Extracts from the papers of Sir Charles Wheatstone

WHEATSTONE 1: Working papers, experimental notes and correspondence relating to the development of the electric telegraph, [1836-1960]

K/PP107/1/1/1-79

[1836-1872]

Papers relating to the development of the electric telegraph, notably including the report of a disputed claim concerning the invention of a version of the voltaic cell developed by John Frederic Daniell (1790-1845), chemist and professor at King's College London, 1836; descriptions of experimental proposals by Wheatstone including those to determine the angular deviations of the needle of Melloni's galvanometer [Macedonio Melloni (1798-1854), Italian physicist] by a constant current, 1841; descriptions of Wheatstone's telegraph, 1844; observations on the phosphorescent effects associated with telegraph cables, 1866; the investigation of the nature of 'extra current'; experiments to test the veracity of the theory of induction by Michael Faraday (1791-1867), natural philosopher; proposals for the improvement of electric light; suggestions for improvements to electrical measurement devices notably including the galvanometer, the rotary discharger, and a type of battery known as the 'electrical torpedo'.

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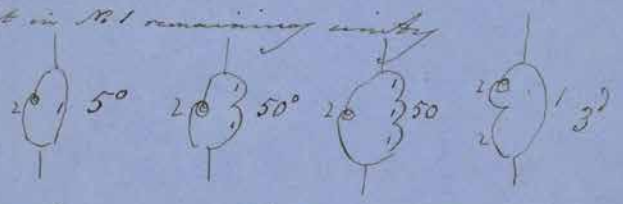
K/PP107/1/1 - Papers relating to the development of the electric telegraph

Nov 25. 1868

To investigate the law of the extra current when coils or magnets were not used the following experiments were made.

A portion of the circuit was divided into two paths in one of which, that in wire coil No 2, the galvanometer was placed. In the 1st experiment the resistances of the two paths were exactly equal, in the 2d the resistance of No 1 was increased double, and afterwards triple, and in the 3d the resistance was doubled in No 2 that in No 1 remaining unity



When 1 was entirely removed, 2 remaining unity the contrary deviation of the galvanometer was very strong.

Hence the deviation in 2 is not owing to the return of the current in 1, circulating in the main circuit as generally supposed; but is occasioned by a return upon itself of the current either in the main circuit or in ~~the~~ divided branches in which the galvanometer is placed.

This is quite contrary to a statement of Faraday's (Ex Res. 9th series) "It was ascertained experimentally that if a strong current was passed through the galvanometer only, and the needle restrained in one direction as above in its natural position, when the current was stopped, no vibration of the needle in the opposite direction took place."

K/PP107/1/1/2

Notes on how 'to investigate the law of the extra current' contrary to a statement by Michael Faraday (1791-1867), natural philosopher, 1868 Nov 25.

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June 20th 1836

At about ½ past 3, Prof. Daniel called upon me with his Brother, and read ~~to~~ a letter which he had received from Mr Rainy, and ~~[illegible]~~ a copy of another which Mr Rainy had sent to Mr Clark. Mr Rainy stated that on the preceding evening Clark had told him that the battery at the Adelaide St Rooms was not Mr Mullins but his own, that it was an improvement on Prof. Daniels and that Mr Mullins had given him five pounds to be considered the Inventor

A short time after Mr Daniel left, Mr Bell Stephens called and asked if Prof. Daniel was here. On being asked in he stated that he called on the part of Mr Clark who was waiting outside, requesting a letter which Mr C. had received from Mr Rainy; he was requested to fetch Mr C. in. When we were all assembled Mr C. entered into a long account of his interview with Mr Rainy, but totally denied every statement in Mr R's letter, and solemnly asserted that it was false (so help me God)

K/PP107/1/1/3

Report of disputed claim concerning a version of the voltaic cell developed by John Frederic Daniell (1790-1845), chemist and professor at King's College London, 1836 Jun 20, page 1.

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He ~~[illegible]~~ said that after his interview with Mr R. he was asked to sup with him that a large jug of ale was brought in, and that he attributed the misstatements in Mr R's letter to its effects.

Mr Stephens suggested that Mr Ronalds had confounded together two distinct things, that Mr C. had mentioned to him another invention for which Mr Mullins had given him five pounds, but which had no relation to the battery. Mr Clark mentioned that this was a mode of applying the electro-magnetic power to a locomotive machine, which was originally suggested to him by Goldsworthy Gurney, but on which he had made a great improvement which he had mentioned to Mr Gurney who offered him five pounds more if he succeeded. He afterwards mentioned it to Mr Mullins who said that he did wrong to confide it to Mr G. as it was well known he could not reward him as he ought to be for it, he would get a much more and that was also; but if he would let him have it he would give him £50 for it.

K/PP107/1/1/3

Report of disputed claim concerning a version of the voltaic cell developed by John Frederic Daniell (1790-1845), chemist and professor at King's College London, 1836 Jun 20, page 2.

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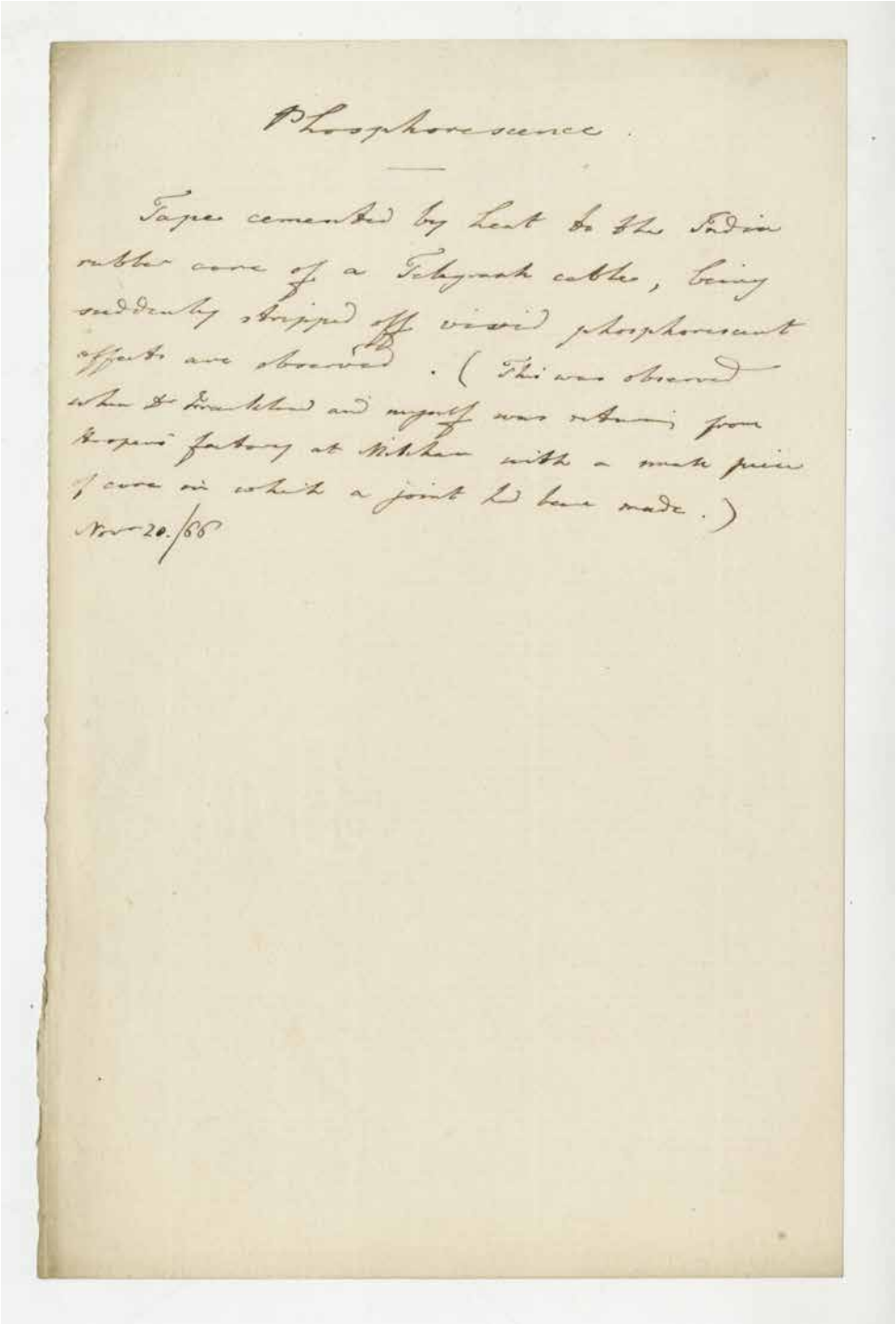

Phosphorescence.

Tape cemented by heat to the India rubber core of a Telegraph cable, being suddenly stripped off vivid phosphorescent effects are observed. (This was observed when Dr Bradley and myself was returning from Kopsi's factory at Millbank with a small piece of core in which a joint had been made.)
Nov 20./66

K/PP107/1/1/5
Observation of phosphorescent effects associated with telegraph cables, 1866 Nov 20.

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K/PP107/1/1 - Papers relating to the development of the electric telegraph

Experiment to prove or disprove Faraday's theory of induction.

Equilibrate two currents in L and λ, the needle in λ' will therefore be at rest. Impede the motion of a needle in one direction by a stop, and open L, the needle will be then forcibly kept in the ~~point~~ position of equilibrium. Complete the circuit to L. If there be a counter current the needle will be deflected; if it be not it will remain in the plane of equilibrium.

If two rheomotors differing very much in electro-motive be employed; the energy of the deflection according as L or λ is opened will probably be different.

The induction current (if L be complete) will divide itself between λ' and λ

K/PP107/1/1/7

Notes on an 'Experiment to prove or disprove Faraday's theory of induction', [Michael Faraday (1791-1867), natural philosopher], [1836-1872].

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K/PP107/1/1 - Papers relating to the development of the electric telegraph

Suggestions for the improvement of the Electric Light.

1 In Serrin's apparatus the charcoal points themselves are made to recede by the action of an electro-magnet which necessitates the movement of a considerable mass. I would allow the charcoal points to remain always at the same distance, and have a branch wire divided with two poles kept in contact when there is no current, but separated by means of an electro-magnet when the current passes.

2. The free ends of the two carbon poles might be kept pressed against a block of non-conducting substance, by means of spiral springs. This, if no inconvenience could arise from the heating of the block rendering it a conductor, or the breaking of the carbon points from the pressure contrived under the combination, would do away with the old complicated mechanism.

3. To avoid passing the current through the long rods of charcoal from end to end, they might be in metal tubes filled with mercury; but in this case the rods must be placed vertically or nearly so, and parallel to each other.

K/PP107/1/1/8

Notes on 'Suggestions for the improvement of the Electric Light [arc light]', [1836-1872], page 1.

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4 Instead of the plan (2) the charcoal points might be kept continually approximating by means of a maintaining power constructed like the maintaining power of the transmitter of the automatic telegraph. The speed would be regulatable, and an adjustment to correspond with the fluctuations of the battery might be easily arranged.

