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XV. Fifth memoir on induction

M. Elie Wartmann

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I did not think it necessary to determine the carbon and hydrogen in this compound, as the sulphur calculated as sulphurous acid, and the nitrogen as the oxide of ammonium, immediately determine the nature of the substance formed, and the near approach of the quantities of these elements found by experiment to the numbers required by theory, leave no doubt as to the correctness of the above formula.

I was in the act of making further investigations on this subject, and had prepared compounds of a most interesting nature, by the action of sulphuretted hydrogen and sulphuret of carbon on cœnanthylammon, when the town in which I was residing became the prey of one of those political convulsions which mark the present æra. The laboratory in which I worked was stormed, being in an exposed position, and everything it contained destroyed amidst the uproar. Instruments and the substances under investigation were alike scattered in fragments around,—only with difficulty I myself escaped. Such must be my excuse for the imperfectness of the present paper, but as soon as possible I purpose continuing this investigation.

XV. *Fifth Memoir on Induction*. By M. ELIE WARTMANN,
Professor of Natural Philosophy in the Academy of Geneva*.

[With a Plate.]

[Continued from vol. xxxi. p. 251.]

§ XVII. *On the non-propagation by radiation of Dynamic Electricity.*

146. **R**ADIATION and conductibility are the only two modes known by which imponderable fluids are propagated. The first, possessed in common by heat and light, has furnished theorists with more than one occasion of discussing the relative value of the systems of emission and undulation. Conductibility is a second form of propagation peculiar to heat, and which light does not present. What is the true character of transmission of electricity? This is an important question, the solution of which requires direct experiments.

147. Analogy furnishes no data which can inspire any confidence. It is generally agreed that the imponderable agents form two distinct groups. Light and radiant caloric are

* Communicated by the Author, having been read before the Société de Physique et d'Histoire Naturelle of Geneva, March 2, 1848.

governed by such similar laws, that M. Melloni* and other philosophers admit the identity of their nature. The same has been the case, since Ampère, with electricity and magnetism, the analogous properties of which are comprised in phenomena of attraction, repulsion, and induction. The only manifestations common to the four fluids are their imponderability, their property of mutually engendering themselves in matter, and of reacting in various cases upon one another, their incapacity of passing freely through certain bodies, (opaque, athermanous, isolating); lastly, their extreme velocity of propagation. But these resemblances do not admit of our deciding whether electricity is transmitted by *radiation*, as might be conjectured from its more rapid motion than that of light, or by *conductibility*, in the manner of the caloric of contact, as has been supposed by a sort of universal convention, to which scientific language gives faith. The expressions of *conducting* bodies and *isolating* bodies have only acquired a theoretical importance from the remarkable works of Ampère on the propagation of electricity†, and of Mr. Faraday on the induction of contiguous particles‡.

148. In his *Recherches sur quelques points de l'Electricité voltaïque*, M. Vorsselman de Heer has given his opinion that the velocity of the current depends only on the *matter* of the conductor, just as the rapidity of sound is modified only by the *nature* of the medium in which it is transmitted§. If this was the case, the proposed hypotheses on the mode of propagation and on the nature of the electric fluid would be very much simplified. But the phenomenon is probably more complicated; and M. Poggendorff has recently shown that the rapidity of transmission of the current of the battery seems to be proportioned to the product of the conductibility of the medium by its section||.

149. The object of this memoir is to establish the fact experimentally, that rectilinear propagation, a fundamental condition of all radiation, is not verified for dynamic electricity, which consequently does not possess the property of being

* On the Identity of the various luminous, calorific and chemical radiations, vibrated by the Sun and the terrestrial sources. *Bibl. Univ.*, vol. xxxix. p. 168.

† On the mode of transmission of Electric currents, and on the Electrochemical theory. This memoir, which had remained inedited, has been published in the Scientific Review of Quesneville, vol. xxxi. p. 171, Nov. 1847.

‡ Experimental Researches in Electricity, §§ 18 and 19, *Phil. Trans.* 1838.
§ *Bulletin des Sciences Physiques et Naturelles en Néerlande*, 1839, vol. i. p. 319.

|| *Annalen der Physik und Chemie* (1848, No. 3), vol. lxxiii. p. 355.

