlying the unseen operations of the physical universe, as to be worthy of almost any effort. Indeed, it would be worth hazarding any chance offered by the conscientious contemplation of known phenomena. And thus I venture to add some considerations, which, without exhausting the subject, may open a new field to those who have the independence, practical energy and firm resolution to pursue pioneer paths in science. These untrodden paths alone offer the hope of important discoveries in the physical universe.

And first we must confirm a new and important theorem on the velocity of wave-progagation in monatomic gases, announced in the first paper, and also make known a new and very remarkable method for determining the density of

the aether based on an extension of recognized processes in the theory of sound. As the only method for attacking the problem of the density of the aether heretofore known is that invented by Lord *Kelvin* in 1854, this new method will prove extremely useful as an independent check on the numerical values attained in these recondite researches; and be found the more valuable because it is absolutely decisive against the doctrine of a large density for the aether, which has recently exerted in science an influence both baneful and bewildering.

(i) The new theorem $v = \frac{1}{2}\pi V$, connecting the mean molecular velocity of a monatomic gas with the velocity of wavepropagation, by means of half the Archimedean number, exactly confirmed by observation in case of oxygen and nitrous oxide.

Since finishing the first paper on the New Theory of the Aether, Jan. 14, 1920, I have had occasion to discuss the new theorem

$$v = \frac{1}{2\pi} V \tag{1}$$

connecting the mean molecular velocity of a monatomic gas and the velocity of wave-propagation, by means of half the Archimedean number π , with the celebrated English physicist Sir *Oliver Lodge*, on the occasion of a public addressat San Francisco, April 11, 1920. And as Sir *Oliver Lodge* kindly showed a great interest in this theorem, regarded it as very important, and urged me to extend the use of the theorem, I have searched for other gases to which it might be accurately applied.

The observed data given in the following supplementary table are taken from Willner's Experimental-Physik, Band 1, p. 804, and were accidentally overlooked in the preparation of my earlier table.

Gas	V(Air = 1)	<i>v</i> observed	molecular wt.	k_2	$ar{v}/V(ext{observed})$	$\left. ar{v} \right V \cdot \left. V(k_1/k_2) ight)$
Oxygen, O	0.9524 (Dulong) = 316.2 m	461.0 m	32.0	1.402	1.458	1.5893
Nitrous-Oxide, NO ₂	0.7865 (Dulong) = 281.1	393.0	44.0	1.295	1.398	1.5858

The last column gives the observed ratio \bar{v}/V as corrected for a monatomic constitution, or

$$\bar{v}/V \cdot V(k_1/k_2) = 1.58$$
 (2)

which verifies with great accuracy the use of half the Archimedean number π , in the theorem,

$$\bar{v} = \frac{1}{2} \pi V$$

connecting the mean molecular velocity with that of wavepropagation in monatomic gases.

As this theorem is now minutely verified for the six best determined gases, namely:

1. Air	. •	4. Carbon dioxide CO_2
2. Hydrogen		5. Oxygen

3. Carbon monoxide CO 6. Nitrous oxide NO_2

all of which are of comparatively simple molecular constitution, we may regard it as fully established by experiment that such a physical law governs the motions of waves in monatomic gases, and that the velocity of wave motion is solely dependent upon the mean velocity of the molecules.

But in addition to the argument thus built up, for a high wave velocity, where we have a rare gas of enormous molecular velocity, we may use the observed velocity of wave-propagation generally to throw light upon the molecular weights of all gases whatsoever. In the reference above given to *Wüllner's* Experimental-Physik, Band 1, p. 804, we find that the velocity of sound in hydrogen was found by *Dulong* to be 3.8123 times that in air, and by *Regnault*, 3.801 times that in air. The mean of the two values is 3.80665. Now

16

15.

the velocity of sound in oxygen found by *Dulong* was 0.9524 times that in air; and on multiplying this by 4, we get 3.8096 for the theoretical velocity of sound in hydrogen.

But since oxygen is supposed to have only 15.98 times the molecular weight of hydrogen, we should use the square root of this number, or 3.9975, instead of 4, for the multiplier, which gives 3.8072; an almost exact agreement with the mean of the velocities of sound in hydrogen found by *Dulong* and *Regnault*.

It follows, from these considerations, that the velocity of wave motion in similar gases varies inversely as the square roots of their densities. The fourfold increase in the velocity of sound in hydrogen compared to that in oxygen gives us a definite law which may be applied directly to all comparable gases, and even to monatomic gases by the use of the faktor $V(k_1/k_2)$.

(ii) New method for determining the density of the aether from the velocity of light and electric waves compared to that of sound in terrestrial gases.

Up to the present time only one general method has been available for calculating the density of the aether, namely, that devised by Lord *Kelvin* for determining the mechanical value of a cubic mile of sunlight, and first published in the Transactions of the Royal Society of Edinburgh for May, 1854 (cf. Baltimore Lectures, 1904, p. 260). This method was somewhat improved by the subsequent researches of Lord *Kelvin, Maxwell*, and the present writer, as duly set forth in the first paper on the New Theory of the Aether (AN 5044, 211.49), yet the principle underlying it remains largely unchanged.

As it would be very desirable to have a second independent method for determining the density of the aether, I have held in mind this great desideratum while occupied with the researches on the wave-theory, and finally it occurred to me to attack the problem from the point of view of the velocity of sound in gases. For we have now shown that the aether is a gas, with particles traveling 1.57 times swifter than light; and this general theory is again confirmed by the discussion above given for waves of sound in oxygen and nitrous oxide.

Owing to its extreme rarity, the aether is the one absolutely perfect gas of the universe; and we may even use the velocity of light in the aether to calculate the density of this medium. It will be shown, especially in the fourth paper, that there is much less difference between the waves of sound and light than we have long believed. In his luminous but neglected memoir of 1830, the celebrated French geometer *Poisson*, showed and thrice repeated, in spite of the earlier repeated objections of *Fresnel*, that in elastic media the motions of the molecules, at a great distance from the source of disturbance, are always normal to the wave front, as in the theory of sound. And we shall show later how optical and magnetic phenomena are to be reconciled with this incontestible result of *Poisson*'s analysis.

From the data given in the first paper on the New Theory of the Aether it follows that the velocity of light is 904268 times swifter than that of sound in air. As sound

in hydrogen has a velocity 3.80665 times greater than in air, this is equivalent to 237550 times the velocity of sound in hydrogen. But hydrogen is a biatomic gas with the ratio $k_2 = 1.401$, while aether is monatomic, with the ratio $k_1 = 1.666$; and therefore to reduce the motion in hydrogen to the basis of a monatomic gas, we have to divide this number by $V(k_1/k_2) = 1.090477$, which leads to the number 217839. This is the ratio of the velocity of light in a monatomic aether to that of sound in a hypothetical monatomic hydrogen, yet with density 0.0000896.

This result is based on the wave theory of sound as given by Sir *Isaac Newton* in the Principia, 1686 (Lib. II, Prop. XLVIII), which was corrected by *Laplace* in 1816 (cf. Mécanique Céleste, T. V. Liv. XII, p. 96, and Ann. Phys. et Chim., T. III, p. 288), to take account of the augmentation of speed due to the ratio of the specific heat of a gas under constant pressure to that under constant volume. As above used the formula for the propagation of sound is further corrected to take account of the increase in velocity in a monatomic gas, first inferred theoretically by *Clausius* about sixty years ago, but since verified experimentally for mercury vapor, argon, helium, neon, xenon, and krypton. The formula thus becomes for aether and hydrogen, as reduced to a monatomic elasticity:

$$V_1/V_2 = V(E_1\sigma_2/E_2\sigma_1) = 217839.$$
 (3)

Under identical physical conditions at the surface of the earth, $E_1 = E_2$, and thus

$$V_1/V_2 = V(\sigma_2/\sigma_1) = 217839$$

 $N_1 = V_1^2/V_2^2 = \sigma_2/\sigma_1 = (217839)^2 = 47453880000$ (4) which is the density of hydrogen in units of that of aether. To get the density of water in units of that of aether, we take

$$N_2 = N_1 / 0.000896 = 529619000000000.$$
 (5)

Accordingly the absolute density of the aether at the earth's surface becomes:

$$1/N_2 = \sigma = 1888.15 \cdot 10^{-18}$$
. (6)

It should be noted that Lord *Kelvin*'s method of 1854, which we used in the first paper on the New Theory of the Aether, is not strictly valid, because although it gives the density at the earth's mean distance, in units of the assumed density at the sun, this latter value itself cannot be found by *Kelvin*'s method, because of the decrease in the aether density near the earth, not heretofore taken account of.

Let σ_3 be the density at the neutral distance, ρ_3 , where the sun's gravitational intensity is just equal to that of the earth. Then, since at the solar surface the mean gravity is 27.86555 times terrestrial gravity (cf. AN 3992), we have:

$$27.86555/(219)^2 = 1/\varrho_3^2$$
 (7)

where $\rho_3 =$ distance at which solar and terrestrial gravity will just balance. This gives by calculation $\rho_3 = 41.4868$ terrestrial radii, about 2/3 of the moons distance. The following table gives the results of similar calculations for the absolute density of the aether at the surfaces of the sun and principal planets of the solar system.

238

Table of the Absolute Density of the Aether near the Principal Bodies of Solar System.

	1	1	1				
Body	i	Mean radius R	Mean gravity at surface gi	Mean distance of planet in solar radii <i>r</i> i	Absolute density of aether at orbit of planet Gi	Distance at which gravity of planet and sun are equal, in mean radii of the planet $\varrho_i = r_i \mathcal{V}(g_i/g_0)$	Absolute density of the aether at surface $\sigma_s = \sigma_i / \varrho_i$
The Sun	0	696098 kms	273.016 m	Ŧ			<u> </u>
Mercury .	I	2175.31	1.87944	84.7746	20222 74:10-18		357.6865 • 10-18
Venus	2	6090.86	8.7537	158.4125	56661.04.10-18	7.0337	4311.1.10-18
The Earth	3	6370.521	9.79762	210.000	$7822224 \cdot 10^{-18}$	28.305	$1997.56 \cdot 10^{-18}$
Mars	4	3365.87	3.7714	333.687	$103550:10^{-18}$	41.4808	1888.15.10-18
Jupiter	5	69449	26.21704	1130.414	407552 1.10-18	. 39.219	3043.3.10-18
Saturn	6	57635	11.4423	2080.006	747200 5 10 -18	.353.085	1154.20.10
Uranus	7	21101	13.0400	4202.804	$1503210 \cdot 10^{-18}$	427.004	1740.19.10
Neptune	8	21643	14.6460	6585.450	2355527 · 10 ¹⁸	729.020	1030.05.10 18
	•••			5 5 75-	-3333-7 10	1525.200	1544.32 . 10 - 13

Accordingly for reasons already indicated we reach the following conclusions.

1. Whatever be the density of the aether at 41.4868 terrestrial radii, where the sun's and earth's attractions are equal, the aether density, from that point, must decrease towards the earth, by the divisor 41.4868, and towards the sun by the divisor 219.

2. That is at the earth's surface

$$\sigma_{3s} = \sigma_3/41.4868.$$
 (8)

3. Owing to this decrease of σ near the earth, where observations are made, *Kelvin*'s method of 1854 is not valid, even for the calculation of the density at the sun's surface, because it rests on the hypothesis of homogeneity throughout interplanetary and interstellar space.

 $\sigma_{3s} = 1888.15 \cdot 10^{-18}.$

At' sun's surface therefore

$$\sigma_{0s} = (1888.15 \cdot 10^{-18} / 219) \cdot 41.4868 = 357.6865 \cdot 10^{-18}.$$
(9)

This is about 178.84 times greater than was obtained by *Kelvin*'s method, which, as above shown, is not applicable without modification. But as the aether density always is excessively small, this latter experimental-theoretical value for the solar surface may be accepted without question as the true value of the absolute density of the aether.

Accordingly at the sun,
$$\sigma_{0s} = 357.6865 \cdot 10^{-18}$$
 (10)
at the earth, $\sigma_{3s} = 1888.15 \cdot 10^{-18}$ (10)

which fulfills the laws of wave action:

Amplitude,
$$A = k/r$$

Force,
$$f = A^2 = k^2/r^2$$
 (11)

in accordance with the observed force of gravitation.

For upon trial we may verify the above calculations:

$$\sigma_{3s}/\sigma_{0s} = 1888.15/357.6865 = 5.27788 = V(g_0/g_3)$$
 (12)
or $(\sigma_{3s}/\sigma_{0s})^2 = g_0/g_3 = 273.016/9.79762 = 27.865555$.

The accompanying table for the absolute density of the aether may be extended to any binary system among the fixed stars in which the masses and dimensions are known, and thus the new theory of the aether has all the accuracy of the theory of universal gravitation.

(iii) The new method based on the velocity of wavepropagation, as in the theory of sound, definitely excludes a large value for the density of the aether. Since it is an observed fact that hydrogen propagates sound 3.9975 times faster than oxygen, and is 15.98 times lighter, we know that the rapidity of the wave-propagation in the aether can only point to a gas of extremely small density. No other hypothesis is admissible. And adopting this experimental method, the result for the density of the aether at the earth's surface becomes

$$\sigma_{3s} = 1888.15 \cdot 10^{-18}$$

in approximate agreement with the density derived from the energy of the sun's radiation, namely:

$$\sigma = 438 \cdot 10^{-18}$$

which however is no longer valid, as already pointed out.

The question may properly be raised as to how far this approximate agreement of the density of the aether, $438 \cdot 10^{-18}$, and $1888.15 \cdot 10^{-18}$, derived from the theory of the sun's radiation, and the theory of sound respectively, is accidental or brought about by systematic tendencies involving constant bias due to unknown and unsuspected causes.

It always is difficult to affirm the total absence of such systematic errors, or causes which bias judgement, but in view of the directness and simplicity of the above reasoning, I cannot see any ground for doubting the accuracy of the new method, which is based on *Newton*'s formula of 1686, as corrected by *Laplace*, 1816, and now further corrected to take account of a gas of monatomic constitution, as experimentally shown to exist in the cases of mercury vapor, argon, helium, neon, xenon, krypton.

For when we have two similar gases, such as oxygen and hydrogen, both biatomic, with the ratio of the specific heat under constant pressure to that under constant volume, $k_2 = 1.401$, we may connect their velocities at the same temperature and pressure by the formula:

$$V/V_2 = V(E\sigma_2/E_2\sigma). \tag{13}$$

And, since the physical condition of the two gases is identical, we may put $E = E_2$, and thus, in accordance with experiment,

$$V/V_2 = V(\sigma_2/\sigma) = 1/3.80665$$
 (14)

as already pointed out.

And when the gases are dissimilar in molecular constitution, as in the case of the aether and hydrogen, but the ratio of the specific heat under constant pressure to that under constant volume is known, we may still calculate their

16*

theoretical value of wave propagation from the use of the ratio $V(k_1/k_2)$. And if the velocity of the wave-propagation be observed in both cases, and we desire to determine the relative density of one of the gases, we may effect this as in the above case of the aether, which absolutely excludes the possibility of a large density. As the aether is a gas of excessively small density, it is therefore compressible, as previously inferred, but only by powerful, quick-acting forces.

The study of the aether as a gas, in accordance with the views entertained by *Newton* in 1721, and approved by *Maxwell* in 1877, thus opens new possibilities, and introduces criteria of the utmost value to physical science.

2. Geometrical and Physical Outline of the Relationship between Light, Magnetism and the Electrodynamic Action of a Current.

In the 3rd edition of the celebrated Treatise on Optics, 1721, Query 28, Sir *Isaac Newton* treats of *Huyghens'* theory of double refraction in Iceland spar, on the hypothesis of two several vibrating mediums within that crystal, for refracting the ordinary and extraordinary rays, but says that *Huyghens* was at a loss to explain them. »For pressions or motions, propagated from a shining body through an uniform medium, must be on all sides alike; whereas by these experiments it appears, that the rays of light have different properties on their different sides.«

In proof of this confession of failure, by *Huyghens*, *Newton* cites from the Traité de la Lumière, 1690, p. 91, the words: »Mais pour dire comment cela se fait, je n'ay rien trouvé jusqu'ici qui me satisfasse.«

Newton then argues effectively against the explanation of *Huyghens*, and points out the improbability of two aethereal media filling the celestial spaces, which has been emphasized in recent times by *Maxwell*, who declared it unphilosophical to invent a new aether every time a new phenomenon was to be explained.

In the early days of the modern wave theory of light, the properties of polarized rays were carefully investigated by *Fresnel* and *Arago*, and subsequently verified by Sir *John Herschel* and *Airy*, who fully confirmed *Newton's* conclusion that such rays have sides with dissimilar properties on opposite sides. The account of *Fresnel's* progress given by *Arago* in his Éloge Historique, July 26, 1830, is very instructive, since *Arago* was associated with many of *Fresnel's* discoveries. Besides the able analysis in the celebrated and comprehensive article Light, Encyclopedia Metropolitana, 1849, Sir *John Herschel's* Familiar Lectures on Scientific Subjects, 1867, are valuable, in showing his mature conclusions.

It being thus recognized that a ray of polarized light has sides, with dissimilar properties on opposite sides, it remains for us to form a clear image of such a ray of light, and to examine the phenomena of magnetism and electricity, to ascertain if a relationship to light can be established.

The late Professor *Paul Drude*'s comprehensive Lehrbuch der Optik, Leipzig, 1900, may be consulted for a modern analysis of purely optical problems; but, as our object is to outline relationships not heretofore developed, we shall make the optical treatment very brief.

$$u = a\sin(2\pi \cdot t/\tau + p) = a\sin(2\pi \cdot x/\lambda + p) \qquad (15)$$

where *u* represents the displacement at right angles to the x-axis, *a* is the amplitude, λ the wave length, and p the phase angle, from which the revolving vector of radius *a* is measured. Such a flat wave represents motion like that propagated along the surface of still water, and the movements are given in detail by figure 1, Plate 4, which is slightly modified from that used by *Airy* in his great treatise on Tides and Waves, 1845.

It will be noticed that each particle of water undergoes an oscillation about a mean position, shown by the centres of the circles, in this very accurate figure, while the wave form moves on, in a direction corresponding to the axis of x in equation (15). Thus the particles undergo not only a vertical oscillation, as the wave passes, but also a longitudinal oscillation. This is typical of all waves in water.

Now it is usual to take (15) as the equation of the motion of the aether in light, and to call u the light vector, and to describe this light vector as revolving, when the wave advances. The motion u in (15), however, is simply a side displacement normal to the x-axis, which may be produced by the revolution of the radius a in the circles, as in our figure modified from Airy's analysis of water wavemotion. The real motion of the aether particles should be somewhat elliptical, but much like those of the water particles, about a mean position of radius a. Equation (15) then will give only the side displacement, normal to the x-axis; and to get the whole motion of the particles we have to take the components v and w normal to the y-axis and z-axis respectively. Then the three components of the directed magnitude, which represents the oscillation of the particle about its mean position, will be

$$u = a \cos(2\pi \cdot t/t + p)$$

$$v = b \cos(2\pi \cdot t/t + q)$$

$$v = c \cos(2\pi \cdot t/t + r)$$

(16)

$$(u/a)^2 + (v/b)^2 + (w/c)^2 = 1$$
(17)

$$s = V(u^2 + v^2 + w^2). \tag{18}$$

It will be proved hereafter that there is a fundamental error in the wave-theory of light, as handed down by tradition from the days of Young and Fresnel; and that in a ray of common light the aether particle not only has transverse motion, but also a corresponding longitudinal motion, depending on the small ratio of the amplitude a to the wave length λ . After polarization these natural free motions of the aether are restricted, by the resistance impressed upon natural light, in the surface action of reflection, or transmission through transparent bodies, crystals, etc., and by unsymmetrical transparency in different directions, as in tourmaline, which forces half the light into one plane and destroys the other half. Originally the general path of the aetheron was elliptical, and although now transformed into oscillations near one plane the vibrations in most cases still are narrow ellipses, because it is proved by the reflection of plane polarized light from

a silver surface that an almost circular polarization results, whereas that reflected from galena has very narrow ellipses. This could not well result unless the polarized light before reflection from these metals described narrow ellipses, which are not exactly straight lines.

Now the elliptical paths established by equations (16), (17), (18), are similar to those analysed by *Herschel* in Section 618 of his great article Light, 1849. Suppose we consider the part of these waves which in a polarized ray have only right-handed rotations. Then if such a selected beam traveling along the x-axis be looked at flat on, from a point on the z-axis, the paths of the aetherons would resemble the motions of the particles of water in Airy's figure given as fig. 1, except that the aetherons may have paths more highly elliptical than are shown by Airy. This is the simplest form of the oscillations in the new wave-theory of light, which will be developed in the fourth paper: and we shall now see if it is possible to find corresponding oscillations in the field of a magnet and of an electric current.

In the year 1845 Faraday made a celebrated experiment in which he passed a beam of plane polarized light along the lines of force; and discovered that when the light travels in a material medium such as heavy lead glass, carbondisulphide, etc., the plane of polarization is twisted by the action of the magnetic field. Not only is the plane of polarization rotated, but the rotation increases in direct proportion to the length of path traversed; and even when the light is reflected back and forth many times the twisting of the plane of polarization is always in the same direction like the helix of a circular winding stairs, as was long ago noted by Sir John Herschel.

In the article Wave-Theory, Encyclopedia Britannica, 9th edition; Lord Rayleigh describes this rotation of the plane of polarization by magnetism as follows:

»The possibility of inducing the rotatory property in bodies otherwise free from it was one of the finest of



known phenomena of magnetism, optics and electrodynamic action.

Faraday's discoveries. He found that, if heavy glass, bisulphide of carbon, etc., are placed in a magnetic field, a ray of polarized light, propagated along the lines of magnetic force, suffers rotation. The laws of the phenomenon were carefully studied by Verdet, whose conclusions may be summed up by saying that in a given medium the rotation of the plane for a ray proceeding in any direction is proportional to the difference of magnetic potential at the initial and final points. In bisulphide of carbon, at 18° and for a difference of potential equal to unit C.G.S., the rotation of the plane of polarization of a ray of soda light is 0.0402 minute of angle.«

»A very important distinction should be noted between the magnetic rotation and that natural to quartz, syrup, etc. In the latter the rotation is always right handed or always left handed with respect to the direction of the ray. Hence when the ray is reversed the absolute direction of rotation is reversed also. A ray which traverses a plate of quartz in one direction, and then after reflexion traverses the same thickness again in the opposite direction, recovers its original plane of polarization. It is quite otherwise with the rotation under magnetic force. In this case the rotation is in the same absolute direction even though the ray be reversed. Hence, if a ray be reflected backwards and forwards any number of times along a line of magnetic force, the rotations due to the several passages are all accumulated. The nonreversibility of light in a magnetized medium proves the case to be of a very exceptional character, and (as was argued by Sir W. Thomson) indicated that the magnetized medium is itself in rotatory motion independently of the propagation of light through it.«

Now if I understand this subject aright - and my personal correspondence with the late Lord Rayleigh shows that he concurred in the present writer's views - we must conceive a line of force, circling around between the poles of a magnet, to be the axis of rotation in magnetic wave-

motion, as shown by figure 2, repeated from the first paper on the New Theory of the Aether.