5 ~~[illegible] are required~~

To keep up a constant light while the batteries are being charged, the means might be employed which I formerly proposed to be used for electric clocks.

6. The intensity of the luminous effects from the secondary coil of an Inductorium would not be materially decreased by adding even a very long thick conductor, because its resistance would bear no comparison with that of the coil. A large Inductorium with thick wire, or a number of Inductoriums placed side by side might be available for the Electric Light.

K/PP107/1/1/8

Notes on 'Suggestions for the improvement of the Electric Light [arc light]', [1836-1872], page 2.

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K/PP107/1/1 - Papers relating to the development of the electric telegraph

Explanation of Drawings.

Figure 1. General sketch of the mode of supporting the wires by the straining and hook posts and by the intermediate standards or supports.

2. Section through a standard or intermediate post showing the mode of applying the case or box on which the insulators are fixed.

3. Side view of standard or intermediate post showing the mode of fixing the insulators or earthenware pieces.

4. Section through case or box showing the mode of fixing the earthenware insulators by means of the strap of iron.

5. Front view of the same showing the bell-mouthed or splayed form of the aperture through which the wire is passed.

6. Section through box covering the winders showing the mode of arrangement of these latter.

7. Side view of pair of winders showing the mode of fixing them and the application of the porcelain insulating collar.

8. Transverse section through post and box showing also the winding square, reel, and catch.

9. Front view and section of Insulating collar in Fig 7.

10. Details of mode of attaching the ends carrying the winding square to the connecting rod.

11. Side view of a second form of winding apparatus

12. Section through post and plan of second winding apparatus

13. Section through box covering the hooks showing the mode of arranging and insulating them

14. Elevation of second form of hooks showing the strap of iron, pin, and porcelain collar carrying the hooks.

15. Section through post and plan of hooks.

16. Elevation of third form of hook connection, showing also the intervening copper wire.

K/PP107/1/1/10

'Explanatory text of drawings showing the mode of putting up the lines' possibly for use with patent drawings, [1836-1872], page 1.

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17. Section through post and plan of third form of hook connection
18. Front view and section of Insulating collar used in Figure 16. & 17.
19. Sketch of method of raising the wires very high above the ground and also of maintaining the wires at a proper distance asunder between the supports
20. Porcelain insulator showing a mode of lashing it to the piece of cane or wood.
21. Form of tongs or pincers available for ~~straining~~ holding the wires when being strained

34/ Explanatory text of Drawings shewing the mode of putting up the lines

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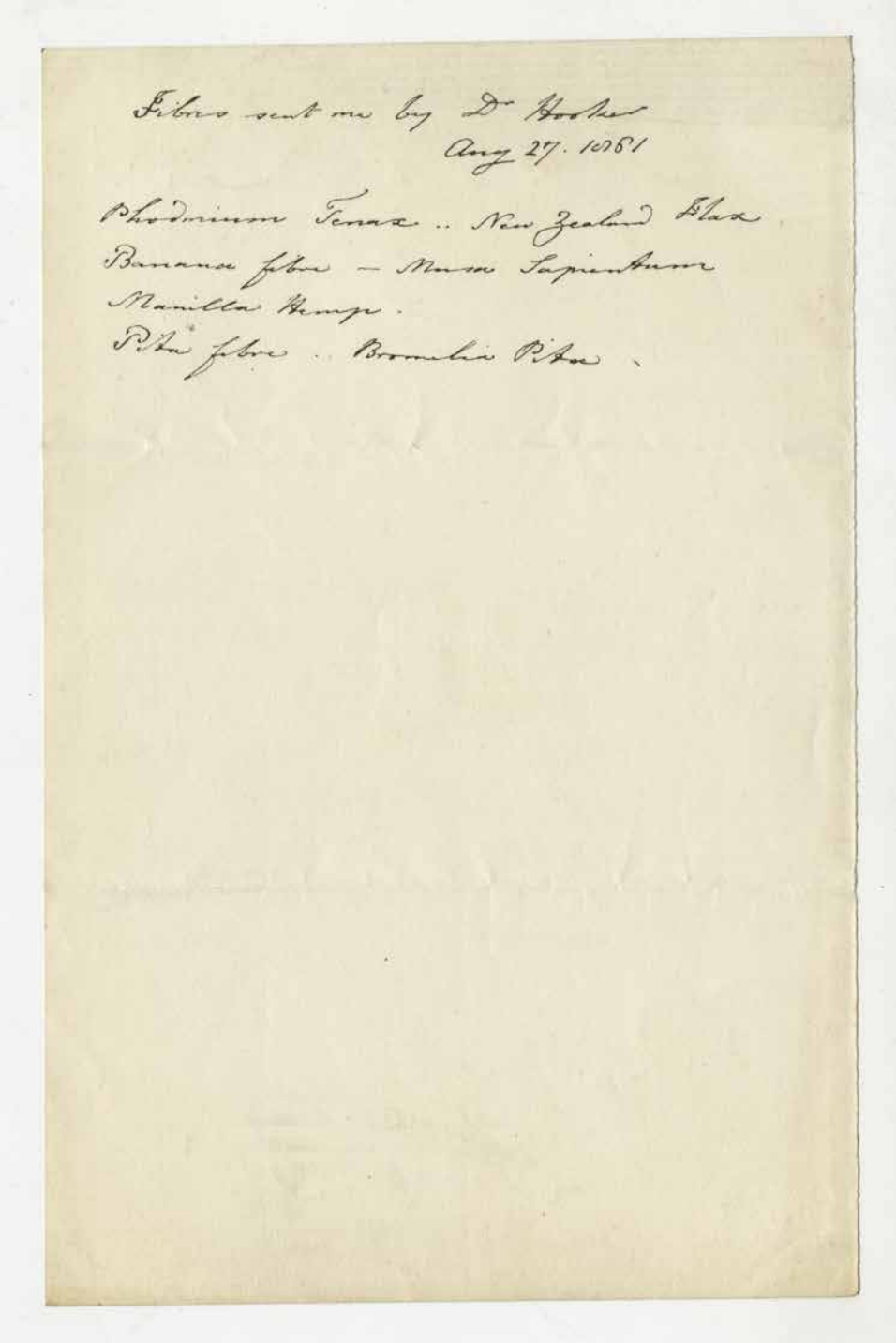

Fibres sent me by Dr Hooker
Aug 27. 1861

Phormium Tenax .. New Zealand Flax.
Banana fibre – Musa Sapientum
Manilla Hemp.
Pita fibre .. Bromelia Pita.

K/PP107/1/1/13
List of fibres sent to Wheatstone by Joseph Dalton Hooker (1817-1911), Assistant Director of the Royal Botanic Gardens, Kew, 1861 Aug 27.

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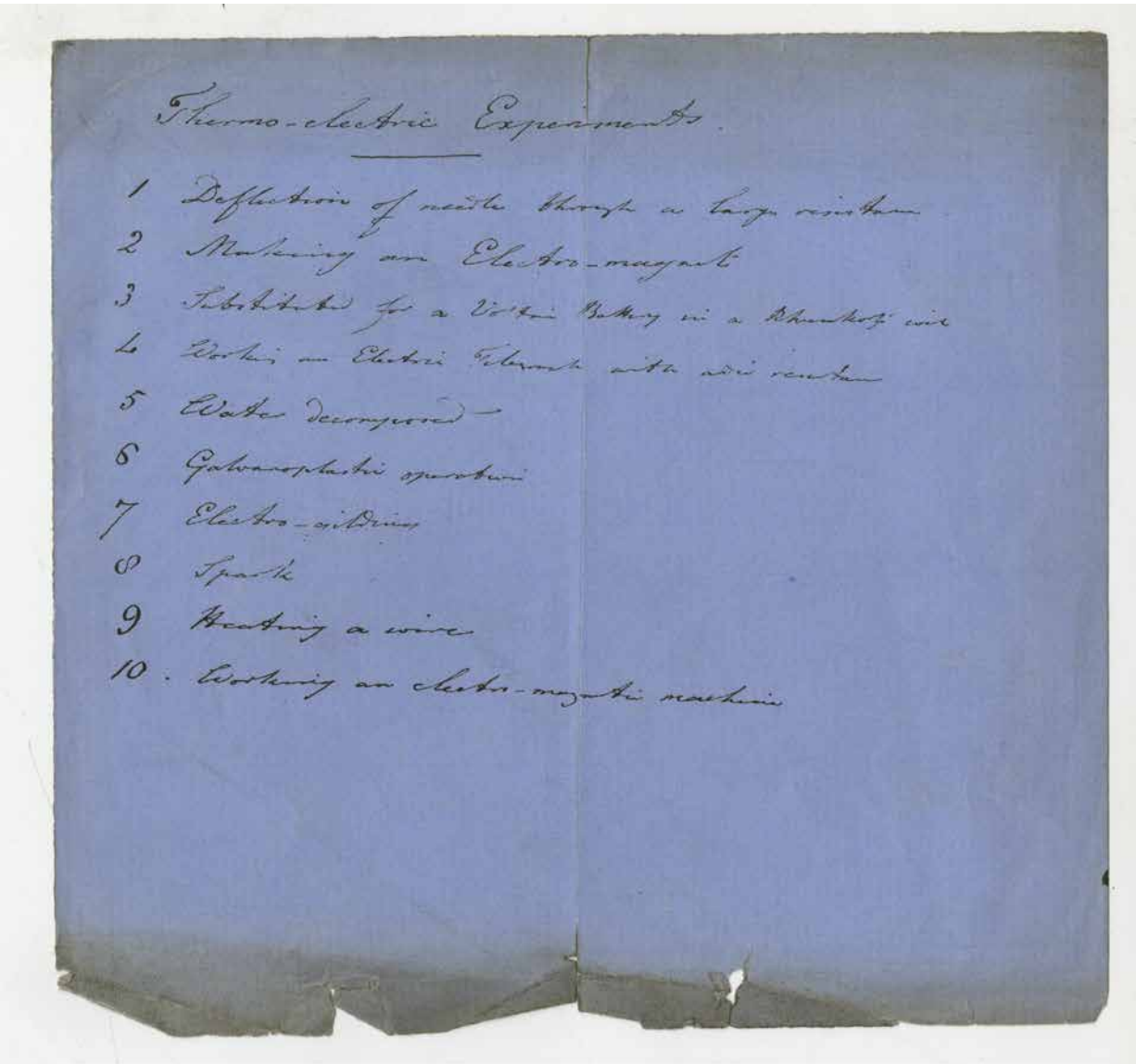

Thermo-electric Experiments.

1 Deflection of needle through a large resistance
2 Making an Electro-magnet
3 Substitute for a Voltaic Battery in a Rheomotor wire
4 Working an Electric Telegraph with adi resistance
5 Water decomposed
6 Galvanoplastic operations
7 Electro-gilding
8 Spark
9 Heating a wire
10. Working an electro-magnetic machine

K/PP107/1/1/16
List of thermoelectric experiments and sketch diagrams, [1836-1872], page 1.

