Extracts from the papers of Sir Charles Wheatstone

WHEATSTONE 3: Series of notes describing experiments to investigate the nature of electricity, magnetism and thermodynamics, [1834-1855]

K/PP107/3/2/72-175

[1859-1871]

Notes relating to the development of the dynamo including designs with plane paper models describing armature rotation; list of applications of magneto-electric devices and summary of the basic principles of their operation; lists of proposed experiments involving electromagnets; description by Charles Wheatstone of an experiment into electrical induction outlined by William Robert Grove (1811-1896), natural philosopher, judge and designer of the Grove Cell, in an article published in *Philosophical Magazine*, 1868; experiments on electrical attraction and repulsion, the differential inductometer and note on the theoretical explanation for induction; description of field experiments involving telegraphic communication, 1859-1871; experiments designed to test conductivity within substances; summaries of some basic observations regarding electrical phenomena including electrical potential, electrical discharge and voltaic batteries.

The Papers of Charles Wheatstone

K/PP107/3/2 - Papers relating to electricity, magnetism and thermodynamics

K/PP107/3/2/74
Diagram of a four coil telegraph generator, [1859-1871].

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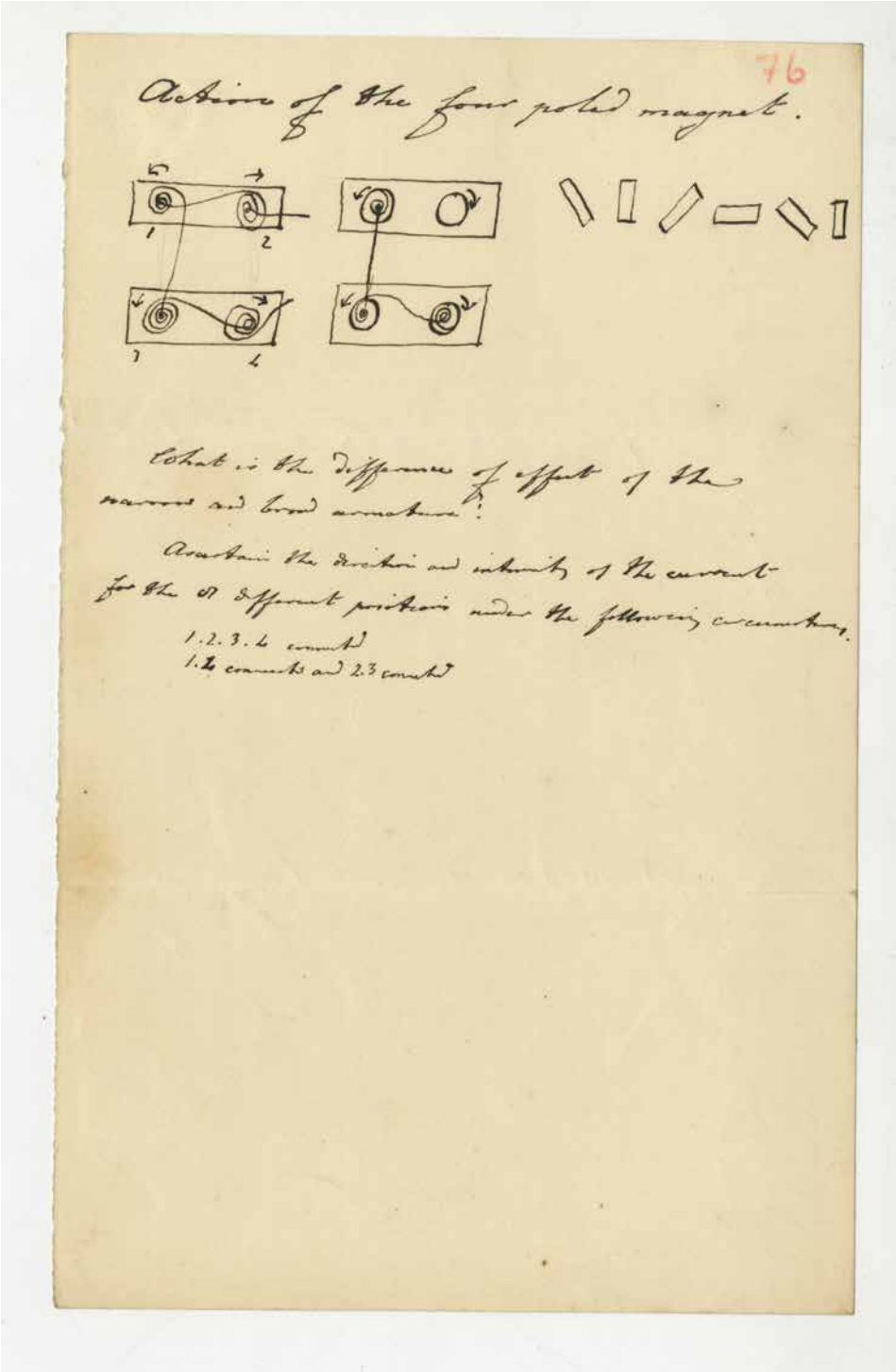

76

Action of the four poled magnet.

What is the difference of effect of the narrow and broad armature?

Ascertain the direction and intensity of the current for the 10 different positions under the following connections.

1.2.3.4 connected

1.4 connects and 2.3 connected

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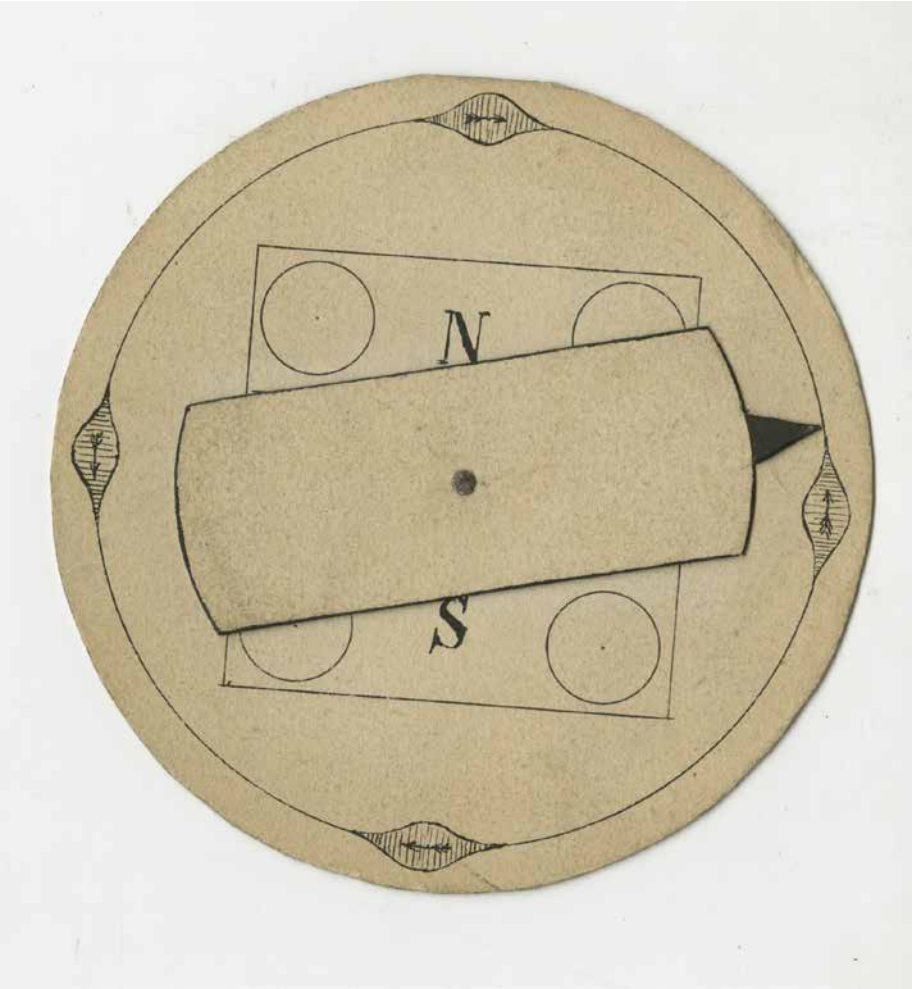

K/PP107/3/2/79

Diagrammatic model of a four coil generator used for the telegraph with explanatory notes on reverse, by John Matthias Augustus Stroh (1828-1914), telegraph engineer and inventor, [1859-1871], page 1.

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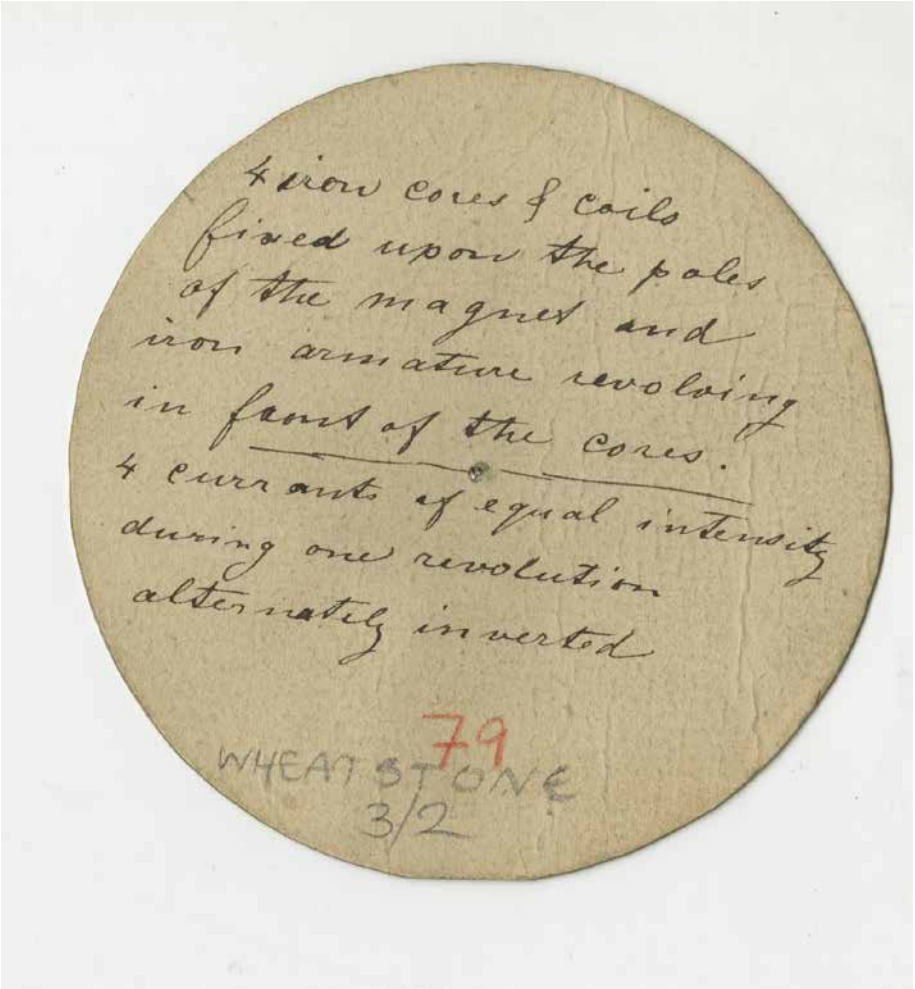

4 iron cores & coils
fixed upon the poles
of the magnet and
iron armature revolving
in front of the cores.