If this interpretation be admissible, we see that just as plane polarized light has sides, - with dissimilar properties on the opposite sides, as remarked by Newton, Fresnel, Arago and Sir John Herschel, so also there are plane waves receding from magnets with exactly the same sides, with dissimilar properties on the opposite sides. It is these sides with oppositely directed rotations in the waves of the aether which gives poles to magnets.¹)

Magnetic polarity is thus directly connected by similarity of the rotations in the plane waves with plane polarized light. And just as the amplitude of light waves decrease inversely as r, the distance from the radiating centre (cf. Drude, Lehrbuch der Optik, 1900, Teil II, Kap. II)

1) » Newton came to the conclusion that each of the two rays (of polarized light) had two sides; and from the analogy of this twosidedness with the two-endedness of a magnet the term polarization arose" - Gage's Principles of Physics, 1897, p. 404.

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so also in magnetism, the wave amplitudes follow the law: A = k/r, giving the force $f = k^2/r^2$, as observed in the actions of magnetism and universal gravitation (cf. Electrod. Wave-Theory of Phys. Forc., Vol. 1, 1917). Accordingly, the connection between magnetism and light is obvious, the moment we do not restrict our conceptions of light to the side displacement in (15)

$$u = a \sin(2\pi \cdot x/\lambda + p) \tag{19}$$

but regard light as a disturbance involving a circular or elliptical displacement of the particles about a mean position, as the vector a representing this displacement in the case of a circle, revolves in a plane, which may be tilted at any angle relative to the coordinate axes.

In his celebrated article Light, 1849, Sir *John Herschel* shows, by carefully considered reasoning, that in the elliptical paths of the aethereal vibrations constituting light, the motion of the aetheron is about the centre of the ellipses, just as is the path of a vibrating conical pendulum, which may also change the path of its motion under the steady application of small impulses.

Suppose the undisturbed position of an aetheron be taken as origin, and let two radii vectores, drawn from the centre of the elliptical path to the disturbed aetheron, be ϱ and ϱ' ; then we have the wellknown equations

$${}^{2} = x^{2} + y^{2} + z^{2} \qquad \varrho'^{2} = x'^{2} + y'^{2} + z'^{2} \varrho \varrho' \cos \theta = xx' + yy' + zz'$$
(20)

 $\cos\theta = \cos\alpha \cos\alpha' + \cos\beta \cos\beta' + \cos\gamma \cos\gamma' \\ \cos^2\alpha + \cos^2\beta + \cos^2\gamma = \cos^2\alpha' + \cos^2\beta' + \cos^2\gamma' = 1.$ ⁽²⁾

The angle θ measures the motion of the light vector in the plane of the ellipse, while the angles α , β , γ , α' , β' , γ' are fixed by the direction cosines of the revolving radius vector at any time.

It now remains to examine the disturbances taking place about a wire bearing an electric current flowing from south to north, as in *Oersted*'s experiment of 1819. Here we notice that if the needle be suspended beneath the wire, the north pole is deflected to the west by the action of the current. If the needle be suspended above the wire, under like conditions, the north pole is deflected to the east.

It thus appears that just as magnets have plane waves — like those of plane polarized light rotating in one direction, and thus having dissimilar properties on opposite sides so also an electric current has plane waves with sides, and with dissimilar properties on opposite sides, as shown by the study of *Oersted*'s experiment of 1819. This follows also from the production of magnets from common steel under the electrodynamic action of a solenoid, as in *Ampèrc*'s experiment of 1822.

The correct theory of an electric current is that it is made up of plane waves, flat in the plane through the axis of the wire, as shown in figure 12, section VI, and more fully in figure 18 (Pl. 6), section IX, below.

In his celebrated address on the relations between light and electricity, Sept. 20, 1890, *Hertz* tried to illuminate the connection previously recognized by *Maxwell*, and distinctly referred both light and electricity to the aether. I am here*, he says, »to support the assertion that light of every kind is itself an electrical phenomenon — the light

of the sun, the light of a candle, the light of a glow-worm. Take away from the world electricity, and light disappears; remove from the world the luminiferous ether, and electric and magnetic actions can no longer traverse space« (cf. *Hertz*, Miscellaneous papers, p. 313).

Hertz was not able to make out the details of the relationship sought, but the experiments which he devised to show that electric waves are refracted, reflected and interfere, like light waves, marked an epoch in the development of radiotelegraphy, and have long since become classic. Yet when others took up the work, after Hertz's premature death, whilst they verified and used his results, they did not add to the theory of the aether, which Hertz considered essential to scientific progress. Hence the need still remained to traverse the lofty summits not yet explored (Hertz, l. c., p. 327), and to make out geometrically the nature of the displacements involved in these waves.

Accordingly we have gone into the nature of light and electric waves in such a way as to illuminate this relationship. *Hertz* remarks that to many persons *Maxwell*'s electromagnetic theory is a book sealed with seven seals. Thus the breaking of the seals, that we may read the details of the illuminated pages, would alone give us a direct view of nature's secrets, and justify any treatment which would throw light on this obscure subject and confirm the doctrine of continuity in natural philosophy.

3. Euler's Defective Theory of Magnetism has misdirected Thought in Modern Science: Simple Explanation of Induction, and of the Dynamo on the Wave-Theory.

(i) *Euler*'s theory of aetherial circulation, and its persistence since 1744.

Nothing could better illustrate the unsatisfactory state of the traditional doctrines of electricity and magnetism, than the old conception of a magnet, first outlined by *Euler* at Berlin, 1744, and since handed down, with very slight changes, and thus copied, with the original defects of symmetry, into hundreds of works on physics used by the principal nations of the world.

It is authenticated, that in his university career at Basel, *Euler* had studied both anatomy and physiology. As an outcome of this anatomical research he was familiar with the circulation of the blood in the human body. Thus he understood the valvular structure in the arteries, which secures the flow of the blood in one direction only, as the heart beats to expel the blood through the arterial system.

Accordingly when *Euler* attempted, twenty years later, to develop a theory of magnetism, which should reconcile all the known facts, including the attraction of unlike and the repulsion of like poles, he assumed a flux of the aether, along the axis of the magnet, inward at the south pole and outward at the north pole, as shown in figure 3 Plate 4 from *Euler*'s work (Dissertatio de Magnete, 1744, published in *Euler*'s Opuscula, vol. III, Berlin, 1751, Plate I).

This remarkable figure has been handed down by tradition for 176 years, and its validity apparently seldom or never questioned, though it probably is less used of late years than formerly. It appears in the physical treatises of all countries, and has vitiated even the mathematical theory of *Maxwell* (Treatise on Electricity and Magnetism, vol. II., p. 28, \S 404).

Maxwell's reasoning is as follows:

The magnetic force and the magnetic induction are identical outside the magnet, but within the substance of the magnet they must be carefully distinguished.«

»In a straight uniformly magnetized bar the magnetic force due to the magnet itself is from the end which points north, which we call the positive pole, towards the south end or negative pole, both within the magnet and in the space without.«

The lack of symmetry and of appropriate physical basis to this reasoning is so truly remarkable as to occasion genuine surprise that it should have been used by *Maxwell*. He continues:

»The magnetic induction, on the other hand, is from the positive pole to the negative outside the magnet, and from the negative pole to the positive within the magnet, so that the lines and tubes of induction are reentering or cyclic figures.«

This artificial and unnatural theory is outlined in the accompanying sketch, see Fig. 4 Pl. 4. Fig. 5 Pl. 4 illustrates the usage of *Euler*'s Circulation Theory of a Magnet in various modern works. The figure above, on the left is from *Millikan* and *Gale*'s First Course in Physics, 1906; that to the right is from *Gazebrook*'s Electricity and Magnetism, 1903; the sphere below is from *Crystall*'s article on Magnetism, Encycl. Brit., 9 Ed., 1875; while the figure to the right, below, is from *Drude*'s Physik des Aethers, 1894.

It appears that *Maxwell* adhered to *Euler*'s conceptions so far as induction is concerned, but added to it to explain magnetic force.

The anomaly of imagining the magnetic force to oppose the induction within the body of the magnet, but not without, is striking, and probably due to the habit of referring all actions to that of a unit north pole.

On the other hand the much simpler conceptions of the Wave-theory, 1917, need no emphasis. We there imagine the stress in the aether to be due to waves from all the atoms, so that the lines of force — which are the axes of rotation of the receding waves — tend to shorten themselves, as *Faraday* had observed, and as we have explained mechanically in the second paper on the New Theory of the Aether.

It is very difficult to account for the defective theory of 1744 except by remembering that *Euler* had injured eyesight, which did not enable him to detect the true symmetrical nature of magnetism, by experiments with soft iron, or with smaller magnetic needles, as shown in the accompanying photograph, see Fig. 6 Pl. 4, of an experiment made by the present writer, 1914.

Soft iron paper fasteners freely suspended by threads are used to indicate the pulling from the equator towards either pole of the magnet. The lines of force thus visibly tighten and shorten themselves by the aetherial suction into either pole; and *Euler*'s defective theory of an inward flow at the south pole and an outward flow at the north pole is disproved by observations which any one can make for himself. To be sure that no injustice was done to *Euler*, I took a small magnetic needle, suspended by a thread accurately fastened to its centre, and found by actual trial how this small magnet behaved when substituted for the soft iron wire described above.

We find by trial that the suspended needle also is drawn from the equator of the magnet towards either pole, exactly as in the case of the soft iron wire above used. The deflection of the supporting thread from the vertical direction of gravity, shown by the glass marble suspended in the centre of the field, under actual trial, shows this clearly and unmistakably.

It seems therefore absolutely certain that *Euler*'s defective theory of magnetism, with fatal lack of essential symmetry, yet copied in all the works on physics for the past 176 years, was an oversight due to the partial blindness of that great mathematician, and thus excusable. But what shall we say of the careless reasoning of physicists, which has enabled this unsymmetrical and unnatural figure to be handed down unchanged through nearly two centuries, or else mended by strained reasoning like that used by *Maxwell* above?

It may perhaps be allowed that the above experimental result definitely establishes the electrod. wave-theory of magnetism, set forth in the Electrod. Wave-Theory of Phys. Forc., vol. I, 1917. Accordingly, since we have attained a natural point of view, based on recognized symmetry, for the theories of electricity and magnetism, we shall see how fully the new theory is confirmed by definite phenomena which are simple and easily understood.

(ii) Maxwell's difficulties overcome by the wave-theory.

But, first of all, we call attention to the fact that in his paper On Physical Lines of Force (Scientific Papers, vol. I, p. 468) *Maxwell* searched diligently but in vain for the answer to the question: "what is an electric current?"

»I have found great difficulty, « he says, »in conceiving of the existence of vortices in a medium side by side, revolving in the same direction about parallel axes. The contiguous portions of consecutive vortices must be moving in opposite directions; and it is difficult to understand how the motion of one part of the medium can coexist with, and even produce, an opposite motion of a part in contact with it.«

»The only conception which has at all aided me in conceiving of this kind of motion is that of the vortices being separated by a layer of particles, revolving each on its own axis in the opposite direction to that of the vortices, so that the contiguous surfaces of the particles and of the vortices have the same motion.«

»In mechanism, when two wheels are intended to revolve in the same direction, a wheel is placed between them so as to be in gear with both, and this wheel is called an ,idle wheel'. The hypothesis about the vortices which I have to suggest is that a layer of particles, acting as idle wheels, is interposed between each vortex and the next, so that each vortex has a tendency to make the neighbouring vortices revolve in the same direction with itself.«

The difficulty here described by *Maxwell* is immediately solved by the wave-theory, for when a continuous series of waves are flowing, the rotatory motions of all the particles

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of the medium are in the same direction, as we see from the above Fig. 1, Pl. 4, from *Airy*, and no such antagonism as *Maxwell* mentions can arise. Surely this removal of *Maxwell*'s difficulty, along with the complicated structure of "idle wheels", which he devised for the stationary aether vortices, in default of wave-motion, must be considered a very remarkable triumph of the wave-theory.

In 1914 I found by careful experiment that a suspended magnetic needle is bodily attracted to a wire bearing a current, owing to the interactions of the waves from the wire and the needle. But it appears from *Maxwell*'s address on Action at a Distance, (Scientific Papers, vol. II, p. 317) that he did not look upon an electric current as bodily attracting¹) a suspended magnetic needle.

»We have now arrived at the great discovery by Oersted of the connection between electricity and magnetism. Oersted found that an electric current acts on a magnetic pole, but that it neither attracts it nor repels it, but causes it to move round the current. He expressed this by saying that ,the electric conflict acts in a revolving manner⁶.«

*The most obvious deduction from this new fact was that the action of the current on the magnet is not a pushand-pull force, but a rotatory force, and accordingly many minds were set a-speculating on vortices and streams of aether whirling round the current.«

And I have not been able to find any clear statement of the proved attraction of needle to a wire bearing a current, in later writers; they all evade it, by arguments as to the behavior of a unit north pole, when no such single pole exists. In the theory of magnetism it is no more pertinent to discuss the actions of half of a magnet than it would be in human physiology to treat of one side of our bodies only, when the whole body is perfectly symmetrical, and not to be split up into halves, and cannot act as such. One leg, one arm, one side of the brain and spinal column performs no functions alone and all such discussion is unscientific and a very imperfect makeshift.

(iii) Induction due to motion of a magnet explained by the wave-theory.

In the year 1824 it was observed by *Gambey* that a compass needle oscillating in its box came to rest sooner if the bottom were made of metal than if of wood. What is the reason of this dragging action of the metal? In the Electrod. Wave-Theory of Phys. Forc., we have explained induction by wave-action, and shown that when waves having, say, positive rotation suddenly penetrate a metallic substance, the effect of these positive whirls is to generate negative metallic whirls, in virtue of the disturbances of the aether.

That is to say, no such permanent disturbances will occur when both the magnet emitting waves and the non-

magnetic metal is at relative rest, but the moment any relative motion takes place, the wave-field penetrating the non-magnetic metal undergoes change, and this change of the wave-field disturbs the equilibrium of the aether in the non-magnetic metal, and the result is induction, or the generation of electric waves in the metal, which becomes temporarily magnetic. The metal therefore emits waves with whirls or rotations opposite to that of the inducing magnet.

Now in our demonstration of the cause of magnetism, 1917, it is shown that the reason why opposite poles attract, is that the opposite rotations in the waves from such poles cause an undoing of the stress of the medium, so that it collapses, and this tendency to contract is what we call attraction. In the same way the relative motion of a compass needle over a metal plate induces in it opposite polarity, with opposite rotations in the waves emitted therefrom; and then the temporary magnetism induced in the plate by the relative motion of the needle, calls forth attraction between the needle and the metal. Accordingly, this induction acts as a drag on the vibrations of the needle, and brings it to rest sooner than would be the case if the vibrations were over wood, which is almost devoid of inductive effect, because it is non-metallic.

(iv) Arago's rotations and the dynamo explained.

Soon after *Gambey*'s observation in 1824, the subject was investigated by *Arage*, who found that a copper plate under the needle was most effective in damping its vibrations. On rotating the copper disc in its own plane beneath the needle, he found that the needle was dragged around by an invisible friction; and when the magnet was rotated near the copper disc, the disc was dragged by the rotating magnet. This action was spoken of for a time, as a sort of magnetism of rotation, but in 1831, *Faraday* discovered induction, and showed that *Arage*'s rotations depend on this cause.

According to *Faraday* a magnet moved near a solid mass or plate of metal, induces in it disturbances which result in currents when they are properly directed, as from a dynamo. If they are not directed through a circuit, they flow from one point to another, and the energy is frittered down into heat, but meanwhile the electromagnetic forces act as a drag on the rotations taking place.

Fig. 7, Pl. 5, illustrates the eddy currents long recognized in such experiments. But from our electrodynamic wave-theory of magnetism, we recognize these whirls as the elements of rotations in waves receding from the magnet.

If we spin the disc of copper as shown in fig. 7, and lead off the disturbances by a circuit of wire connecting the points a and b we get the current generated by a dynamo, which was also invented by *Faraday*.

The above explanation of the generation of a current.

¹) Wheneell, History of the Inductive Sciences, 3^{rd} ed. 1857, vol. III, p. 73, expresses himself in about the same way: "On attempting to analyse the electro-magnetic phenomena observed by Oersted and others into their simplest forms, they appeared, at least at first sight, to be different from any mechanical actions which had yet been observed. It seemed as if the conducting wire exerted on the pole of the magnet a force which was not attractive or repulsive, but transverse; — not tending to draw the point acted on nearer, or to push it further off, in the line which reached from the acting point, but urging it to move at right angles to this line. The forces appeared to be such as Kepler had dreamt of in the infancy of mechanical conceptions; rather than such as those of which Neuton had established the existence in the solar system, and such as he, and all his successors, had supposed to be the only kinds of force which exist in nature. The north pole of the meedle moved as if it were impelled by a vortex revolving round the wire in one direction, while the south pole seemed to be driven by an opposite vortex. The case seemed novel, and almost paradoxical."

But we should look into the history of the subject since the earliest experiments, eighty years ago, in order to get a connected view of the whole subject of electric oscillations.

4. In 1842, Professor Joseph Henry was occupied with the study of the discharge of a Leyden jar, and reached the conclusion that what appears to the naked eye as a single spark, »is not correctly represented by the single transfer of an imponderable fluid from one side of the jar to the other.« »The phenomena,« he adds, »require us to admit the existence of a principle discharge in one direction and then several reflex actions backward and forward, each more feeble than the preceeding until equilibrium is obtained. »Henry's conclusions were drawn from observations of the irregular magetizations of steel needles when Leyden jar discharges are directed through a coil, as in Savary's experiments.

5. *Henry*'s conclusions were mathematically confirmed in 1853 by Lord *Kelvin*, who reached the formula for the time of these oscillations:

$$T = \frac{2\pi}{V(1/KL - R^2/4L^2)}$$
(23)

where K is the capacity of the condenser, now usually expressed in Farads; L the inductance, now usually expressed in Henrys; and R the resistance, in Ohms. If K = 0.01 Microfarad, L = 0.00001 Henry, and R = 0, the time of an oscillation will be found to be 1:503000, or the frequency of the oscillations 503000 per second. They may be made as rapid as 10000000 per second, or even of higher frequency; yet we cannot make them as rapid as the waves of light, because our physical apparatus is not of atomic dimensions.

6. When $R^2/4L^2$ is so small as to be negligible compared to 1/KL, the time of oscillation becomes like that of undamped simple harmonic motion:

$$T = 2\pi V KL. \tag{24}$$

But if $R^2/4L^2$ is small, yet not wholly insensible, the discharge is oscillatory, for under the damping due to resistance, the period is altered, and the time of oscillation becomes of the form used in radio telegraphy:

$$T = 2 \sqrt{(\pi^2 + l^2)} \cdot \sqrt{KL} \qquad (25)$$

where l is the logarithmic decrement.

7. In 1858 *Feddersen* experimentally confirmed Lord *Kelvin*'s theory of the oscillatory character of the Leyden jar discharge, by photographing the image of the spark in a rotating mirror, and found that the image of light was drawn out into a series of images, due to sparks following each other in rapid succession. The illustration of this oscillatory discharge in Fig. 8, Plate 5, was obtained in 1904 by Zenneck, who used a *Braun* tube as an oscillograph.

8. Now in the case of a steady electric current, the conductor connects points having difference of potential: this difference tends to adjust itself, by the electric contact, resulting from the conductor, and thus the aether is set in oscillation and the waves travel along the wire, just as water runs down hill from higher to lower gravitational potential, and in this transfer some dissipation of energy results.

Inductance is present in the wire, and as it has also capacity, the contact yields electric oscillations, when energy

is released, as in the discharge of a Leyden jar. If only one of these factors, inductance or capacity, were present, but not both, the disturbance would rise and fall according to some exponential function of the time, yet without regular oscillations.

When both inductance and capacity are present, as in all metallic systems, the disturbance calls forth both elasticity and inertia, because the electric disturbance is physically impeded and the aether is set into wave motion of the kind above described.

9. So long as difference of potential is maintained at the two ends of a circuit this electric wave oscillation is maintained along the wire. As in the case of the Leyden jar, so also for a battery; the oscillatory discharge begins the moment the circuit is complete, and continues to flow as a steady current. Since there is finite but small loss of wave energy through the body of the whire, owing to its physical resistance to the free movements of the aether, the wave disturbance envelopes the wire cylindrically, traveling more rapidly in the free aether outside; but the wave front is continually bent inward towards the metallic cylinder, just as the wireless wave is bent around the globe, by the greater resistance to the motion of the radio wave in the solid globe of the earth.

The above explanation of the waves propagated from a conductor gives a very satisfactory account of the phenomena from a physical standpoint. But it is advisable to look into the matter also from the historical point of view, in order to perceive the drift of research during the past sixty years.

10. In the celebrated Treatise on Electricity and Magnetism, 1873, §771 et seq., Maxwell first brought out the fundamental difference between electromagnetic and electrostatic units, and showed that the ratio is always equal to L/T = v, a velocity. Upon this basis Maxwell erected the foundation of the electromagnetic theory of light, which has come into general use, though the mystery of the connection between light and electricity was not fully cleared up. For example, Lord Kelvin never could see how it helped the wave-theory of light (Baltimore Lectures, 1904, p. 9).

As already pointed out, it will be seen from the table given below, that the dimensions of resistance, in electromagnetic units, is LT^{-1} , which represents a velocity. This is a very remarkable fact, having profound physical significance, which may well claim our attention. Is it possible that the resistance felt in all conductors, and obeying *Ohm*'s law, is an indication of the motion of electromagnetic waves along the wires, by which the resistance is generated? If so, the dimensions in electromagnetic units should be v^2 times that in electrostatic units, as actually observed.

11. In his celebrated discussion of the electric medium *Maxwell* showed how vv^{\ast} could be determined experimentally. In fact, *Weber* and *Kohlrausch* as early as 1856, 17 years before *Maxwell*'s treatise appeared, had already carried out a numerical determination, and obtained the approximate value v = 310740000 metres per second (Poggendorff's Ann., 1856, Aug., pp. 10-25).

This constant has since been determined by many

253

5079

investigators, working along lines indicated by *Maxwell*, with very accordant results, the latest and no doubt the best being that by Professor *E. B. Rosa* and *N. E. Dorsey* of Washington, 1907, Bulletin of the Bureau of Standards, vol. 3, nos. 3 and 4, p. 601, namely:

$$v = 2.997 \cdot 10^{10}$$

12. As these publications are universally accessible, we shall not go into the details of these electrical experi-

ments. It suffices to confine our attention to a physical explanation of the results obtained, but apparently not yet clearly understood by natural philosophers.

On comparing the dimensions of the electromagnetic units with those of the electrostatic units, we find that there is always a uniform difference depending on the common factor L/T = v, or $L^2/T^2 = v^2$, as shown in the following tables.