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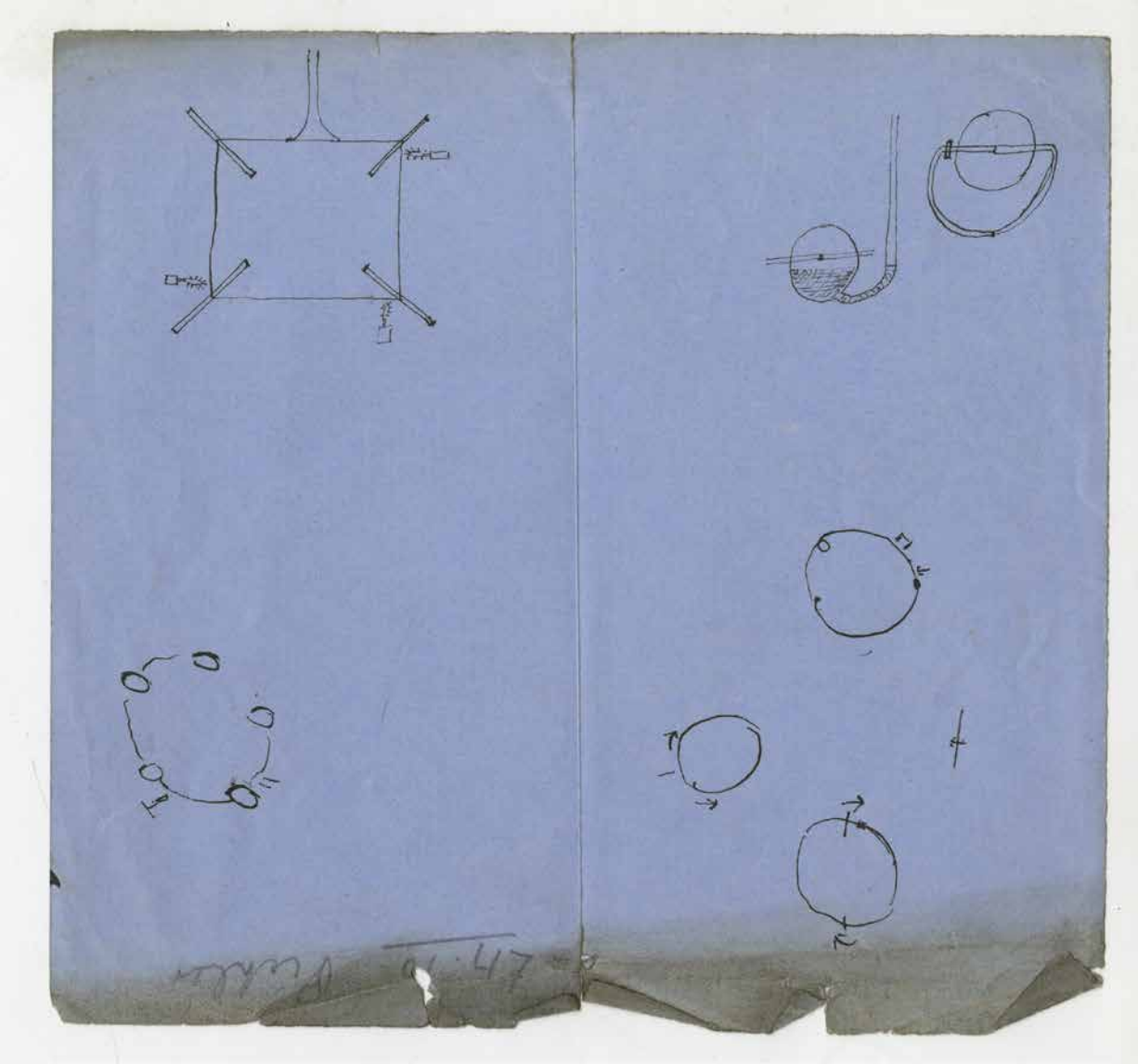

K/PP107/1/1/16
List of thermoelectric experiments and sketch diagrams, [1836-1872], page 2.

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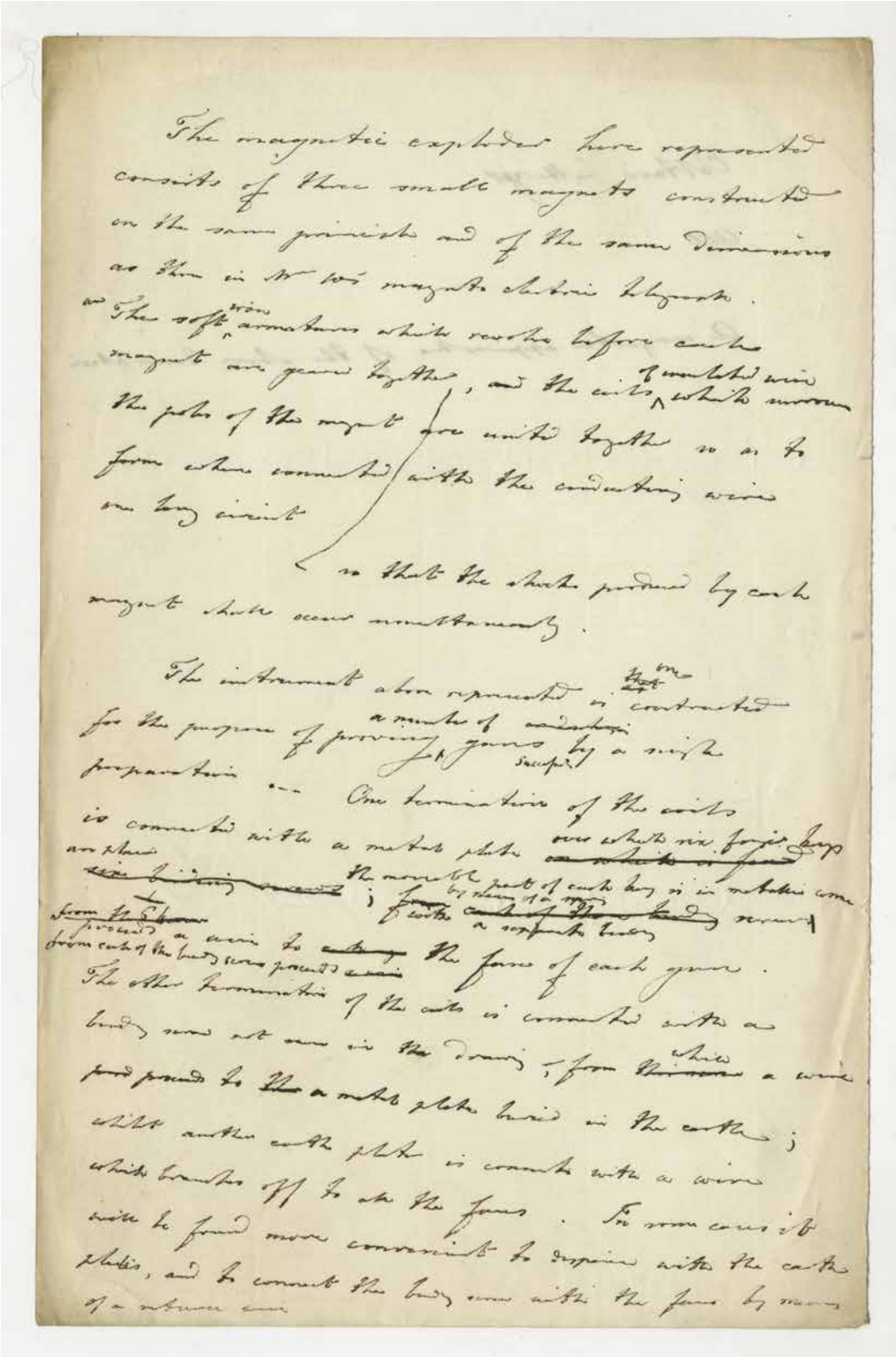

The magnetic exploder here represented consists of three small magnets constructed on the same principle and of the same dimensions as those in Mr Wd's magneto electric telegraph.

The soft iron armatures which revolve before each magnet are geared together, and the coils of insulated wire which surround the poles of the magnet are united together so as to form one long circuit which connects with the conducting wire

so that the shocks produced by each magnet shock occur simultaneously.

The instrument also represented is constructed for the purpose of producing a series of sparks by a single preparation. One termination of the coils is connected with a metal plate ~~on which rest forgings~~ ~~are placed~~ ~~the living earth~~ the remote part of earth being is in metallic connection by means of a wire ~~from the frame~~ ~~of the earth~~ ~~earth of the living body~~ a respective living ~~from the frame~~ ~~produced~~ a wire to ~~entering~~ the frame of each gauge. from each of the living series pounds ~~a wire~~ The other termination of the coils is connected with a living wire not seen in the drawing, from which ~~Thence~~ a wire pond pounds to ~~the~~ a metal plate buried in the earth; with another earth plate is connected with a wire which branches off to all the frames. In some cases it will be found more convenient to dispense with the earth plates, and to connect the living wire with the frame by means of a return wire.

K/PP107/1/1/18

Note describing a magnetic exploder, [1836-1872].

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The instrument employed for these experiments was my keyed magnetic dial telegraph. All that will be necessary here to explain respecting its construction is: that the indicating part consists of a magnetic bar oscillating between two electric magnets in consequence of alternately inverted currents being directed into them, the bar being connected by means of a propelment with a hand which points successively to the letters of the alphabet on a dial; and the transmitting part of of magnetic electric machine sending alternately inverted currents into the circuit.

When this instrument works by itself, the finger keys of the communicator being touched the corresponding letter is shown on the dial.

But when the condenser of 60 inches is placed anywhere in the circuit, this curious effect takes place. On touching a key of the communicator, the letter pointed to on the dial will always be the one in advance of that corresponding to the touched key, so that however long the prop may be continued it will always have to stop with one letter in advance.

To explain this let us at first confine our attention to what takes place when the index points to + and the key A is touched, the handle being turned. The first effect of stopping at A goes on to B. There are therefore two currents in opposite directions, one proceeding from the magneto-electric machine the other from the reaction of the condenser. If the key B be now touched the pointer will

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proceed to C, and so on until the they corresponding letter is touched when the hand will stop at A. The reason that in all the subsequent instances the hand only advances one stop is this; though two currents are in all cases produced, the first ~~quite~~ which is always that produced by the magnetic reaction, acts merely to restore the magnetic bar in its position due to the preceding current, the second arising from the reaction of the condensor is the only one which causes the hand to advance.

If the poles of the magnet be reversed the alphabetic dial will work right, but in this case if the condensor be cut off the letter of the dial will feel one behind that of the communicating.