4 currents of equal intensity
during one revolution
alternately inverted

79

WHEATSTONE
3/2

K/PP107/3/2/79

Diagrammatic model of a four coil generator used for the telegraph with explanatory notes on reverse, by John Matthias Augustus Stroh (1828-1914), telegraph engineer and inventor, [1859-1871], page 2.

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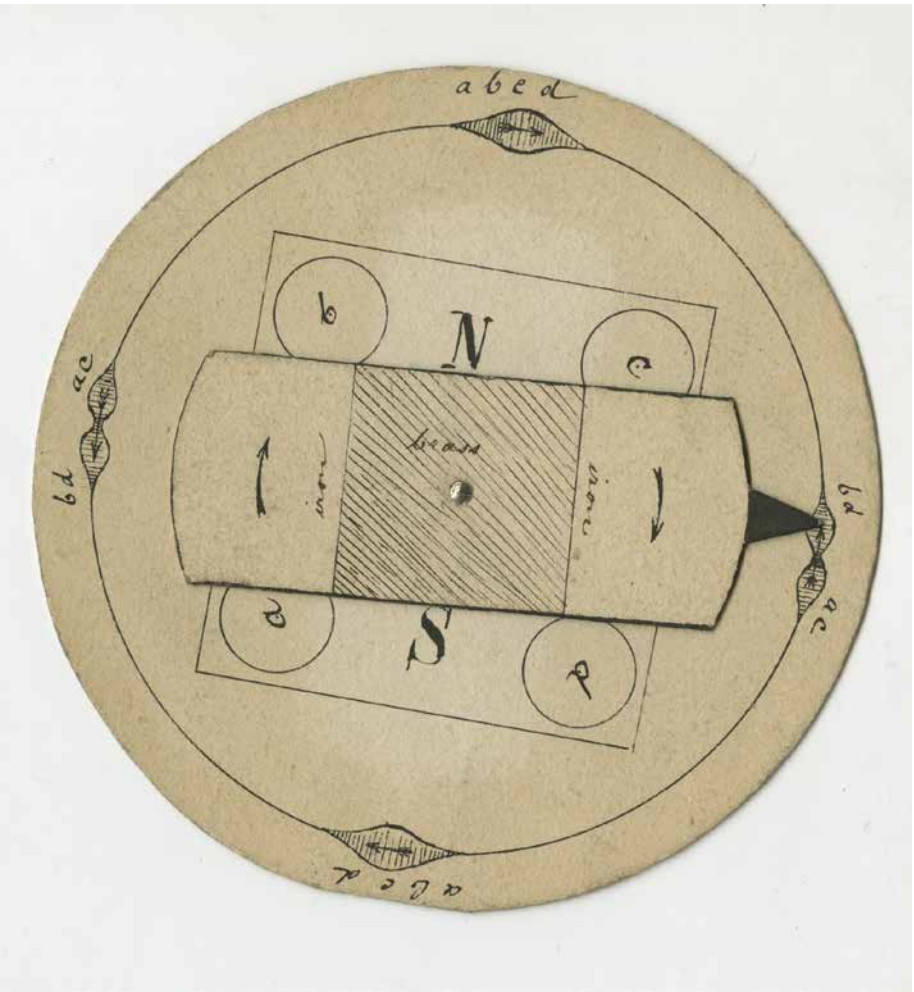

K/PP107/3/2/80
Diagrammatic model of a four coil generator used for the telegraph with explanatory notes on reverse, by John Matthias Augustus Stroh (1828-1914), telegraph engineer and inventor, page 1.

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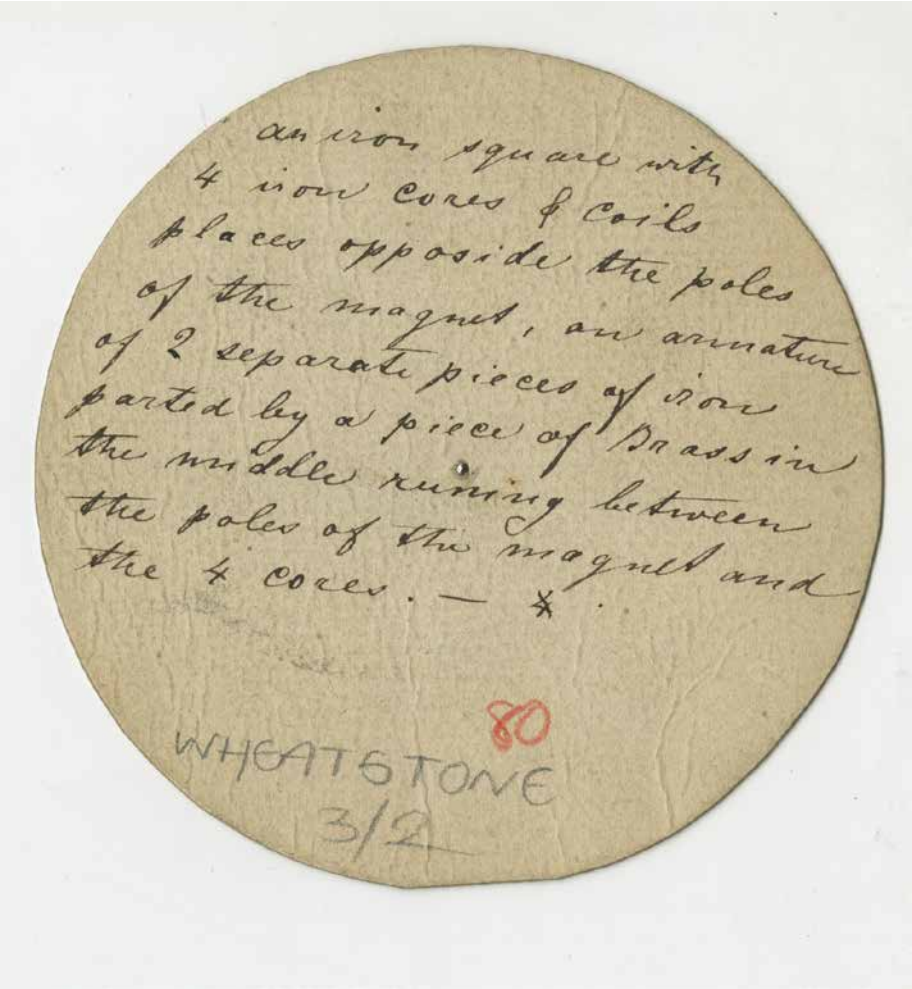

an iron square with
4 iron cores & coils
places opposite the poles
of the magnet, an armature
of 2 separate pieces of iron
parted by a piece of Brass in
the middle running between
the poles of the magnet and
the 4 cores. — *

80

WHEATSTONE
3/2

K/PP107/3/2/80

Diagrammatic model of a four coil generator used for the telegraph with explanatory notes on reverse, by John Matthias Augustus Stroh (1828-1914), telegraph engineer and inventor, page 2.

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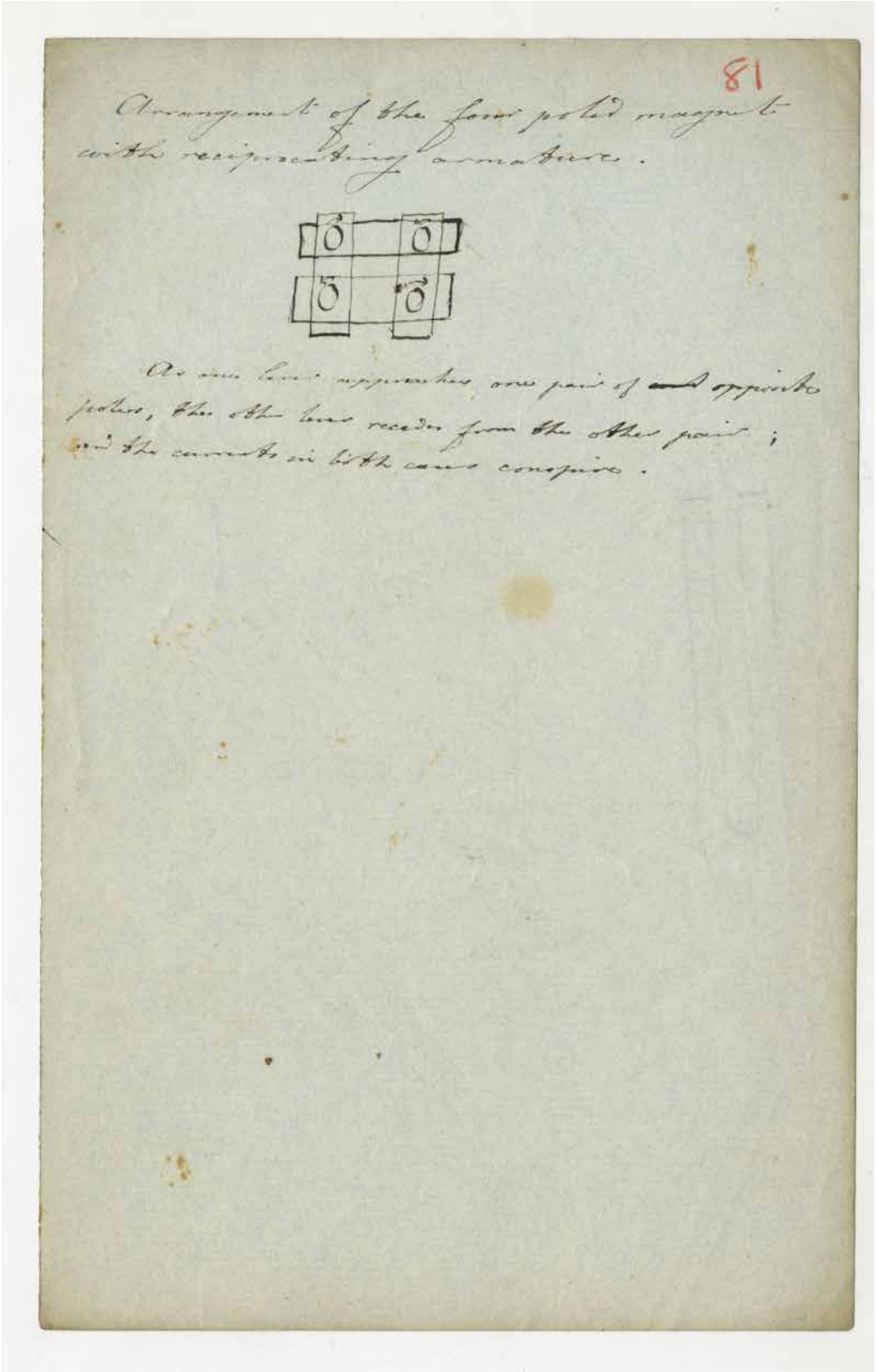

81

Arrangement of the four poled magnet with reciprocating armature.

As one bar approaches one pair of opposite poles, the other bar recedes from the other pair; and the currents in both cases conspire.

K/PP107/3/2/81

Notes and rough diagram relating to the development of the four coil telegraph generator, [1859-1871].