13. Table of the equivalent dimensions in the two theoretical systems of units.

1. Charge of electricity	e	$M^{1/2} T^{3/2} T^{-1}$	$\frac{1}{1} \frac{1}{2} \frac{1}{2} \frac{1}{2}$	Electromagnetic	
2. Density	0	11/1 I - 1/2 m-	$-M L \cdot v$	$M^{*/2}L^{*/2}$	
2. Electromotive force	ę "	M L TT	$M = M^{1/2} L^{-n/2} \cdot v$	M1/2 L 8/3	
J. Electromotive force	E	$M^{1/2} L^{1/2} T^{-1}$	$= M^{1/2} L^{3/2} T^{-2} \cdot I/n$	$M^{1/2} I^{3/2} T - 2$	
4. Electric intensity	R(X, Y, Z)	$M^{1/2} L^{-1/2} T^{-1}$	$M^{1/2} T^{1/2} T^{-2} - 1$		
5. Potential	V	M1/2 11/2 T-1	= 1/2 - 1/2	$M = L^{-1} - 2$	
6. Electric polarization	D(f = 1)	$\frac{1}{2} \int \frac{1}{2} \int \frac{1}$	$= M + L' + T' - 2 \cdot 1/v$	$M^{1/2} L^{1/2} T^{-2}$.	
7 Capacity	I(f, g, n)	$M = L^{-1/2} T^{-1}$	$= M^{1/2} L^{-*/2} \cdot v$	M1/2 7-3/2	
7. Capacity	<i>C</i>	L	$= L^{-1} T^2 \cdot n^2$	$7 - 1 \pi^{2}$	
8. Current	i	M1/1 L8/1 7-2	$- M^{1/2} T^{1/2} T^{-1}$		
9. Current per unit area	(11 11 . 111)	$M^{1/2} I = \frac{1}{2} \pi = 9$		$M^{-/3}L^{-/3}T^{-1}$	
10. Resistance	$(u, v, w) \in D$		$= M^{-1} L^{-1} r^{-1} v$	$M^{1/2} L^{-3/2} T^{-1}$	
tt Specific maint	Λ	$L^{-1}T$	$= L T^{-1} \cdot I/v^2$	$I T^{-1}$	
11. Specific resistance	τ .	T	$= L^2 T^{-1} \cdot I/n^2$	$I^{2}T - 1$	
12. Strength of magnetic pole	m	M 1/2 T 1/2	$- M^{1/2} I^{3/2} T^{-1} I$		
13. Magnetic force	$H(\alpha R w)$	M1/1 71/2 77-9	= M + L + I + I/v	$M^{*/*} L^{*/*} T^{-1}$	
14. Magnetic induction	$n(\alpha, \mu, \gamma)$	M = L = 1	$= M^{1/2} L^{-1/2} T^{-1/2} \cdot v$	$M^{1/2} L^{-1/2} T^{-1}$	
The dust's a line	B(a, b, c)	$M^{*/*}L^{-*/2}$	$= M^{1/2} L^{-1/2} T^{-1} I/n$	X11/2 I-1/2 T-1	
15 inductive capacity	K	I	$= L^{-2} T^2 m^2$	T = 2 = 2	
10. Magnetic permeability	μ	$L^{-2} T^{2}$	/ 2		

Table of practical units in the two systems.

Quantity	Name of Unit	Measure in electromag. units	Measure in electrostatic units
Charge of electricity Electromotive force	Coulomb	10-1	$v = 3 \cdot 10^{10} \text{ CGS})$
Electric intensity Potential	Volt	108	1/(3 · 10 ²)
Capacity Capacity Current Resistance	Farad Microfarad Ampère Ohm	10^{-9} 10^{-15} 10^{-1} 10^{9}	$9 \cdot 10^{11} \\ 9 \cdot 10^{5} \\ 3 \cdot 10^{9} \\ 1/(0 \cdot 10^{11})$

It will be seen from the element, resistance, no. 10, in the above table, that to establish equivalence, the electrostatic unit must be divided by $(TL^{-1})^2$ or by v^2 , which is the square of the dimensions in electromagnetic units. This indicates that electromagnetic waves resisted by a conductor do work depending on the square of the velocity with which they travel, which conforms to general experience in all physical problems where energy is expended.

14. It thus appears that the ratio between the two sets of units is uniformly L/T = v, in the first or second power, and thus v undoubtedly represents a velocity, as first clearly set forth by *Maxwell*, Treatise on Electricity and Magnetism, § 771 et seq. Fortunately it happens that this ratio can also be determined experimentally, from a current of electricity in motion, and from an identical electrostatic charge, at rest: thus v admits of electric measurement, independently of any theory of light. But as the value of v is the same as the velocity of light, *Maxwell* naturally concluded that the electric medium is identical with the luminiferous aether. The following is an outline of the method of measurement. For simplicity, suppose a condenser is charged with electricity, and let its quantity, Q, be measured in electrostatic units, by determining for instance the repulsion which a given proportion of the total charge produces in a torsion balance of known dimensions.

Let the condenser be again charged to the same extent, and let it be discharged through a galvanometer. By measuring the deflection produced, the constants of the instrument being known, we may determine the quantity of electricity which deflected the galvanometer. This gives by direct observation

$$Q(e.m.)/Q(e.s.) = C \cdot 3.0 \cdot 10^{10}/C = 3.0 \cdot 10^{10}$$

= velocity of light.

16. The process may be numerically illustrated in the following way. The e. m. f. of a Daniell's cell may be measured by such an instrument as Lord *Kelvin*'s absolute electrometer, and found to give in electrostatic units of potential say 0.0036.

The same difference of potential measured in electromagnetic units will be found to have the value $1.088 \cdot 10^8 = 0.01088 \cdot 10^{10} \cdot 3/3 = 0.0036 \cdot (3.0 \cdot 10^{10}).$

Hence the ratio of the electromagnetic to the electrostatic units is $3.0 \cdot 10^{10} =$ velocity of light.

The electrostatic quantity Q(e. s.) is the quantity of electricity which attracts or repels another equal quantity at a distance of r cm, with a force of a dyne. The electromagnetic quantity Q(e. m.) is the quantity of electricity which traverses the wire of the galvanometer in a second when the current set up by the discharge has unit intensity.

17. The ratio between the units is always of the dimensions of a velocity, and as it holds under the condition that the centimetre is the unit of length, and the second the unit of time, we see by experiment that the

254

ratio is the actual velocity of light, $3.0 \cdot 10^{10}$, which establishes the identity of the electric medium with that of the luminiferous aether.

This was also shown by *Hertz* in the celebrated experiments which led to the development of wireless telegraphy, and thus the subject requires no further treatment at present. We merely call attention to the electrodynamic waves about a wire bearing a current as diagrammed in the author's work of 1917, Fig. 12, below, and now somewhat better represented in Fig. 18, Plate 6.

18. This picture shows clearly that an electric current is nothing but a certain type of aether waves propagated away from the wire. Accordingly, when such a current is set up in the aether, through the waves generated and maintained by the e.m. f. of the battery, it is obvious that the electromagnetic measure of this electric action should involve the motion of the waves or velocity; while in the case of the electrostatic action no velocity is involved, but only a stationary difference of potential.

This theory completely accounts for the difference vin the units, and harmonizes all known electrical phenomena, and is an especially satisfactory termination of a half century of scientific discussion of the relation between electromagnetics and electrostatics. It is not by chance that only vand v^2 appear in the above table.

If the actions of the medium involved something besides say induction, where v appears, or resistance, where v^2 appears, it should be expected to find v in perhaps the third or fourth powers; but no such powers are established by observation, which confirms the above interpretation.

5. The Geometrical and Physical Significance of *Biot* and *Savart*'s Law for the Intensity of a Curtent on a Straight Wire, and of *Ohm*'s Law for the Resistance.

it. I. The law of *Biot* and *Savart* for an electric current on a straight wire has the simple form (*Biot* et *Savart*, Ann. Chim. Phys., 15 p. 222, 1820):

 $I = KH/r \tag{26}$

where K is a constant, and I the intensity of the electric action which varies inversely as the distance r from the wire, and directly as the current strength H.

2. We shall give a simple geometrical basis for *Biot* and *Savart's* law of the inverse distance. In the Electrod. Wave-Theory of Physic. Forc., we have shown that the action of an electric current is due to flat waves, with their planes of rotation containing the axis of the straight wire, the rotation of the wave elements being around the lines of force, which are circles about that axis. All points of the wire emit waves, but the waves are so conditioned as to expand in the form of a cylindrical surface, thus spreading as a circular cylinder around the wire, but not in the direction of the wire. The element of cylindrical surface becomes:

 $ds = dlr d\omega \qquad (27)$

where $r d\omega$ is an element of the circles of expansion, increasing as the radius r, and dl is constant, along the length of the cylinder.

3. Now since the element of length dl is constant, as

the wave spreads outward, and only $r d\omega$ varies, the cylindrical sector thus increases like the circumference of a circle, $2\pi r$, perpendicular to the axis of the wire. The expansion of the radius of the circle thus determines the increase in the area of ds, the elementary area of the cylindrical surface, in which the electrical waves must expand.

4. Now the area of the circular cylindrical sector varies as $rd\omega$ or as the radius, $d\omega$ being constant in a fixed element of the sector. And as the waves thus become less crowded, in the direct ratio of the distance, r, it follows that the intensity of the wave action decreases, varying inversely as r. This is a direct and simple view of the geometrical basis of *Biot* and *Savart*'s law, heretofore apparently little studied by natural philosophers.

5. This remarkable law of *Biot* and *Savart* thus has the simplest of explanations: namely, the elementary cylindrical surface ds increases directly as r, and the resulting electrical action therefore decreases inversely as r. The law thus follows at once from the restricted freedom of the waves propagated from the wire: and as it was confirmed by experiments of *Biot* and *Savart*, 1820, the law in turn establishes the dependence of current action on electrodynamic waves. No other agency than waves could produce this result, because waves involve expansion, and the agitation has to follow the geometrical inverse law of the increase of space.

6. By extending the above reasoning, we see that if the waves from a body can spread in all directions, they will fill a sphere surface, $s = 4\pi r^2$, and hence the law of decrease of the intensity for the action varies inversely as r^2 , namely: $f = m/r^2$, which holds for universal gravitation, magnetism, and other physical forces of nature.

7. As the coincidence between the requirements of waves and the space expansion is rigorous, from x = o to $x = \infty$, the chances against such a mere accidental conformity, without physical cause, are infinity to one. Accordingly, *Biot* and *Savart*'s law furnishes direct proof of the utmost rigor that waves underlie electrodynamic action, as well as gravitation, magnetism, etc.

There has been such a bewildering confusion of thought connected with the whole subject of physical action across space that it is necessary to bear in mind clearly the fundamental principles of natural philosophy. To this end we need obvious proofs of the causes underlying physical action, under the simplest of nature's laws. The simple laws exclude the larger number of complicating circumstances, and enable the cause involved to stand out in such a way that we may recognize it.

Very different indeed is the confusion of thought carried on in certain scientific circles. At a discussion of the Theory of Relativity, as reported in the Monthly Notices for December, 1919, Sir Oliver Lodge justly complains that Professor Eddington thinks he understands it all. »To dispense with a straight line as the shortest distance between two points, and to be satisfied with a crazy geodesic that is the longest distance between two points, is very puzzling.« ... »The whole relativity trouble arises from giving up the ether as the standard of reference — ignoring absolute motion through the ether —, rejecting the ether as our standard of reference, Astronom. Nachrichten Bd. 212.

T. J. J. See. New Theory of the Aether.



Fig. 1. *Airy*'s illustration of the motion of the particles in a wave of water. Each particle moves about a mean position, which is shown by the centre of the circles; and the radius vector drawn from the centre, shows the water vector at various phases of the oscillation.



Fig. 3. Euler's Theory of Magnetism, 1744, which conceived a magnet as having valves in the »Arteries« along its axis, permitting the aether to flow in one direction only, from the South to the North Pole, AB. This misleading principle has been used in nearly all works on magnetism for the past 176 years, though it sometimes is adapted to modern thought by the round about and complicated processes of Maxwell.



Fig. 4. Diagram showing the adaptation of *Euler's* theo of 1744 made by *Maxwell*, Treatise on Elect city and Magnetism, 1873, vol. II, § 404.



Fig. 5. Illustrations of the usage of *Euler*'s Circulation Theory of a Magnet, 1744, in various modern works.



Fig. 6. Experimental confirmation of the Electrodynamic Theory the attraction of soft iron to magnetic poles.

T. J. J. See. New Theory of the Aether.



Fig. 7. Diagram of the Eddy Currents induced in a disc of metal by motion relative to a magnet, and thence the generation of a current, as in a dynamo.



Fig. 9. Illustration of the restricted amplitudes of the waves

receding from a straight wire, under Biot and Savart's law, which permits space expansion, and thus decrease of amplitude, varying inversely as the square root of the distance r.



Fig. 8. Photograph of the oscillatory character of the discharge of a Leyden jar, taken in 1904 by Zenneck, who used a Braun tube as an oscillograph.



Fig. 10. Illustration of Biot and Savart's law, 1820, where we measure the intensity I as the distance r varies; and of Ohm's law, 1826, in which at a constant distance and with uniform electromotive force we measure the resistance \mathcal{K} , or current strength I.



Fig. 11. Illustration of a magnetic whirl about a wire, with Wave-theory of this whirl, on the right. Each little piece of iron filing becomes a small magnet, and they are drawn together by the attractions of their opposite judge.



Fig. 14. Illustration of the Wave-theory of the Earth's magnetism, showing the magnetic forces directed towards either pole. The annexed diagram on the right shows the rotations taking place in the field as the magnetic waves recede, while above it is the figure of a small magnetic needle pointing along the line of force, which is the rotation-axis of the waves. The magnetic field is found by *Gauss* to depend on about 1:1380th part of the atoms, while the remaining 1379:1380^{ths} of the atoms, under haphazard orientation, give the central action of gravitation.



Fig. 18. Illustration of the Wawe-field about a wire bearing a steady current. The oscillatory discharge diagrams on the left are from *Floming*'s Principles of Electric Wave Telegraphy and Telephony, 1916. As the wire has both inductance and capacity, the discharge along it is oscillatory, and the wave-field develops as drawn. It is illustrated in *Oerstea*'s experiment of 1810, and in *Acagn's* experiment with ropper wire, 1830.





Fig. 1. Illustration of the effect of orthogonal projection, by which molecular motions, in *Poissen's* elongated ellipses normal to the wave front, at different parts of a sphere surface, become mainly transverse to the direction of the ray, at a great distance from the source. The outer circle is magnified to distinct visibility, so as to render the cause of the transverse vibrations in light more obvious to the imagination, as shown also by the darkened areas of the enlarged ray at the centre of the figure.



Fig. 3. Graphical illustration, by means of the shaded portion, of the enormous concentration of light vibrations in the periphery of a beam, under orthogonal projection of the sphere, with *Poisson*'s elliptical paths for the molecular oscillations along the radii from the centre, and, by means of the small factor $A_i \lambda$, thus making nearly all the vibrations transverse to the direction of the ray.

T. J. J. Sec. New Theory of the Aether.



Fig. 5. General view of the magnetic field about the earth, with a specimen of the waves to which the field is due, shown on the right. The magnetic needle lies in the hollow of the waves, and thus we see why it points to the north. *Gauss'* Theory of the Earth's magnetism corresponds to the wave-theory for the part of the atoms which are lined up in parallel, to produce the earth's magnetic field, about 1'1380th of the whole. The rest of the atoms, 1379/1380ths of the whole, give the central action called gravitation, but the gravitational wave field is too complex to be shown in the diagram.



Fig. 6.

Illustration of the restriction of free vibrations when the wave motion is suddenly resisted at the boundary of a solid body. Owing to the resistance to one side of the ray the beam of light is flattened like a reflected stream of water, and thenceforth becomes polarized, vibrating with greatest freedom and largest amplitude in the plane perpendicular to the plane of polarization, as held by *Fresnel*. Tafel 8.



Fig. 7. Illustration of light polarized by reflection from the blue sky. The vibrations are normal to the plane of polarization passing through the sun and the zenith, and the polarization attains a maximum at a point equally distant from the zenith.



Fig. 8.

Undulatory explanation of the interference of polarized light, when the paths of the actherons are circles. It will hold for ellipses, and even for straight lines, but such restrictions are not necessary. In the upper part of the figure the wave phases differ by $1/_2\lambda_i$ in the lower part the phases concur, and give double intensity. The light and dark bands above correspond to the present position of the wave, indicated by the heavy line, while the arrows show the advanced position of the wave when it has moved to the right after an interval dt.



Fig. 10. Illustration of the diffraction fringes due to a rectangular aperture, with the corresponding visibility curve above it, on slightly different scale (*Michelson*). The central band of light is nine times more intense than the first secondary maximum, while the higher orders of bands, all parallel to the sides of the rectangular slit, are still fainter.

C. Schaidt, Inhaber Georg Oheim, Kiel.

and replacing it by the observer. By putting the observer in the forefront and taking him as the standard of reference you get complexity. If you describe a landscape in terms of a man in a train looking out of the window, the description is necessarily complicated. The surprising thing is that this theory has arrived at verifiable results.« . . . »The theory is not dynamical." There is no apparent aim at real truth. It is regarded as a convenient mode of expression. Relativists seem just as ready to say you are rising up and hitting the apple as that the apple is falling on you. It is not common sense, but equations can be worked that way.«

8. It is quite remarkable that heretofore the law of *Biot* and *Savart* should have been so little studied by investigators. A law of such simplicity (compare Fig. 9, Plate 5) has enormous advantages over any complex law, especially when it comes to searching for the causes which produce the phenomena observed in nature. Thus it is preeminently these simple laws, which admit of one interpretation and only one, that should claim the attention of natural philosophers.

9. In the closest analogy with what *Biot* and *Savari's* law puts before us, for the intensity of an electric current, on a straight wire, the Newtonian gravitational potential, for a homogeneous sphere or a heterogeneous sphere made of concentric layers of uniform density, presents to us the excessively simple formula:

$$V = M/r \tag{28}$$

which we have already interpreted in terms of waves freely expanding in tridimensional space.

Any other interpretation than that given for the Newtonian potential function in these simple cases seems absolutely excluded, by virtue of the simplicity and directness of the most obvious special relations, as when the waves expand outwardly from a spherical mass such as the sun.

10. Any modification which renders these formulae complicated or non-homogeneous is to be viewed with profound suspicion. Thus the substitution of *Gerber*'s formula:

$$V = M/r(1 - 1/c \cdot dr/dt)^2$$
(29)

for Newton's as cited in equation (28) above, is unjustifiable and indefensible; yet in the perverse search for complexity instead of simplicity, such bewildering confusion goes on.

Dr. P. Gerber first published this unauthorized formula in the Zeitschrift für Mathematische Physik, Band XLIII, 1898, p. 93-104, and the exploitation of it since made by *Einstein* and his followers ignores the fundamental fact that by introducing the second power factor, $\gamma^2 = (1 - 1/c \cdot dr/dt)^2$ in the divisor, the dimensions of the equation are changed, which is physically inadmissible and equivalent to violating the essential mathematical condition of homogeneity for the equation for the potential. Such an objection is fatal¹), since it rests upon both geometrical and physical grounds; and thus we witness the adoption of a mere convenience, in violation of recognized scientific principles.

11. The fact that the *Einstein* speculations involve this fatal contradiction seems to have been overlooked by previous

investigators, who thus exhibit a feeble grasp of the most essential conditions of geometrical and physical research.

Accordingly, since this *Gerber* formula is invalid, when applied to a homogeneous sphere, or a spherical mass made up of concentric layers of uniform density like the sun, its general admissibility must be wholly denied. In fact it has neither geometrical nor physical validity; and its use in contemporary journals and the transactions of learned societies is is a bizarre performance, in vague and chimerical reasoning, little to the credit of our time.

12. We have now to consider the geometrical and phy^{\downarrow} sical significance of the law of electric resistance discovered by Dr. George Simon Ohm (Ann. d. Phys. VI, 1826, p. 459): I = H/R (30)

where R is the resistance, H the electromotive force, and I the intensity, as measured at any point by a suitable apparatus, such as a galvanometer. This law of *Ohm* likewise is remarkably simple, and quite similar to that of *Biot* and *Savart*, above explained. Accordingly let us see what connection, if any, exists between *Ohm*'s law and that of *Biot* and *Savart*.

a) In *Biot* and *Savart*'s law we vary the distance, with fixed electromotive force, and observe the change in the intensity: the observed result confirms the wave-theory.

b) In Ohm's law we also deal with a current in a wire, or wires, and when the electromotive force is fixed, we study the law of resistance (R), or intensity of action (I), at a fixed distance, where the needle of the galvanometer may be located.

c) Thus *Biot* and *Savart*'s law, with a fixed steady current, serves for calculating the varying intensity at any, distance, in accordance with the requirements of the wave-theory. In the same way, *Ohm*'s law, when H is constant, but with varying resistance, R, serves for calculating the intensity at a fixed distance.

13. Accordingly it appears that these two laws are mutually supplementary. For all the effects, in the field of electrodynamic waves about a wire, should include both those occurring at a fixed distance, as calculated by *Ohm's* law, and those occurring at a varying distance, as calculated by the law of *Biot* and *Savart*. The two laws are thus brought into immediate and necessary relationship, and both conform to the wave-theory.

We may write *Biot* and *Savart*'s law in the form: I = KH/r

and Ohm's law in the form:

$$I = H/R$$
.

Accordingly on combining the two expressions which we may do by equating the identical intensity at any point, we obtain

$$KH/r = H/R$$
 or $K = r/R$. (33)

Therefore, we find on substituting for K its value, for any value H and r,

$$I = rH/Rr = H/R$$
(34)

¹) This may be made a little clearer by noticing what would happen if the exactly analogous formula for the velocity, V = L/T, had a factor γ^2 introduced into the divisor T. Such an arbitrary modification of the expression for the potential is purely a change de convenance, and not permissible on mathematical or physical grounds

257

259

14. These two laws therefore confirm the wave-theory of the entire field about a wire bearing a steady current. Ohm's law implies a cylindrical wave field — the resistance and intensity being the axes of a rectangular hyperbola referred to its asymptotes — *Biot* and *Savart*'s law also represents a rectangular hyperbola of the same type, but with r varying instead of R (compare Fig. 10, Plate 5).

These two laws give the complete theory of the electrodynamic wave-action, in the whole field about a wire bearing a steady or variable current, and thus greatly simplify the theory of the electromagnetic field.

6. Oersted's Experiment, 1819, Arago's Experiment with copper wire, 1820, and the Magnetic whirl shown by iron filings near a conducting wire all confirm the wave-theory, which also agrees with Ampère's theory of elementary electric currents circulating about the atoms.

In the Electrod. Wave-Theory of Phys. Forc. we have given a simple and direct explanation of the deflection of the magnetic needle first observed by *Oersted* in 1819, the adherence of iron filings to copper wire conducting a current, first observed by Arago in 1820. We also explained the circular whirl assumed by iron filings near a conducting wire, and finally were enabled to harmonize the wave-theory with Ampère's theory of elementary electric currents about the atoms (comp. Fig. 11, Plate 5).

magnetic field is too remarkable to rest on mere chance; and thus we shall describe the argument briefly, as the best means of unfolding the true order of nature. The electrodynamic waves propagated from the wire bearing the current lie in planes through the axis of the wire, and are of the type

$$s = a \sin(2\pi x/\lambda + p)$$

$$a \sin(2\pi y/\lambda + p)$$
(35)

where x and y are interchangeable, owing to the symmetry of the waves about the z axis, which is taken as the axis of the wire. Owing to cylindrical symmetry the axes of xand y might be rotated about that of z without any change in the expressions for the waves receding from the wire under the action of the current.

