in rocks of the Chemung group. It is a fragment of a well-characterized stem, with parts of five petioles attached to it, and associated with remains of the leaves. It must have been entombed in an erect position, and is not improbably the upper part of one of the species of *Psaronius* from the same locality.

The second species, *Caulopteris antiqua*, Newberry, is of much larger size, but less perfectly preserved. It is a flattened stem on a slab of marine limestone from the Corniferous formation in the lower part of the Middle Devonian (Erian) of Ohio.

The third species, *Protopteris peregrina*, Newberry, is from the same formation with the last, and constitutes the first instance of the occurrence of the genus to which it belongs, below the Carboniferous. The specimens show the form and arrangement of the leaf-scars, the microscopic structure of the petioles, and also the arrangement of the aërial roots covering the lower part of the stem.

The fourth species is a gigantic *Rhachiopteris*, or leaf-stalk, evidently belonging to a species quite distinct from either of the above, and showing its minute structure. It is no less than four inches wide at the base. In the cellular tissue of this petiole are rounded grains similar to those regarded by Corda and Carruthers, in Carboniferous and Eocene specimens, as starch-granules.

In addition to these species, the paper described a new *Nœggerathia* (*N. gilboensis*), and noticed a remarkable specimen from Caithness, in the collection of Prof. Wyville Thomson, throwing light on the problematical *Lycopodites Vanuxemii* of America; also interesting specimens of *Psilophyton* and other genera seen by the writer in the collection of Mr. Peach of Edinburgh.

XXVIII. *Intelligence and Miscellaneous Articles.*

ON THE VELOCITY OF PROPAGATION OF ELECTRODYNAMIC EFFECTS. BY DR. HELMHOLTZ.

MANY investigators have recently been occupied with the question, how are electrodynamic effects produced at a distance,—whether (according to W. Weber) by forces of the moved electric particles themselves operating immediately on the distant point, but which depend on the velocities and accelerations of these particles in the direction of the line joining them, or (according to C. Neumann, jun.) by forces which diffuse themselves through space with a finite velocity—or whether (according to Faraday and Maxwell) they are occasioned only mediately, by a variation in the medium which fills space. It is indeed a question of prime importance for the foundations of physical science. According to the two last-mentioned views the distant electrodynamic effects of electric currents will not be produced instantaneously, but the impulse to them will be propagated through space with a finite velocity. In the theories of Neumann and Maxwell this velocity is supposed, from electrodynamic measurements, to be nearly equal to that of light. Nevertheless the discussion lately published by me*, of electrodynamic theories, showed that, according to what is accepted respecting the capability

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* *Journal für reine und angew. Mathematik*, vol. lxxii. Berlin.

of the air for magnetic and dielectric polarization, other values of this velocity of propagation will agree with the rest of the facts.

Meanwhile a long series of experiments have now been published by P. Blaserna*, from which he concludes that the propagation, at least of the inducing effects of electrical currents, in the air proceeds with a very moderate velocity. According to his experiments with induction-discharges from open circuits (which he considers the most reliable), this velocity in air amounts to only 550 metres, in gum-lac to not more than 330 metres, and is consequently, in the latter case, about equal to the velocity of sound in air. From his experiments with a closed induction circuit he deduced much smaller velocities; yet he has himself acknowledged that the reaction of the induced upon the inducing spiral made the interpretation of the result of his experiments doubtful.

It is to be remarked that in these experiments the distances between the inducing and the induced spiral were very small, varying between 1 and 3 centims.; besides, the two spirals were wound flat. The time corresponding to the propagation through the interval of 2 centims. amounted, in the experiments with open induction, to only $\frac{1}{22000}$ of a second. Neglecting the irregularities occasioned in delicate measurements of time, by the contact between solid metals being always broken by successive leaps, it appeared to me doubtful whether such minute differences of time might not be conditional on the variable duration of the spark at the place of interruption of the inducing current. In my experiments hereinafter described, I convinced myself that, even in much more unfavourable conditions than were present in M. Blaserna's experiments, the interruption-spark may have a duration of $\frac{1}{46000}$ of a second; MM. Lucas and Cazin recently found $\frac{1}{80000}$ for larger electrical batteries with 2·292 millims. striking-distance, $\frac{1}{15000}$ with 5 millims. striking-distance†. While M. Blaserna employed several Bunsen's elements for the production of the current, I used only one Daniell's element; and while his spirals contained close-pressed coils of wire, mine had a very large periphery and few coils, and was therefore much less calculated to produce a strong extra-current; and yet the duration of the spark reached the quantity stated. Now, when we consider that, as is well known, the approach of a second spiral, in which an induction-current is produced, seriously diminishes the intensity of the spark, because the induced current counteracts the inducing, and that M. Blaserna's spirals were always proportionally very near each other, the doubt occurs whether the longer duration of the spark did not produce an apparent retardation of the operation with a greater distance of the spirals.