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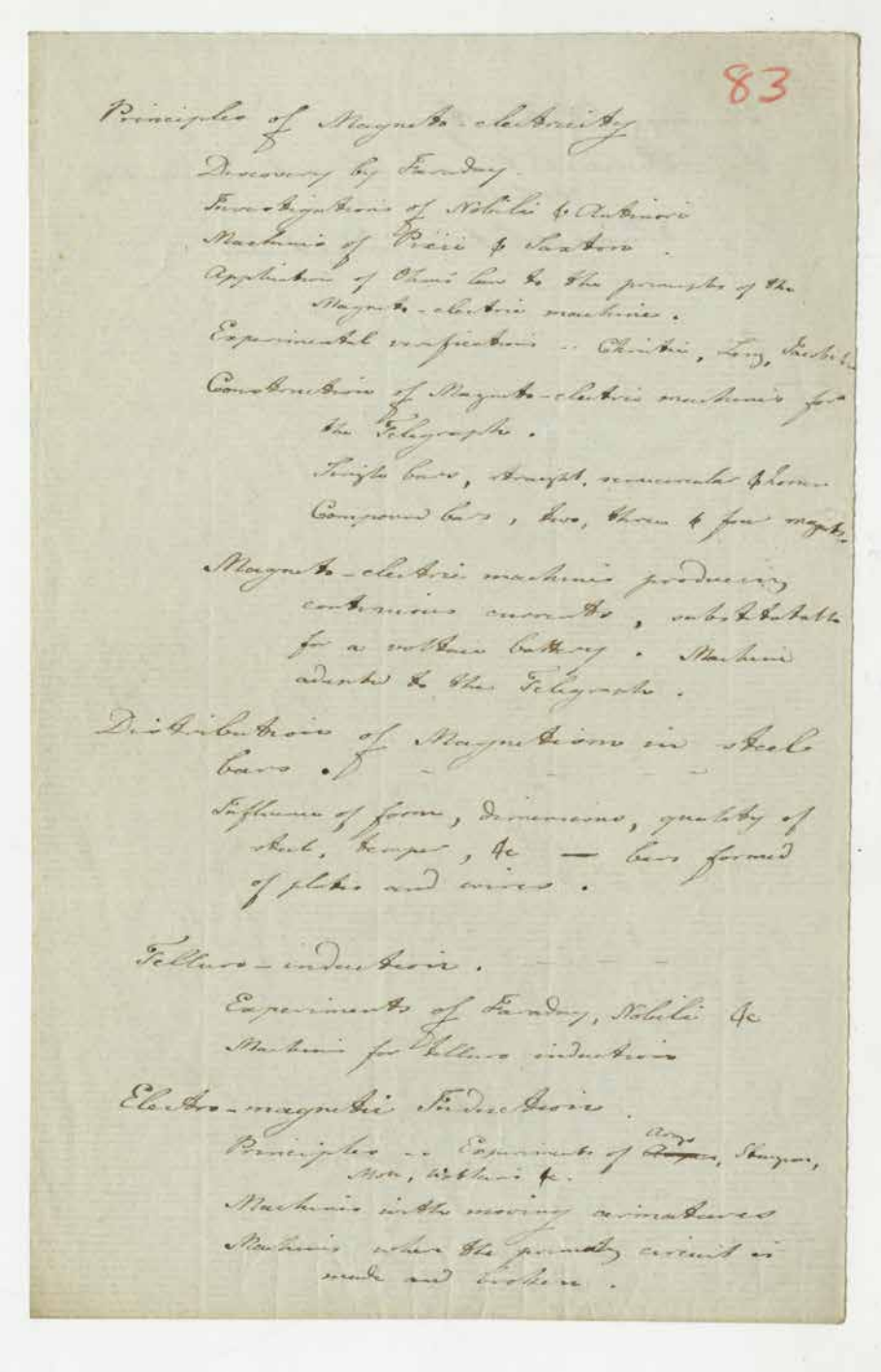

83

Principles of Magneto-electricity

Discovery by Faraday.

Investigations of Nobili & Antinori

Machines of Pixii & Saxton.

Application of Ohm's law to the principles of the Magneto-electric machines.

Experimental verifications — Christie, Lenz, Jacobi

Construction of Magneto-electric machines for the Telegraph.

Single bars, straight, semicircular & horse-shoe

Compound bars, two, three & four magnets

Magneto-electric machines producing continuous currents, substitutable for a voltaic battery. Machines adapted to the Telegraph.

Distribution of Magnetism in steel bars.

Influence of form, dimensions, quality of steel, temper, &c — bars formed of plates and wires.

Voltaic-induction.

Experiments of Faraday, Nobili &c

Machines for Voltaic induction

Electro-magnetic Induction.

Principles — Experiments of Arago, Stenger, Moll, Weber &c.

Machines with the moving armatures

Machines where the primary current is made and broken.

List of significant developments relating to the 'Principles of Magneto-electricity' from the discovery by Michael Faraday (1791-1867), natural philosopher, to thermoelectricity, [1859-1871], page 1.

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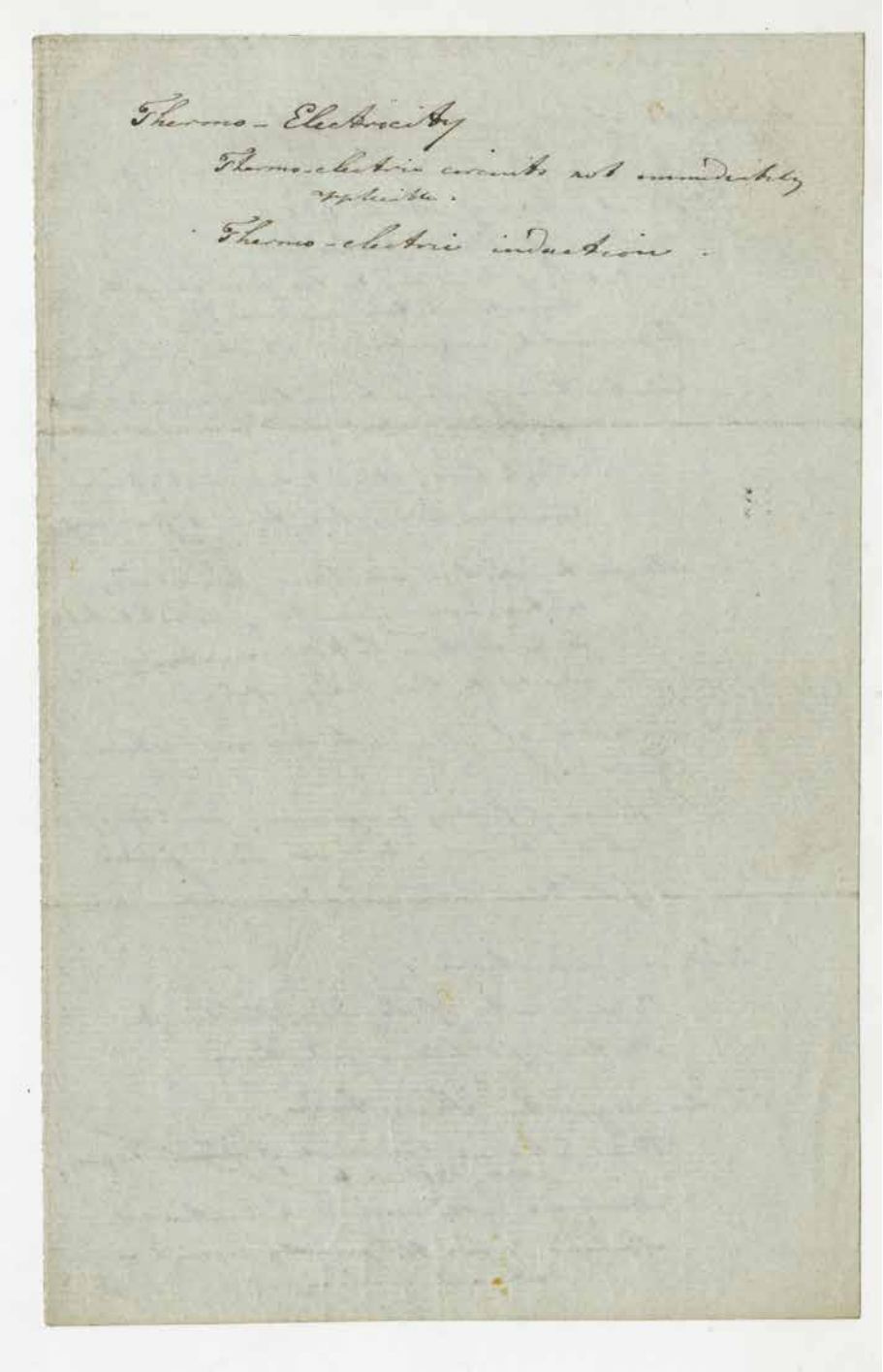

Thermo-Electricity

Thermo-electric currents not immediately applicable.

Thermo-electric induction.

K/PP107/3/2/83

List of significant developments relating to the 'Principles of Magneto-electricity' from the discovery by Michael Faraday (1791-1867), natural philosopher, to thermoelectricity, [1859-1871], page 2.

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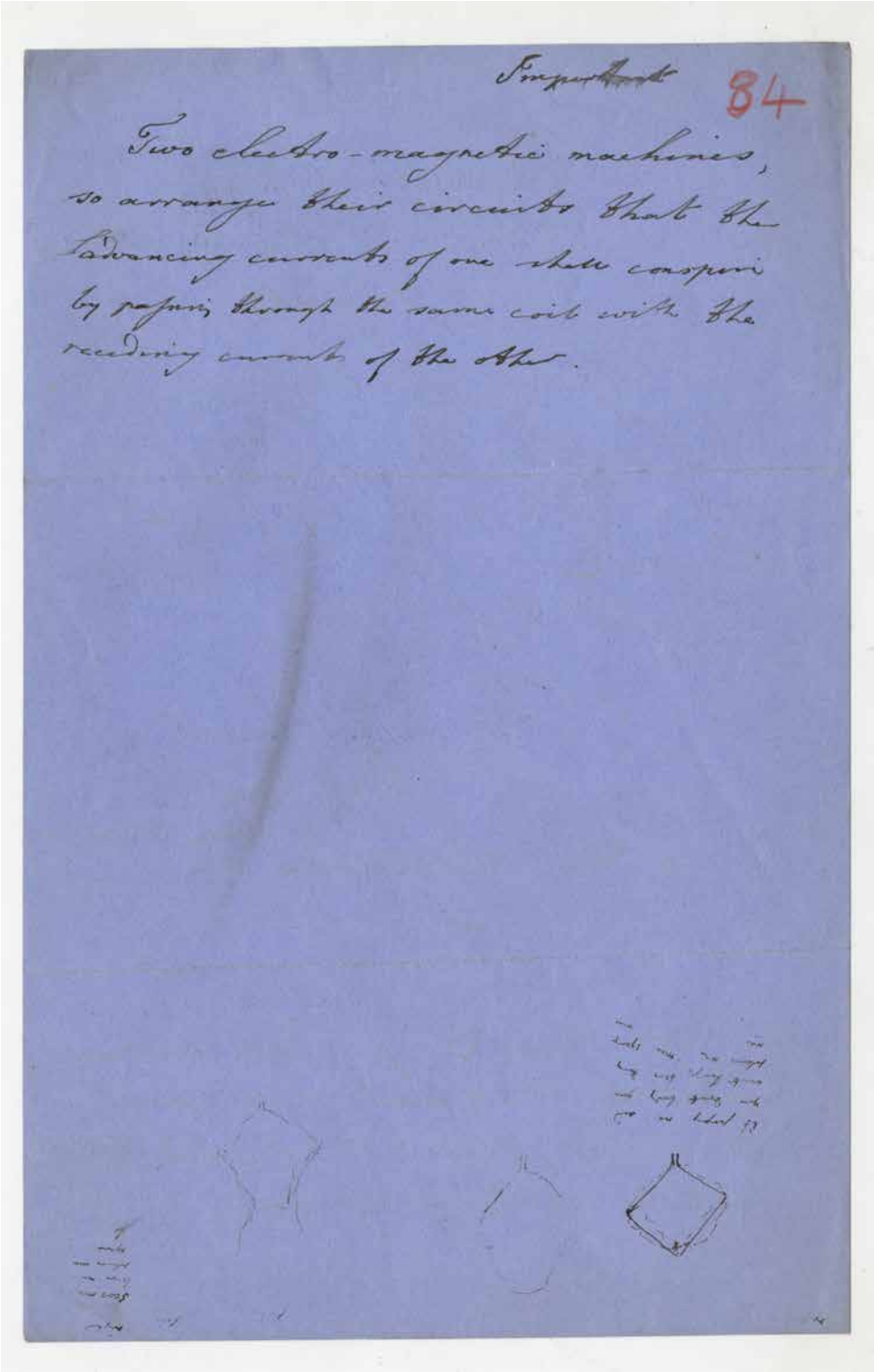


Important 84

Two electro-magnetic machines, so arrange their circuits that the advancing currents of one shall coexist by passing through the same coil with the receding currents of the other.