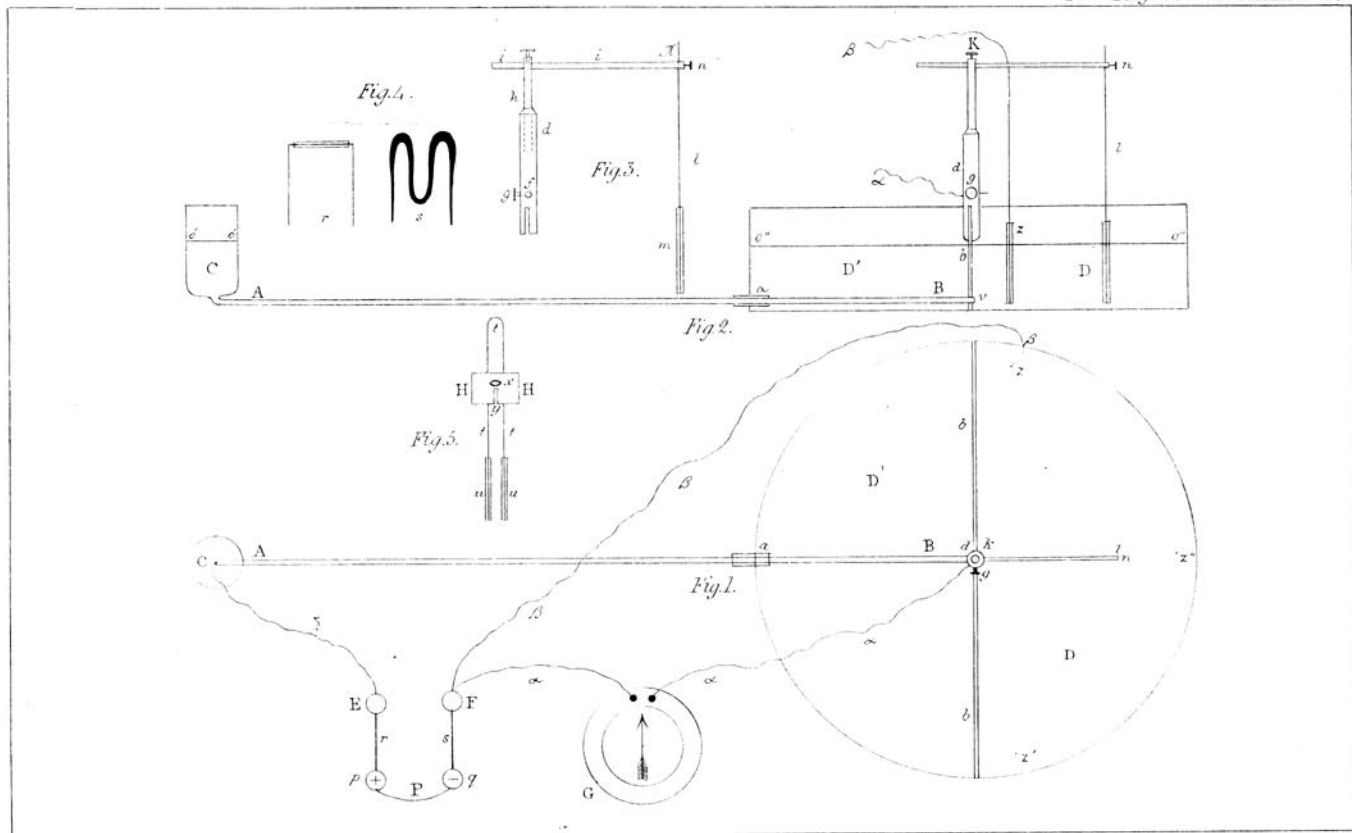
reflected, refracted and polarized. The experiments which I proceed to describe were made at the invitation and with the assistance of my friend M. Ch. Cellérier. They are in a manner well-timed from the recent publication of Prof. Maas*.