As I had for a long time been occupied with experiments on the course of electric currents of very short duration, and had had apparatus manufactured for this purpose, it seemed to me before all things necessary to prove whether the velocity of propagation of electrodynamic effects has really so low a value as M. Blaserna has concluded.

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* *Giornale di Scienze Naturale ed Economiche*, vol. vi. 1870. Palermo.

† M. J. Bernstein, in a close-coiled spiral of fine wire, $\frac{1}{20000}$ (Poggendorff's *Annalen*, vol. cxlii. p. 65).

The experiments I have hitherto carried out refer to the propagation through air only. The very note-worthy influence of electric insulators shown in the Italian physicist's experiments required still further study. That also in insulators electrical movements of very brief duration occur which in some circumstances may well operate inductively on their vicinity, similarly to the excitement of magnetism in iron, appears very probable from the influence which such media have as dielectrics. For the time I did not prosecute this part of the inquiry. The interruption-apparatus used by me for the conduction of the currents consisted of a heavy and solid iron pendulum, the support of which was let into the wall, and which was always let fall from the same height. At the lower end it had two projections overlaid with plates of agate, which at the moment when the pendulum passed through the position of equilibrium struck the steel ends of two light little levers, by the motion of which two current-conductions were interrupted. One of these levers rested on a fixed support, the other on a slide which could be shifted by means of a micrometer-screw, so that the stroke on this moveable lever resulted, by any small period chosen, now sooner, now later than that on the other. The interval of time was calculated from the micrometrically measured displacement of the striking-point and from the velocity of the fall of the pendulum; the latter was calculated from the time and arc of oscillation of the pendulum. A division-mark on the head of the micrometer-screw corresponded to $\frac{1}{231170}$ of a second. With present arrangements it would have been useless to take more accurate readings, on account of the inequality of duration of the spark.

As it was important to have the distances between the spirals as great as possible, I gave to them the form of rings of about 80 centims. diameter. The inducing spiral had only $12\frac{1}{4}$ turns of copper wire 1 millim. thick, covered with $\frac{1}{2}$ millim. thickness of gutta percha. The induced spiral, on the contrary, had 560 turns of copper wire, spun round with silk, of $\frac{1}{2}$ millim. diameter. This spiral could be placed at a distance of 170 centims. from the inducing one without the inducing effect ceasing to be evident. But even the nearest distance to which the two coils were brought amounted still to 34 centims., in order to make the reaction of the induced on the inducing current imperceptibly small—which, so far as could be judged by time-measuring experiments, was accomplished.

In the experiments the following was the arrangement adopted:—

The circuit of the inducing current contained a Daniell's element, the smaller spiral, and the first-struck place of interruption. By the stroke the current was stopped; and its interruption operated inducingly on the alone remaining second circuit. This was not perfectly closed, but its ends led to a condenser (after Kohlrausch) with two gilt metal disks, which were brought to $\frac{3}{8}$ millim. distance from one another. This circuit consisted of the larger wire spiral, one end of which was connected immediately with the fixed plate of the condenser, in communication with the earth. The other end communicated, through the second interruption-lever, with the insulated moveable plate of the condenser. The electricity put in motion by induction thus flowed into the condenser up to the moment when the second interruption-place was struck. Thenceforth the moveable plate of the condenser was insulated, and retained the charge it had received.

Its quantity and kind were then measured by an electrometer constructed on Sir W. Thomson's principle, after removing the plates of the condenser one from the other.

The process which was thus submitted to observation is therefore the series of electrical oscillations remaining, after the interruption of the primary current, in the induced spiral connected with the condenser. Since these oscillations proceed from one plate of the condenser to the other in an unbroken conduction without any issue of sparks, they pass much more regularly and are much more numerous than those observed in the connecting arcs of Leyden batteries. The length of my micrometer permitted the reading-off of 35 positive and the same number of negative phases when the distance between the spirals was 34 centims. The time of an entire oscillation (positive and negative together) amounted to $\frac{1}{2811}$ of a second; the total duration of the 35 oscillations observed was therefore $\frac{1}{80}$ of a second; and when I was obliged to break off the observations, the oscillations were still by no means so feeble that, with a greater play of the micrometer, a long series of them could not have been observed.