K/PP107/3/2/84a

Note, marked important, relating to the arrangement of two electromagnetic machines and their circuits, on reverse of a letter from the Meteorological Office, [1871], page 1.

The Papers of Charles Wheatstone

K/PP107/3/2 - Papers relating to electricity, magnetism and thermodynamics

(No. 9.)

Meteorological Office,
116, Victoria Street, London, S.W.

10 August 1871

Sir,

You are requested to attend a Meeting of the Meteorological Committee at this Office, on Monday, the 14th Instant at the hour of 3 P.M.

Your obedient Servant,

Henry Lynde
For the Director

To Sir Chas. Wheatstone FRS

Business to be considered.

Mr. Scott's Report of Inspection.
Quarterly Statement of Accounts.
Monthly Accounts. Colonel Sykes' Motion on Storm Signals.

K/PP107/3/2/84

Note, marked important, relating to the arrangement of two electromagnetic machines and their circuits, on reverse of a letter from the Meteorological Office, 1871 Aug 10, page 2.

From the author

91

From the PHILOSOPHICAL MAGAZINE for March 1868.

AN EXPERIMENT IN MAGNETO-ELECTRIC INDUCTION.

BY

W. R. GROVE, F.R.S. ETC.

SHORTLY after the publication of Mr. Wilde's experiments on magneto-electric induction, it occurred to me that some of the ordinary effects of the Ruhmkorff-coil might be produced by applying to it a magneto-electric machine. I tried an ordinary medical machine with a small coil made by Mr. Apps, of $3\frac{1}{2}$ inches length by 2 inches diameter, and having about $\frac{3}{4}$ of a mile of fine secondary wire.

The result was very unexpected. The terminals of the magneto-electric coils being connected with the primary coil of the Ruhmkorff, and the contact-breaker being kept closed so as to make a completed circuit of the primary wire (a condition which would have appeared *à priori* essential to success), no effect was produced; while if the circuit was interrupted by keeping the contact-breaker open, sparks of 0·3 of an inch passed between the terminals of the secondary coil of the Ruhmkorff, and vacuum-tubes were readily illuminated. Here there was in effect no pri-

Offprint of paper entitled 'An Experiment in Magneto-electric induction' by William Robert Grove (1811-1896), natural philosopher, published in the *Philosophical Magazine*, March 1868, sent to Wheatstone from the author, 1868 Mar, page 1.

mary coil, no metallic connexion for the primary current; and yet a notable effect was produced.

I did not at the time publish this experiment further than by communicating it to a few friends, hoping to be able to find a satisfactory explanation of it. All I have observed since is that the effect is dependent upon the condenser; for when that is removed no result is produced.

It would appear, then, to depend on an electrical wave or impulse shot, so to speak, into the uncompleted primary coil, similar to the wave which will deflect in succession magnetic needles placed at different distances on a telegraphic cable, without the current passing through the whole length of wire, as shown in the experiments of Mr. Latimer Clark and others. But why there should be no effect, or an inappreciable one, when the primary circuit is completed, the current being alternated by the rotation of the coils of the magneto-electric machine, I cannot satisfactorily explain.

K/PP107/3/2/91
Offprint of paper entitled 'An Experiment in Magneto-electric induction' by William Robert Grove (1811-1896), natural philosopher, published in the *Philosophical Magazine*, March 1868, sent to Wheatstone from the author, 1868 Mar, page 2.

The Papers of Charles Wheatstone

K/PP107/3/2 - Papers relating to electricity, magnetism and thermodynamics

92

Grove's Experiment

This perfectly succeeded with the 3 magnet exploder. The spark in the secondary coil was about 3/00th of an inch, and the small vacuum tube shewed well. For this instrument the currents are alternately inverted and interrupted and pass through the circuit at the moment of greatest intensity.

An admiring magnetic commutator with Appi's machine produced no effect though the currents were alternately inverted; but there was no interruption in the magnetic circuit as it had only one magnet.

The Commutator of an Arbonvil was employed having alternately inverted currents and two magnets. A paper disc which interrupts the circuit was employed; But this no effect

A Battery of 6 Bunsen cells was employed with Appi's machine. but it did not succeed; nor when the current was alternately inverted.

—

With the 3 magnet Exploder Grove's effect did not take place when the Interrupter was removed; though the Royal Magnetic Telegraph worked equally well under both circumstances.

—

With the self exciting Magnetic Machine, when Appi's machine was placed in the circuit a brilliant but small continuous spark was produced in the secondary circuit when the interrupter was completely closed.

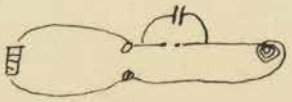
K/PP107/3/2/92

Notes describing an experiment by William Robert Grove (1811-1896), natural philosopher and judge, [1868].

94

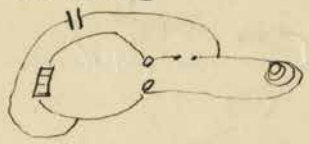
Condenser applied to the Inductorium.

The way the condenser is usually applied is thus

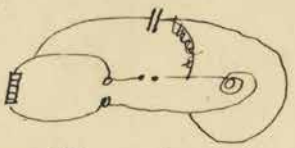


The extra current which is produced on breaking the circuit is in the opposite direction; it cannot circulate in the main circuit on account of the break but it proceeds into the branch wire and charges the plates of the condenser; when the circuit is again completed the electricity condensed on the plates returns as a current in the opposite direction which circulates through the main circuit in the same direction as the original current.

When the condenser is placed thus so that its terminals shall include the battery resistance the effect is nearly the same



But when it is placed thus a very small effect indeed is produced



In this case the extra current has to return through the primary coil and opposite direction to the original coil before it arrives at the condenser plates

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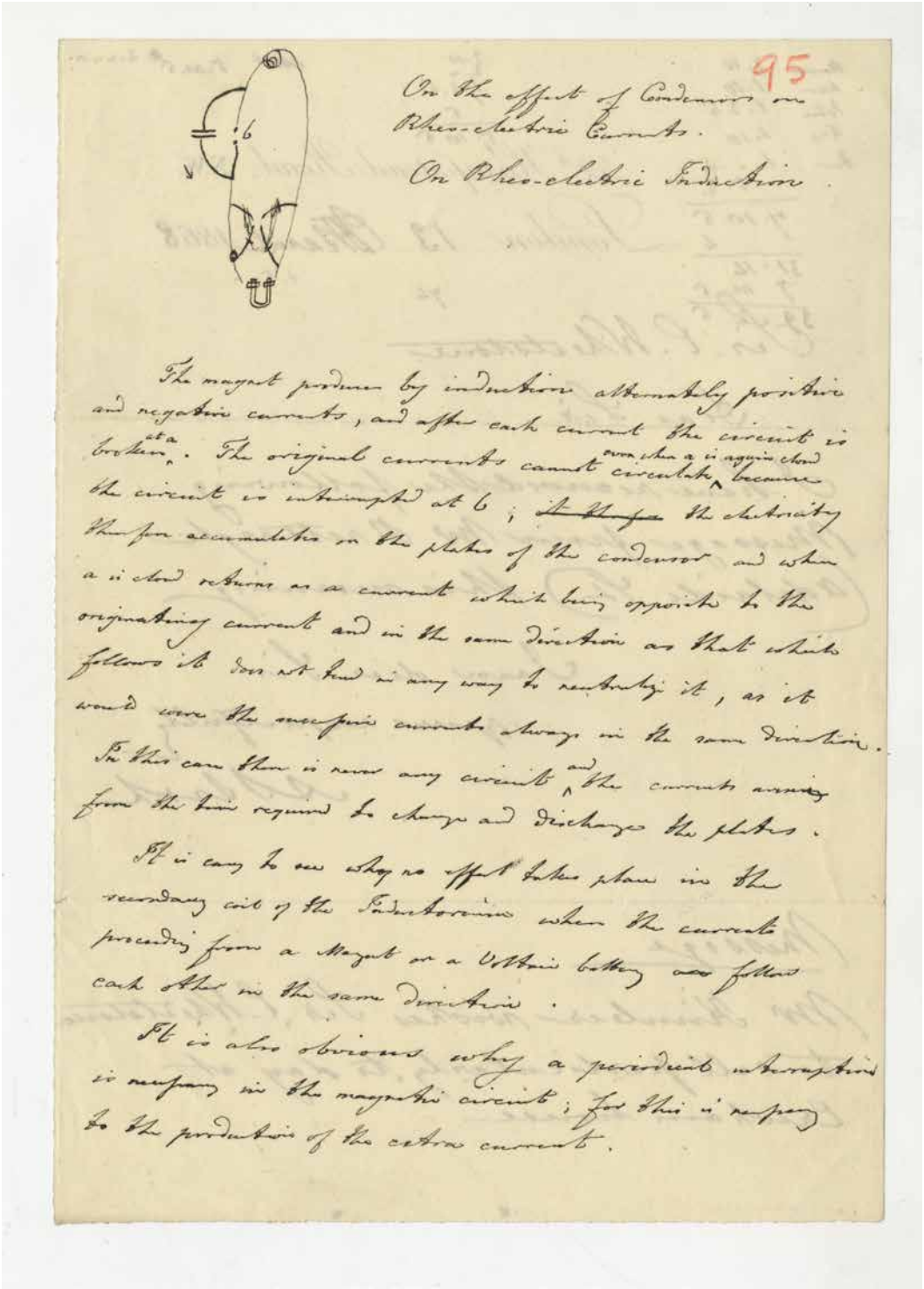

95

On the effect of Condensers on Rheo-electric Currents.

On Rheo-electric Induction.

The magnet produces by induction alternately positive and negative currents, and after each current the circuit is broken at a. The original currents cannot even when a is again closed circulate, because the circuit is interrupted at b; ~~it therefore~~ the electricity therefore accumulates on the plates of the condensers and when a is closed returns as a current which being opposite to the originating current and in the same direction as that which follows it does not tend in any way to neutralize it, as it would were the successive currents always in the same direction. In this case there is never any circuit, and the currents arising from the time required to charge and discharge the plates.