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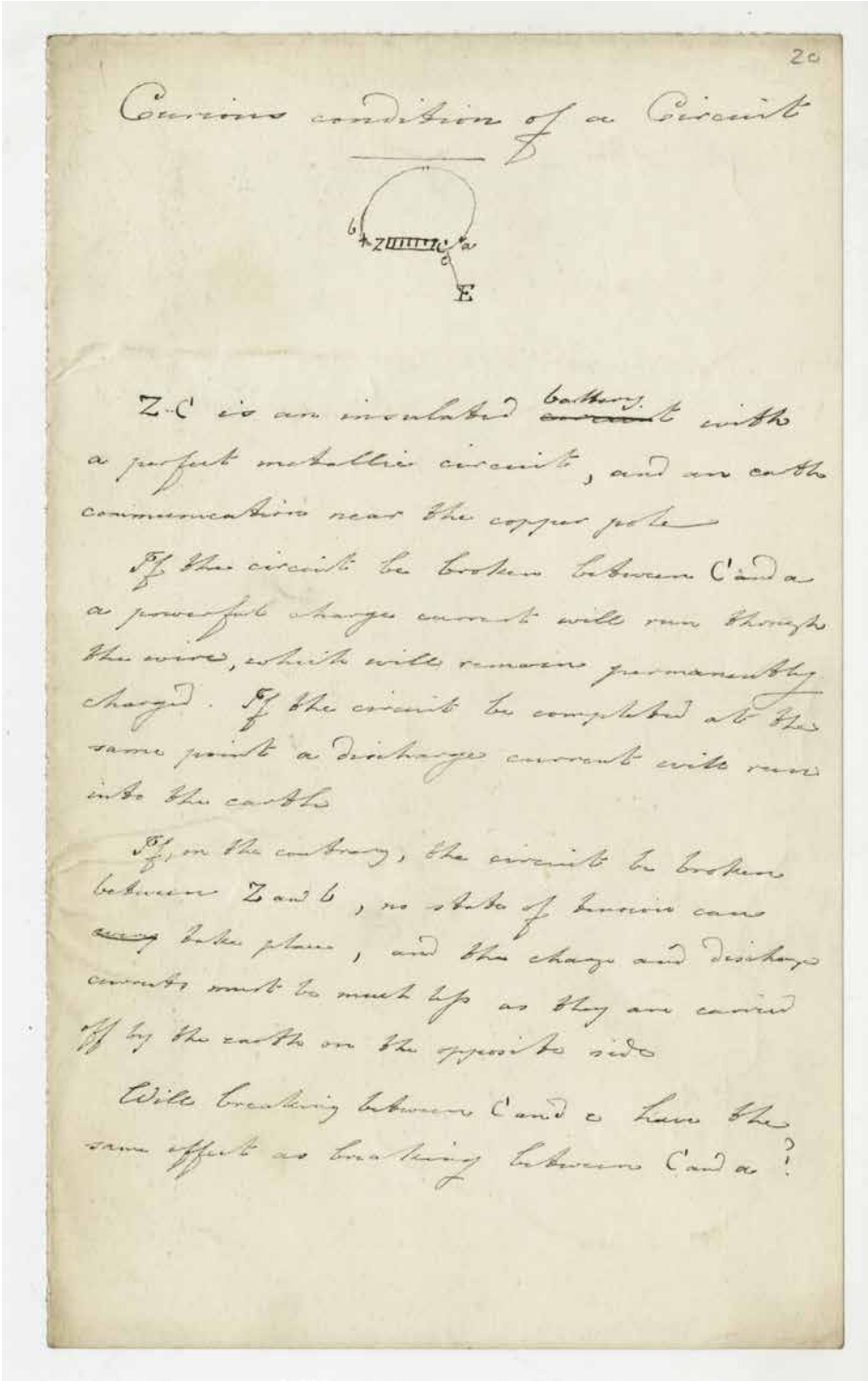

20

Curious condition of a Circuit

Z-C is an insulated ~~circuit~~ battery with a perfect metallic circuit, and an earth communication near the copper pole

If the circuit be broken between C and a a powerful charge current will run through the wire, which will remain permanently charged. If the circuit be completed at the same point a discharge current will run into the earth

If, on the contrary, the circuit be broken between Z and b, no state of tension can ~~exist~~ take place, and the charge and discharge currents must be much less as they are carried off by the earth on the opposite side

Will breaking between C and a have the same effect as breaking between C and a?

K/PP107/1/1/20

Notes describing the 'curious condition of a circuit', [1836-1872].

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It is easy to estimate from Ohm's formula the quantity of electricity accumulated in the conjunctive wire; we have only to multiply this formula by the unit of length of the wire $= l$.

When the wire is so long that the resistance of the battery may be neglected, the quantity of accumulated electricity may be considered the same however the length may be increased; only in one case it will be diffused over a larger extent than in the other. But when the wire is so short that the resistance of the battery are considerable when compared with the resistance in the wire itself, then more inspection of the formula will show that the quantity of accumulated electricity becomes greater in proportion to the length, but the difference is perceived less sensible as the length increases. Thus then if all the electricity accumulated in the wire were rendered sensible as a spark the spark should increase in intensity with the length of the wire rapidly at first, and insensibly after a certain stage. But we shall see hereafter that there are other circumstances to be taken into consideration.

To simplify the circumstances we will at first limit our observation to experiments made with a single pair of elements. The spark I attribute to the electricity accumulated in the wire jumping across the interval made by the disjunctions, the contact being broken the current no longer exists. No spark exists in a very short wire because the whole of the electricity is neutralized before a sufficient interval to render the spark visible is obtained; the smaller quantity of electricity in a short wire is also another reason for the minuteness or invisibility of the spark

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~~The spark is at its maximum bright~~

When the wire is very long the discharge of electricity is of longer duration, and on breaking contact the wire are removed to a distance sufficiently great to break the communication entirely before all the electricity is discharged. The spark is at its maximum brightness when the length of the wire is such that all the electricity in the wire is discharged on breaking contact. ~~According~~ It is a confirmation of these views that the spark from a comparatively short wire is increased by breaking contact rapidly; and the spark from a very long wire ~~with~~, according to the same views to be diminished by the same action, and increased by breaking slowly.

But it may be asked, if this theory be true, how is it that

K/PP107/1/1/27
Notes relating to the use of Ohm's formula, [Georg Simon Ohm (1789-1854), German physicist], [1836-1872], page 2.

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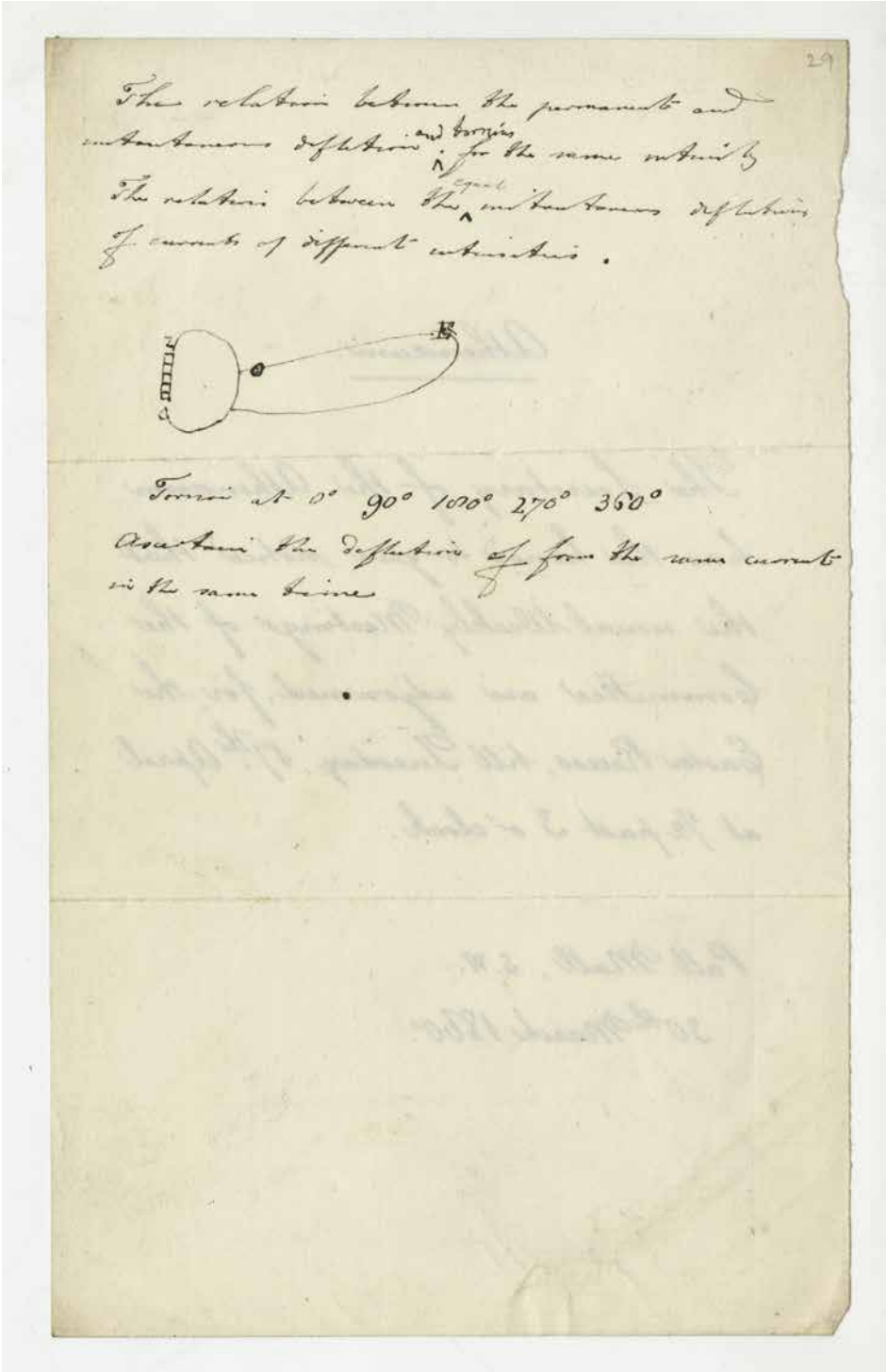

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The relation between the permanent and instantaneous deflection and torsion for the same intensity

The relation between the equal instantaneous deflection of currents of different intensities.

Forces at 0° 90° 180° 270° 360°

Observations the deflection of from the same current in the same time

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These are all the specimens I have
I also send you 7 wires coverd with silk and
shallac varnish I spon together.
I have tryed experiments with the cable
and find that certainly the insulation
is not perfect there is a leakage
to the neighbouring wires but not
enough to work an Indicator

yours obedt
J A Stroh

K/PP107/1/1/31

Note from John Matthias Augustus Stroh (1828-1914), telegraph engineer and inventor, regarding experiments with different types of insulation, [1852-1872].