But as we have already pointed out the amplitude a decreases as in *Biot* and *Savart's* law, inversely as

$$\cdot = \sqrt{(x^2 + y^2)}.$$

(i) Oersted's Experiment of 1819.

In the experiment of 1819, it was observed by *Oersted* that if the magnetic needle be below the wire, and the current from the copper positive pole of the battery directed north, the deflection of the north pole would be to the west.

If the needle be above the wire, but the other circumstances unchanged, the deflection of the north pole was observed to be towards the east. The needle might thus be revolved in a circle about the wire, without any change of the relative position in relation to the axis of the wire. Accordingly it appears that the axis of the needle, sets itself

tangential to the lines of force, which are circles normal to the axis of the wire.

If now, without other circumstances being altered, the direction of the current be changed, the two poles of the needle immediately interchange at all points about the wire: The south pole is deflected to the west when beneath the wire, and to the east when above the wire. And in general, every point in the orientation is exactly reversed.

What can be the meaning of this phenomenon in which the current acts as if it has sides, when reacting on the magnetic needle? We shall see that just as the magnet has two poles of opposite properties, so also the current has two sides, due to waves which appear to be righthanded rotations when viewed from the opposite point.

Consider the case first cited above, with the current from the positive copper plate of the battery flowing north and the needle suspended beneath the wire, but with the north pole deflected to the west when the current flows. This means that the waves descending below the wire have vortices rotating righthanded, as shown in the following figure, from the writer's work of 1917.



Fig. 12. New theory of *Oersted's* and *Arago's* experiments, 1819-20, and of induction.

It means also that the rotations of the waves receding from the south pole of the needle have the opposite direction of rotation, as shown in the figure.

I. For it is found by experiment that the needle is bodily attracted to the wire, by the action of the current, and hence the waves from the wire must undo the opposite rotations in the waves from the needle. Accordingly the medium tends to collapse, and by this contraction of the volume of the medium the needle is drawn to the wire.

2. In all the works on electricity and magnetism which I have seen including *Maxwell*'s great treatise, this question is somewhat evaded by the claim that the north pole tends to wrap itself around the wire, in one direction, while the south pole tends to wrap itself around the wire in the opposite direction; and that this actual bending of the needle would occur if the needle were flexible. I proved by direct experiment in 1914, that the needle is bodily attracted to the wire in 5079

every possible position it may take, but I cannot find so simple a statement of this essential fact in any earlier work on electricity and magnetism.

3. The usual discussion about the tendency of the unit north pole is very unsatisfactory, because while the tendency thus outlined is fairly accurate, it conveys the impression that all power is centred in the pole, rather than in all the particles, — notwithstanding the fact that if we break the magnet we get as many separate magnets as we have fragments, and since this subdivision may be extended to molecular dimensions, we know that the theory of pole action is altogether misleading, yet such vague teaching continues to be handed down from generation to generation, and eminent scholars have often remarked how difficult it is to get rid of the most obvious errors, when entrenched in authority by the lapse of time.

4. Further proof of the above theory of the action of an electric current upon a magnetic needle might be deduced from the fact that in nature physical actions always are mutual. Thus if the needle is attracted to the wire, the conducting wire obviously is equally attracted to the needle otherwise action and reaction would not be equal, as proved by universal experience. Accordingly, no other conclusion can be held than that waves of the kind outlined proceed from the needle and also from the wire, and by their interpenetration develop forces of the kind observed in nature. It is not enough that waves proceed from one body, but not from the other: there undulations must proceed from both bodies incessantly, and travel with the velocity of light. This is proved by observation, for the wave actions propagated along the wire, and thence inferred also for the waves of a magnet itself, though the velocity of the waves from a natural magnet have never been directly measured. Yet since magnets are made by the action of a current upon a bar of steel inserted in a solenoid 1), it follows that the velocity of the two classes of waves, one from the current and the other from the magnet, must be the same, and in both cases identical with the velocity of light, $v = 3.0 \cdot 10^{10}$ cms.

(ii) Arago's Experiment of 1820.

5. As to *Arago*'s experiment of 1820, it is obvious that copper wire conducting a current will give a wave field about it similar to any other wire. If iron filings be near

such a conducting wire, it is obvious that they should adhere to it, since each filing will become a temporary magnet, the ends having opposite poles, owing to the nature of the whirl of magnetic waves about the wire. Accordingly *Arago*'s experiment is simply a verification of *Oersted*'s experiment, but rendered more general by the use of a copper wire, and soft iron filings, which therefore fall off when the current stops, and the wave field about the copper wire disappears. 6. It is worthy of note that since the lines of force about a magnet are rentrant vortices, — the filaments within the axis of the magnet rotating in exactly the opposite direction to those in the magnetic equator, for example, — the waves emitted by the conducting wire in *Oersted*'s and *Arago*'s experiments, described above, will have their elements rotating in perfect agreement with the vortices inside the body of the magnetic needle. The waves from the wire thus support the physical oscillations within the more resisting body of the needle, and by rendering the sum total of the mutual actions a minimum, the balanced needle is in equilibrium in the position observed by *Oersted*, 1819.

7. It is now easy to reconcile *Ampère*'s theory of elementary electric currents about the atoms of a magnet with the wave-theory. The formula for a plane wave is

$$s = a \sin\left(\frac{2\pi x}{\lambda + p}\right). \tag{36}$$

And as we may shift the point of the revolving vector, by altering the phase angle p, we see that by changing pfrom o° to 2π , we should have a complete oscillation of the wave. This would correspond to the movement of the electric current once about the atom; and also to the advance of the wave along the x-axis by one periodic oscillation. The wave-theory is therefore in perfect accord with Ampère's theory of elementary electric currents about the atoms of matter.

8. If it be imagined that the atoms probably have a smaller circumference than a wave length λ of the wave emitted from the atom, all we need to do is to point out that we do not know the mechanism by which waves originate, and it does not follow that the wave length in the aether should correspond to that of the atom. An undetermined multiplier probably is involved here, but at present we cannot fix it with any accuracy.

(iii) Nature of atomic vibrations considered.

For in the case of sound, the dimension of the *Helm-holtz* resonators is not closely related to the length of the corresponding sound waves received and emitted by the elastic oscillation of the resonator. And even if this could be found in air, it would not be the same in hydrogen, oxygen, nitrogen, or other gases, but depend on the properties of these media, as well as on the physical properties of the resonator, its shape, mass, elasticity, rigidity, etc.



Fig. 13. Ampère's theory of elementary electric currents about atoms reconciled with the wave-theory.

¹) As far back as 1820 Ampère showed that if a wire be wound into a solenoid, delicately pivoted in mercury contacts, and a current passed through it, it behaved as a magnet, with a north and south pole. Hence Ampère was impressed with the solenoidal character of magnets; and imagined that the elementary currents about the atoms mutually destroyed each other within the body, and remained effective only in the surface layer of the magnet, which was thus viewed as a shell. But Ampère's reasoning is equally useful for proving that there are waves proceeding from the wires bearing the current, and that they are flat in the plane through the axis of the wire.

For So also within the aether, the vibrations of the atoms are determined by causes which at present are but little understood; and we can only infer that the atomic dimensions are not directly related to the wave length, or wave lengths emitted, though there probably is some correspondence which may be made out in time.

by 'o, It appears from the researches in spectroscopy heretofore made that the atom of a single element may emit a complicated series of spectral lines, which means a very complicated series of vibrations, some of which are connected by the formulae of Balmer and other investigators. Now most of the vibrations of the visible spectrum are below the resolving power of the microscope, and thus the waves are so short that such vibrations do not penetrate solid or even transparent fluid bodies to any appreciable depth. But we know by the transmission of the sun's rays through such a medium as the terrestrial atmosphere that longer waves have increased penetrating power. And since Langley extended the length of the solar spectrum to some 20 times that observed by Newton, without finding any indication of an end, it is natural to hold that the waves upon which gravitation, magnetism, electrodynamic action, etc., depend must be of comparatively great length, otherwise they would not penetrate solid masses as they are observed to do in actual nature.

ro. It thus appears that the shorter atomic waves therefore do not produce forces acting across sensible spaces, and in dealing with the long range forces of the universe we must look to waves of considerable length, which have the required penetrating power, and are least delayed in propagation through solid masses. Such waves will explain gravitation, magnetism, electrodynamic action, and are the only means of making intelligible the correlation of forces and the conservation of energy, since light and heat certainly are due to waves in the aether. Unless the other energies be due to waves also there would be violation of the doctrine of continuity, which is so fundamental in natural philosophy.

(iv) The wave-theory establishes the attraction of currents flowing in the same direction, and the repulsion of currents flowing in opposite directions, and therefore assigns the true physical cause of these electrodynamic phenomena.

1. From the foregoing discussion it follows that when from the east of the meridian we look at a positive current flowing to the north (from the copper terminal of a battery) we find the elements of the waves propagated away to be rotating righthanded (clockwise) beneath the wire, but lefthanded (counterclockwise) above the wire (cf. Fig. 18, Plate 6). This follows also from the relative positions taken by the freely pivoted magnetic needle, which presents to us a south pole when beneath the wire, but a north pole when above the wire.

2. Now suppose we have two such independent currents flowing north: what will be the mechanical effects of the mutual interactions of their waves? If we imagine one wire above the other, for conformity to the wave picture just outlined in paragraph s, we perceive that between the wires, the wave elements from the two conductors will rotate in opposite directions: which will cause the undoing of the separate wave stresses, and a collapse of the medium, and the result of this contraction will be attraction.

3. On the outside of the two wires, on the other hand, the rotations of the wave elements will be in the same direction, the stress or agitation of the medium will therefore be increased, so that it expands: which will tend to press the wires together from the outside. Hence the wires will be made to attract both from the internal and the external wave actions. Accordingly, we have a simple and natural explanation of the mutual attraction of currents flowing in the same direction. And it is based upon the same conceptions as are involved in the attraction af magnets presenting unlike magnetic poles. In fact by the suspension of magnetic needles close to the two conducting wires, the same conclusions follow: for unlike poles are presented in proximity, which means attraction.

4. Now let the direction of one of the currents be reversed. It is easy to see that between the wires the rotations of the wave elements will appear to be in the same direction, as viewed from the east of the meridian; and thus the agitation of the medium will be increased, the medium will expand, and the wires be forced apart, so that the action leads to repulsion, just as when like poles are presented by two magnets.

5. On the outside of the two wires, however, the rotations of the waves, flowing in opposite directions, will each tend to undo the other: in the external region the medium will tend to collapse, which will allow the wires to be forced apart, so that repulsion from the region between the wires will be accentuated by this external tendency of the medium to collapse. Accordingly mutual repulsion will be observed whenever two currents flow in opposite directions.

6. This is equivalent to the mutual repulsion of two magnets which present like poles: the interpenetration from opposite directions of waves with like rotations caused the medium to expand between the bodies, and to collapse beyond them, so that repulsion immediately follows. Accordingly the whole theory of the attraction and repulsion of electric currents flowing in the same and in opposite directions respectively, is analogous to the mutual actions of two magnets, and the causes are one and the same. And as the outcome greatly simplifies our theory of electrodynamic action, so also we are correspondingly assured that the results conform to the true laws of nature. The harmony of so many distinct phenomena would not be possible unless based upon the true causes involved: for the probability of such an accidental outcome approaches zero.

7. Weber's Law indicates that Gravitational, Magnetic, and Electrodynamic Actions are all due to Waves traveling with the Velocity of Light; thus explaining the Semidiurnal Tide in the Earth's Magnetism depending on the Moon, which Newton's Law will not account for.

As we have previously pointed out, *Weber*'s fundamental law of electrodynamic action, published in 1846, has the form:

 $f = (mm'/r^2) \{ \mathbf{I} - (\mathbf{I}/c^2) (\mathrm{d}r/\mathrm{d}t)^2 + (2r/c^2) \cdot \mathrm{d}^2r/\mathrm{d}t^2 \}.$ (37)

The first term of the second member is identical with *Newton*'s law of gravitation, 1686, and of course gives the

principal part of the force which regulates the motions of the heavenly bodies. But there are slight effects resulting from the second and third terms, which were first numerically investigated by *Tisserand* in 1873 (cf. *Tisserand*'s Mécanique Céleste, Tome IV, last chapter), but the theory was rendered more complete in the present writer's Electrodynamic Wave-Theory of Phys. Forc., vol. I, 1917, where tabular data will be found for the planets, satellites, comets and binary stars.

The chief effect of the minor terms of equation (37) is to give the perihelion a small progressive motion, which in the case of the planet Mercury amounts to $\delta \overline{\omega} = +14.51$ in a Julian century. This reduces the anomaly in the outstanding motion of that perihelion to about two-thirds of its value, namely from $\delta \overline{\omega} = +42.95$ to $\delta \overline{\omega} = +28.44$, but does not obliterate the anomaly, which is more exhaustively investigated in the second paper on the new theory of the aether.

It was in his celebrated paper of 1864, A Dynamical Theory of the Electromagnetic Field, that *Maxwell* reached the conclusion that the velocity of electrodynamic action is identical with that of light, as already indicated by *Kohlrausch's* experimental determination of v, in 1856. But although such a conclusion followed from *Kohlrausch's* experiments, and from *Maxwell's* theory of the electromagnetic field, it was necessary to form a more definite conception of the nature of the action, than was then available, before the use of vcould be introduced as a working hypothesis.

Maxwell's electromagnetic theory of light was put in such shape that the existence of electric waves was rendered probable, but not directly verified by any tangible experiment, till Hertz's discovery of the electric waves (1887-94) which bear his name, along with a method for investigating their properties, including an experimental demonstration that they travel with the velocity of light.

This practical development of the theory of electric oscillations, with experimental determination that the velocity of the electric waves is identical with that of light, left no doubt of the identity of the electric medium with the luminifereus aether. Otherwise it is inconceivable that the two velocities should be identical. The previous and subsequent determinations of v have confirmed this conclusion, so that such a result has now been accepted for about a quarter of a century. It remained, however, to form some demonstrable physical conception of magnetism and of gravitation, which would justify the claim not only that electric waves travel with the speed of light, but also that magnetic and gravitational forces are due to a similar cause, which was the aim of the writer's researches, 1914-1917.

1. First, it was necessary to show that a physical theory of magnetism may be based on the mutual action of waves ¹), and to disclose the nature of these waves, which must meet certain requirements in electrodynamics, and cosmical magnetism, so as to be adaptable to the more hidden problem of universal gravitation. This requirement was met by the theory of waves from atoms, shown to conform to *Ampère*'s theory of elementary electric currents about these particles, but of such length that they may be propagated through solid masses without very great loss of energy.

2. The wave is taken to be flat in the equator of the atom, so that in this plane, the waves are perfectly plane waves, while in the two hemispheres of the atom the rotations give righthanded or lefthanded helices, as actually observed in polarized light when propagated through certain crystals. This specification fulfilled the most necessary optical requirements, and thus presented no difficulty from the point of view of light or electricity.

3. The magnetic requirement, that common steel should be capable of magnetization by the action of an electric current, was met by the theory of Ampère that before magnetization the planes of the atoms lie haphazard, with their equatorial planes tilted indifferently in all directions. The action of the electric current, with waves flat in the planes through the axis of the conducting wire, will yield electric oscillations in the form of plane waves, oriented at right angles to the axis of a bar of steel under magnetization in a solenoid. Hence these electric oscillations or plane waves due to the current, will force the atoms of the steel bar to tilt around, so as to make their vibrations conform to those due to the current in the solenoid; and when the magnetized steel bar is cooled suddenly, by plunging into water or oil, the result will be a permanent electromagnet of the type first made by Ampère about 1822. Thus the atoms of the magnet are set in planes at right angles to the axis through the poles, and all vibrate in concert.

4. Accordingly, we find a direct relation between magnetism and electrodynamic action, and as dynamic electricity is found by experiment to travel on wires with nearly the velocity of light, it is impossible to doubt that the waves emitted by natural and artificial magnets travel also with the same speed. In fact it follows that before magnetization the steel emitted waves of the same type as after action by the electric current, yet prior to the action of the current through the solenoid the orientation of the atoms was a haphazard one. The act of magnetization consists in forcing the equators of the atoms into parallel planes, so that they may vibrate in concert, which explains the great strength of magnetism in comparison with the feeble force of gravitation.

5. This brings us directly to the problem of cosmical magnetism and of gravitation. In steel magnets of good quality all or nearly all the atoms are forced into parallelism by the agitations of the current through the solenoid. Now the heavenly bodies contain some iron, nickel and other magnetic elements, but much of their matter, of a stony or glassy character, exhibits magnetic properties in a very feeble degree. Moreover, the planets are subjected to no very strong solenoidal action other than that due to the sun's magnetic field. It is not remarkable therefore that they are only partially magnetic. Their magnetism may have been acquired or considerably modified by the secular action of the sun since the formation of the solar system.

6. Accordingly, *Faraday's* great discovery that under current action all bodies are more or less magnetic, while

18

¹) The fact that waves will explain the attraction and repulsion of magnets, under the observed laws of magnetism, must be regarded as a very notable triumph. As no other explanation is known, the simple cause thus assigned must be held to be the true cause.

nickel, iron, steel, etc., are the most perfectly adaptable to the process of magnetization, would lead us to expect cosmical magnetism to be a very general phenomenon, but always somewhat feebly developed, in accordance with actual observation. Herein lies the connection with universal gravitation, which *Maxwell* found so difficult to conceive. When the equators of the atoms are not lined up in parallel planes, so as to oscillate in concert, they naturally are tilted haphazard, and do not lead to poles, - as in a magnet, which Airy describes as exhibiting a duality of powers, - but to the central action called gravitation. As the heavenly bodies are partially magnetic, this means that they have feeble magnetic poles, in addition to the powerful central gravitational action, and thus two independent wave fields are developed. about them, one due to the atoms lined up and acting in concert, called magnetism, and the other to gravitation (cf. Fig. 14, Plate 6).

267

7. It is impossible to hold any other view of the interlocked magnetic and gravitational fields observed about a planet. In the case of the earth Gauss found that about 1:1380th part of the matter acts as if it were magnetized (Allgemeine Theorie des Erdmagnetismus, 1838, p. 46), while the remainder, 1379:1380ths, should give the central action of gravitation. By the observations taken at Mt. Wilson Solar Observatory the sun's magnetic field appears to be some 80 times stronger than that of our earth. Whether this is due to the heat of the sun, and the resulting greater conductivity of wave action through its matter, so that the action on the planets produce a larger secular effect upon their atoms, or to some unknown cause, cannot at present be determined. The strength of the sun's magnetic field has no doubt added to the cosmical magnetism of the planets, though the changes are excessively slow.

8. It is more than probable that the secular changes in the earth's magnetism should be ascribed to the working of the sun's strong magnetic field, which is not equally powerful at all times, but varies appreciably with the sunspot cycle, the relative position, and seasonal tilt of the earth's axis, etc. As the magnetic storms are definitely shown to be related to the cycles of the sunspots, as is also the aurora, and the earth currents, these related phenomena deserve a more detailed investigation than they have yet received. The periodic phenomena all appear to depend on the sunspots, with their magnetic fields uncovered, and thus are more active with the maximum of the spot cycle.

9. For many years a great difficulty existed in accounting for the semidiurnal tide in the magnetism of the earth, depending on the action of the moon. This was first detected by *Kreil* at Prague in 1841, but independently discovered by *John Allan Broun*, 1845. A very accurate analysis of the observations at Dublin was published by Dr. *Lloyd* about 1858, which showed that the magnetism of the earth had the same semidiurnal period as the tides of our seas. Accordingly *Airy* declared that there is »a true lunar tide of magnetism, occurring twice in the lunar day, and showing magnetic attraction backward and forward in the line from the Red Sea to Hudson's Bay« (Treatise on Magnetism, 1870, p. 206).

10. This semidiurnal tide in the earth's magnetism depending on the moon's action is shown to be coperiodic with that of gravitation (cf. Electrod. Wave-Theory of Phys. Forc., 1917, pp. 50-53). And on examining Lloyd's analysis in the Philosophical Magazine for March, 1858, I have shown it to be vitiated by a subtile error, in that he retained the hour angle θ instead of the 2θ which occurs in the expressions for the tide-generating potential. Apparently he did not suspect that there could be such a thing as a magnetic tide, and thus his mode of analysis simply begs the question, and the resulting error is repeating in many later works. For example, in his Mathematical Theory of Electricity and Magnetism, 1916, p. 402, Jeans asserts that the daily variation of the earth's magnetism is not such as the heavenly bodies could produce - thus repeating Lloyd's error of 1858. Of course this is not true, for a careful examination of the problem shows that the larger part of the terrestrial magnetism is constant, as depending on the arrangement of $1/1380^{\text{th}}$ of the atoms of the globe, whilst the variable effects are superposed by the actions of the sun and moon. Thus all the known periods of the terrestrial magnetism are shown to follow from those of the heavenly bodies.

11. Now it is found that *Newton*'s law will explain all gravitational phenomena, but not the phenomena of the magnetic tide depending on such a body as the moon. For as *Airy* points out, this implies attraction backward and forward, in the line from the Red Sea to Hudson's Bay, which is along the line of force of the earth's magnetism. The intensity of the earth's magnetism thus varies in semidiurnal/ periods, just as the direction of the vertical varies under the gravitational attraction of the moon, and in similar periods.

12. Accordingly, the attraction to the earth's magnetic pole is subjected to a true tide in the earth's magnetism, and can only be explained by Weber's law, which takes account of induction under the changing distance of the partially magnetized matter of the globe, the lines of force towards the magnetic pole being subjected to the same ebb and flow as the central forces called gravitation. This connects magnetism with gravitation, by direct observation: for the earth has feeble polarity, with magnetic lines of force directed to the magnetic poles, as well as the much more powerful central lines of force producing the phenomenon of gravitation. Now the phenomenon of local gravitational change, due to the moon's action, is indicated by the oscillations of the sea, while that due to the moon's magnetic action is felt only by magnetic instruments which show the variation of the northward component of the earth's magnetism.

13. When the tide-generating potential is developed in hour angle λ_0 (westward), longitude l and latitude λ of the place of observation, declination of the moon δ , the components of the gravitational attraction are shown to be:

	$V = (\frac{3}{2}ma^2/r^3) \left\{ \frac{1}{2}\cos^2\lambda\cos^2\delta\cos 2(h_0-l) + \sin 2\lambda\sin\delta\cos\delta\cos(h_0-l) + \frac{3}{2}(\frac{1}{3}-\sin^2\lambda) \right\}$	(38)
Westw.	$\operatorname{Comp.} = \frac{\partial V}{a} \cos \lambda dl = \frac{3}{2} (m/M) (a/r)^3 \left\{ \cos \lambda \cos^2 \delta \sin 2(h_0 - l) + \sin \lambda \sin 2\delta \sin(h_0 - l) \right\}$	(39)
Southw	$. \operatorname{Comp.} = -\partial V/a \mathrm{d}\lambda = {}^{3}/_{4} (m/M) (a/r)^{3} \{ \sin 2\lambda \cos^{2} \delta \cos 2(h_{0}-l) - 2\cos 2\lambda \sin 2\delta \cos(h_{0}-l) + \sin 2\lambda (1-3\sin^{2}\delta) \}.$	(40)

It will be noticed that the westward component is made up of two periodic terms, one going through its variations twice and the other once a day, while the southward component undergoes like periodic oscillations, as illustrated by the following figure, from Sir George Darwin's Tides and Kindred Phenomena of the Solar System, 1899.