It is easy to see why no effect takes place in the secondary coil of the Inductorium when the currents proceeding from a Magnet or a Voltaic battery are followed each other in the same direction.

It is also obvious why a periodical interruption is necessary in the magnetic circuit; for this is necessary to the production of the extra current.

K/PP107/3/2/95

Notes on the effect of condensers, or capacitors, on electric currents, on reverse of letter from John Matthias Augustus Stroh (1828-1914), telegraph engineer and inventor, regarding a message from William Brettargh, Secretary, Universal Private Telegraph Company about a Mr Kimber [possibly from Kimber & Ellis, solicitors], 1868, page 1.

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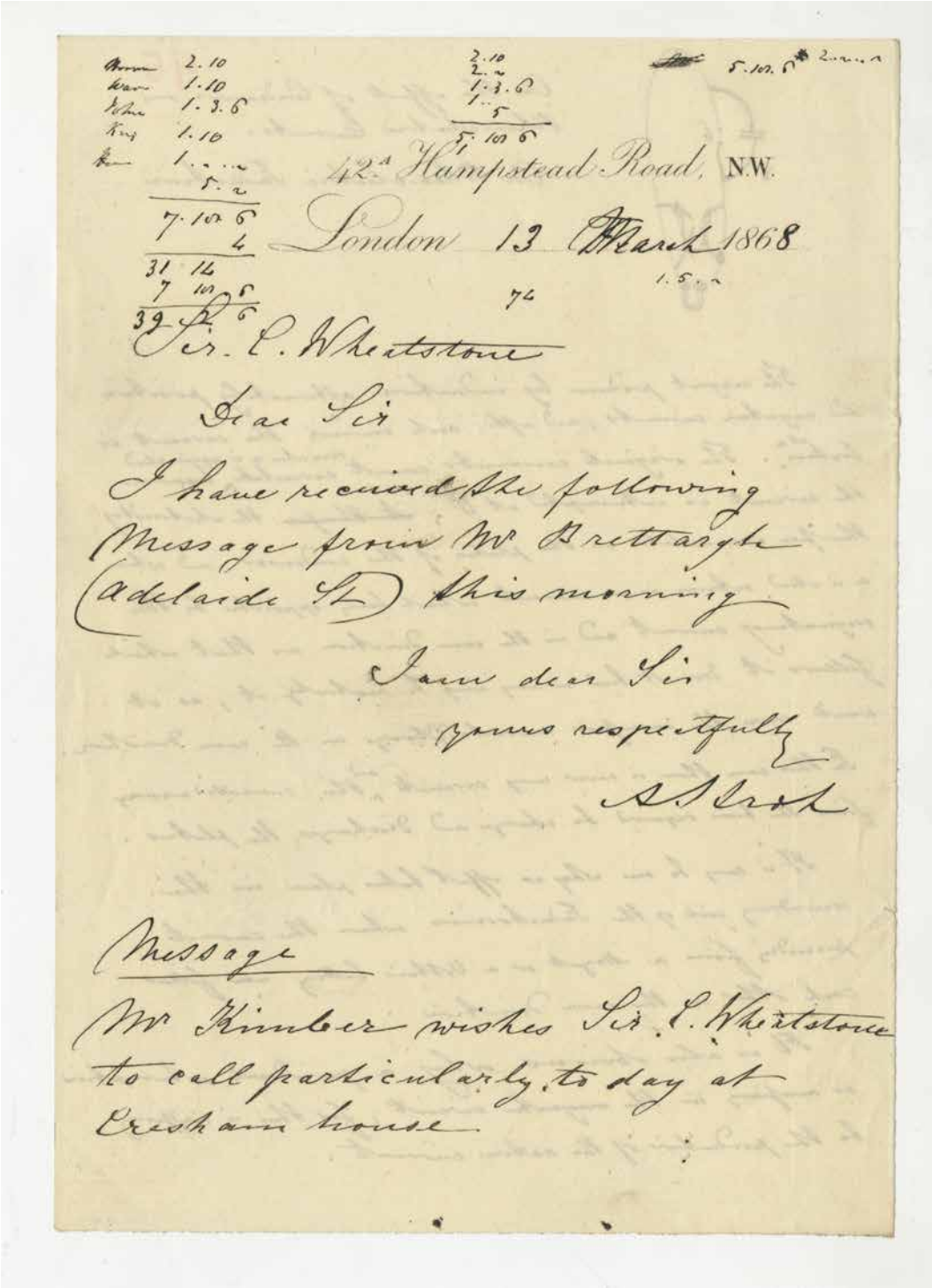

42A Hampstead Road, N.W.

London 13 March 1868

Sir C. Wheatstone

Dear Sir

I have received the following Message from Mr Brettargh (Adelaide St) this morning

I am dear Sir
yours respectfully
A Stroh

Message

Mr Kimber wishes Sir C. Wheatstone to call particularly to day at Cresham house

K/PP107/3/2/95

Notes on the effect of condensers, or capacitors, on electric currents, on reverse of letter from John Matthias Augustus Stroh (1828-1914), telegraph engineer and inventor, regarding a message from William Brettargh, Secretary, Universal Private Telegraph Company about a Mr Kimber [possibly from Kimber & Ellis, solicitors], 1868 Mar 13, page 2.

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100

The Franklinian theory of plus and minus electricity is sufficient to account for the most obvious fact of induction, viz. that is of the presentation of opposite effects at the two extremities of a conductor in presence of an over or undercharged body. Matter attracts electricity, and electricity repels itself; therefore when the inducing body is overcharged its electricity repels the electricity in the conductor to the remote end which then shows positive signs while the near end shows negative signs; and when it is undercharged its matter attracts the electricity in the conductor leaving the remote end undercharged which consequently shows negative signs while the near end exhibits positive signs. This theory affords at least a plausible explanation of the phenomena of the Leyden jar, the Condenser and the Electrophorus; but the ~~phenomena~~ those of attraction and repulsion renders an addition to this theory in order to explain them necessary, and subsequent writers were obliged to supplement ~~the theory~~ it by the assumption that matter repels itself; an assumption which it is not easy to reconcile with the known fact of the universal attraction of all bodies towards each other

~~The experiments above recorded seem to be totally irreconcilable, even with the improved Franklinian theory, and I cannot conceive in what manner the neutral points can be explained by it.~~

K/PP107/3/2/100a

Notes on the theory of plus and minus electricity proposed by Benjamin Franklin (1706-1790), US President, [1859-1871], page 1.

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~~The production~~

The conductor being under ~~under~~ induction if it be made to communicate with the ground the remote end loses all electric signs, but if the inducing body be removed either nearer or farther electric signs but of opposite character reappear. This the Franklinian theory is quite competent to explain, and I need not ~~explain~~ say in what manner.

in one case in consequence of its free electricity passing off to the ground, in the other because free electricity enters it from the same source

K/PP107/3/2/100

Notes on the theory of plus and minus electricity proposed by Benjamin Franklin (1706-1790), US President, [1859-1871], pages 2 and 3.

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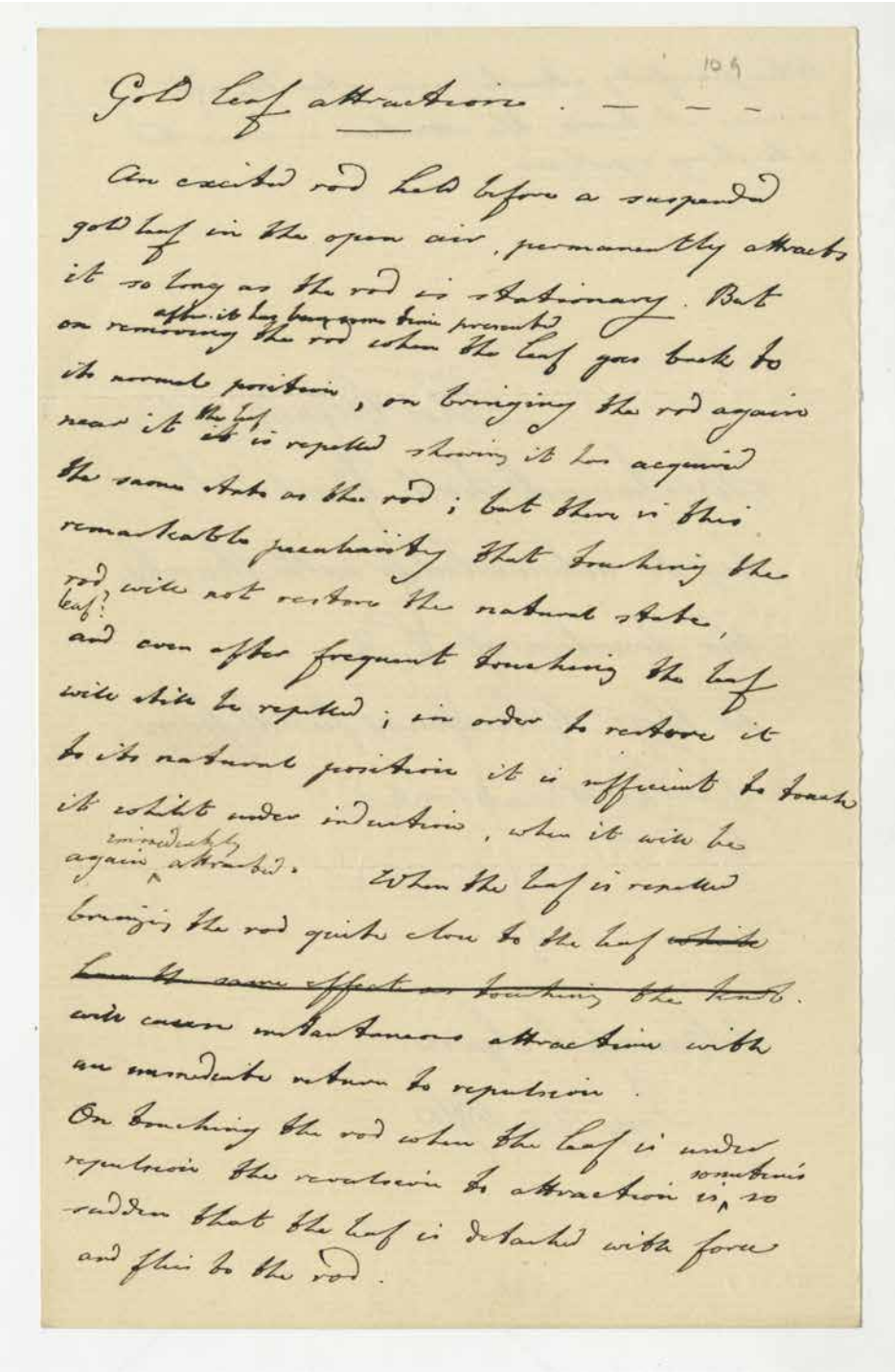

109

Gold leaf attraction. — — —

An excited rod held before a suspended gold leaf in the open air, permanently attracts it so long as the rod is stationary. But on removing the rod after it has been in this position when the leaf goes back to its normal position, on bringing the rod again near it the leaf is repelled showing it has acquired the same state as the rod; but there is this remarkable peculiarity that touching the rod with the leaf will not restore the natural state, and even after frequent touching the leaf will still be repelled; in order to restore it to its natural position it is sufficient to touch it whilst under induction, when it will be again immediately attracted. When the leaf is repelled bringing the rod quite close to the leaf ~~which has an effect on touching the rod~~ will cause instantaneous attraction with an immediate return to repulsion.