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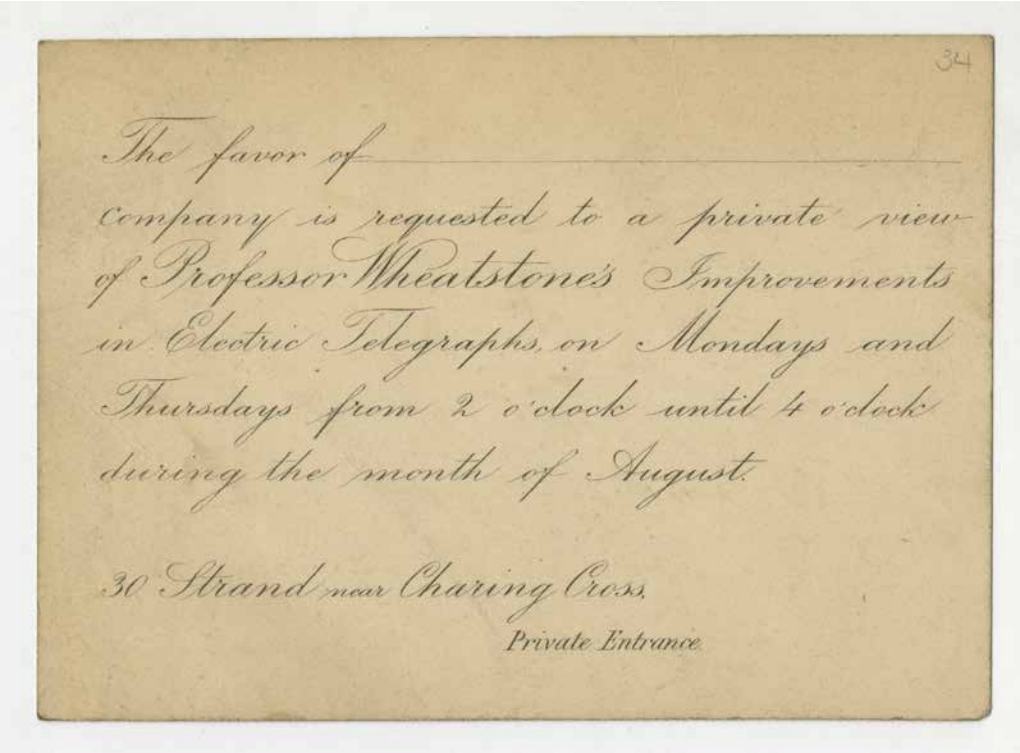

34

The favor of _____

company is requested to a private view of Professor Wheatstone's Improvements in Electric Telegraphs on Mondays and Thursdays from 2 o'clock until 4 o'clock during the month of August.

30 Strand near Charing Cross.

Private Entrance

K/PP107/1/1/34

Invitation to 'private view of Professor Wheatstone's Improvements in Electric Telegraphs' [patent with same title dated 1845 but diagram was used in paper published in 1861 *On the Circumstances which influence the Inductive Discharges of Submarine Telegraphic Cables*], [1845-1861], page 1.

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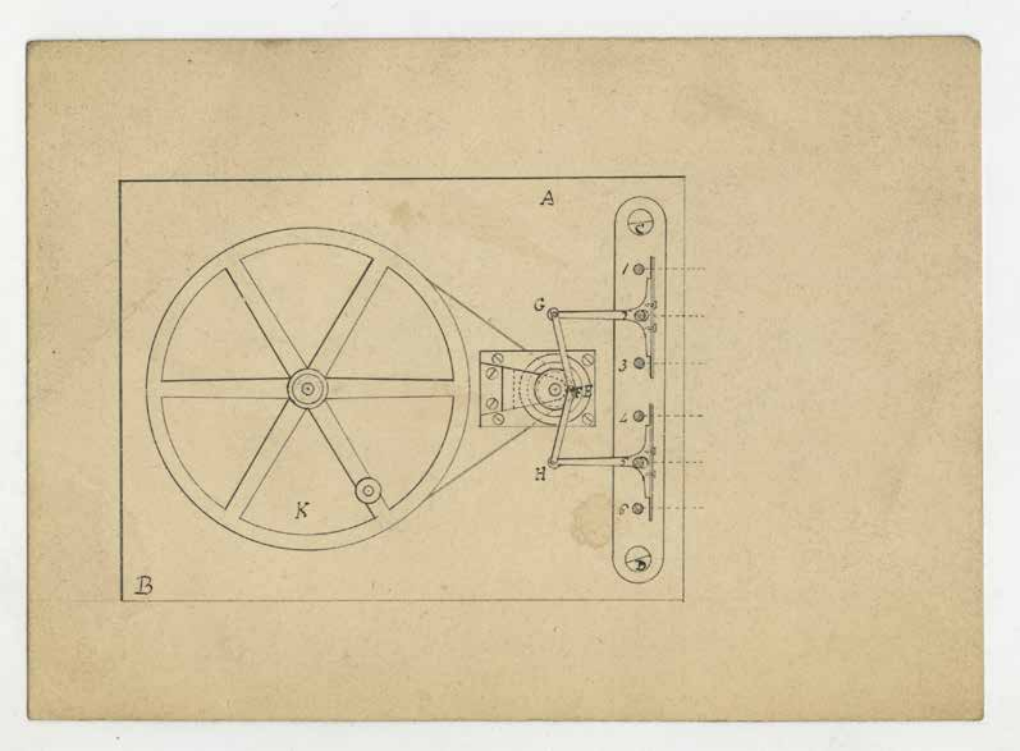

K/PP107/1/1/34

Invitation to 'private view of Professor Wheatstone's Improvements in Electric Telegraphs' [patent with same title dated 1845 but diagram was used in paper published in 1861 *On the Circumstances which influence the Inductive Discharges of Submarine Telegraphic Cables*], [1845-1861], page 2.

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The Royal Society,
Burlington House, London W.
March 25 – 1870

My dear Sir Charles,

I send you a paper by Mr Airy "Note on an Extension of the Comparison of Magnetic Disturbances &c" which has been referred to you by the Council. Will you learn the fandness to inform

K/PP107/1/1/35

Letter from George Gabriel Stokes (1819-1903), physicist and Secretary of the Royal Society, regarding a paper by George Biddell Airy (1801-1892), mathematician and Astronomer Royal, 1870 Mar 25, page 1.

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the Council as to its
eligibility for publication
in the Phil. Trans. ?

Yours very truly
G. G. Stokes

Sir Charles Wheatstone

K/PP107/1/1/35
Letter from George Gabriel Stokes, (1819-1903), physicist and Secretary of the Royal Society, regarding a paper by George Biddell Airy, (1801-1892), mathematician and Astronomer Royal, 1870 Mar 25, page 2.

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Nov 13. 1868

36

Pouillet's Thermo-electric element was placed in circuit with the telescope galvanometer and rheostat. It required 13 turns to reduce the needle from 10° to 5°. Precisely the same number of turns was required when the 25 plates of a thermo-electric battery was also placed in circuit.

A single cell of my liquid amalgam battery was substituted for the thermo-electric element. It required 70 turns to reduce the index from 45° to 40°. The same number of turns also were required when the thermo-electric battery was interposed in the same circuit.

The thermo-electric battery seems therefore only to act as a resistance, and does not sensibly oppose a contrary electromotive force. Either but is sensibly produced it do doubt does, ~~but the~~

K/PP107/1/1/36

Description of an experiment using a thermoelectric element by Claude Servais Mathias Pouillet (1791-1868), French physicist, in a circuit with telescope galvanometer and rheostat, 1868 Nov 13.

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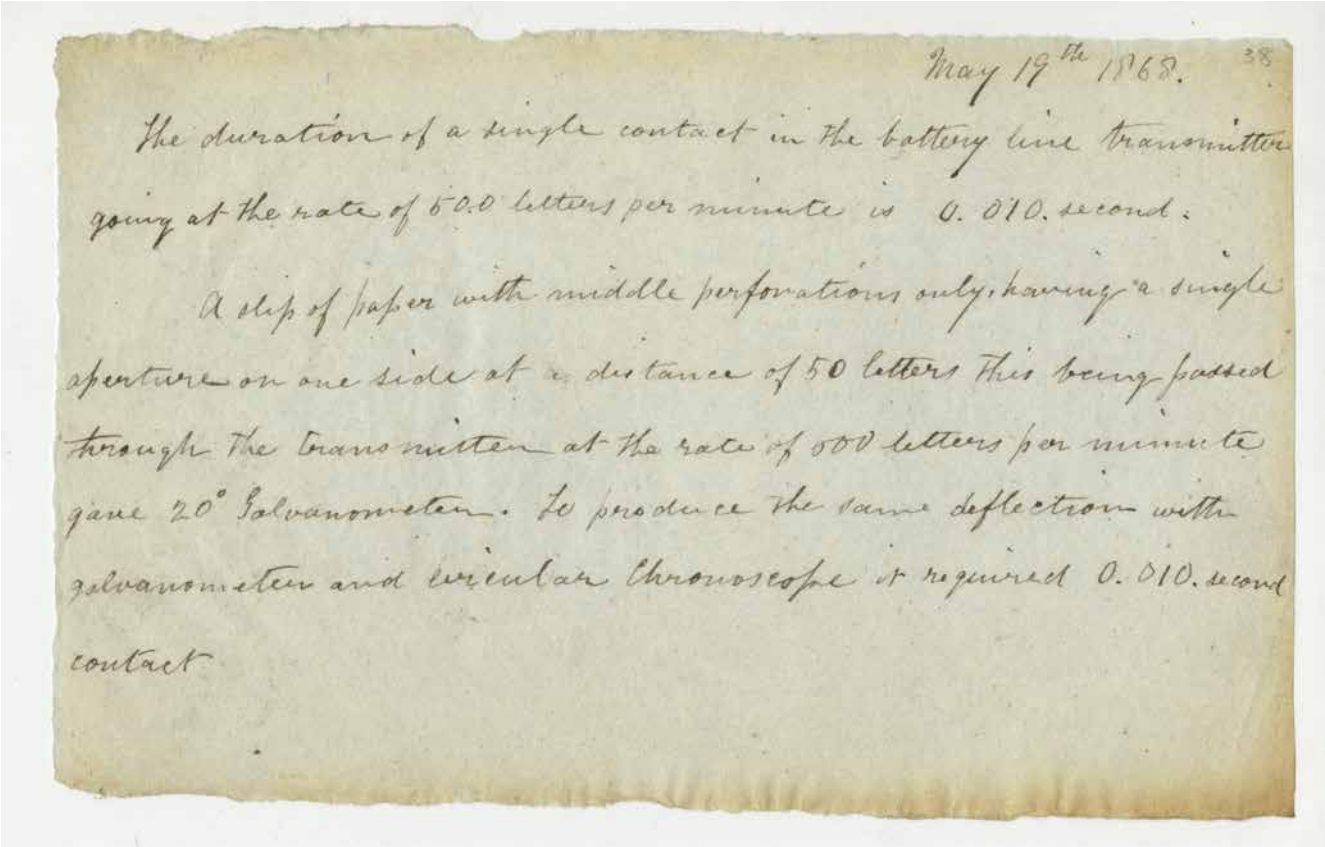

May 19th 1868. 38

The duration of a single contact in the battery line transmitter going at the rate of 600 letters per minute is 0.010. second.