Fig. 15. Darwin's Diagram of the semidiurnal movements of a pendulum.

14. As Newton's law will explain the periodic variations of gravitation depending on the heavenly bodies but not the observed magnetic tides due to these bodies, it follows that Newton's law is only a first approximation, though accurate enough for two centuries of astronomical science. The universe is governed by electrodynamic laws, and Weber's fundamental law of 1846 is the chief law of nature. This is another reason why we must use Weber's law in calculating the motion of Mercury's perihelion, which therefore should progress $\delta \varpi = +14.51$ per century, instead of the arbitrary and accidental amount of 43", as inferred by Einstein, without first taking account of the time of progagation of gravitation. By connecting magnetism with electrodynamic action and with gravitation we know all these actions take place with the velocity of light.

15. Since magnetism is thus connected with electrodynamic action, and shown to travel with the velocity of light, and on the other hand directly connected with gravitation through the semidiurnal magnetic tide depending on the moon, we perceive that gravitation must be propagated with the velocity of light, and therefore all these forces necessarily depend on waves.

It is not wonderful therefore that in the earth's magnetism the main dependence is on the orientation of the atoms of the globe, at the same time we have minor terms depending on the following periods:

(1) A semidiurnal magnetic tide depending on the sun; also a smaller but very definite semidiurnal magnetic tide depending on the moon, discovered by Kreil at Prague in 1841, but independently detected by John Allan Broun in 1845.

(b) A solar diurnal variation of the magnetic declination, changing slowly through the year.

(2) A fluctuation in 25.93 days depending on the sun's mean rotation period.

(3) A fluctuation in 29.53 days, which is the synodic month.

(4) A yearly period depending on the motion of the sun.

(5) An 11-year fluctuation depending on the sun spot cycle.

(6) A period of 18.6 years — which is the cycle of the revolution of the moon's nodes.

16. This result confirms John Allan Broun's discovery that the diurnal variation depending on the moon follows very accurately the law of the inverse cube of the moon's distance. Broun remarks that »the ratio of the moon's mean distance from the earth in the half orbit about apogee is to that in the half orbit about perigee as 1.07 to 1; as the cube of 1.07 is 1.23 nearly, we see that the mean range of the curves for the two distances are in the ratio of the inverse cubes of the moon's distance from the earth, as in the theory of the tides.« (Stewart's Article Meteorology, Encyc. Brit. 9th ed., p. 179).

As Broun had observed the lunar magnetic effects to be as 1 to 1.24, and Sabine had found similar results, he naturally regarded the verification of this tidal law in the lunar semidiurnal variation as very important. With the above correction of Lloyd's error of analysis, this result of Broun shows conclusively that all the diurnal effects observed can be explained by the magnetism of the sun and moon.

It is not strange therefore that in his celebrated article on Terrestrial Magnetism, § 139, Balfour Stewart recognized that as the moon's magnetic influence follows as nearly as possible Broun's law of the inverse cube of the distance from the earth, it is impossible to refrain from associating this magnetic influence either directly or indirectly with something having the type of tidal action. Stewart points out that Airy found a similar semidiurnal inequality depending on the sun in the Greenwich records, and A. Adams found corresponding »Earth Currents« to be induced in the crust of the globe at the corresponding hours.

8. Plane Waves propagated from the Equators of the Atoms of a Magnet fulfill Poisson's Equation of Wave Motion $\partial^2 {\cal O}/\bar{\partial}t^2 = a^2 \,
abla^2 \, {\cal O}$, and yield the Law of Amplitude required to produce the Forces observed in Magnetism.

The oscillatory motion in a plane wave propagated along the x-axis may be defined by the well known equation:

$$\xi = a \cos(2\pi x/\lambda + p) \tag{41}$$

where the zero of the angle $(2\pi x/\lambda + p)$ is reckoned from the parallel to the y-axis.

But in plane wave motion the particles not only undergo a periodic side displacement like that exhibited in a curve of sines, but also a longitudinal motion, supplementing the above, which may be expressed in the form:

$$\eta = \beta \sin\left(2\pi x/\lambda + \beta\right). \tag{42}$$

In general the particles thus undergo elliptical motion defined by the equation:

$$\xi^2 / \alpha^2 + \eta^2 / \beta^2 = 1. \tag{43}$$

This may become circular motion for surface waves in still water, as illustrated graphically in the foregoing figure 1, Plate 4, from Airy's celebrated Treatise on Tides and Waves, Encyc. Metrop., 1845.

In the electrodynamic wave-theory of magnetism it is held that when the magnetism is imperfect the atoms may

18*

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. 271

5079

272

have their equatorial planes tilted at any angles in respect to the coordinate axes: The plane waves above outlined would apply to the midplane of a perfect magnet, but it is necessary to consider the most general case.

Now the equation of a plane passing through the origin
of coordinates is
$$lx+my+nz = 0$$
. (44)

If the wave be flat in this plane it will travel with the velocity a and at the end of the time t, will have spread to a distance at. Accordingly, the argument

$$s = lx + my + nz - at \tag{45}$$

will represent the motion of the disturbance with velocity a. But s is the equation of a plane whose normal has the direction cosines d, m, n, and whose distance from the origin is at+s. It is inferred that the plane is therefore traveling in the direction of its normal with the velocity a; but it is equally logical to say that a wave originating in the plane is traveling in all directions with this velocity, and at the end of time t, the sphere surface $(at)^2 = x^2 + y^2 + z^2$ would be this distance (at+s) from the original centre of disturbance. Thus instead of considering the plane to travel, we may consider the wave to travel and carry a plane s+at = lx+my+nz, with it parallel to the plane in (45). The directions cosines of the plane fulfill the law

$$l^2 + m^2 + n^2 = 1. (46)$$

Now with the value of s in (45), we may take the equation $\boldsymbol{\Phi} = \boldsymbol{\Phi} (lx + my + nz - at)$ (47)

and derive the following results by simple differentiation :

$$\frac{\partial \Phi}{\partial x} = l \Phi'(s) \qquad \frac{\partial \Phi}{\partial y} = m \Phi'(s) \qquad (47 \text{ a})$$

$$\frac{\partial \Phi}{\partial z} = n \Phi'(s) \qquad \frac{\partial \Phi}{\partial t} = -a \Phi'(s) \qquad (47 \text{ a})$$

$$\frac{\partial^2 \Phi}{\partial x^2} = l^2 \Phi''(s) \qquad \frac{\partial^2 \Phi}{\partial y^2} = m^2 \Phi''(s) \qquad (47 \text{ b})$$

$$\frac{\partial^2 \Phi}{\partial z^2} = n^2 \Phi''(s) \qquad \frac{\partial^2 \Phi}{\partial t^2} = a^2 \Phi''(s) \qquad (47 \text{ b})$$

Therefore, by addition of these terms we find: $\partial^2 \Phi / \partial x^2 + \partial^2 \Phi / \partial y^2 + \partial^2 \Phi / \partial z^2 =$

 $\partial^2 \Phi / \partial t^2 =$

$$= \nabla^2 \boldsymbol{\Phi} = (l^2 + m^2 + n^2) \, \boldsymbol{\Phi}^*(s) = \boldsymbol{\Phi}^*(s) \,. \tag{47 c}$$

And hence by the last of the above second differen

tials we obtain

In

$$a^2 \nabla^2 \boldsymbol{\Phi}$$
 (48)

which is *Poisson*'s celebrated equation of wave motion. (Sur l'intégration de quelques équations linéaires aux différences partielles, et particulièrement de l'équation générale du mouvement des fluides élastiques, « Mémoires de l'Académie Royale des Sciences, Tome III, Juillet 19, 1819.)

If u represents the displacement of the particles above considered, in the direction of the x-axis, we may derive a less general but more obvious form of *Poisson*'s equation, which was applied by *Euler* to the theory of sound.

Put
$$u = \sin(nt - kx)$$
 $n = 2\pi a/\lambda$ $k = 2\pi/\lambda$. (49)

And then we may derive immediately:

$$\partial u/\partial t = n\cos(nt-kx)$$
 $\partial u/\partial x = -k\cos(nt-kx)$ (50)

$$\frac{\partial^2 u/\partial t^2}{\partial t^2} = -n^2 u \qquad \frac{\partial^2 u/\partial x^2}{\partial t^2} = +k^2 u \qquad (51)$$

whence
$$\frac{\partial^2 u/\partial t^2}{\partial t^2} = -(n^2/k^2) \frac{\partial^2 u}{\partial t^2} \qquad (52)$$

ence
$$\partial^2 u/\partial t^2 = -(n^2/k^2) \partial^2 u/\partial x^2$$
. (52)

$$\partial^2 \boldsymbol{\varrho} / \partial t^2 = a^2 \nabla^2 \boldsymbol{\varrho} \tag{48}$$

we may multiply both sides of the equation by the element

of volume dx = dx dy dz, and integrate throughout the volume bounded by a closed surface S

$$\int \int (\partial^2 \Phi / \partial t^2) dt = a^2 \int \int (\partial^2 \Phi / \partial x^2 + \partial^2 \Phi / \partial y^2 + \partial^2 \Phi / \partial z^2) dt =$$

= $-a^2 \int \int (\partial \Phi / \partial n) dS$. (53)

If the surface S is a sphere of radius r with its centre at the point P, we may proceed as follows:

 $-\iint (\partial \Phi/\partial n) dS = \iint (\partial \Phi/\partial r) r^2 d\omega = r^2 (\partial/\partial r) \iint \Phi_r d\omega \quad (54)$ where Φ_r denotes the value of Φ at points on the surface of the sphere of radius r, about the centre P.

When we introduce polar coordinates into the first member of (53) we obtain:

$$(\partial^2/\partial t^2) \iint \mathcal{O} \,\mathrm{d} r = (\partial^2/\partial t^2) \iint \mathrm{d} \omega \left(\int_{0}^{\infty} \mathcal{O}_r \, r^2 \,\mathrm{d} r \right). \quad (55)$$

On differentiating the right member relative to r, we get from the original equation (48) by means of (53):

$$a^{2}(\partial^{2}/\partial r^{2})\int \int \mathcal{O}_{r} \,\mathrm{d}\omega = a^{2}(\partial/\partial r) \left(r^{2}(\partial/\partial r)\int \int \mathcal{O}_{r} \,\mathrm{d}\omega\right). \quad (56)$$

Yet the surface integral $\iint \mathcal{O}_r \, d\omega$ which appears in both members of (56) is 4π times the mean value of the function \mathcal{O}_r on the surface of a sphere of radius r. Suppose this mean value be denoted by \mathcal{O}_r ; then since $\iint \mathcal{O}_r \, d\omega$ $= 4\pi \, \mathcal{O}_r$ we have

$$r^{2}(\partial^{2}\overline{\boldsymbol{\Phi}}_{r}/\partial t^{2}) = a^{2}(\partial/\partial r)(r^{2} \cdot \partial \overline{\boldsymbol{\Phi}}_{r}/\partial r).$$
(57)

On differentiating and dividing by r, we may put this in the form:

$$\partial^2 (r \boldsymbol{\varphi}_r) / \partial t^2 = a^2 \partial^2 (r \boldsymbol{\varphi}_r) / \partial r^2 .$$
 (58)

We may now introduce two new variables u und v, as follows: u = at + r v = at - r. (59)



Fig. 16. Illustrating the Wave Theory of *Poisson*, as in reflected Light.

Then if, for brevity, we put $r\Phi_r = \psi$ we have for the derivatives:

$$\partial \psi / \partial t = \partial \psi / \partial u \, \partial u / \partial t + \partial \psi / \partial v \, \partial v / \partial t = a \left(\partial \psi / \partial u + \partial \psi / \partial v \right) \tag{60}$$

$$\frac{\partial \psi}{\partial r} = \frac{\partial \psi}{\partial u} \frac{\partial u}{\partial v} \frac{\partial v}{\partial t} + \frac{\partial \psi}{\partial v} \frac{\partial v}{\partial t} \frac{\partial v}{\partial t} \frac{\partial v}{\partial t} \frac{\partial \psi}{\partial v}$$
(61)

$$\partial^2 \psi / \partial r^2 = \partial^2 \psi / \partial u^2 - 2 \partial^2 \psi / \partial u \partial v + \partial^2 \psi / \partial v^2$$
(62)
$$\partial^2 \psi / \partial r^2 = \partial^2 \psi / \partial u^2 - 2 \partial^2 \psi / \partial u \partial v + \partial^2 \psi / \partial v^2$$
(63)

By equation (58) we have through the addition of the terms of the right of (62) and 63

$$\partial^2 \psi / \partial_u \partial_v = o . \tag{64}$$

$$\psi = f_1(u) + f_2(v) \tag{65}$$

where f_1 and f_2 are perfectly arbitrary functions of their arguments.

If r = o, the left member vanishes:

$$o = f_1(at) + f_2(at)$$
. (66)

And as this holds for all values of t, it follows that the functions f_1 and f_2 are not independent, but one is the negative of the other, namely

$$f_1(at) = -f_2(at) \tag{67}$$

by (66), whatever be the value of the argument *at.* Accordingly we now put

$$f_1 = f$$
 $f_2 = -f$ (68)
and then we have

$$r \mathcal{O}_r = f(at+r) - f(at-r). \tag{69}$$

When we differentiate relative to r, we get:

$$\boldsymbol{\Phi}_r + r \,\partial \,\overline{\boldsymbol{\Phi}}_r / \partial r = f'(at+r) + f'(at-r) \,. \tag{70}$$

And on putting
$$r \Longrightarrow 0$$
, this leads to
 $\Phi_r = 2 f'(at)$ (7)

$$= 2f'(at) \qquad (71)$$

$$= \Phi_P$$
, when $r = 0$. (72)

On differentiating (69) relative to r and t, we get successively:

$$\begin{pmatrix} \partial/\partial r \end{pmatrix} (r \mathcal{O}_r) = f'(at+r) + f'(at-r)$$

$$\begin{pmatrix} \partial/\partial r \end{pmatrix} = (q'(at+r) + f'(at-r))$$

$$\begin{pmatrix} \partial/\partial r \end{pmatrix} = (q'(at+r) + f'(at-r))$$

$$(7.3)$$

$$(0/01)(rO_r) = a \{f'(at+r) - f'(at-r)\}.$$
(74)

Accordingly, by addition, we obtain

$$\frac{\partial (r\boldsymbol{\Phi}_r)}{\partial t} = \frac{1}{2} f'(at+r) \qquad (75)$$

$$\left[\partial(r\overline{\Phi}_r)/\partial r + (1/a) \cdot \partial(r\overline{\Phi}_r)/\partial t\right]_{t=0} = 2f'(r). \quad (76)$$

When we use the original value of $\mathcal{O}_r = (1/4\pi) \iint \mathcal{O}_r d\omega$ it thus appears that we obtain:

$$z f'(\mathbf{r}) = \left[(\partial/\partial r) \left\{ r/_4 \pi \cdot \iint \mathcal{O}_r \, \mathrm{d}\omega \right\} + (\mathbf{1}/a) \left\{ r/_4 \pi \cdot \iint (\partial \mathcal{O}_r/\partial t) \, \mathrm{d}\omega \right\} \right]_{t=0} \dots (77)$$

Now suppose that at the initial instant, t = 0, the values of $\boldsymbol{\Phi}$ and its time derivative $\partial \boldsymbol{\Phi}/\partial t$ are given in functions of the coordinates of a point in space:

$$\begin{bmatrix} \boldsymbol{\sigma} \end{bmatrix}_{t=0} = F(x, y, z) \qquad \begin{bmatrix} \partial \boldsymbol{\sigma} / \partial t \end{bmatrix}_{t=0} = f(x, y, z) . \tag{78}$$

Then by (77) we have

$$pf'(r) = (\partial/\partial r) \{ (r/4\pi) \iint F_r d\omega \} + (r/4\pi a) \iint f_r d\omega .$$
(79)

But when r = at, we have by $(72) 2f'(at) = \mathcal{O}_P$ at the centre, and thus finally we obtain:

$$\mathcal{D}_P = (1/4\pi) \left[(\partial/\partial at) \left(at \iint F_{at} \, \mathrm{d}\omega + t \iint f_{at} \, \mathrm{d}\omega \right) \right] \quad (8\circ)$$

which is *Poisson*'s general solution of the equation (48), for wave motion.

From this solution, it follows that the value of \mathcal{O} may be computed for every point P if we know the mean value of $\partial \mathcal{O}/\partial t$ at a time earlier by the interval at, for all points on the surface of a sphere of radius at about P, as well as the rate of the variation of the mean value of \mathcal{O} as the radius of the sphere changes. This is the typical condition specified in wave motion. Suppose, for example, that initially $\mathbf{\Phi}$ and $\partial \mathbf{\Phi}/\partial t$ are both zero, except for a certain region R, whose nearest point is at a distance r_1 from P, while the remotest point lies at a distance r_2 .

Then so long as $t_1 < r_1/a$ the mean value of $\boldsymbol{\mathcal{O}}$ on the sphere of radius *at*, is zero, because the waves from the nearest point have not yet reached *P*. After an interval $t_2 > r_2/a$ there will be no more waves and $\partial \boldsymbol{\mathcal{O}}/\partial t$ will again be zero at *P*.



Fig. 17. Illustrating Poisson's Theory of Waves.

Accordingly disturbances will prevail only in the time $r_1/a < t < r_2/a$ and the power of disturbance, or velocity potential $\boldsymbol{\Omega}$, is propagated in all directions with the velocity \boldsymbol{a} . By using polar coordinates *Poisson* has obtained a more direct solution, because $\boldsymbol{\Omega}$ then becomes independent of the angular coordinates. Equation (48) becomes:

$$\partial^2 \Phi / \partial t^2 = a^2 \left(\partial^2 \Phi / \partial r^2 + \frac{2}{r} \cdot \partial \Phi / \partial r \right)$$
(81)

$$C^{2}(r\boldsymbol{\Phi})/\partial t^{2} = a^{2} \cdot \partial^{2}(r\boldsymbol{\Phi})/\partial r^{2}.$$
(82)

A solution of this equation is

$$r \Psi = f(at - r) \tag{83}$$

(84)

which yields: $\Phi = f(at-r)/r$.

Thus for all points of space, and all times for which at-r has the same particular value we have the same value $r \mathcal{D}$, as the particular value of \mathcal{D} travels outward with the velocity a.

It should be noted that the value of $\boldsymbol{\Phi}$ is inversely proportional to the distance r traversed. And although the analytical form (84) makes $\boldsymbol{\Phi}$ infinite when r = 0, yet in reality this condition does not occur, because physical limitations imposed by the structure of matter excludes the value r = 0, and $\boldsymbol{\Phi}$ is always finite.

Following the method of *Poisson*, Lord *Rayleigh* and other writers on sound are accustomed to take the velocity potential: $\mathcal{O} = \Omega(x, t) = A \cos[2\pi/\lambda \cdot (x-at)]$ (85)

$$\int \mathrm{d}\boldsymbol{\varPhi} = \int (u\,\mathrm{d}x + v\,\mathrm{d}y + w\,\mathrm{d}z) = \circ. \tag{86}$$

But it is a fact of great importance, which will be discussed at length in the fourth paper on the new theory. of the aether, that *Poisson* never concurred in the theory of transverse vibrations for light. *Poisson*'s dissent from *Fresnel*'s assumptions was based on the mathematical theory of waves

274

in an elastic fluid. Besides the celebrated memoir of 1819, already cited, *Poisson* treated the matter in another able paper, presented to the Academy of Sciences, March 24, 1823, Mémoire sur la Propagation du Mouvement dans les Fluides Élastiques, finally published under the title: Sur le Mouvement de Deux Fluides Élastiques Superposés (Mémoires de l'Institut, Tome X) in which this celebrated geometer confirmed the conclusions previously reached, namely, that whatever be the direction of the original disturbance, the vibratory motions of the particles finally become normal to the wave front.

When *Fresnel* and his followers objected to *Poisson*'s processes as founded on mathematical abstraction, though deduced from the assumption of contiguous elements, the celebrated geometer returned to the subject in a series of later memoirs, as follows:

1. Mémoire sur l'Équilibre et le Mouvement des Corps Élastiques, Avril 14, 1828. Mémoires de l'Institut, Tome VIII, pp. 357-627.

2. Mémoire sur l'Équilibre des Fluides, Nov. 24, 1828. Tome IX, 1-88.

3. Mémoire sur la Progagation du Mouvement dans les Milieux Élastiques, Oct. 11, 1830, Tome X, pp. 549-605.

4. Mémoire sur l'Équilibre et le Mouvement des Corps Crystallisés, Tome XVIII, pp. 3-152.

In all of these memoirs the earlier conclusions of 1823 are confirmed and emphasized, that whatever the primitive disturbance may have been, at a great distance the motion of the molecules finally becomes perpendicular to the wave surface. This is deduced in the memoir of 1830, pp. 570-571, by an argument which cannot well be evaded, and announced in these words:

*11 en résulte donc qu'à mesure que l'on s'éloigne du centre de l'ébranlement primitif, la vitesse du point M approche de plus en plus d'être dirigée suivant son rayon vecteur r, et qu'à une très-grande distance, où l'onde mobile peut être regardée comme sensiblement plane dans une grande étendue, on doit, en même temps, considérer le mouvement des molécules qui la composent, comme perpendiculaire à sa surface, quel qu'ait été l'ébranlement primitif.«

On pages 574-5 of the same memoir of 1830, Poisson deduces the formula $\boldsymbol{\varphi} = 1/r \cdot \psi(r-at,\mu,\lambda)$ and passes to the case $at > r+\varepsilon$,

$$\boldsymbol{\Phi} = \mathbf{I}/r \cdot \boldsymbol{\Psi}(\boldsymbol{\mu}, \boldsymbol{\lambda}) \tag{87}$$

where we should have

$$s = \frac{1}{a^2} \cdot \frac{\partial \Phi}{\partial t} = 0. \tag{88}$$

»Il résulte de cette discussion que dans le cas où la formule udx + vdy + wdz ne satisfait pas à la condition d'intégrabilité, les lois de la propagation du mouvement, à une grande distance de l'ébranlement, ne diffèrent pas essentiellement de celles qui ont lieu, lorsque cette condition est remplie, ainsi que je l'avais supposé dans mon ancien mémoire sur la théorie du son.*

>Le mouvement imprimé arbitrairement à une portion limitée d'un fluide homogène se propage toujours en ondes sphériques autour du lieu de cet ébranlement. A une grande distance, ces ondes sont sensiblement planes dans chaque partie, d'une petite étendue par rapport à leur surface entière; et alors, la vitesse propre des molécules est, dans tous les cas, sensiblement normale à leur plan tangent. Mais on peut aussi considérer directement la propagation du mouvement par des ondes infinies et planes dans toute leur étendue. Or, on va voir que la vitesse des molécules sera encore perpendiculaire à ces sortes d'ondes en mouvement.«

Accordingly, in his most mature memoirs, after researches on the theory of waves extending over 25 years, *Poisson* confirmed the conclusion that in elastic media, of the type of a gas, the motion of the molecules is always like that of sound. This result will be found to have great significance when we come to deal with a fundamental error in the wave-theory of light, in the fourth paper on the New Theory of the Aether.