On touching the rod when the leaf is under repulsion the reversion to attraction is sometimes so sudden that the leaf is detached with force and flies to the rod.

K/PP107/3/2/109

Notes describing the effects on gold leaf of a charged rod, [1859-1871].

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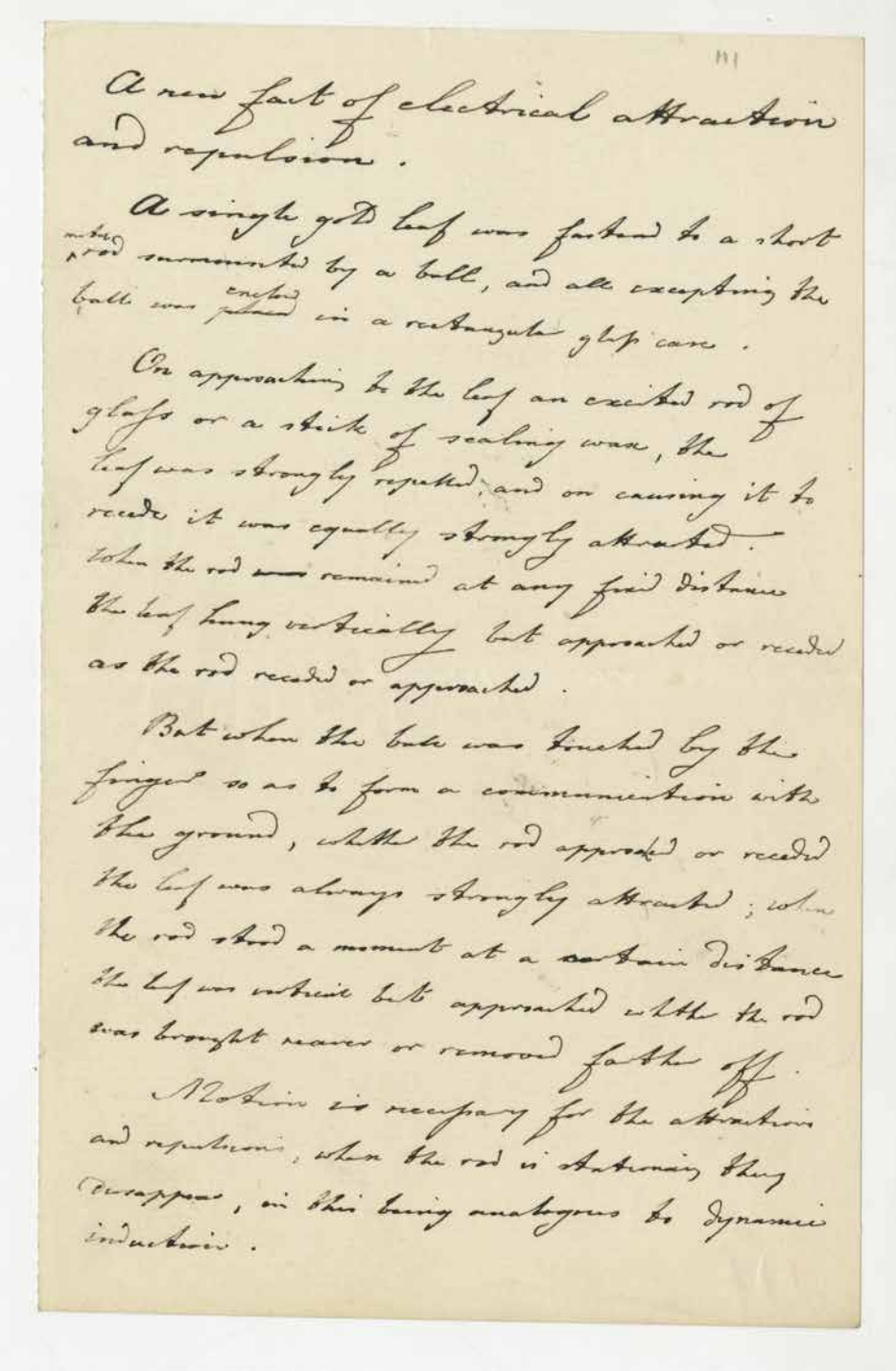

111

A new fact of electrical attraction and repulsion.

A single gold leaf was fastened to a short wire rod surmounted by a ball, and all excepting the ball was enclosed in a rectangular glass case.

On approaching to the leaf an excited rod of glass or a stick of sealing wax, the leaf was strongly repelled, and on causing it to recede it was equally strongly attracted. When the rod ~~was~~ remained at any fixed distance the leaf hung vertically but approached or receded as the rod receded or approached.

But when the ball was touched by the finger so as to form a communication with the ground, while the rod approached or receded the leaf was always strongly attracted; when the rod stood a moment at a certain distance the leaf was vertical but approached while the rod was brought nearer or removed farther off.

Motion is necessary for the attraction and repulsion, when the rod is stationary they disappear, in this being analogous to dynamic induction.

K/PP107/3/2/111

Notes describing electrical attraction and repulsion as demonstrated through the effects on gold leaf of a charged rod, [1859-1871].

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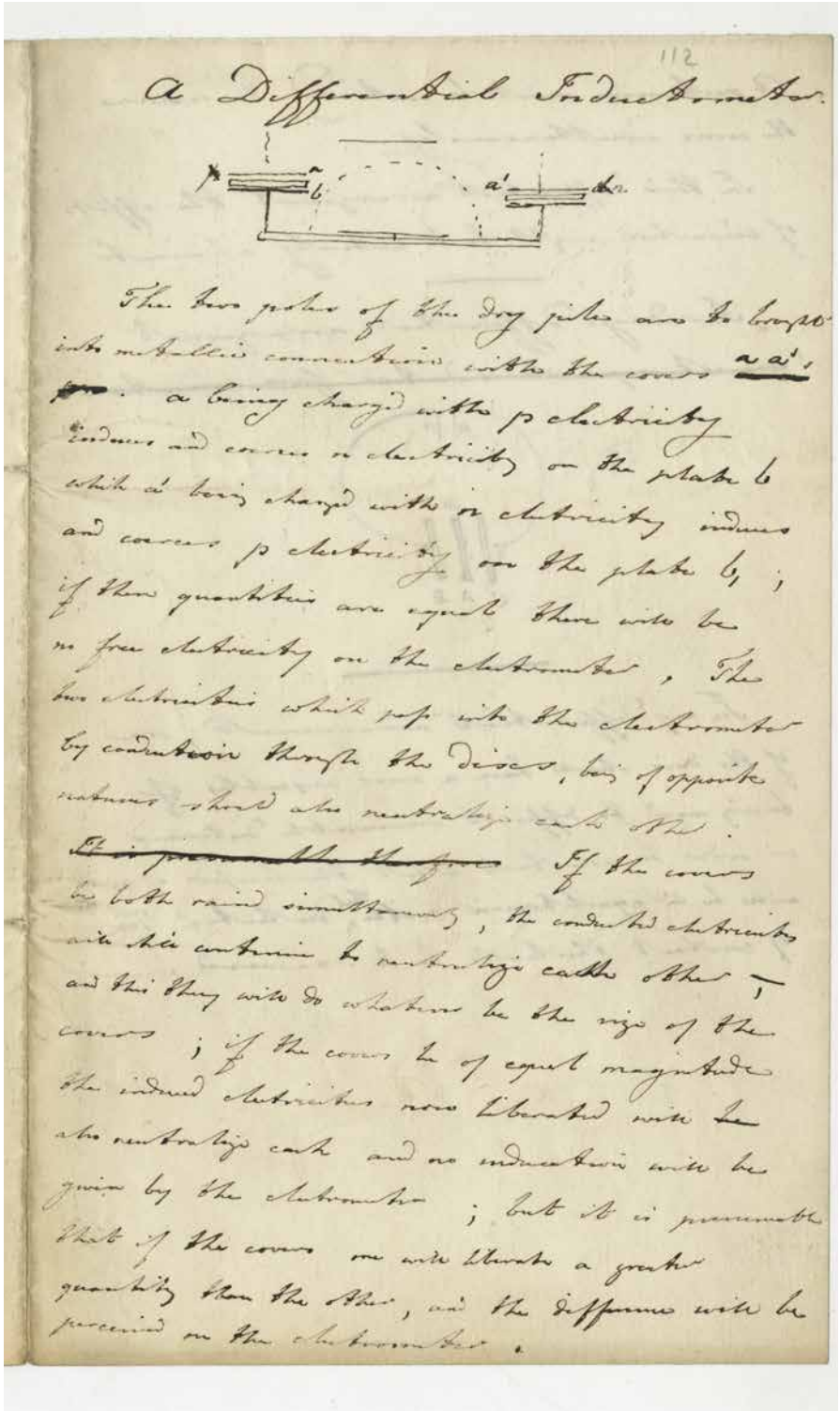

112

A Differential Inductometer.

The two poles of the dry pile are to be kept in metallic connection with the covers a a'; a being charged with p electricity induces and covers n electricity on the plate b while a' being charged with n electricity induces and covers p electricity on the plate b, ; if these quantities are equal there will be no free electricity on the electrometer, The two electricities which pass into the electrometer by conduction through the discs, being of opposite natures should also neutralize each other. ~~This presumes therefore~~ If the covers be both raised simultaneously, the conducted electricity will still continue to neutralize each other, and this they will do whatever be the size of the covers; if the covers be of equal magnitude the induced electricities were liberated with the also neutralize each and no indication will be given by the electrometer; but it is presumable that if the covers are not liberate a greater quantity than the other, and the difference will be perceived on the electrometer.

K/PP107/3/2/112

Notes and diagrams describing 'A Differential Inductometer' or instrument to measure induction, [1859-1871], page 1.

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K/PP107/3/2 - Papers relating to electricity, magnetism and thermodynamics

A mechanism must be contrived to remove the covers simultaneously.

In this differential arrangement the effects of conduction ought to be entirely eliminated

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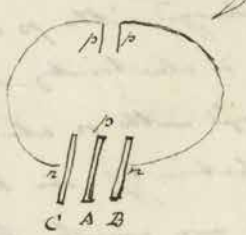
Faradays differential arrangement

~~[illegible]~~



In any differential arrangement; one of the discs should have a cover capable of being moved to different measurable distances in order to ascertain what thickness of air will be in equilibrium with the dielectric disc if contact thickness to be examined.

The Papers of Charles Wheatstone

K/PP107/3/2 - Papers relating to electricity, magnetism and thermodynamics

Neither Faraday nor Harris succeeding in showing any inductive capacity with liquids. Faraday 1200–1200 made experiments with rectified oil of Turpentine and Naptha as being two of the best insulating liquids, but the loss of charge by conduction prevented him from obtaining any reliable result. Harris (18) says I found all the fluid bodies I examined viz oil of turpentine, common oil, naptha be incapable of assuming the charged state, or at least if they did so, they became immediately discharged.

A Leyden jar with wires as the dielectric will not hold its charge, when left to itself for an instant; but if it be charged by a battery so that the charging does not cease, when the coatings are united a considerable charge will be given.