A slip of paper with middle perforations only, having a single aperture on one side at a distance of 50 letters this being passed through the transmitter at the rate of 600 letters per minute gave 20° Galvanometer. To produce the same deflection with galvanometer and circular chronoscope it required 0.010. second contact

K/PP107/1/1/38

Note on experiment recording the number of letters per minute transmitted, 1868 May 19.

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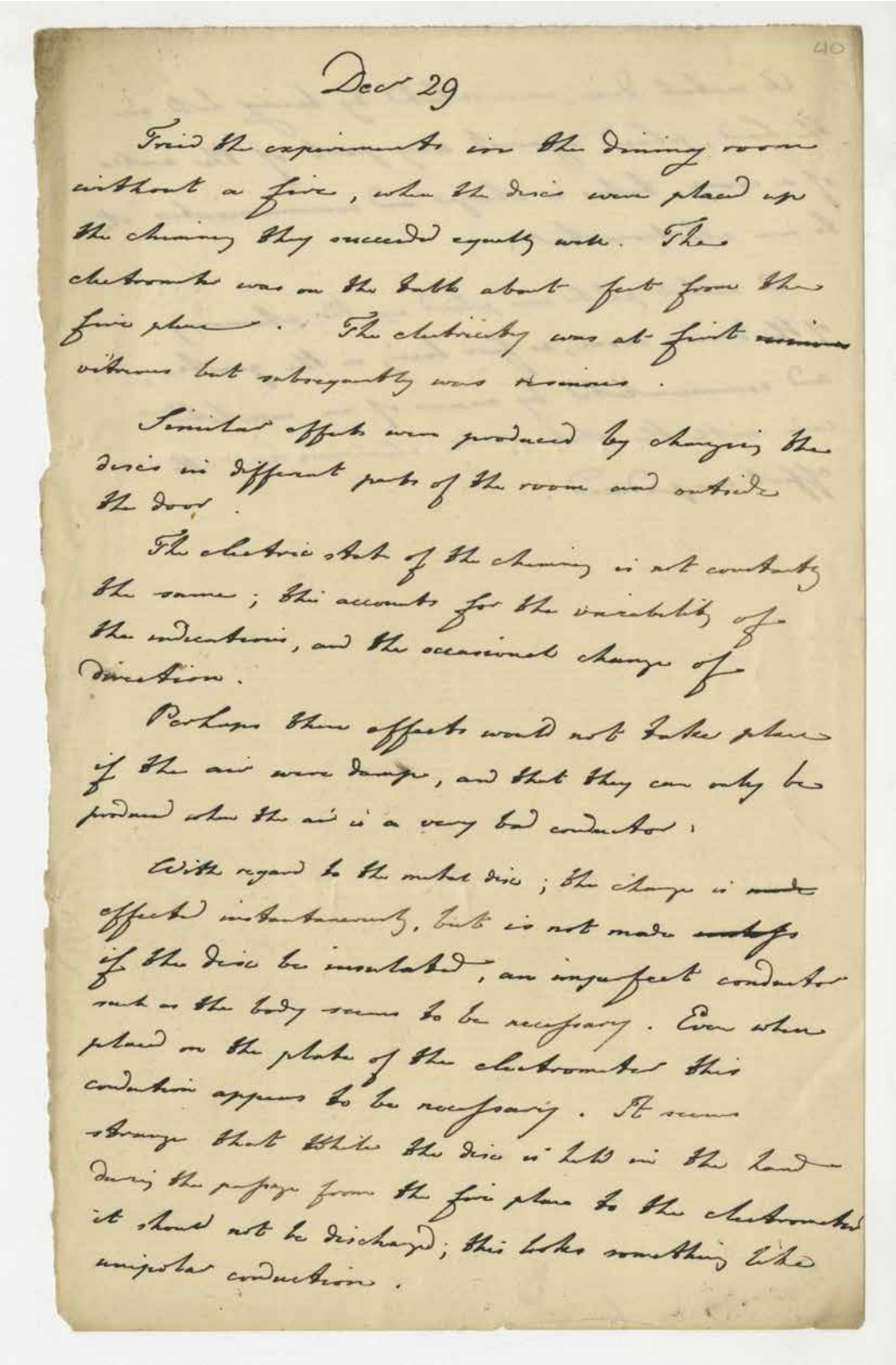

40

Dec 29

Tried the experiments in the dining room without a fire, when the discs were placed upon the chimney they succeeded equally well. The electrometer was on the table about feet from the fire place. The electricity was at first ~~minus~~ vitreous but subsequently was resinous.

Similar effects were produced by changing the discs in different parts of the room and outside the door.

The electric state of the chimney is not constantly the same; this accounts for the variability of the indications, and the occasional change of direction.

Perhaps these effects would not take place if the air were damp, and that they can only be produced when the air is a very bad conductor.

With regard to the metal disc; the charge is made effected instantaneously, but is not made ~~[illegible]~~ if the disc be insulated, an imperfect conductor such as the body seems to be necessary. Even when placed on the plate of the electrometer this conduction appears to be necessary. It seems strange that while the disc is held in the hand during the passage from the fire place to the electrometer it should not be discharged; this looks something like unipolar conduction.

K/PP107/1/1/40

Original notes used in paper 'On a cause of error in Electroscopic Experiments' published in *Proceedings of the Royal Society*, vol xviii pp 330-333, April 1870, 1869 Dec 29, page 1.

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A metal disc, insulated by being held in the hand, placed against any part of the walls of a room, takes a charge and communicates it to an electrometer.

A metal plate was placed up the chimney of the dining room, no fire being in the grate, and communicated by means of an insulated wire with the plate of the electrometer. No effect was produced.

K/PP107/1/1/40

Original notes used in paper 'On a cause of error in Electroscopic Experiments' published in *Proceedings of the Royal Society*, vol xviii pp 330-333, April 1870, 1869 Dec 29, page 2.

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32 Park Road
13th May 1865.

My dear Sir,

I enclose you the "heads" or rather the general particulars of improvements made in the construction, manipulation, and use of the Electrical Torpedo.

I have to day had a conversation with Mr Tremlett regarding the question of Patent &c. and as the matter is one of great importance, I have appointed Monday at 2 o'clock for him to meet me at your house to consult with you and carefully consider the best course to pursue. I hope that the hour of two o'clock will be convenient to you on monday. As I have one or two

K/PP107/1/1/41
Letter from Nathaniel John Holmes ([1824]-1888), electrical engineer, Universal Private Telegraph Company, regarding the patent for an 'Electrical Torpedo', 1865 May 13, page 1.

matters to speak about I will be with
you at 1.45. Monday.

Have you a Rheostat you could
lend me for a few days. Elliott Brothers
have not one, and I must ask Mr. Shock
to make me one. meanwhile if you could
spare yours for a little it will greatly
assist me.

I am dear Sir
Yours truly
Nath.l J. Holmes.

K/PP107/1/1/41
Letter from Nathaniel John Holmes ([1824]-1888), electrical engineer, Universal Private Telegraph Company, regarding the patent for an 'Electrical Torpedo', 1865 May 13, page 2.

The Papers of Charles Wheatstone

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A telegraphic cable which had been laid from Altdorf to Lucerne across the lake of Lucerne a distance of about 20 miles ~~had become~~ was so defective in insulation as to become quite useless. Experiment showed that the defective fault (contact of the wire with the water) or rather the mean point of all the defects was 2000 feet from the shore. Mr. Hipp (the superintendent of the Swiss telegraphs) adopted with much ~~the following~~ a simple, ingenious means of curing this defect.

The origin of the idea he thus states "

"It is known that when two wires leading from the poles of a battery are placed in a vessel containing water, oxygen is developed at the positive wire and that when this wire consists of an oxidable metal, the oxygen combines with the metal to form an oxyde. It is also known that metallic oxydes are bad conductors. Now if my conjecture was right that much defective had been made in the gutta percha on the process of laying the cable, and if these defects could be filled by the long continued action of a strong battery connecting the positive pole with the conductor and the negative pole with the earth, the object would be obtained.

K/PP107/1/1/42

Description of an unsuccessful trial by Matthias Hipp (1813-1893), German clockmaker, to lay cables under Lake Lucerne from Lucerne to Altdorf in December 1836, [1836-1872], page 1.

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph

The battery employed for the purpose consisted of 72 elements.

The loss of current was indicated by from ~~72~~ 36 to 37° of the galvanometer employed

"The operation was commenced on the 5th of Dec 1836; on the 8th of that month I received the following official despatch.
"The operation does wonders. Deviation from upon the subaqueous line from Altorf to Luzern, 3°, from Altorf to Luzern 2°. More by post."

By the letter which followed I was informed that the whole of the first day during which a constant current was transmitted, the deviation remained equally strong; on the second day it first descended to 20°, on the third day to 8° below, and on the fourth day it showed the above result.

After three weeks, during which time the battery was always maintained in good condition, the loss was only 1°.

—

K/PP107/1/1/42

Description of unsuccessful trial by Matthias Hipp (1813-1893), German clockmaker, to lay cables under Lake Lucerne from Lucerne to Altdorf in December 1836, [1836-1872], page 2.

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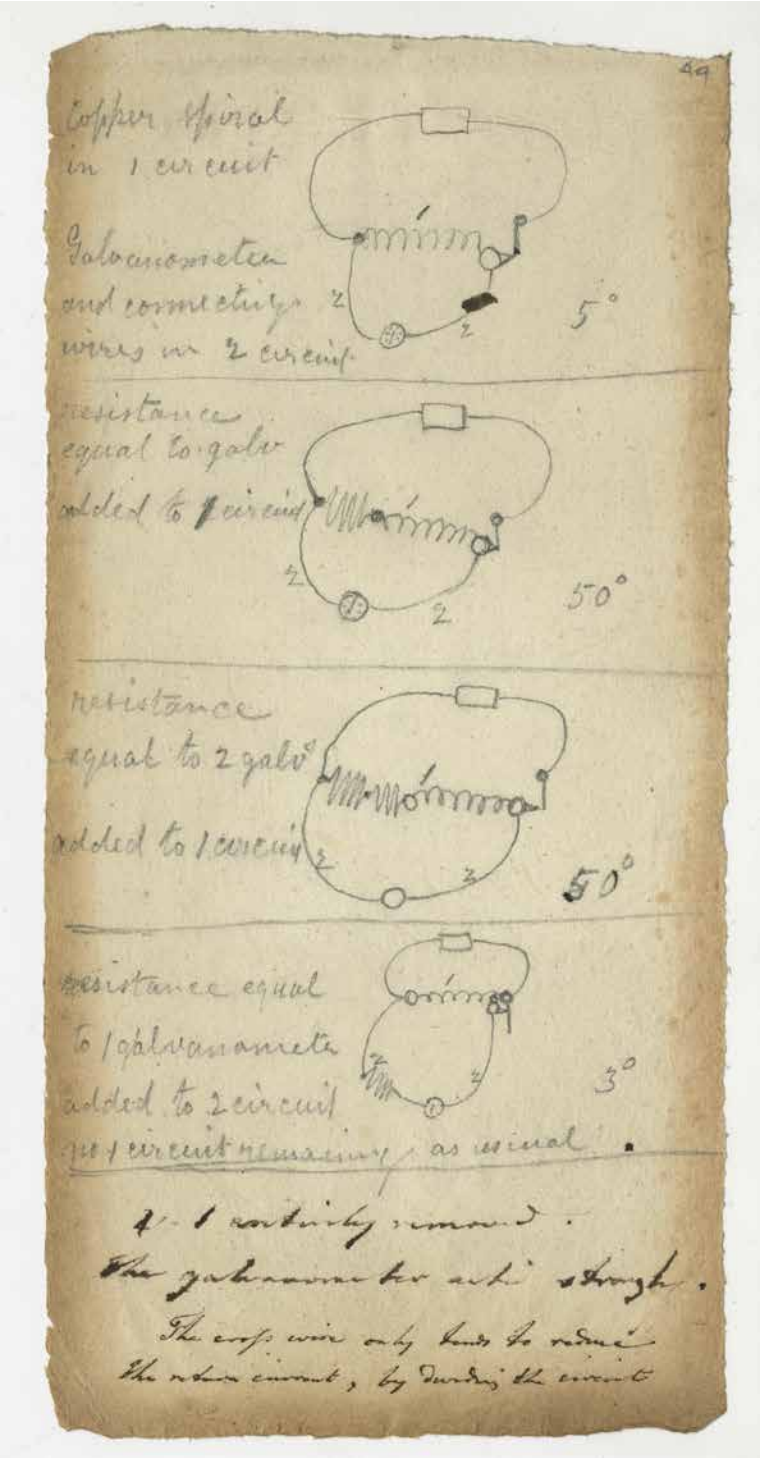