9. Rejection of *Thomson*'s Corpuscular Theory of an Electric Current, because of the Small Velocity thus attainable: Theory of a Magneton also rejected because of its Inconsistency with Electrodynamic Action: observed High Velocity of Electron under Charge explained by Acceleration due to Aether Waves.

(i) *Thomson* and other electronists hold that an electric current is due to the motion of electrons.

In his Corpuscular Theory of Matter, 1907, Sir \mathcal{F} . \mathcal{F} . Thomson put forth the view that an electric current consists in the motion of the electrons. »On the corpuscular theory of electric conduction through metals the electric current is carried by the drifting of negatively electrified corpuscles against the current.«...»The corpuscles we consider are thus those whose freedom is of long duration. On this view the drift of the corpuscles which forms the current is brought about by the direct action of the electric field on the free corpuscles.« (p. 49.)

»As, however, the mass of a corpuscle is only about 1/1700 of that of an atom of hydrogen, and therefore only about 1/3400 of that of a molecule of hydrogen, the mean value of the square of the velocity of a corpuscle must be 3400 times that of the same quantity for the molecule of hydrogen at the same temperature. Thus the average velocity of the corpuscle must be about 58 times that of a molecule of hydrogen at the temperature of the metal in which the molecules are situated¹). At o° C. the mean velocity of the hydrogen molecule is about 1.7 · 10⁵ cm/sec, hence the average velocity of the corpuscles in a metal at this temperature is about 10⁷ cm/sec, or approximately 60 miles per sec. Though these corpuscles are charged, yet since as many are moving in one direction as in the opposite, there will be on the average no flow of electricity in the metal. Although the change produced in the velocity of the corpuscles by this force is, in general, very small compared with the average velocity of translation of the corpuscles, yet it is in the same direction for all of them, and produces a kind of wind causing the corpuscles to flow in the opposite direction to the electric force (since

¹) The spacing-out of the concluding sentence is mine - not in the original.

the charge on the corpuscle is negative), the velocity of the wind being the velocity imparted to the corpuscles by the electric force 1). «

Thomson's calculations of the velocity of 60 miles per second are based upon the formulae cited in Section 12, below, which I had made before I found the above statement. Thomson does not dwell on the inadequacy of this velocity of 60 miles per second to explain the transmission of electric signals on wires, which have a velocity only slightly less than that of light.

On page 68, however, he points out that in a Röntgenray-bulb giving out hard rays the velocity of the corpuscles in air may be about 10^{10} cm/sec, or 10^3 times the velocity of those in the metals.

It is held in the theory of ionization of gases by X-rays, that the positive and negative parts of the atoms are separated. "The positive ions are attracted to the negative electrode and the negative ions to the positive electrode, and the movement of these electric charges constitutes a current," says Duffs, Text Book of Physics, (ed. 1916, p. 498). This is used at the University of California, and this discussion was written by Prof. R. K. McClung of the University of Manitoba, who is a Doctor of Science of the University of Cambridge, England, and thus speaks with authority.

Likewise, *Crowther* says on p. 139 of his Molecular Physics: »We have now come to connect electricity with electrons, and hence an electric current is a flow of electrons from a place of high to a place of low potential. We may regard a conductor, then, as a substance containing electrons which are free to move under the action of an electric field, while in non-conductors the electrons are fixed and unable to follow the impulse of the field.« Again, (p. 140) Crowther adds: *These electrons, if no electric force be acting, will be moving in all directions, so that if we take any cross section of the metal the number of electrons crossing it in one direction will be the same as the number crossing it in the opposite direction, and so the total transference of electricity across the section will be zero.«

*If, however, we apply an electric field to the body there will be a force on each electron urging it in the direction of the field. Thus in addition to the irregular motion due to the heat energy of the body, there will be a steady drift of the electrons as a whole in the direction of the electric force.«

This discussion, like that of *Thomson*, admits that an electric field is necessary so set the electrons in motion, but the nature of the electric field itself is not explained, beyond the general phrase that difference of potential is involved. This is almost as unsatisfactory as the failure of the electronists to account for the high velocity of electric signals on wires.

(ii) Experimental tests of the velocity of electric waves on wires.

The problem of the velocity of the electric waves along wires has been much discussed, and formulas given in such works as *Cohen*'s »Calculation of Alternating Current Problems«, whilst the propagation of waves in metals has been treated theoretically by *Drude*, Lehrbuch der Optik, 2, Chap. IV, and by other authorities.

But when we come to deal with concrete measurements of actual velocities, such measurements do not seem to be plentiful: yet we note a few values in the following table.

Observed V	Authority .	Remarks		
463133Km. 310475	Wheatstone, Phil. Trans., 1834 Kirchhoff, Ganot's Physics § 706	Duration of Electric Spark Method.	nt Flootrio	C
179890 99938	Fizeau and Gounelle	Signals on Copper Wire. Signals on Iron Wire.	In Liectric	Currents.
230500) 256600 (Siemens and Frölich, Poggend. Ann. Bd. CL VII.	Observations on Telegraph Wires of Iron, 23372 Kr	ns. long.	11
241800	» » »	Observations on Telegraph Wires 7352 Kms. long.	 	

These measurements, which are of very unequal value, give a mean of 254618 Kms., which would not seem improbable, in view of the fact that the *Siemens-Frölich* series, apparently by far the best, give a mean 242966 Kms. for electric waves on iron wires. As the electric disturbances should travel with the velocity of light, 300000 Kms., except for the resistance of the wires, it would thus appear that the velocity is reduced about $1/_5$ th or $1/_6$ th of the whole. The resistance causes the disturbance to travel slower in the wire and thus the waves around the wire envelope it, and necessarily follow it as a conductor.

A more modern investigation of the velocity of electric waves on wires was made by Prof. John Trowbridge and

W. Duane, and published in the Philosophical Magazine for 1895, vol. 40, p. 211. They used a pair of parallel short wires, 58.6 metres long, but determined the duration of the electric oscillation in the wire very accurately by photography of the sparks in a rapidly rotating mirror. The wave length was 56.77 m, and the duration of the spark was found to be $1.8907 \cdot 10^{-7}$ second. The mean value of the velocity of the wave on the wire came out $V = 3.003 \cdot 10^{10}$ cm/sec., which slightly exceeds the adopted velocity of light.

But a much more thorough direct comparison of the velocity of electric waves on wires with light itself was quite recently undertaken by the French physicist *C. Gutton*, Journal de Physique, 1912 (5), vol. 2, p. 41. This experiment

¹) I quote at length from the chief authorities, in order to feel sure that the views of the electronists are correctly cited. As I consider the electron theory to be greatly overrated, this precaution is deemed necessary, in justice to their researches, which I might find difficulty in accurately condensing into any briefer statements.

277

was arranged with great ingenuity, and the apparatus so designed as to show a small difference in the two velocities, if such difference existed. The first observations showed that the two velocities were nearly identical, yet not rigorously the same.

Under the delicate and dependable means of adjustment used *Gutton* discovered that the velocity of the electric wave on the wire was a little less than that of light. And he found that the difference thus very accurately determined amounted to about one-half of one percent. Accordingly for the velocity of electric waves on wires *Gutton*'s values would be:

> Electric waves V = 298500 Kms. Light $V \doteq 300000$ Kms.

This retardation of the electric waves by wires is small, but fortunately the experiment of *Gutton* was so well designed that no doubt can attach to the reality of the difference. We must therefore admit that the electric waves on wires are slightly retarded by the resistance in the wires. This has been probable on general principles, and indicated by the older experiments, and it now takes its place as an established fact of observation.

The result is similar to that reached in the first paper on the New Theory of the Aether, where we showed that wireless wawes travel more slowly through the solid mass of the earth, and the wave front is thus bent around the globe, — which explains the observed fact that the wireless wave travels around the earth. This propagation of the wireless wave around the globe had proved very mysterious, and no satisfactory explanation of it had been forthcoming.

As we have now definite proof of the retardation of electric waves by the resistance encountered within a metallic wire, we see that the wire is surrounded by an envelope of waves in the free aether tending to proceed with the velocity of light, yet held back by the resistance within the wire, and thus the advancing wave envelopes and is made to follow the wire. Is it not probable that we have here the true explanation of the nature of a conductor?

Of course a conductor must be metal, which has both the power of inductance and capacity, — otherwise the electric disturbances would not take the form of waves, thus expending the energy due to difference of potential. Yet, there must be another physical cause at work to make the disturbance follow the wire. It is this, that the wave in the free aether travels more rapidly than within the dense resisting wire, and owing to this resistance, the waves follow the wire, being bent towards it on all sides, as shown in the inner part of the Fig. 18, Plate 6.

The discharge spark of a Leyden jar is due to the oscillations of the invisible aether, rendering particles of air luminous by the agitation; and when this spark is photographed in a rapidly revolving mirror, the oscillations are shown as indicated on the axis of the wire to the left. We must therefore assume electric surges from one side of the wire to the other, just as in a Leyden jar. Moreover, as the aether is compressible, this compressibility contributes to the development of waves.

It is to be noted that the oscillations photographed in the mirror have their phases spread along in time, and therefore the disturbances are spread along in space, when we deal with a wire on which the disturbance travels, so that the oscillations diagrammed on the left are repeated throughout the wire.

The reflection of any element of the aether wave outside the wire is given double effect by the surge from the opposite surface of the wire, as shown in the diagram. And thus the wave rotations take the reversed directions shown above and below the wire. This is the wave field we investigate in *Oersted*'s experiment, and find to follow *Biot* and, *Savart*'s law, as already explained in Section 5.

Accordingly the delay in propagation through the wire causes a slight whirling of the aether particles against the wire, then a rebound, with rotations in the opposite direction — in waves which are propagated away as shown in the diagram of the wave field. In regard to such reflection from metallic surfaces, Prof. *Fleming* says: »This electrical radiation (waves of length approaching 4 cms.), penetrates easily through dielectric bodies. It is completely reflected from metallic surfaces, and is also more or less reflected from the surfaces of insulators« (p. 411).

(iii) Rejection of the theory of a magneton as contrary to electrodynamics.

We now pass to the discussion of the so-called magneton.

r. It appears that the existence of the so-called magneton is purely hypothetical. It was at first admitted, with some hesitation, as a possible corpuscle, in magnets, analogous to the electron in the problems of electricity. This idea seemed logical in terminology, and the name appeared in certain papers of the Philosophical Transactions of the Royal Society, and it has since come into more general use.

2. But the above described terminology apparently overlooks the fact that magnets are produced by the action of an electric current. If therefore electrons be active in a current, and the current generates a magnet, it is more natural to explain magnets by the effects of electrons, and to do away with the magneton as superfluous.

3. In the present author's work, however, waves are made the basis of the generation of a magnet out of steel by the lining-up action of an electric current. It is thus illogical to introduce fictitious corpuscles imagined to have rotatory properties, when simple waves in the aether suffice for all practical purposes.

4. In the Principia, Lib. III, 1686, *Newton* lays down as the first rule of philosophy: »We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.« »To this purpose the philosophers say that nature does nothing in vain, and more is in vain when less will serve; for nature is pleased with simplicity, and affects not the pomp of superfluous causes.«

5. Under the circumstances, there is no need for the hypothesis of a magneton, and thus we reject it because its use in inconsistent with electrodynamic phenomena as explained by the wave-theory.

(iv) Velocity of the electron made to approximate that of light by the action of electric waves.

In his later researches on the ratio of the charge to-

the mass of cathode ray particle, *Thomson* devised a method for exactly balancing the electric and magnetic forces, and was able to determine the ratio e/m, and get V from the ratio of the strength of the electric field X to the strength of the magnetic field H, both of which could be measured. In this way he found $V = 2.8 \cdot 10^9$ cms. per second, or about one-eleventh of the velocity of light.

This value was found to be not quite constant, but to vary somewhat with the potential in the tube, yet the value e/m was found to be $1.7 \cdot 10^7$, and shown to be independent of the nature of the gas used in the tube. The greatest value of e/m known in electrolysis is for the hydrogen ion, and comes out 10^4 , whence it was concluded that the value for the cathode particle is 1700 times that for the hydrogen ion. As the charge e carried by the cathode particle was found to be the same as for the hydrogen ion, it was held that the mass of the cathode particle is 1/1700 of the hydrogen ion or atom.

It will be seen that notwithstanding the great ingenuity displayed by *Thomson* and his pupils, this whole subject is involved in considerable uncertainty. Perhaps it may fairly be asked whether any of these phenomena are yet interpreted on their final basis. No doubt the experiment as described supports the result found, but it is always difficult to feel sure that some entirely different view of these matters may not develop hereafter, owing to further experimentation, or improvement in the theory of the aether.

The net result is therefore as follows:

1. Viewing the electron as a corpuscle of a gas, it would attain a velocity of only about 98 kms. (60 miles) per second, or $1:3000^{\text{th}}$ of the velocity of light. This is very insignificant compared to the velocities observed in light and electric waves.

2. Under the action of impulses in the tube not yet fully understood, but generated under considerable electric tension, the velocity of the charged particle may be augmented nearly 300 fold, so as to become a little less than a tenth of the velocity of light and electric waves.

3. The mass of the corpuscle is considered to be due wholly to the charge, but too little is yet known to justify this claim, and it cannot be admitted. Apparently wave action alone could produce the velocity of the electron, 2.8 10⁹, approaching one tenth that of light, because the aetherons move 1.57 times faster yet.
4. In his work on Molecular Physics, p. 7-8, Crowther

4. In his work on Molecular Physics, p. 7–8, Crowther describes how much energy may be given to a small mass by increasing its speed to about $1/15^{th}$ of the velocity of light.

»Such particles, however, actually exist, and it is the discovery of these particles and the measurements made upon

them that have led to the great advances in molecular physics which we are about to describe. Particles having this velocity are shot out in large numbers from radioactive bodies. To anticipate a little we may say that the α -particles from radium consist of atoms of helium shot out with a speed of this order of magnitude, and bearing a positive charge. Thus it is that a single α -particle is able to cause a flash of light when it strikes upon a screen covered with a suitable material.«

The view that the high velocity attainable by the electron is due to the action of electric waves is suggested by *Crowther's* further remarks:

*The α -particles consist of helium atoms only. Velocities approaching that of the α -particles can be given to atoms and molecules of other substances by passing an electric discharge through them in the gaseous state at very low pressures. The phenomena of the discharge tube have indeed afforded the best means of investigating the properties of moving electrified particles, and we shall proceed to their consideration immediately.«

Accordingly it seems that the electron researches strongly support the wave-theory as the only means of generating the velocity of the electron found by observation¹). If helium atoms or α -particles can be given such high velocities by electric charges, still more may electrons, in view of their very small size, be given the high velocities approaching $1/10^{\text{th}}$ that of light. For as helium gas is monatomic but twice as heavy as hydrogen, the electron is about 6800 times lighter than helium, and under gaseous laws a velocity of over 80 times that of a helium atom might be expected for the electron, if equal energy were concentrated in a single corpuscle. This gives ample power to account for the observed velocity of projection of the electron, and the high velocity therefore is naturally attributed to wave-action.

It is worthy of note that, with *Crowther*'s estimate that the electrons attain a velocity of $1:15^{\text{th}}$ of the speed of light, the aetherons have a speed $15\cdot 1.57 = 23.55$ times that of the swiftest corpuscle heretofore recognized. The New Theory of the Aether thus bids fair to give quite an impetus to the study of high velocities.

10. The Identity of the Velocity of Electric Waves with that of Light shows that the Aether underlies both Classes of Phenomena: the Formal Public Discussions on doing away with the Aether recently held before the Royal Societies in London striking Evidence of the General Bewilderment.

(i) The physical significance of the identity of the velocity of electric waves with that of light.

282

¹) In his History of the Inductive Sciences, *Whewell* bestows high praise on *Roemer*, — who lived about a century in advance of his contemporaries, so that his discovery of the velocity of light was accepted by very few, chiefly by *Newton* and *Huyghens*, — because this celebrated discoverer noticed that the eclipses of Jupiter's satellites were delayed in time in proportion to the distance of the earth from Jupiter. Thus when Jupiter was near opposition, the eclipses came about 16 minutes earlier than when the earth was on the opposite side of the sun; and *Whewell* remarks on the highly philosophic character of *Roemer*'s argument for the gradual propagation of light across space, which no one before him had suspected from the earliest ages.

Now in our time the researches of the electronists have occupied great prominence, but without any inquiry, so far as I know, being instituted by them to account for the known velocity of electric waves on wires and radio waves across free space. This neglect greatly weakens the position of the electronists, and when they propose to do away with the aether, without accounting for the propagation of light and electricity, they add presumption to carelessness; and therefore if *Roemer*'s course was highly philosophic the course adopted by the electronists has been just the reverse — unphilosophic and indefensible!

The early evidence deduced by *Maxwell*, in 1864, and his successors during the next quarter of a century, to the effect that electrical actions travel sensibly with the velocity of light, received a remarkable confirmation from the physical discoveries of *Hertz*, who devised methods for investigating electrical waves of the type since used in radio-telegraphy. And the progress of radio-telegraphy has been such that the velocity of these waves between Paris and other parts of France, and between Paris and Washington, has been measured as accurately as is humanly possible in the determination of intervals of time less than a fiftieth of a second.

We cannot say indeed that the measurements between Paris and Washington give incontrovertible experimental proof that the electrical waves travel with exactly the velocity of light. Perhaps the velocity of propagation is involved in say five percent of uncertainty; yet all the observations are consistent with the speed of light. And in view of the accuracy of the determinations of V, by such methods as were employed by the American Bureau of Standards in 1907, we must hold that the radio-waves between Washington and Paris travel with the observed laboratory velocity, which appears to be exactly identical with that of light.

The fact that approximately the same speed is attained by light and radio-electric waves, reduces us to the necessity of admitting:

1. Either the two classes of waves travel with precisely the same velocity.

2. Or we must assume the existence of two media with slightly different elastic powers, yet giving waves of practically the same velocity.

Maxwell long ago protested against the unphilosophic habit of inventing a new medium every time we have a new phenomenon to explain; and fortunately in this case measurement supports Maxwell's contention, by showing more and more conclusively that the two velocities are identical. The difference between the velocity of electric waves in free aether and light is now so small as to be within the probable error of the separate determinations; and it is difficult to decide which method affords the greater accuracy of measurement. We must therefore wholly reject any claim for two media, and acknowledge that light and dynamic electricity depend on one and the same medium - the aether. And we have discussed the physical character of that medium, and fixed the constants with such great accuracy that when the density is calculated by a new method, in the present paper, it is found to be

 $\sigma = 1888.15 \cdot 10^{-18}$

as against the other value, now no longer admissible, as shown above in section I,

 $\sigma = 438 \cdot 10^{-18}$

yet found in the first paper by the method invented by Lord *Kelvin* in 1854 and since improved by *Kelvin*, *Maxwell* and the present writer.

The physical significance of the identity of the velocity of light and electricity is therefore unmistakable; namely, electricity in motion consists of waves in the aether, and as they travel with the same velocity as light, we know that electricity and light both depend on the aether, and are simply waves of different length and type in this all-pervading medium.

(ii) Accordingly, as Sir *Oliver Lodge* correctly says, *Einstein* has not done away with the aether, but simply ignored it, and thereby shown a remarkable lack of understanding of the physical universe.

In a public address at San Francisco, April J1, 1920, Sir *Oliver Lodge* dealt with the physical properties of the aether, as the vehicle of energy, and emphasized the view that although totally invisible, the aether is capable of exerting the most stupendous power throughout space, and thus is the medium or vehicle which transmits the forces which govern the motions of the planets and stars in their orbits.

Not only is the aether necessary for conveying the light of the sun and stars across space, but also for conveying the stresses to generate the planetary forces, which are equivalent to the breaking strength of gigantic cables of steel stretched between the sun and planets. These stupendous gravitative mechanisms are wholly invisible, and yet from the observed operation of centrifugal force, we know that the gravitative forces for balancing them do really exist. Under the circumstances, as Sir *Oliver Lodge* pointed out, we cannot hold that appearances correspond to reality. We know of the aether chiefly from its transmission of wave action, which in free space travels with the velocity of light.

Accordingly, after tracing the physical properties of the aether, Sir *Oliver Lodge* justly exclaimed: »You have heard of *Einstein*, and probably know that he has **p**o use for the aether. He has, however, not done away with the aether, but simply ignored it.«

This concise statement covers the case exactly; but in view of the fact that *Einstein* shuts his eyes to the unseen operations of the physical universe, which *Newton* attributed to impulses in the aethereal medium, it is not remarkable that the many sagacious investigators of natural phenomena are obliged to reject the mystical and misleading doctrines of *Einstein*.

To turn away from a mechanical explanation of the world, and attempt to account for phenomena by mere formulae reposing on the supposition of action at a distance, and to further complicate the reasoning by the assumption of the curvature of space, — when such an hypothesis is unnecessary and purely fictitious, — is not a sign of penetration, but of lack of experience in natural philosophy.

It is just such unwarranted procedure which *Newton* denounces as resting on »vain fictions«, in the second sentence of the discussion following the statement of Third Rule of Reasoning in Philosophy: »We are certainly not to relinquish the evidence of experiments for the sake of dreams and vain fictions of our own devising; nor are we to recede from the analogy of nature, which uses to be simple and always consonant to itself« (Principia, Lib. III).

It appears from *Newton*'s discussion that electrical actions conveyed along wires and across space, as in radio-telegraphy, and found by actual experimental measurements to be transmitted with the velocity of light, are the very kind of »evidence of experiments« which that great philosopher says we are not to relinquish for the sake of dreams and vain fictions of our own devising; yet *Einstein* and his followers have thus plainly violated *Newton*'s Third Rule of Philosophy, in proposing to do away with the aether. Without this medium the phenomena here cited are not explainable, so that even a child can see the necessity for the aether. The sun and stars are the perpetual witnesses to the existence of the aether, and all who live and behold the light, as *Homer* says, thereby recognize this superfine medium $(\mathcal{A}i\partial \eta'_{\ell}\varrho)$.

(iii) The formal discussions on the theory of relativity before the Royal Astronomical Society, Dec., 1919, and Royal Society, Feb. 5, 1920, wholly unprofitable, in default of a kinetic theory of the aether.