If the upper and under coat be connected by a galvanometer will the needle be affected by the discharge?

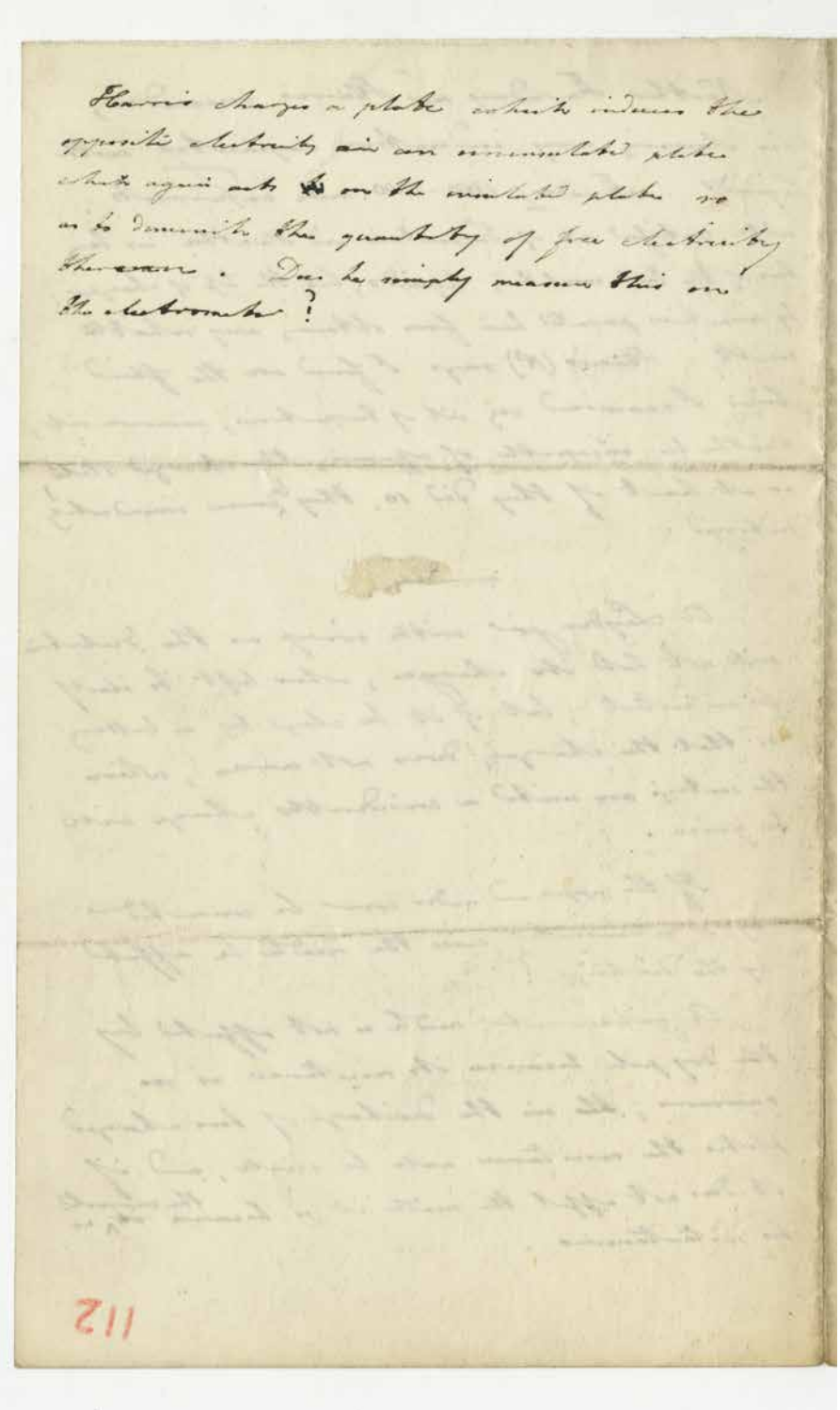
A galvanometer needle is not affected by the dry pile because its resistance is so enormous; the in the discharge of two charged plates the resistance will be small, and if it does not affect the needle it is because the current is instantaneous.

K/PP107/3/2/112

Notes and diagrams describing 'A Differential Inductometer' or instrument to measure induction, [1859-1871], page 3.

The Papers of Charles Wheatstone

K/PP107/3/2 - Papers relating to electricity, magnetism and thermodynamics



Electric charge a plate which induces the opposite electricity in an insulated plate that again acts on the insulated plate so as to diminish the quantity of free electricity thereon. Does he simply measure this on the electrometer?

112

K/PP107/3/2/112

Notes and diagrams describing 'A Differential Inductometer' or instrument to measure induction, [1859-1871], page 4.

120

Attempt to explain the difference between positive and negative insulating bodies.

Each insulating substance contains a certain quantity either of positive or negative electricity appropriate to its particular matter and which never leaves it. This attracts from the surrounding air a stratum of the opposite electricity which neutralizes or disguises its inductive action. To render its inductive action evident it is necessary to remove this stratum, which may be done by bringing into contact with it another substance in a different electrical state, or still better by rubbing them together; the electric atmospheres being become combined, and when the substances are separated if their atmospheres were completely neutralized each substance would present its peculiar action; but this can only occur in one particular case, viz. when one is as much below the natural state as the other is above it. When both are positive with respect to the natural condition of things this is what takes place: previous to contact the electricity of the interior of the substances and their atmospheres are in equilibrium, and consequently exhibit no inductive action on objects at a distance, but after contact the electric atmospheres having assumed the same condition offer no longer neutralize the natural electricity of the

The Papers of Charles Wheatstone

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substances, and the inductive action of each is that of the natural electricity plus that of its atmosphere; they are consequently in different states.

One objection to this theory is that if it were true we might remove the atmosphere of a disc by placing between it and the plate a disc of moistened blotting paper, and thus render the electricity of the substance evident. ~~We might however get over the difficulty~~.

Government Telegraph Cable Experiments.
Electric Telegraph Factory,
Gloucester Road,
Regents Park N.W.

Jany 24th/60

Professor Wheatstone,

Dear Sir,

I give you herewith the result of the Expts on Battery tension as requested in yours of the 19th Inst.

Jany. 21st Peltier put to short zinc terminal at 10.45 pm. & left on till
Jany 23rd 11.40 am, when Peltier read 43°.
The other pole showing 46°.
Jany 23rd One mile put on Copper pole of Battery, & 8 miles on zinc pole, previously discharged, at 7.0 pm. & left on till
Jany 24th 9.30 am, when Peltier read 14°.
The other pole showing 50°.

I think the latter Expt afford satisfactory evidence of the very great period

K/PP107/3/2/121
Letter from Eugene George Bartholomew ([1827-1880], Government Telegraph Cable Experiments, regarding the results of experiments on battery tension using a Peltier [Jean Charles Athanase Peltier (1785-1845), French physicist] electrometer, 1860 Jan 24, page 1.

of time before a Battery with unequal terminals will equalize its tension which has been once disturbed.

Respecting the various specimens of covered wires you wrote about, I have requested Mr Rowland to prepare a series after the Experimental series for you, & have written to the G. Percha Co for specimens similar to those I have, which when they arrive shall be kept for you.

I am Dear Sir

Yours faithfully

E G Bartholomew

K/PP107/3/2/121b

Letter from Eugene George Bartholomew ([1827-1880], Government Telegraph Cable Experiments, regarding the results of experiments on battery tension using a Peltier [Jean Charles Athanase Peltier (1785-1845), French physicist] electrometer, 1860 Jan 24, page 2.

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Electroscopical Experiments.

Dec 21.

Battery 504 elements C to E

PE stood at 60°. When the battery was disconnected from E the electrometer showed

with terminal wire only	52°
with two miles	41°
with four miles	37°
with eight miles	23°
with sixteen miles	17°

When C was again placed to earth the last tension was augmented to 22°; and ~~when~~ after an earth contact had been made with 16 miles the tension was 60°

Four miles of wire, insulated at the opposite ends were placed to each pole of the battery

	Chatterton A	Chatterton C
C to PE	32. 35. 30	31. 37½. 39
Z to PE	45. 49. 47	40. 41. 40

The C end of the battery was evidently ~~the~~ perfectly insulated than the Z end.

K/PP107/3/2/131

Notes describing experiments undertaken using an electroscope, or electrometer, on a circuit of insulated wire up to 16 miles in length, [1859-1871], page 1.

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cont

A circuit of eight miles was completed; a short wire in contact with the Z pole was brought to touch the electrometer but without any effect.

A circuit of 16 miles was completed with the same result.

Instead of a short extra wire, four miles of wire were employed; still no effect.

In the circuit of 16 miles the water damper (5½ divisions of water) was interposed in the middle; a short wire from the Z pole touched PE. which showed

When wire was to Z pole ... 27°
— — — — C pole ... 31°

When the water damper was interposed in a short circuit PE showed 9°

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Test Needles

It is well to be provided with three equal test needles, the first to be charged with positive electricity, the second with negative electricity and the third to remain uncharged.

Repulsion of the similarly charged needle is the best test of the existence of the electric state, for attraction may be produced in a charged needle by a body in the neutral state. The best test of the neutral state is the want of action on an uncharged needle.

K/PP107/3/2/144

Note describing the use of three needles in tests, [1859-1871].

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When test needles are employed the repulsion of a needle similarly charged is the most certain indication of the electric state of a body, for if ~~the needle oppositely charged~~ attraction takes place ~~either~~ it remains uncertain whether this arises from a body oppositely charged or from a body in its natural state.

If a body be very feebly charged with either electricity, it will always attract the test needle with whichever electricity it is charged, as in one case the two attractions will coincide, and the other case the repulsion due to the excess of electricity will be more than counterbalanced by the attraction arising from the decomposition of the natural quantity.

Very feeble traces of electricity may be indicated in the following way. Observe the attraction of an insulated disc on the test needle, then charge it with the same electricity as the needle and place it at which an attraction takes place; if then the disc be touched attraction will take place if when there has been the slightest excess of electricity over its natural state.

This is not to be depended upon as touching the disc, when it has no excess of either electricity, because the attraction

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Experiments to be made with Thomson's Quadrant Electrometer at Telegraph St.

~~Place~~ Connect the Electrometer always to one of the poles of the Battery, first without any wire attached and afterwards with the 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000 units attached. (The longer the wire the greater the tension?)

Repeat these experiments with the electrometer placed to the other pole communicating immediately with the earth. Will any indication appear.

Measure with the same electrometer the full tension of the battery first without any wire then with 9000 units.

Place the electrometer near one of the poles when the circuit is completed by a wire joining the two poles.

Insulate the battery, ~~connect~~ it and the earth by a long wire (say 5000 units), interpose a galvanometer. Draw off the tension near one of the poles. Since the galvanometer will remain unaffected.

Cut a wire connecting the battery with the earth and the electrometer placed near the battery, with touching with the earth draw off all the tension leaving the current unaffected

K/PP107/3/2/157
List of experiments to be undertaken using Thomson's Quadrant Electrometer [William Thomson (1824-1907), mathematician and physicist], [1859-1871], page 1.

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Ascertain the force tension of the battery by placing the electrometer on the short terminal, then place a long wire proceeding to the earth increasing the length until half tension is obtained. Measure the length of added wire.

Diminish the length by one half. Will the tension be halved?