150. The apparatus employed is represented in plan in Plate I. fig. 1, and a section of it in fig. 2. AB is a glass tube one metre in length, perforated by a small internal canal, and arranged horizontally. One end terminates at the bottom of a vertical chamber C, of the same substance, and the other at the centre of a cylindrical earthen vessel DD', into which it penetrates by an aperture which is closed by means of a stopper *a*. The vessel is divided into two equal chambers, isolated by the plate of glass *bb*, cemented in a perpendicular position to the axis of the tube. All the sides of these two chambers were covered with several layers of varnish of gum-lac. On the middle of the plate was fixed a piece figured in detail in fig. 3. It is composed of a large copper cylinder, the foot of which is slit at *e*. The excentricity of this slit allowed of the vertical axis, to which it is parallel, being made to coincide exactly with the mouthpiece *v* of the tube AB. Higher up is seen a diametral aperture *f*, into which is fixed, by the screw *g*, the extremity of the wire *αα*. Lastly, the upper part of the cylinder *dd* is pierced in the direction of the axis for the length of 0^m.095, with a slightly conical aperture, in which the piece *h* turns with gentle friction. This piece is furnished with a support which regulates its insertion. At its extremity, this piece has a square hole which receives the stem *i* held tight by the screw *k*. The arm *i* is itself pierced so as to receive the copper wire *l*, the serviceable length of which is regulated by the screw *n*, and the lower part of which, isolated in a glass tube *m*, is exposed only at the base of the latter.

151. The experiment is made with a voltaic element P, the nature of which varies according to the sensibility of the rheometer G. The first experiments were performed with a pair formed of two square plates, copper and zinc, of 0^m.095 thickness; the others with a copper and an iron wire immersed in pure water. The polar extremities terminate in the mercury contained in the glasses *p* and *q*.

152. These glasses communicate with two other similar cups E, F, by means of the metallic branches *r* and *s*, in fig. 4. The first, *r*, is a large copper wire curved twice, and the horizontal portion of which is inclosed in a glass tube; the other, *s*, is a wire of the same diameter with three bends: its central

* *Considérations sur le mouvement de la Dynamie Electrique: Bulletins de l'Académie Royale de Bruxelles*, July 10, 1847. *L'Institut* of Jan. 5, 1848.



portion is isolated in a coating of wax. These two pieces have their extremities amalgamated: they constitute a very simple rheotrope, which has proved very useful to me in a great number of researches*.

153. The reservoir C, the tube AB, and the two compartments D, D' are filled with purified mercury up to the general level 0 0' 0'' 0'''. C is then connected with the cup E by the metallic wire δ . The current then follows the mercury of the channel AB. To conduct it back from D into F, two ways are presented, the resistances of which are equal, or nearly so. One is the wire α , which terminates at the aperture f of the piece represented in figs. 2 and 3; an excellent Gourgon's multiplying rheometer G, the needles of which only make a simple oscillation in twenty-six seconds, was interposed in its development. The other way is furnished by the wire β of determined dimensions, and which is immersed at z in the mercury of the chamber D: it communicates with this liquid only by its lower point, and is isolated for a sufficient length, by means of a covering of glass. This arrangement is analogous to those which I have described in employing the method of derivations (74 to 79.).

154. The principle on which this mode of experimenting is founded is easily understood. Let us suppose that the wires α and β exert an equal resistance, and that the second terminating in z , at a distance Bz from the extremity of the channel AB, any suitable lengthening of the stem z causes the first to terminate in z' , the length Bz' being equal and symmetrical to Bz. Each of them will then afford a passage for a current of the same intensity, and that intensity will be half that which flowed off by the channel AB. Now the pair P being of small dimensions and feebly excited, whilst the wires α and β are thick and good conductors, any one of the latter, taken singly, would suffice for the discharge. If the electricity is propagated by radiation, the portions of the total current transmitted by each of the circuits will vary with the respective positions of the points of contact of the wires with the mercury. The extremity of β being constantly immersed in z , let us bring that of α into z'' . Thus placed in the prolongation of the axis of the tube, and in the course of the electric rays which issue from it in a *parallel bundle*, this wire α will be traversed by a stronger current, and the rheometric deviation will increase. The quantity of the fluid which will run off by the wire β will be proportionately diminished.