In view of the above criticisms it is unnecessary to emphasize the unprofitable character of the formal discussions held before the Royal Astronomical Society, Dec., 1919, and the Royal Society, Feb. 5, 1920. But the fact that two of the oldest scientific societies in Europe did not refuse to waste their time and resources of publication on the vague and chimerical theory of relativity — thereby still further confusing the public mind, already bewildered by the misapplication of mathematics which rests on no physical basis, when the problem is primarily a physical one — may well deserve our attention.

A report of these meetings will be found in the Monthly Notices, and in the Proceedings of the Royal Society, and other journals, such as the Journal of the British Astronomical Association, for Nov., 1919, and Jan., 1920, which appear a month or so late. We may condense the discussion as an American physicist summarized a similar discussion held in Washington about ten years ago:

»When we got through, we did not know any more than when we started.«

Now we submit that such methods are not those by which science is advanced. And when the proceedings of learned societies take the form of unprofitable debates, on mere subtleties, or on reasoning which rests on false premises, — such as a mere mathematical foundation, when a physical foundation is required, — it is a sign of the mysticism which usually accompanies intellectual decadence. There can be no defense for the policy of exploiting *Einstein*'s theory without first considering the kinetic theory of the aether, which renders such mystical doctrines unnecessary and wholly inadmissible.

To cite an example of historic interest, the chimerical character of *Kepler*'s early speculations is judiciously pointed out by *Laplace* (Précis de l'Hist. d'Astron., p. 94):

»Il est affligeant pour l'esprit humain de voir ce grand homme, même dans ses dernières ouvrages, se complaire avec délices dans ses chimériques spéculations, et les regarder comme l'âme et la vie de l'astronomie.«

Delambre is even more severe, and subscribes to the judgement of *Bailly* in regard to *Kepler* (Astron. du moyen âge, 1819, p. 358):

»After this sublime effort (discovering the planetary laws, is meant) *Kepler* replunges himself into the relations of music to the motions, the distance, and the eccentricities of the planets. In all these harmonic ratios there is not one true relation; in a crowd of ideas there is not one truth: he becomes a man after being a spirit of light.«

The results brought out in the first and second papers on the New Theory of the Aether, show the worthless character of the whole theory of relativity. We are justified in saying it is a foundation laid in quicksand, when a foundation of granite was near at hand. And therefore the whole theory of relativity, as heretofore taught, is now shaken to its foundations, and thus no longer deserves the serious consideration of natural philosophers.

As throwing some historical light upon the unprofitable subtleties of the theory of relativity, and the vague and chimerical discussions which the Royal Astronomical Society and the Royal Society have inflicted upon a bewildered and long suffering public, we recommend an attentive reading of the latter part of the first volume of *Whewell's* History of the Inductive Sciences. *Whewell* dedicated this justly celebrated work to Sir *John Herschel*, and it ought to be familiar to every modern investigator.

Whewell's luminous discussion of the »Indistinctness of Ideas in the Middle Ages«; »Collections of Opinions«; »Indistinctness of Ideas in Mechanics«; »Indistinctness of Ideas in Architecture«; »Indistinctness of Ideas in Astronomy«; »Indistinctness of Ideas shown by Skeptics«, (pp. 253-268) is especially worthy of study.

In opening the treatment of »Indistinctness of Ideas shown by Skeptics« *Whewell* remarks:

»The same unsteadiness of ideas which prevents men from obtaining clear views, and steady and just convictions, on special subjects, may lead them to despair of or deny the possibility of acquiring certainty at all, and may thus make them skeptics with regard to all knowledge. Such skeptics are themselves men of indistinct views, for they could not otherwise avoid assenting to the demonstrated truths of science; and, so far as they may be taken as specimens of their contemporaries, they prove that indistinct ideas prevail in the age in which they appear. In the stationary period, moreover, the indefinite speculations and unprofitable subtleties of the schools might further impel a man of bold and acute mind to this universal skepticism, because they offered nothing which could fix or satisfy him. And thus the skeptical spirit may deserve our notice as indicative of the defects of a system of doctrine too feeble in demonstration to control such resistance.«

Accordingly, from the considerations here advanced, it follows that the recent formal discussions before the Royal Society and Royal Astronomical Society of the theory of relativity, which is both vague and chimerical, have confused rather than clarified the subject in the public mind; and thus in the cause of truth I have felt obliged to protest against the misuse of the powers of these learned societies.

11. Rejection of the Theory of ,Electrical Mass' except for Small Particles of Common Matter expelled under Electric Charges: the so-called,Electrical Mass' thus not applicable to the Aetherons, or Corpuscles of which the Aether is made up.

(i) Description of the so-called ,electrical mass'.

Of late years a number of physicists occupied with

19*

experiments involving the ejection of small charged particles, in an electric field of very considerable intensity, have laid much stress upon the so-called ,electrical mass', and even gone so far as to entertain the view that all mass is electrical (cf. *Crowther*, Molecular Physics, 1914, pp. 67-85). It is true no doubt that under the charges involved in these experiments there is an ,electrical mass' because the small mechanical mass is thereby thrown out of electric equilibrium with its surrounding field.

But when we deal with the aether as an all-pervading medium, we have to do with the motions of the aetherons only, and as common matter is not involved, we have to reject the ,electrical mass' as applied to the aether, for the reason that the aetherons make up the field, and normally are in kinetic equilibrium, so as not to be subjected to any forces except those due to passing waves in the aether, involving concerted displacement of neighboring aetherons.

It is well known that *Newton* was quite aware of the effect of the resistance of a medium upon the motion of a sphere or other body projected through it. In the Optics, 1721, pp. 342-3, *Newton* discusses the very problem here treated of in the following manner:

»The resistance of water arises principally and almost entirely from the vis inertiae of its matter; and by consequence, if the heavens were as dense as water, they would not have much less resistance than water; if as dense as quick-silver, they would not have much less resistance than quick-silver; if absolutely dense, or full of matter without any vacuum, let the matter be ever so subtile and fluid, they would have a greater resistance than quick-silver. A solid globe in such a medium would lose above half its motion in moving three times the length of its diameter, and a globe not solid (such as are the planets) would be retarded sooner. And therefore to make way for the regular and lasting motions of the planets and comets, it's necessary to empty the heavens of all matter, except perhaps some very thin vapours, steams or effluvia, arising from the atmospheres of the earth, planets and comets, and from such an exceedingly rare aethereal medium as we described above. A dense fluid can be of no use for explaining the phenomena of nature, the motions of the planets and comets being better explain'd without it.«

In this passage we have spaced the sentence especially applicable to the problem of the ,electrical mass', which is explained as follows. Let m be the ordinary mechanical mass of the moving particle; then the ordinary kinetic energy .due to its motion becomes

$$E = \frac{1}{2}m v^2.$$
 (89)

But electrical experiments on small particles ejected under considerable charge, show that there is in addition a quantity of energy due to that charge. The total energy is found to be made up of the two parts shown in the right member of the following equation:

$$E = \frac{1}{2}m v^2 + \frac{1}{3}e^2 v^2/a = \frac{1}{2}[m + \frac{2}{3}e^2/a] v^2 \quad (90)$$

the first term yielding the mechanical energy depending on m, and the second that depending on the so-called ,electrical mass', $\frac{2}{8}e^2/a$, where e is the electrical charge borne

by the particle, and a is the radius of the spherical space occupied by the charge. The electrical mass' is not quite constant for all velocities, but the above formula holds approximately for moderate speeds.

(ii) The rejection of the theory of the so-called ,electrical mass', as an effect of the aether due to the systematic arrangement of the waves, justified by *Thomson*'s views of the motion of a corpuscle through an electrical field.

In his Elements of Electricity and Magnetism, 4th ed., 1909, p. 521, Prof. Sir \mathcal{F} . \mathcal{F} . Thomson indicates that if *m* be the mass of an uncharged sphere, the kinetic energy of such a sphere with charge e, magnetic-permeability μ , and radius of action a, is

$$E = \frac{1}{2} \left[m + \frac{2}{3} \mu e^2 / a \right] v^2 \,. \tag{91}$$

The effect of the charge is to increase the mass of the sphere by $2/{_{8}\mu e^{2}/a}$. This is a resistance called the ,electrical mass', and the question arises whether it should be regarded as an increase of mass, as described by *Thomson*, or an effect of the field in which the sphere moves, as described by *Newton* in the discussion above cited from the Optics, 1721.

Sir \mathcal{F} . \mathcal{F} . Thomson compares the motion of a corpuscle through an electrical field with that of a sphere through a liquid, which he says leads to an increase in the effective mass, because the moving sphere drags some of the liquid along with it. Thus when a sphere moves through a liquid it behaves as if the mass were increased from m to $m+1/_2m'$, where m' is the mass of the liquid displaced by the sphere. Again, when a cylinder moves at right angles to its axis through a liquid, its apparent mass is m+m', where m' is the mass of the liquid displaced by the cylinder.

»In the case of bodies moving through liquids«, says *Thomson*, »the increase in mass is due to the motion of the body setting in motion the liquid around it, the site of the increased mass is not the body itself but the space around it where the liquid is moving. In the electrical problem, we may regard the increased mass as due to the *Faraday* tubes setting in motion the ether as they move through it» (p. 522).

This reasoning concedes that the so-called ,electrical mass' depends not on the sphere itself, but on the field about it; in other words the ,electrical mass' is an effect due to the surrounding field, and not inherent in the body itself. For that reason it is necessary to consider carefully whether the ,electrical mass' in the larger mechanics, ought not to be rejected altogether as fictitious, and due to disturbances in the aether filled with waves and thus polarized, the arrangement of the waves exerting the force called the ,electrical mass'.

(iii) Theory of J. A. Crowther, 1914.

In his Molecular Physics, 1914, p. 70, (Philadelphia, Blakiston's Son & Co.), \mathcal{F} . A. Crowther, also of the Cavendish Physical Laboratory, Cambridge, points out that the extra or ,electrical' mass is due to the fact that the particle carries a charge. Crowther even says that if the ,mechanical' mass m be zero, the ,electrical' mass will still persist. Analytically this follows from the above formula (91), but physically there is no proof that such an ,electrical' mass can exist independently of matter, and thus *Crowther*'s claim cannot be admitted.

Crowther announces his final conclusions thus (pp. 70 and 71):

»Since this ,electrical' mass is really that of the magnetic field surrounding the particle, it resides not in the particle itself but in the medium surrounding it, that is, in that mysterious fluid which we call the ether ¹). As soon, however, as we attempt to alter the motion of the particle this energy flows into it from all sides, so that, as far as experiments upon the particle itself are concerned, the results obtained are precisely the same as if it resided permanently there.«

»To make this somewhat novel idea a little clearer we may consider a close and very servicable analogy, where the mechanism of the extra mass is a little clearer than in the electrical case. If any body is moving through water, or any viscous fluid, it carries with it a certain amount of the liquid through which it is moving. In the case of a sphere, for example, the quantity carried along by the motion of the body amounts to half the volume of the sphere itself. A long cylinder moving at right angles to its own length will carry with it a quantity of fluid equal to its own volume. On the other hand, if it moves in the direction of its own length the fluid entangled is practically nil. Thus, in order to set the body in motion with a velocity v, we have to supply to it energy enough to give this velocity, not only to the sphere itself, but also to the mass of fluid which it carries with it. That is to say, if M is the mass of the sphere itself, and M' the mass of the attached fluid, the work done in starting the body is $\frac{1}{2}(M+M') \cdot v^2$. In other words, the body will behave as if its mass were increased by the mass of the fluid entangled by it. Just as in the electrical case, this extra mass resides in the surrounding medium.«

Accordingly, it clearly appears, from *Thomson*'s and *Crowther*'s arguments, that the electrical mass $2/3e^2/a$ depends wholly on the field in which the charged corpuscle is moving, not upon the body itself, and changes when the motion through the field is altered. All that the arguments can be said to prove therefore is that the aether in a magnetic field, exerts an influence on bodies moving through it. This shows that the aether really exists, is polarized near magnets and electric wires bearing currents, and acts physically according to definite laws.

This is a reason therefore why the theory of the aether cannot be rejected, as some superficial writers have held. The other reasons for admitting the aether are as convincing as stupendous cables of steel would be if we could actually see them stretched from the sun to the several planets for holding these huge masses in their orbits. For the centrifugal force of the planets has to be balanced and the aether is the medium which sustains the tremendous forces required to curve the paths of the planets at every point, and enable them to describe Keplerian Ellipses about the sun as the focus.

¹) The spacing-out is mine.

(iv) We therefore conclude that the ,electrical mass depends wholly upon the aether.

As the ,electrical' mass admittedly depends on the aether, and the influence it exerts depends on the wave motion in this medium, it is better for most purposes to reject the doctrine of a so-called ,electrical mass' as fictitious, and consider separately the common Newtonian mass m, and the influence exerted by the field in which m is moving. In case of the ,electrical mass':

$$E = \frac{2}{3}\mu e^2 v^2/a \tag{92}$$

where a is the radius of the space occupied by the charge, and μ the magnetic-permeability of the medium, e the charge, it is thus obvious that E becomes truly a drag exerted on the moving mass m. It is evident that this effect ought to depend on e^2 , and v^2 , since the induction due to the waves is thus developed like ordinary mechanical work done.

For it must be remembered that there are waves in the field, produced by the bodies and charges of the universe, and also waves, or Faraday tubes of force, produced by the moving corpuscle itself, with charge e. Since the charge e is a measure of the electrification of the corpuscle, the field about it necessarily will have a corresponding condition, but negative in character, and the interaction of the charged corpuscle on the field will be measured by the product of these charges, and thus by e^2 .

This explains the nature of the formula (92), except the divisor *a*. And *Crowther* (pp. 162-3) shows that the total energy in the field is the integral of the total magnetic energy between two spheres of radius *r* and r+dr, when taken from the surface of the electron of radius *a* to infinity, becomes:

$$E = \frac{1}{3} \mu \, e^2 \, v^2 \int_a dr / r^2 = \frac{1}{3} \mu e^2 v^2 / a \,. \tag{93}$$

From this line of investigation it appears that we are justified in rejecting, and even required to reject, the ,electrical mass' for the aetherons, which pervade the universe, and by their vibrations render the aether the vehicle of energy. Accordingly our conclusions are:

1. It appears that Prof. Sir J. J. Thomson's argument for the electrical mass' is an extension of that given by *Newton*, but is likely to be misapplied, unless the specific condition of non-electric equilibrium underlying the experiments with small particles is clearly borne in mind.

2. The doctrine of the ,electrical mass' has therefore a very limited field of validity. On page 81 of the work above cited *Crowther* says that most physicists cherish the belief at the bottom of their hearts that all mass is electrical in origin, »but it cannot at present be said to be much more than a pious hope.«

(v) The nature of the X-rays investigated.

It will be recalled that for a long time great mystery attached to the nature of the X-rays. Soon after these rays were discovered by *Röntgen*, in the winter of 1895-6, three different theories were formed of their nature: (1) Electrified material particles projected with great speed from within the

289

bulb quite through the walls of the glass tube; (2) the Ultraviolet theory, which supposes the energy to be aether-wave motion of the same character as light, but of only about $I: I0000^{th}$ part of the wave length of visible light; (3) the longitudinal aether-wave theory, at first favored by *Röntgen*, *Jaumann* and others, which ascribed the observed effect to longitudinal motion in the aether waves.

Probably something could still be said in favor of each of these theories, and it is not yet certain that the nature of the X-rays is understood. In the usage of men of science however, the ultra-violet wave-theory has found most favor.

In 1912 the Swiss physicist Dr. Laue first made use of X-rays to investigate the structure of crystals, and from this beginning has grown a resourceful method for attacking the problem of molecular arrangement in crystals, which may even throw light on the internal structure of the atoms themselves. An article on this subject by Prof. W. L. Bragg, on >Crystal Structure«, will be found in Discovery, Feb., 1920; and a review of the subject appears in the Journal of the British Astronomical Association for March, 1920, pp. 199 till 200.

The following table gives an outline of the different types of waves, expressed in Ångström units, or tenth-metres, $I m \cdot Io^{-10}$, *Duff*'s Physics, p. 640:

Gamma rays	0.1
X-rays	I
Shortest ultra-violet waves	600
Shortest visible waves (violet), about	3800
Violet, about	4000
Blue	4500
Green	5200
Yellow	5700
Red	6500
Longest visible waves (red)	7500
Longest waves in solar spectrum, more than	53000
Longest waves transmitted by fluorite	95000
Longest waves by selective reflection	
from rock salt	500000
from potassium chloride	612000
Longest waves from mercury lamp	3140000
Shortest electric waves	4000000 == 4 m

It is very difficult to understand how such very short waves as X-rays are supposed to be, on the ultra-violet theory, could penetrate so easily through the human body and other semi-solid substances, as they are found to do in practice. The experiments of *Laue*, *Bragg* and others in crystal photography show the extreme fineness of the X-rays, and their great penetrating power.

But it is perhaps possible that what appears to be a passage of X-rays through resisting structures is rather a general agitation of the aether by which the atoms emit waves ¹) which can impress the photographic plate, than an

actual passage of such short waves through these resisting masses. If so, the facts of experience would lend a strong support to the wave-theory since it might be much easier to evoke vibration of appropriate length than for such short waves to actually pass. The waves evoked by agitation of the aether would show crystalline structure, and even the diffraction of X-rays, quite as well as the passage of X-rays waves.

In confirmation of this view that the X-rays observed are waves evoked by agitation, we quote from *Duff*'s Text-Book of Physics, 1916, p. 641:

»Glass is opaque to waves shorter than 3500 Ångström units, and longer than about 30000 Ångström units. Quartz is transparent between the wave-lengths 1800 and 70000, and for some longer waves; rock salt is transparent between 1800 and 180000, and fluorite, one of the most transparent substances, will transmit ultra-violet waves from about $\lambda =$ 1000 to $\lambda = 95000.$ «

A similar argument has also been adduced by Prof. Sir \mathcal{F} . \mathcal{F} . Thomson to the effect that X-rays depend on collisions by negatively charged particles. They are evoked by the somewhat irregular agitation of the wave-field, the disturbance produced being due not so much to regular continuous wave motion, as to isolated wave impulses, which travel throughout the neighboring aether, and set free the corpuscles from the atoms. Such X-rays could not well interfere, and their diffraction, if observed, would be of the type photographed by Laue in crystals, corresponding to short waves, probably produced by the degeneration and breaking up of longer aether impulses of no considerable regularity of movement.

This puts the ultra-violet theory in a new light, in line with the wave-theory, and at the same time explains the mechanically injurious effects of X-rays in surgery²) as due to the irregular wave impulses, which regular ultra-violet waves could hardly produce. And it explains also why calcium tungstate may render the X-rays capable of casting shadows visible to the eye. For the irregular impulses would come with sufficient rapidity to give an effect which optically is apparently continuous. When observing the X-ray through calcium tungstate I have noted an appearance of rapid flickering, as in the case of rapid but irregular electric sparks, or lightning flashes in quick succession but at unequal intervals.

In connection with this subject it is well to bear in mind that magnetism, which in the wave-theory depends on polarized waves of perfect regularity, can penetrate thick plates of glass or any other substance, but the action seems to take a little time. Probably the polarized character of magnetic waves and their length makes this penetration possible, whereas it is possible for the confused waves of light only within fixed limits. Thus we hold that the irregular impulses in X-rays correspond to long waves, which under degeneration call forth the very short ones used for the newer investigations in crystals.

¹) This idea is suggested by *Röntgen*'s original experiment of cutting off all cathode rays with black card board, yet noting that some crystals of barium platino-cyanide in the darkened room were rendered luminous by the general agitation in the aether.

²) A dispatch from Paris, May 26, quotes M. *Daniel Berthelot* as reporting, May 25, to the Academy of Sciences a new method for protecting operators against the injurious effects of X-rays, which are neutralized by a simultaneous application of infra-red rays. This use of infra-red rays to counteract the X-rays confirms the theory here developed; unless the agitations underlying the X-rays were long, the long infra-red rays could hardly afford the protection reported. — Note added, May 26, 1920.

12. The acknowledged Failure of the Electron Theory, which represents a Subordinate Phase of Scientific Progress: The Larger Problems of the Universe can only be attacked through the Wave-Theory based on the Kinetic Theory of the Aether.

(i) The acknowledged failure of the electron theory.

In his interesting but unconvincing work on Molecular Physics, Philadelphia, 1914, *Crowther* treats of many molecular phenomena from the point of view of the electron theory. Including the effect of the electrical mass, $\frac{2}{3}e^2v^2/a$, *Crowther* concludes (p. 81) that the mass of an electron is $8.8 \cdot 10^{-28}$ gms., while the value of the charge it carries is $1.57 \cdot 10^{-20}$ units. Thence he deduces for the radius of the electron $1.87 \cdot 10^{-13}$ cms.¹)

Calling attention to the conclusion that the radius of an atom is of the order of 10^{-18} cms, he adds a comparison which I give spaced:

»We may now say that small as the atom is, the electron is so much smaller that the electron bears to the atom which contains it very much the same relation as a pea to a cathedral.«

»We have seen that the whole of the mass of the electron is due to the charge which it carries. The thought at once suggests itself: Are there indeed two kinds of mass or is all mass electrical in its origin? Probably most physicists cherish this belief at the bottom of their hearts, but it cannot at present be said to be much more than a pious hope. The mass of a negative electron is about $1/_{1700}$ part of the mass of a hydrogen atom. Neglecting the positive charge of the atom, of which we know practically nothing, it would require 1700 electrons to make up the mass of a single hydrogen atom. This of course is not a priori an impossible number considering the smallness of the electron; and speculations along these lines were for a time freely indulged in. In this case, however, experiment failed to confirm the bold conjecture. The number of electrons in the atom has been determined at any rate approximately, and affords no support for such a theory.«

Crowther then examines at some length the question of the number of electrons in an atom, and after admitting the obscurity of positive electrification, finally concludes, pp. 8_{3} - 8_{4} as follows:

»Unfortunately, we are not yet acquainted with the nature of positive electricity. Prof. Sir \mathcal{F} . \mathcal{F} . Thomson's experiments on the positive rays, brilliant as they have been, have not at present thrown much light upon this exceedingly difficult problem. For the present the term ,positive electrification' remains for the physicist very much what the term ,catalytic action' is for the chemist — a not too humiliating

method of confessing ignorance. If we suppose that the positive electricity is distributed uniformly over a sphere of the size of the atom (a hypothesis which lends itself very readily to mathematical treatment), the author's result would indicate that the number of electrons in an atom is almost exactly three times its atomic weight. That is to say, the number of electrons in a hydrogen atom would be three.²) If we go the other extreme, and suppose that the positive electrification is a sort of nucleus at the centre of the atom. and that the electrons revolve around it somewhat after the manner of the rings of Saturn, the number of electrons in a hydrogen atom works out at unity, the number in any other atom being equal to its atomic weight. The assigning of unit atomic weight to hydrogen would then have a very definite physical significance, as it would be the lightest atom which could possibly exist. In either case the number of electrons in an atom is only a very small multiple of its atomic weight. We cannot, therefore, assign any appreciable fraction of the mass of the atoms to the negative electrons it contains.«

»There still remains, of course, the possibility that the mass is electrical, but that it resides in the positive portion of the atom. If the formula for the electric mass be examined, it will be seen that for a given charge the mass is inversely proportional to the radius of the sphere upon which it is concentrated. If we suppose the positive charge on the hydrogen atom to be concentrated upon a sphere of 1/1700 of the size of the negative electron, its mass would be 1700 times as great, that is to say, equal to that of the hydrogen atom. Our perfect ignorance of the nature of positive electricity renders the suggestion not untenable, though evidence for it is sadly lacking.«

This is a very frank confession of a failure of the electron theory, for two chief reasons.

r. In size the electron bears to the atom about the ratio of a pea to a cathedral.