The result of experiments in which I varied the distance of the condenser-plates, and consequently the electric capacity of the condenser, was, that the duration of the oscillations was but very little affected by the capacity of the condenser. I have, in a previous communication*, pointed out that even a close-wound spiral itself operates as a condenser, since the turns at one end become charged positively, and those at the other end negatively, and are only separated from the less strongly charged positive or negative layers in their vicinity by the very thin insulating layers of silk; hence an electric coating is accumulated on both sides of the insulating layer. Since the lessening of the capacity of the condenser has so little influence on the duration of the oscillation, it follows that the condensatory capacity of the spiral must have considerably exceeded that of the condenser.

In order to discover the possible retardation of the distant effect, it was necessary to discover a conspicuous point in the course of the electric oscillations that could be very sharply determined. The first moment of the commencement was unsuitable, since, apparently, the current commences with a velocity rising from zero, and this only gradually increases; hence the strength of the current at first increases, at the most, proportionally to the square of the time. The reason of this is to be sought in the fact that the primary current also, during the time of the spark, vanishes only gradually, and hence the induced electromotive force in the secondary circuit is by no means suddenly developed there in perfection, but itself first

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* *Verhandlungen des naturh. med. Vereins zu Heidelberg,* April 30, 1869. In the earlier observations, with the aid of the current-testing leg of a frog, I had verified as many as 45 oscillations, the total duration of which amounted to $\frac{1}{50}$ of a second.

grows continuously. But in our case the duration of the spark is about equal to the tenth part of the whole period of an oscillation, and therefore by no means inconsiderable [*]. Its average length is determined by comparing the time between the stroke of the pendulum which breaks the primary conduction and the first zero-point of the current, with the time between the successive zero-points. The former is longer, because, besides the period of half an oscillation, it comprises also the duration of the spark; and the amount of this can be approximately found by means of such a comparison.

On the other hand, the successive zero-points of the current can be very sharply determined, even with the more distant position of the secondary spiral. As, even with such feeble electromotive forces and spirals of so few turns as I used in the primary circuit, the duration of the spark is never constant (the reason of which is probably to be sought in the throwing-off of platinum particles by the sparks), the deflections about the division-mark corresponding to zero are, even with a good arrangement of the apparatus, sometimes positive, sometimes negative; on the contrary, at the preceding and succeeding divisions they are either exclusively or preponderantly in one definite direction.

With the arrangement described, at which I had arrived after many trials, it was shown that *the greater distance of the two spirals* (136 *centims.*) *did not alter the situation of the zero-point of the induced current by one division of the micrometer—that is to say, by* $\frac{1}{231170}$ *of a second. If, then, the inducing effects are actually propagated with a definable velocity, this must be greater than* 314,400 *metres, or about* 42·4 *geographical miles* [about 195 British statute miles] *in a second.*

I have hit upon preparations for a further refinement of these measurements. How far this can be carried, will, it appears to me, depend chiefly on how far the spark at the place of interruption can be reduced when a very small resistance and very small electromotive force are given to the primary circuit, and when the turns of wire forming it are removed as far as possible from one another.—*Monatsber. d. Kön. Preuss. Akad. Berlin,* May 1871, pp. 292–298.

ON A NATIVE SULPHIDE OF ANTIMONY FROM NEW ZEALAND. BY M. M. PATTISON MUIR, F.C.S., STUDENT IN THE LABORATORY OF THE ANDERSONIAN UNIVERSITY, GLASGOW[†].

In the gold mines at the Thames (New Zealand) there are found tolerably large quantities of grey antimony ore or stibnite, associated with the quartz and other rocks of the older series from which gold is extracted. The analysis of a sample of this stibnite, which I obtained about a year ago, I have now the honour to lay before the Association.

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[*] The relatively slow decrease of intensity of the primary current during the spark is also evidently the reason that, as I previously found, in an induced spiral with more than 7000 electric oscillations in a second the latter turned out so feeble: the interruption is then not sufficiently sudden for the brief duration of the oscillation.

[†] Communicated by Prof. T. E. Thorpe, having been read at the Meeting of the British Association held at Edinburgh, August 1871.