—

Place 5000 units of wire to one pole of the Battery and a similar quantity to the other pole; place the electrometer near the point of junction. Then break the circuit and communicate the end of one wire with which the electrometer is in contact with the earth.

—

In a long wire communicating at one end with the battery and at the other end with the earth, and having free tension at the pole, observe by means of the Dewind current electrometer whether the strength of the current is the same or different at different portions (If the latter, is it owing to the cause of electricity?)

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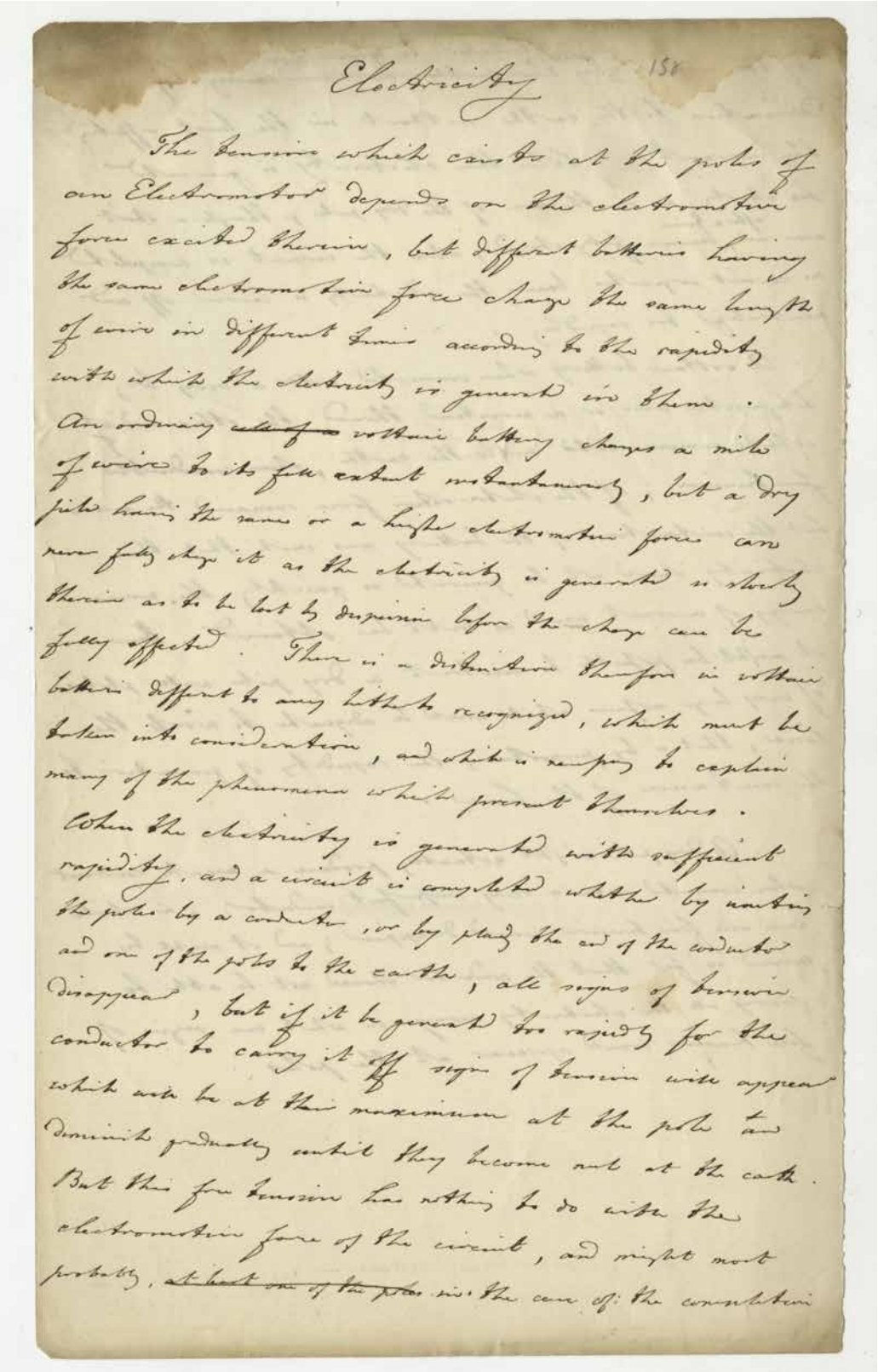
K/PP107/3/2/157

List of experiments to be undertaken using Thomson's Quadrant Electrometer [William Thomson (1824-1907), mathematician and physicist], [1859-1871], page 2.



Electricity 158

The tension which exists at the poles of an Electromotor depends on the electromotive force excited therein, but different batteries having the same electromotive force charge the same length of wire in different times according to the rapidity with which the electricity is generated in them. An ordinary ~~[illegible]~~ voltaic battery charges a mile of wire to its full extent instantaneously, but a dry pile having the same or a higher electromotive force can never fully charge it as the electricity is generated so slowly therein as to be lost by dispersion before the charge can be fully effected. There is a distinction therefore in voltaic batteries different to any little to recognized, which must be taken into consideration, and which is sufficient to explain many of the phenomena which present themselves.

When the electricity is generated with sufficient rapidity, and a circuit is completed whether by uniting the poles by a conductor, or by placing the end of the conductor and one of the poles to the earth, all signs of tension disappear, but if it be generated too rapidly for the conductor to carry it off signs of tension will appear which will be at their maximum at the pole and diminish gradually until they become nil at the earth. But this free tension has nothing to do with the electromotive force of the circuit, and might not probably, ~~at least on of the poles~~ in the case of the constitution

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of the circuit by ~~the earth be carried away by~~ a conductor be carried away at one of the poles derivation to the earth without in the least affecting the current. When the electricity is generated too slowly, as in the case of the dry pile, though a short wire after a time becomes fully charged, when the circuit is completed no current ensues because the electricity is carried off and neutralized too rapidly.

A voltaic battery when connected with a very long telegraphic wire or a moistened thread the other end of which communicates with the earth, shows considerable free tension; if the electro-motive force remains the same but the construction of the battery was such that the electricity should not be generated so quickly the same energy of current would no doubt be obtained. Hence it might be possible to construct a dry pile with plates of very large surface which would be adequate to work the line, that is by proportioning the rapidity of generation to the resistance of the line.

A dry pile might actually produce a weak current when connected with a very imperfect conductor, in which case all free tension would disappear; and it might be carried so far that the conductor should not be able to carry off the electricity away in which case signs of free tension would appear at the poles.

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Notes on 'Electricity' and how different batteries alter the electromotive force, [1859-1871], page 2.

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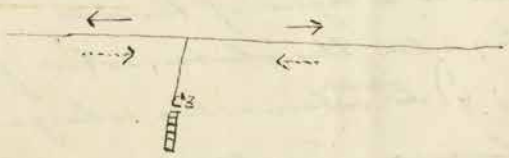
When an insulated wire of considerable length is brought into contact with one of the poles of a voltaic battery, the other pole of which communicates with the earth, it is instantly charged throughout its length with the kind of electricity corresponding with that pole and to a degree of tension commensurate with the electro-motive force of the battery. 2) The wire retains the charge, becoming however gradually dissipated, after the wire is separated from the pole. ~~While the wire is being charged~~

1) If a ~~galvanometer~~ rheoscope be interposed between the battery and the wire while the latter is being charged, the existence of a current is indicated by the rheoscope in the same direction as that which appears when the circuit is completed; this current continues until the wire is fully charged, when it ceases.

3) If, while the ~~wire~~ line remains thus charged, it be touched with a wire communicating with the ground, and if a rheoscope be interposed ~~between the two~~ in the latter, a current will

be indicated opposite in direction to that produced by on charging the wire, which will continue until the line is entirely discharged.

If the wire be charged or discharged not at its extremity, but at any point of its length; the instantaneous currents will proceed in opposite directions towards or from the two ends



If, while the wire is charged at one extremity its other extremity communicates with the earth, a state of permanent tension is never attained but a continuous current is determined. If now the contact with the battery be broken, the current will only continue after that occurrence until the line is ~~completely~~ discharged. But if before this discharge can be completely effected, the end which was in communication with the battery be placed in communication with the earth, a portion of the electricity with which

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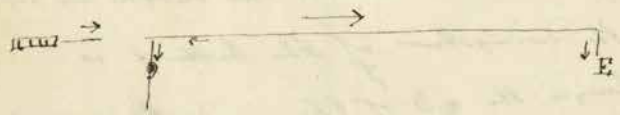
the line is charged, will return through this channel and give rise to a current in the opposite direction ~~to that which passes to the earth at the other end~~, and also to that by which the wire was charged.



This return current is of longer ~~proportion~~ duration in proportion to the amount of induction in the line. It is a serious impediment to the rapid transmission of telegraphic messages, for if the signs consist of short currents in the same direction confusion results from the interference of the transmitted currents with the return or discharge currents which are in opposite directions to the former. ~~Two~~ The methods have been proposed for obviating this inconvenience. 1st After the battery contact is broken to cause the near end of the line to communicate with the earth in order to discharge it. 2d ~~To After cut off the current to~~ To ~~operate~~ construct the telegraphic instruments so as to be operated upon by alternately inverted currents

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3d To construct a relay worked by alternately inverted currents, which shall act upon a local circuit closed at only when the currents are in the same direction (Varley). 4th Instead of simply discharging the current to the earth as in 1st after the disruption of the battery is effected bring the end of the conducting wire into contact with the pole of a separate battery by which act a current is determined in the opposite direction to the return current; the current from the battery being so regulated as to produce the most perfect neutralization

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Electric Telegraph Compy. Jan 5. /69 166

A water moistened battery of 20 cells of Minotti's construction (Daniell's with saw dust) was employed; and Thomson's Mirror Quadrant Galvanometer.

One end of the battery was connected with the earth, and to the other end resistance coils containing 10.000 B.A. units. A wire connected with the galvanometer was placed at different distances from the pole of the battery with the following results.

Near the pole	175°	Near the pole	175°
5000 units from	90	1000 units	160°
3000	125	2000	120°
5000	90	3000	125°
2000	120	5000	90°
1000	160	7000	52°
7000	52	8000	30°
5000	90°	9000	19°
8000	30	Dead earth	0°
9000	19°		
Dead earth	0°		

The average decrease for every 1000° units is 17.5

The attempt to make similar experiments with a battery into a metallic circuit were unsuccessful. Precautions respecting promptly discharging the wire for long range

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Telegraph St. August 3. 1871

A Declanché Battery of 36 elements was employed. The strong polarization renders the tension very unsteady. The full tension off one pole, the other being connected with the earth varied from 270 to 280 and these numbers were at first attained. The following experiments, which can only be considered preliminary were made

Zinc to Earth 36 elements, Electrometer to the Carbon pole.

Without wire	270°	
1500 BA units add	202.5	
335 BA units	135°	
98 BA units	67.5	
33 BA units	33	nearest

Do — 18 elements

Without wire	120°	
520 BA units	90°	
110 BA units	60°	
35 BA units	30°	
8 BA units	15°	nearest

nearly the same as the previous

One end of the resistance coils went to the earth, the other end to the C pole of the battery to which Thomson's electrometer was also applied.

~~Earth the~~

Results of experiments conducted at Telegraph Street using a Declanche [sic] battery [George Leclanche (1839-1882), French electrical engineer], 1871 Aug 3.