K/PP107/1/1/44
Notes and diagrams relating to resistance, [not in Wheatstone's hand but with his annotations], [1836-1872].

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K/PP107/1/1 - Papers relating to the development of the electric telegraph

45

$$\frac{E-e}{1} = \frac{E}{R}$$

$$R(E-e) = E$$

$$R = \frac{E}{E-e}$$

$$RE - Re = E$$

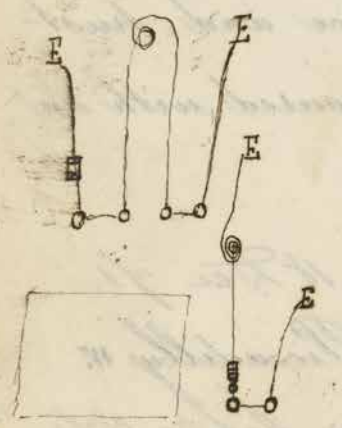
$$RE - E = Re$$

$$E(R-1) = Re$$

$$E \div 1 = e \div 1$$

$$\frac{E}{e} = 1$$

$$E - e = 1$$



$$\frac{E}{R+r} = \frac{E-e}{R}$$

$$ER = ER - er + rE -$$

$$\frac{E}{R+r} = \frac{E}{R} - e = \frac{E+Re}{R}$$

$$\frac{E}{R+r} = \frac{E+Re}{R}$$

$$RE = RE + Re + rE + Rre$$

$$rE =$$

$$\frac{E}{R+r} = \frac{E-e}{R}$$

$$\cancel{E}\cancel{R} = \cancel{E}\cancel{R} - Re + rE - re$$

$$rE = Re + re = e(R+r)$$

$$r = \frac{e(R+r)}{E}$$

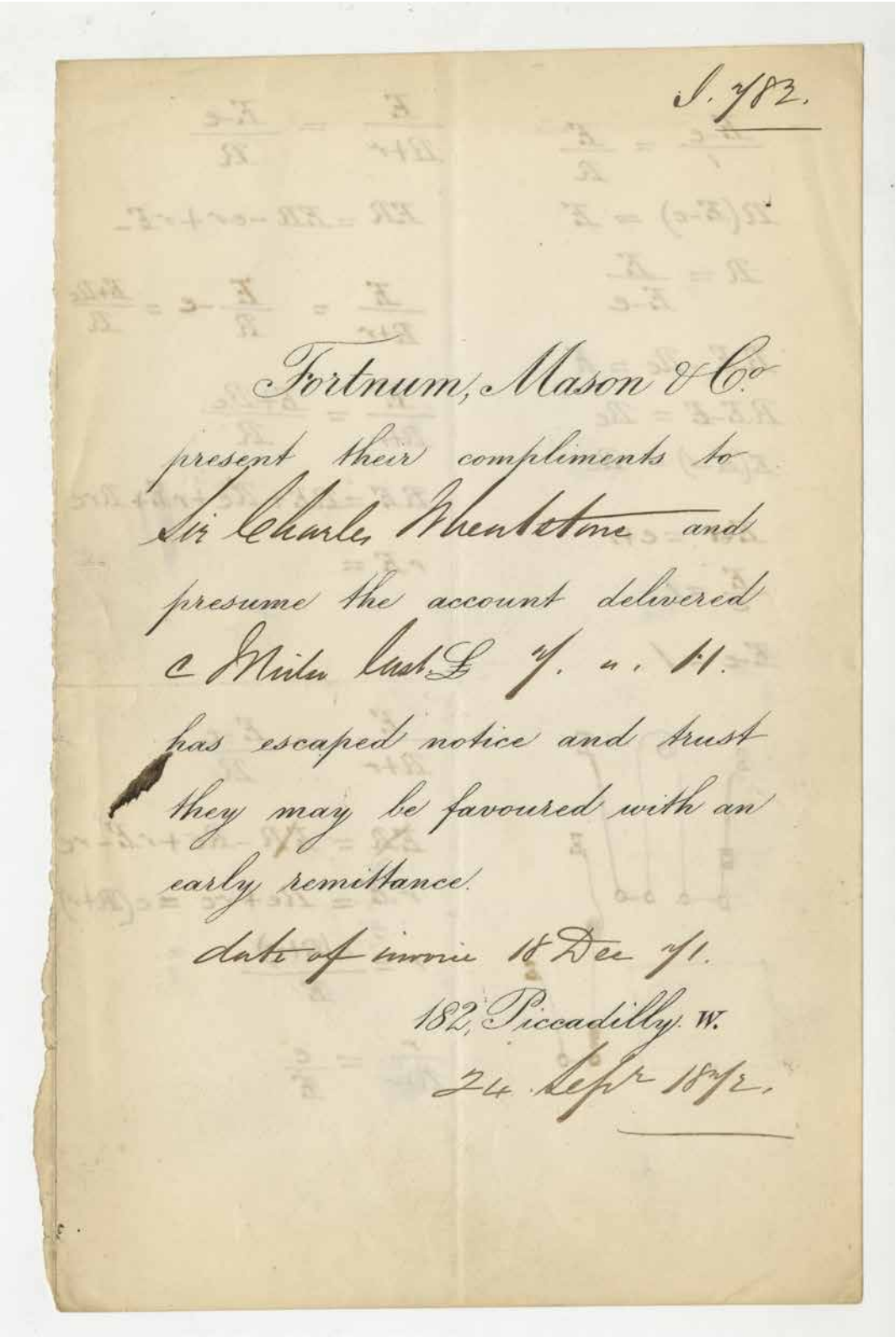
$$\frac{r}{R+r} = \frac{e}{E}$$

K/PP107/1/1/45

Formula and calculations on measuring resistance on reverse of invoice reminder from Fortnum, Mason & Co, 1872 Sep 24, page 1.

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph



S. 782.

Fortnum, Mason & Co.
present their compliments to
Sir Charles Wheatstone and
presume the account delivered
2 Miles last £ 7. 4. 11.
has escaped notice and trust
they may be favoured with an
early remittance.
date of invoice 18 Dec 71.
182, Piccadilly. W.
24 Sept 1872.

K/PP107/1/1/45

Formula and calculations on measuring resistance on reverse of invoice reminder from Fortnum, Mason & Co, 1872 Sep 24, page 2.