2. The number of such electron peas to the atom cathedral is very small, either 1 or 3 for hydrogen, and always a small multiple of the atomic weight. Hence the important conclusion: »We cannot, therefore, assign any appreciable fraction of the mass of the atoms to the negative electrons it contains.«

Accordingly it is not surprising that *Crowther* admits that »for the present our belief in the electro-magnetic nature of all mass remains an expression of our faith that all the varied phenomena with which we have to deal are manifestations of some single principle or essence which underlies them all.«

Another important and much more elaborate work, »The Electron Theory of matter«, by Prof. O. W. Richardson

²) The spacing-out is mine.

¹) Another proof of the great uncertainty attaching to the theory of the electron is afforded by conflicting deductions as to the absolute dimensions of this little mass.

^{1.} Crowther, pp. 81-165, gives for the radius of the electron $1.87 \cdot 10^{-18}$ cm, and for the radius of a hydrogen atom $1.21 \cdot 10^{-8}$ cm. Thus the hydrogen atom has about 66000 times greater diameter, yet it has only 1700 times the mass of the electron, which makes the electron relatively very heavy for its small diameter. If of equal density with the hydrogen, this mass would make the hydrogen atom have a diameter 11.93 times that of the electron.

^{2.} But the diameter of the electron itself must be very uncertain. In Phys. Rev. vol. 114, pp. 247-259, Sept. 1919, *A. H. Compton*, who had previously estimated the diameter to be $2 \cdot 10^{-10}$ cms, now finds it to be $(1.85\pm0.005) \cdot 10^{-10}$ cms, or $r = 0.925 \cdot 10^{-10}$ cm. This is about 2000 times larger than *Crowther's* value; so that apparently no confidence whatever can be put in these results.

of King's College, London, appeared under the auspices of the University Press, at Cambridge, 1914, pp. 1-612. We cannot attempt to describe the treatment, except to say that it is similar to *Crowther*'s work, but less experimental, and sets forth the mathematical theory in greater detail.

In spite of the elaborateness of this treatise, *Richardson* is obliged to admit the short-comings of the electron theory. On page 592 the author admits that "we cannot be sure that the mass of the electrons is not appreciably different in different substances." Accordingly it would appear that the mass of the electron is definitely fixed only in particular substances which have been experimentally investigated. It is acknowledged that nearly all the atomic problems are clouded in great obscurity.

Under the head of General Conclusions, p. 600, we read: »A review of the preceding discussion shows that the electron theory is not in a position to make very definite assertions about the nature of gravitational attraction. It seems likely that the Newtonian law of attraction between elements of matter is one between elements of mass or confined energy and that it is of a very fundamental character. It is doubtful¹) if it can be replaced by a modified law of electrostatic force between electrons or elements of electric charge, unless the modified law includes the associated mass explicitly. Even so, the case does not appear very simple.«

In closing *Richardson* concurs in the opinion of *Lorentz* that gravitation may be an electrodynamic effect propagated with the velocity of light, like that since developed in greater detail by the present writer.

(ii) The electrons usually assumed to be more or less bound to atoms, and set free chiefly in metals (conductors), to make up an electric current: but this will not explain the propagation of electric disturbances with the velocity of light, and thus the electrons cannot replace the aether.

It is well known that the electrons usually are taken to be more or less ,bound' to the atoms, with which they are associated. A vast amount of discussion has arisen as to the setting free of the electrons, by heat and electric disturbances. It will be noted therefore:

1. The electrons are not taken to be entirely free, to pervade all space and all bodies, like the aetherons, which travel with a velocity 1.57 times that of light, 471238 kms.

2. The speed of the electrons is not taken to be in any case greater than one third that of light. As the mass of the electron is considerable, though only about $1/_{1700}$ of that of a hydrogen atom, this smaller velocity, of say 100000 kms. is very intelligible.

The hypothesis of *Crowther*, and others, (Molecular Physics, p. 139), that »an electric current is a flow of electrons from a place of high to a place of low potential« cannot be admitted, because the observed velocity of 300000 kms. for light and electricity could not be attained by such heavy masses as electrons.

Crowther states this electron theory as follows:

»We may regard a conductor, then, as a substance |

¹) The spacing-out is mine.

containing electrons which are free to move under the action of an electric field, while in non-conductors the electrons are fixed and unable to follow the impulse of the field.«

»How are these electrons set free? In the first place it may be noticed that the only good conductors of electricity are metallic, that is to say, electro-positive in character, substances which we know from other phenomena readily part with an electron under the slightest provocation. Now in a solid such provocation may well be supplied by the close propinquity of the neighbouring molecules. It is well known that a charged body will attract light uncharged substances. The attraction of a well-rubbed stick of sealing wax for small pieces of paper is generally our first introduction to the science of electricity. The attraction is of course mutual, the force on the charged body being equal to that on the uncharged paper. Hence an electron in one atom is attracted by a neighbouring uncharged atom, and under favourable circumstances, and especially in the case of an atom only too ready to part with its electrons, the attraction may well be sufficient to enable it to make its escape.«

It is obvious without further discussion that this theory is so very defective that it cannot be seriously entertained by investigators who are familiar with the propagation of electric and radio-telegraphic waves and light across free space. For, in the first place, it claims to account for disturbances along conductors, which cannot be done with electrons of the recognized mass. And, in the second place, the electron theory gives no explanation of light and radiotelegraphic waves across free space, where the aether alone is involved.

Accordingly the electron theory cannot explain the phenomena of the aether, and it must be admitted that the subject of the electron is still involved in great obscurity. So far as we can judge it can only be cleared up by the further development of the wave-theory, deduced from the new kinetic theory of the aether.

For although the mass of the aetheron given in the first paper on the New Theory of the Aether, will have to be multiplied by about 4.31 to take account of the increased absolute density of the aether, found by the new method of section I above, after Lord *Kelvin*'s method was shown to be invalid: yet the total change in the mass of the aetheron is comparatively slight, namely: molecular weight $= 67.077 \cdot 10^{-12}$.

Accordingly the general mass and dimensions of the aetheron are but slightly altered, yet the size of this corpuscle is somewhat increased and becomes:

1. The radius of the aetheron $= \frac{1}{2461.2}$ of that of a hydrogen molecule.

2. This radius is equivalent to $5.44 \cdot 10^{-12}$ cms., that of hydrogen being taken as $1.34 \cdot 10^{-8}$ cms.

(iii) The electron theory like that of radio-activity is a subordinate phase of scientific progress.

The electron theory developed during the last quarter of a century by a considerable group of experimental physicists led by Prof. Sir \mathcal{F} . \mathcal{F} . Thomson and others, has now acquired such definite form and shows such defects, that we

11

are safe in considering it a subordinate phase in scientific progress. If it should prove to be an ultimate development, apparently this can only be owing to the more fundamental wave-theory, which underlies the electron-theory and gives a physical basis for the phenomena of electrons.

r. The alpha-, beta-, gamma-rays, recently so much observed, are held to give experimental proof that small particles, under electric charges of greater or less intensity, are ejected from certain bodies with velocities which may be one third that of light.

2. It is very difficult to understand how alpha-, beta-, gamma-particles can be ejected with this enormous speed unless commotions incident to wave action underlie the ejections. For electrodynamic waves travel with the velocity of light, and material particles caught up by a combination of such waves might travel more slowly than light, but yet with so great a speed as to approach that speed or a large fraction of it.

3. It is inconceivable that velocities approximating one third that of light could be generated without some association with the release of elastic action in the aether, which speeds on with the enormous velocity of 300000 kms per second. Even in solid bodies the aether waves advance at a rate which is a large fraction of that in free space. +

4. Now molecular and atomic velocities are very small indeed compared to that of light. Hence it is apparent that no ordinary molecular collisions or disturbances could eject particles with these enormous speeds. But if invisible electrodynamic waves underlie these ejections their speeds are easily accounted for. Under oscillating electric charges the particles might be carried along from the surface or even into the interior of a solid anode or cathode, or similar terminals.

5. In the author's work of 1917, p. 20, we have explained the nature of an electric current, and illustrated the waves about a conducting wire by a figure (cf. fig. 12, p. 260, above) showing the rotations which make up the waves. The waves act in concert, the elements whirling everywhere in the same direction. If therefore, there be a particle small enough to be ejected, yet observable, it might be carried away with great speed.

6. But in a Geissler-tube, or similar rarified gaseous medium, we have rarified gas itself for the conductor or discharge of the electric strain at the terminals. In such a good conducting partial vacuum, it apparently would be much easier for a small particle to be ejected with great speed than from any conductor of metallic constitution.

7. Thus, in all the phenomena of electric discharges through rarified gases, on which Prof. Sir \mathcal{F} . \mathcal{F} . Thomson has experimented for so many years, the indications are that the observed velocities of the ejected particles are attained under wave influences or releases of electric stresses, by commotions in the aether traveling with the velocity of light.

8. Since the rarified gas acts as a conductor - Prof. John Trowbridge of Harvard University having found that rare air is a more perfect electric conductor than even copper wire -, we should in fact expect certain solid particles to be transported along with a large fraction of the velocity of light. Thus the electron phenomena are not remarkable, but naturally follow from the wave-theory. 9. Accordingly, it hardly seems possible that the alpha, beta-, gamma-particles, so much studied in the electron theory, can be other than a temporary phase in the progress of science. Important as the results attained are, they do not disclose to us any workable theory of the universe. Even the ejections of small charged bodies must rest on the wavetheory: there is no other possible way in which we can explain the ejection of these corpuscles, and their enormous velocities, whereas the wave-theory makes their ejection natural and requires it to be at high speed.

10. Incidently, the electron theory renders the corpuscular theory of the aether more probable than it otherwise would be. It all implies excessively rapid motion for very small bodies. Unless there be waves traveling with the velocity of light, it is impossible to explain the phenomena of radio-activity.

To show the difficulty of reconciling these results, we add a few calculations. Let us assume in the first case that the free electrons behave as a gas, and thus follow the law announced by *Maxwell*, that all molecules have equal kinetic energy, which is verified by experience for many actual gases. Then, if m and v denote respectively the mass and the velocity of a molecule of hydrogen, while m' and v' denote corresponding quantities for an electron, we have:

$$\frac{1}{2}mv^2 = \frac{1}{2}m'v'^2$$
. (94)

Accordingly if v = 1696 ms, and $m' = \frac{1}{3400}$ of a hydrogen molecule, which contains two atoms, we find

$$= V_{3400} \cdot v = 58.31 \cdot 1696 \text{ ms} = 98.893 \text{ kms}.$$
 (95)

This is a comparatively small velocity, a little over 60 miles per second; and thus we find the electron as a gas particle could not attain a sensible fraction of the velocity of light, 300000 kms. Different authorities give different velocities for charged particles: *Crowther* (p. 76) considers a particle moving with one tenth of the velocity of light, and *Millikan* has asserted the probability of a speed of one-third that of light. Such high velocities are wholly impossible, on the kinetic theory of gases; but as expelled under electric charges they might be possible, if carried along by the wave action traveling at 300000 kms per second. But the acceleration of the velocity appropriate to a gas, under the kinetic theory, would have to be very great.

For the above value 98.893 kms is less than $\frac{1}{3000}$ th that of light; and if we take *Millikan*'s estimate of $\frac{1}{3}$ the velocity of light for the swiftest charged particles, ejected, the above kinetic velocity will have to be accelerated a thousand times its calculated value, or receive energy augmented by the factor $(1000)^2 = 1000000$ fold.

Now in view of our ignorance of molecular physics, it is difficult to say upon what forces such an acceleration may depend; but I know of nothing adequate except waves traveling with the higher velocity of 300000 kms per second. A particle having a speed of $1/_3 V$, would have only $1/_9$ th of the energy of a particle traveling with the velocity V. It looks therefore as if waves passing by with much greater velocity might have given the particle a velocity which is a considerable fraction of the velocity of light.

On p. 81, *Crowther* attributes the whole mass of the electron to the charge which it carries. We can not admit

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297

such a supposition, for reasons already given; yet if the charge exerts a drag on the aether in which the waves are traveling, the velocity attained will be reduced to a fraction of that of light, in accordance with observations. No other hypothesis than that here adopted will explain the phenomena; and it seems certain that the electron phenomena are explicable by means of the aether, but not without this much finer medium.

(iv) Explanation of inertia, momentum, the laws of motion and of static electricity.

Ever since the formulation of the Newtonian philosophy in the Principia, 1686, the problem of inertia, momentum and the laws of motion have appeared to natural philosophers as phenomena requiring elucidation; yet for a long time no solid progress could be made in this inquiry, because there was no adequate theory of the aether. Now that a kinetic theory of the aether is outlined, and the properties of the medium somewhat understood, we consider it advisable to suggest an explanation of the chief mechanical actions which underlie natural philosophy.

r. Since the aether is filled with waves and presses symmetrically upon bodies at rest, or in uniform motion, and all bodies carry their wave fields with them, — whatever their state of rest or motion, we perceive that the high elasticity of the aether makes it impossible to move a body at rest, or alter the velocity of a body in motion, without expending energy upon it. For in every case the wave-field about the body must be readjusted, and under the elastic power of the aether, this involves work, — just as the aether waves of solar radiation, for example, do work when arrested in their motion at the surface of the earth. The kinetic theory of the aether therefore accounts for inertia, which represents the energy to be overcome in readjusting the wave-field about any body.

2. To make this a little clearer we recall a remark of *Tyndall* in his work on sound, 3rd ed., 1896, p. 73:

»A certain sharpness of shock, or rapidity of vibration, is needed for the production of sonorous waves in air. It is still more necessary in hydrogen, because the greater mobility of this gas tends to prevent the formation of condensations and rarefactions.«

In further proof of *Tyndall*'s remark as to the increased difficulty of starting waves in hydrogen compared to air, we cite the fact that heretofore Prof. F. E. Nipher of St. Louis is the only experimenter who has been able to generate waves in the aether by mechanical means. To this end Nipher used dynamite, which generates tremendous forces acting with extreme quickness — exactly as *Tyndall* points out should be the case for a gas having very great mobility of its molecules. This confirms the kinetic theory of the aether and the cause assigned for inertia by an experimentum crucis.

3. In the case of momentum, the physical cause involved is the same as that assigned for inertia, for very obvious reasons. For momentum is the product of mass by velocity, mv, and as the mass does not change, the change can only occur in v, the velocity, and thus momentum and inertia are identical as to physical cause.

We may even go a little further, and say that all

kinetic energy depends on the aether; for the formula for the kinetic energy

$$E = \frac{1}{2}mv^2 = \frac{1}{2}m\,\mathrm{d}^2s/\mathrm{d}t^2 \tag{96}$$

involves only mass m, which is constant, and the velocity v, any change in which is resisted by the moving wave-field about the body, exactly as in the case of inertia.

4. As *Newton*'s laws of motion, Principia, Lib. 1, are concerned with motion, which involve chiefly changes of velocity, we perceive that these laws have their recognized form in virtue of the kinetic medium of the aether; and that all changes of motion involve changes in the aether wave-fields about bodies, and are thus proportional to the forces acting, and produce effects in the direction of these forces, or stresses, in the aether.

5. It only remains to point out that as we ascribe dynamic electricity, or electric currents, to waves of the aether in motion, so also we ascribe static electricity to a non-equilibrium of the wave-field of the aether due to the escape of certain waves, under friction or other disturbing causes, which facilitates the escape faster than restoration takes place, and thus leads to the development of charges of static electricity. Thus it is easy to throw the universe out of electric equilibrium, and develop electric stresses.

6. As a charge of static electricity is not permanent, but accompanied by a gradual discharge, it is natural to hold that the insulators on which the electric stress accumulates do not allow of an adequate flow of aether waves to maintain the electric equilibrium in the local field of the universe. Hence static charges accumulate, and may be discharged by various causes.

This may involve gradual restoration of the equilibrium, by wave dissipation through the air or other media, or a sudden restoration, when metallic contact is made by a conductor connecting the so-called positive and negative charges, and a motion of aether waves along the wire restores complete equilibrium.

It will be seen that the views set forth in this paper and maintained with vigor are very different from those previously current among investigators. In the search for truth we do not enter upon such new paths from any mere love of novelty, but only from the hope of finding a way out of the general confusion heretofore recognized to exist.

If it be thought somewhat audacious to depart from these old ways of thinking, in extenuation thereof I must point to the triumph of the theory of a very small density for the aether, after a density of 2000 million times that of lead had been held by the electronists, as outlined in the first paper. The small density now appears to be established on an unshakable basis, by the discovery of the new method for determining the absolute density of the aether. And in general when nothing is hazarded in the hope of the discovery of new truth, history shows that important discoveries cannot be made.

Thus I think it infinitely better to venture upon paths which promise progress rather than to hold to lines of mere conservatism, which return to some part of the old dark labyrinth, without leading out to real light under a clearer and brighter sky. If others are able to add to the development here brought forth I shall heartily welcome their advance; and I ask no more of others, in respect to following the new path here struck out in the hope of discovery, than I voluntarily exact of myself, in the search for light, more light!

As this paper is somewhat lengthy I shall defer going into further details of static electricity, till we come to deal with the phenomenon of lightning and the molecular forces.

I am indebted to Mr. E. L. Middleton, Mr. G. L. Haley, and especially Mr. W. S. Irankle, for facilitating the completion of this paper.

Starlight on Loutre, Montgomery City, Missouri,

1920 May 8. T. J. J. See.

Postscript:

Since this paper was finished, I have just received Science Abstracts, No. 270, June 30, 1920, with notice of the Theoretical and Experimental Researches on Gravitation by Prof. *Q. Majorana*, of Rome (Phil. Mag., vol. 39, pp. 488-504. May, 1920), who raises the question as to the absorption by a dense medium of the energetical flux which is supposed to proceed from all matter and cause gravitative attraction.

Mr. P. E. Shaw gives the following account of Majorana's researches:

»A particle of mass dm would put forth a flux kdm. If this flux passes through distance x of a dense medium, having quenching factor H, the flux at the end would be $kdm \cdot e^{-Hx}$. Here H is proportional to the density of the medium $= h\partial_{\nu}$. Now, suppose the particle of mass dm to be a particle inside a sphere, the author finds that the total flux emerging from all points in the sphere is

$$F = k \pi \partial_{\nu} R^{3} \left[\frac{1}{p} - \frac{1}{2p^{3}} + e^{-2p} \left(\frac{1}{p^{2}} + \frac{1}{2p^{3}} \right) \right]$$

where $\partial_{\nu} =$ density of the sphere, R = radius of the sphere, and p = RH. Let $M_a =$ the apparent mass of the sphere. This is less than the true mass M_{ν} on account of this abr sorption effect. Let $M_a = M_{\nu}\psi = \frac{4}{3}\pi \partial_{\nu} R^3 \psi$, where

$$b = \frac{3}{4} \left[\frac{1}{p} - \frac{1}{2p^3} + e^{-2p} \left(\frac{1}{p^2} + \frac{1}{2p^3} \right) \right].$$

The relation of p to ψ is shown graphically. The case of the sun is specially considered. The astronomical density of the sun is 1.41. This is the apparent density. On certain hypotheses we can arrive at a value for the true density, and from this deduce the values of ψ , p, and H successively. The values of ψ , p, and H the author draws up in a table, giving a range of hypothetical density from 1.41 to 20.0. For a material of density 1.0 the value of H is h. This factor h is supposed to be a universal constant of value between 10^{-12} and 10^{-11} .«

»In order to find the value of h, the author has performed the following experiment. From a delicate balance in vacuo hangs a lead sphere, counterpoised by a similar sphere. One lead sphere is hung in a chamber surrounded by one which can be used empty or filled with mercury, so as to surround the lead symmetrically. The lead has mass 1274 gm, the mercury has mass 104 kg. By means of a mirror, the balance, and a distant scale it is possible to estimate the mass to $\frac{1}{1700}$ mgm on each reading. On trying the experiment, the author finds that in all cases the weight of the lead is reduced when it is surrounded by mercury. This indicates an absorption effect by the mercury. The observed decrease in weight is (0.00209 ± 0.00007) mgm. But various corrections must be applied. These include the attraction of the mercury on the counterpoise, and on the beam, and on other parts used. The greatest admissible error for asymmetry of the mercury is ± 0.00009 mgm. The net effect after the application of these corrections is (0.00098 ± 0.00016) mgm. The author next considers other possible causes of error, such as electrostatic or magnetic action, radiometric or electromagnetic action, heat effects, and mechanical perturbation. He considers these effects negligible.«

»The value found for k is $6.73 \cdot 10^{-12}$. On applying these results to the sun, the author considers the sun's true density to be 4.27, which is three times as great as that believed in by astronomers.«

This remarkable result seems so striking as to be worthy of careful attention. It may be recalled that in the Electrod. Wave-Theory of Phys. Forc., vol. 1, 1917, p. 155, paragraph 18, I pointed out that »up to the present time the researches of astronomers throw but little light on the amount of matter within the heavenly bodies. They have simply calculated the amount of matter within these masses which may make itself effective by external attraction; and the amount of matter actually there may be considerably larger than we have heretofore believed.«

Perhaps it may appear premature to claim that my prediction of 1917 is already definitely verified by *Majorana*'s researches, but as his experiments were well planned, and executed with such care as to command approval in the highest scientific circles, the evidence certainly indicates the detection by delicate physical experiment of a screening effect in the action of universal gravitation which I first discovered from the fluctuations of the moon's mean motion, Dec. 10, 1916, as recurring with the eclipse cycles, and thus depending on the interposition of the solid globe of the earth in the path of the sun's gravitative action on the moon.

The course of this celestial-terrestrial progress is the more remarkable, because Prof. E. W. Brown, the leading lunar theorist, had pronounced against the theory, after Bottlinger and Seeliger had been unable to confirm the interception of part of the sun's gravitation near the time of eclipses. It would now seem that Majorana's experiments open a new line of attack on the nature of gravitation, which can scarcely be interpreted except in terms of the wave-theory.

If so, it will no longer be admissible to speak of action at a distance, when the sun's action on the moon is 'shown to be partly cut off by the interposition of the earth's mass near the time of lunar eclipses, while terrestrial gravitation can be sensibly reduced by the layer of mercury made to surround one of two delicately balanced lead spheres, in *Majorana*'s laboratory experiments.

It may be noted also that the explanation of the progression of the perihelion or mercury given by me in AN 5048, p. 143, seems to be triumphantly verified, and that too without resorting to relativity or the theories of *Einstein*, which I believe to depart from the laws of nature, because they are both lacking in physical basis. It is not by accident that *Majorana*'s experiments confirm my lunar researches of 1916, and the simple explanation of the outstanding motion of Mercury's perihelion given in AN 5048.

1920 August 18.

T. J. J. Sec.