155. This inequality in the distribution of the parts of the

* *Mémoires de la Société de Physique et d'Histoire Naturelle de Genève*, vol. ix. p. 119. *Archives de l'Electricité*, vol. i. p. 74.

total current between the two circuits may be increased by shortening the arm $k\pi$, and thus approaching the point z'' to the opening v . We have even inserted the end of the wire α 0^m.025 into the channel AB, the diameter of which was larger, so that there still remained a thin ring of mercury around the wire.

156. The position of the extremity of the wire β may be changed at will, and all possible arcs be described around the point v , by the terminal surface of the wire α , giving any value to the ray of rotation $k\pi$: the deviation of the rheometer remains absolutely *constant*. This is due to the great conducting property of the mercury; for if a saturated solution of sulphate of copper is substituted for it, differences are found in the position of the index. But these differences are produced by the variations of resistance of the filaments of liquid interposed between the aperture of the tube AB and the extremities of the circuits.

157. The same constancy in the rheometric indication continues when the depths of immersion of the wires α and β are modified in a successive or simultaneous manner.

158. The result of these experiments cannot be attributed to a phenomenon of internal reflexions. Admitting a perfect cylindricity of the vessel DD', all the electric radii would have been brought, by lateral reflexions, toward the aperture v of the tube AB which occupies its centre. Although the vessel does not present exactly this geometric form, it differs so little from it that we may admit that a very small number of reflected rays reached the wire β immersed in z at 0^m.13 of the aperture.

159. I also wished to demonstrate, that the relative distribution of electricity between the two wires α and β is not due to a total reflexion of the fluid on the surface of the mercury; and with this view I constructed the apparatus represented in fig. 5. A large copper wire ttt is curved so that its extremities become parallel and not far apart: they are moreover encased in glass tubes uuu , which leave only the terminal surfaces of the wire exposed. The latter is fixed between two pieces of wood H, one of which is pressed against the other by means of a clamp x . A slit y permits of establishing this forked system on the glass plate bb , and extending it over the entire length right and left of the cylinder d . The extremity of the wire β is then introduced into the compartment D'. Experience proves that the deviation of the rheometer is in no degree affected by the diversities of position and immersion of the wires β and t , whether they are or are not accompanied by analogous changes in the place and depth of immersion of the other wire l , the extremity of α .

160. The tube AB was arranged in the centre of another, upon which was wound four metres of a copper wire covered with silk. In this wire the current of ten powerful Grove's elements was excited (139.), and rendered intermittent by means of the commutator described (122.). The rheometer was sheltered from the electro-magnetic influence of this long bobbin. The induction produced in the mercury contained in AB in no degree changed the constancy of indication of the instrument.

161. The same result was obtained by inserting into the inductor cylinder the portion of the wire α which joins the rheometer with the cup F. These two experiments confirm the conclusions detailed in § XIII.

162. Care was taken to alternate the direction of the current of the battery P in each of the preceding experiments, by placing the pieces r and s one while parallel, at another cross-ways; that is to say, by putting the cup p in communication with E, then with F, and joining the cup q with F, then with E. These changes in the direction of the current caused in it corresponding ones in the direction of the deviation of the needle of the rheometer, but did not alter the magnitude of that deviation.

163. Thus the fundamental fact is established, that electricity in the form of a current is not transmitted by rectilinear radiation. Does its propagation result from section to section in the bodies called conductors, as is admitted in the case of caloric by contact? This daily appears more probable, notwithstanding the extreme velocity with which it is effected. I propose very soon to examine the electricity of tension in the same point of view.

164. I may observe, that the conclusions of the present investigation confirm those of my second memoir. It may have been objected, that if electricity is propagated by undulations, comparable from their extreme minuteness to those which constitute light, none of the three methods which I have employed is sufficiently precise to testify for or against the interference. I shall not appeal to the probability that this latter would be shown, at least once, in the hundreds of repetitions which have been made of each experiment: it is sufficient for me to observe, that as rectilinear propagation does not exist, *interference is impossible.*