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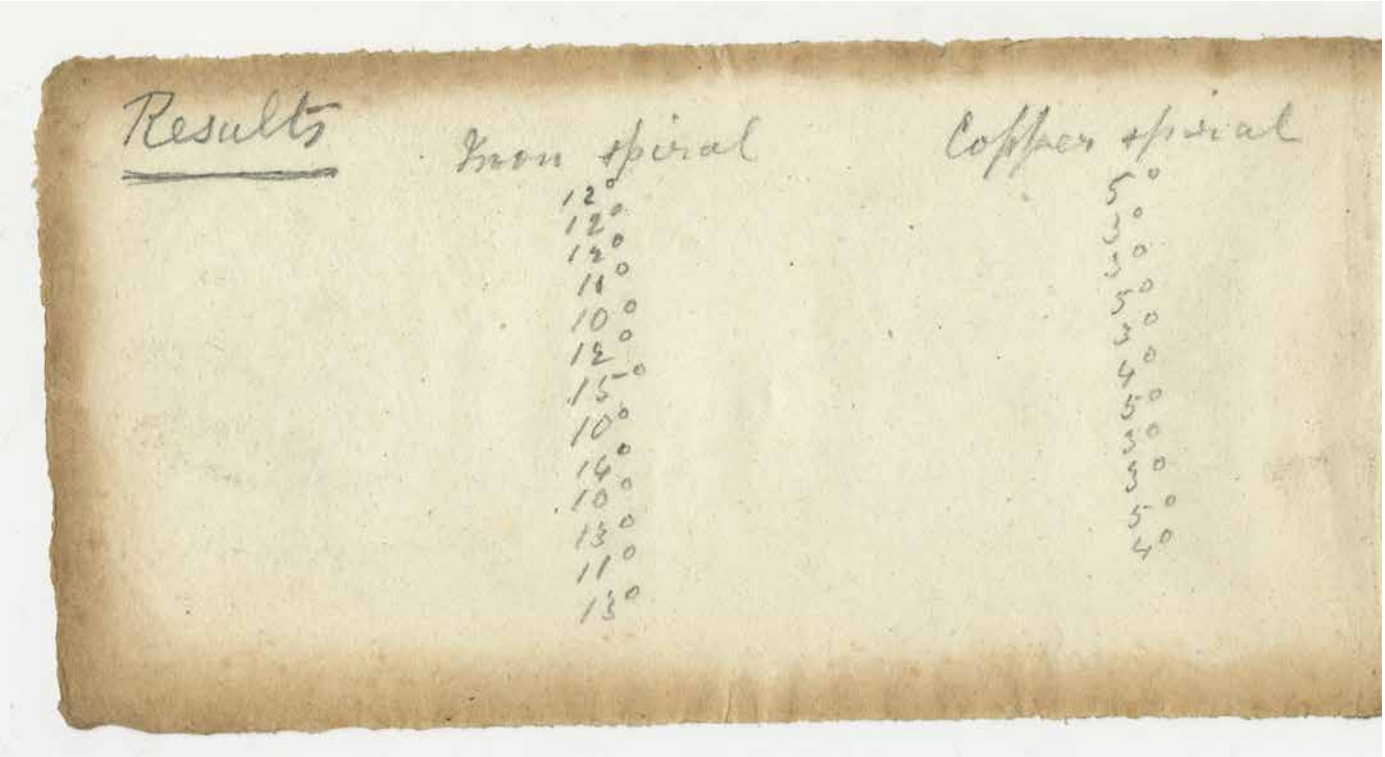
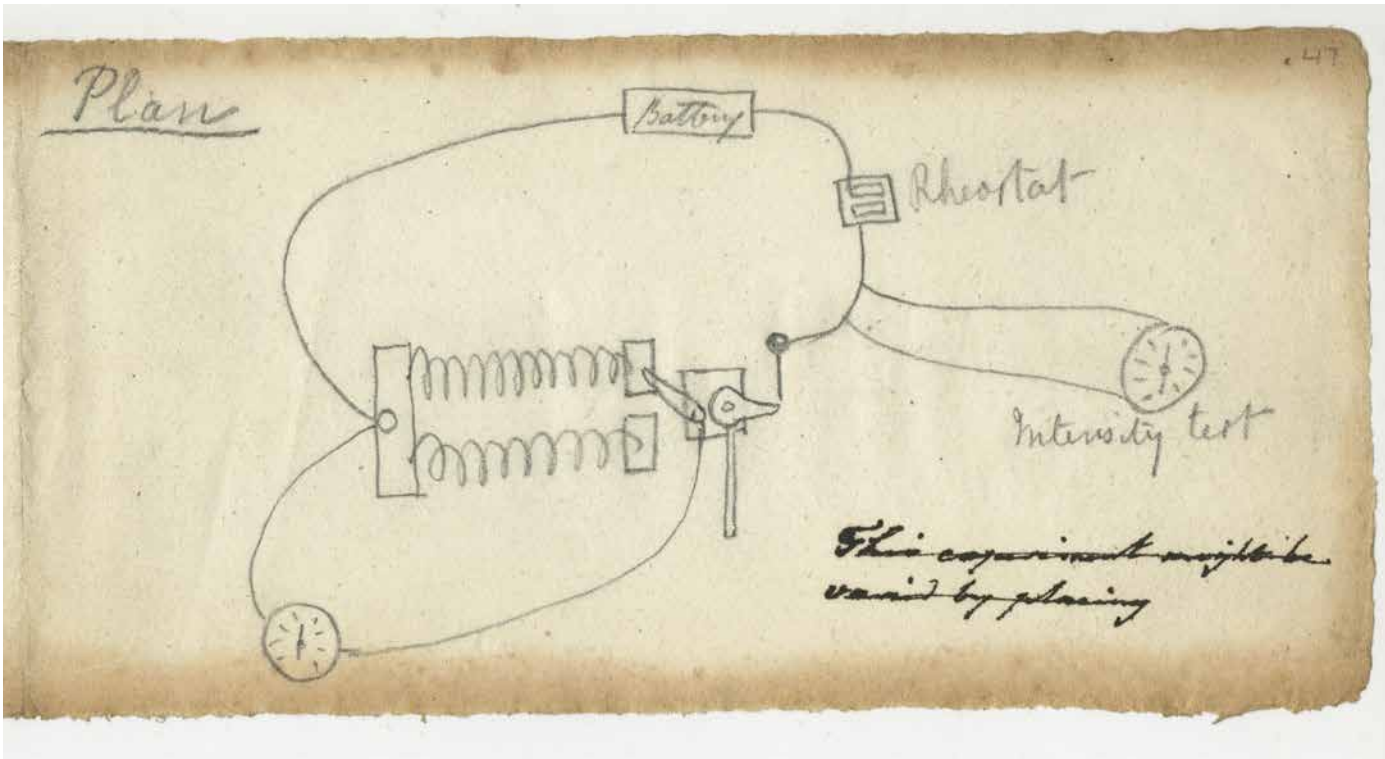


Results

Iron spiral	Copper spiral
12°	5°
12°	3°
12°	3°
11°	5°
10°	3°
12°	4°
15°	5°
10°	3°
14°	3°
10°	5°
13°	4°
11°	
13°	



K/PP107/1/1/47

Sketch diagram of experiment testing intensity, [not in Wheatstone's hand but with his annotations], [1836-1872].

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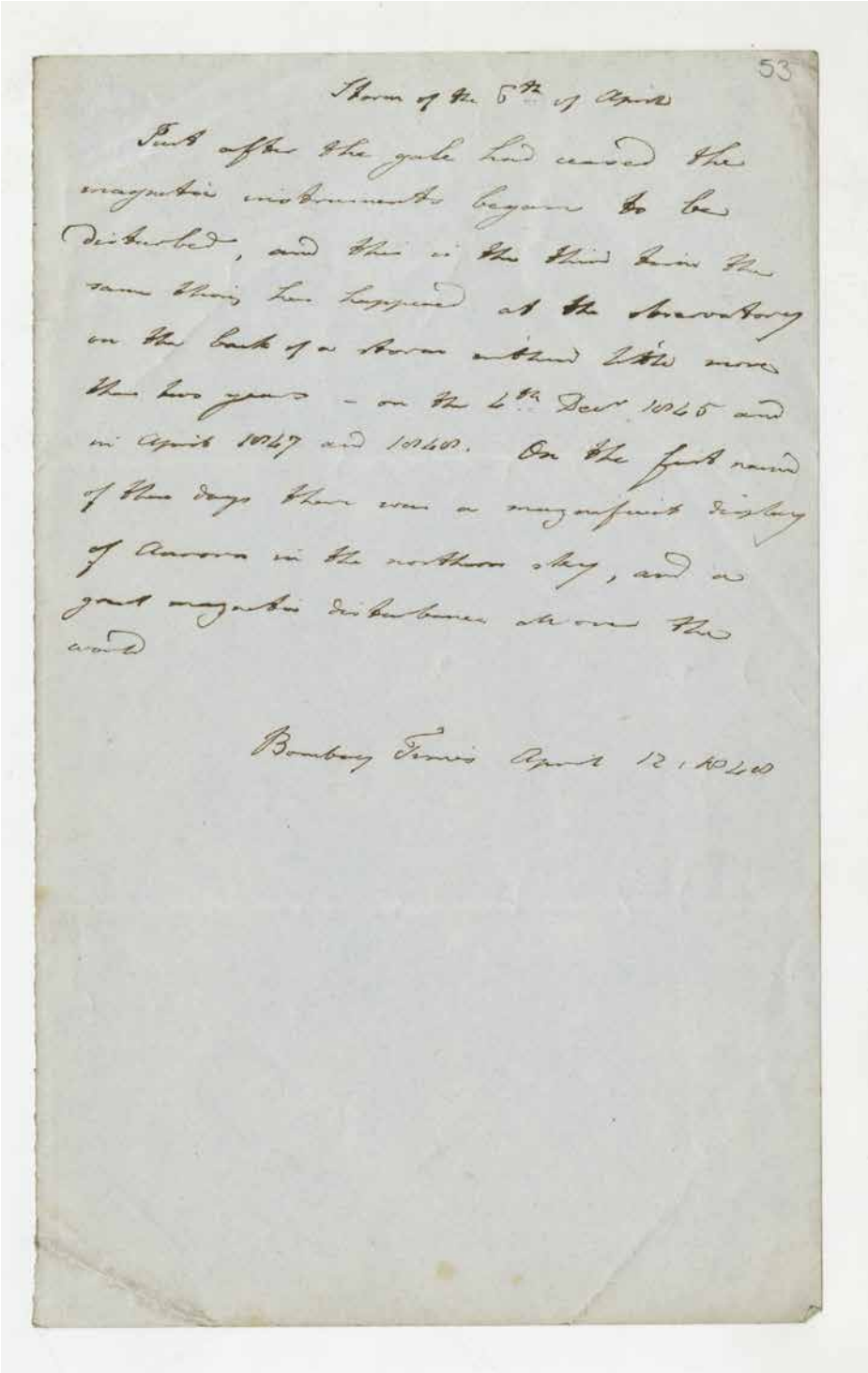
K/PP107/1/1 - Papers relating to the development of the electric telegraph



53

Storm of the 5th of April

Just after the gale had ceased the magnetic instruments began to be disturbed, and this is the third time the same thing has happened at the Observatory on the back of a storm within little more than two years – on the 6th Decr 1845 and in April 1847 and 1848. On the first round of these days there was a magnificent display of Aurora in the northern sky, and a great magnetic disturbance all over the world

Bombay Times April 12, 1848

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph

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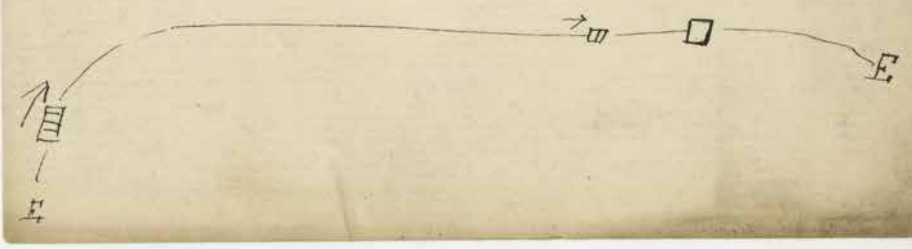
It is sometimes advantageous to keep a constant current in the circuit, not of sufficient intensity to produce any action in the receiving instrument, but so adjusted that a small excess of action shall enable it to do so. This can be easily effected with single current instruments. A wire with a ~~[illegible]~~ variable resistance placed as an extra path to the transmitter will do this; in this case the constant current plus the excess determines the action, and a small quantity of current is kept up during the blanks, but the same amount of power would be required as in the ordinary case.

A preferable method is to place a wire of derivation joining the two ends of the electro-magnet of the receiving instrument, interposing therein a weak battery; this has the advantage of requiring no extra power in the sending battery

The auxiliary battery must be one of considerable electromotive force, but may be of small quantity

Or the auxiliary battery may be placed ~~in the~~ main circuit of the receiver on either side of it



K/PP107/1/1/56

Notes on the advantages of keeping a constant current in a circuit, [1836-1872].

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph

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Royal Observatory
Greenwich
1844 April 29

Four or five years ago I accompanied my brother the Astronomer Royal to King's College Somerset House, to see Mr Wheatstone's Electric Telegraph. I remember perfectly well that, on this occasion, Mr Wheatstone spoke of a plan founded on some modification of the principle of the Telegraph, by which one clock could be made to communicate motion to any number of clocks.

There were present during some parts of this time, Mr Francis Baily, Mr Martin the painter, some persons of the Cornish family of Fox, I think also Sir Charles Lemon, and other persons whose names I do not know.

Elizabeth Airy.

K/PP107/1/1/57
Manuscript copy of letters from George Biddell Airy (1801-1892), mathematician and Astronomer Royal, and his sister Elizabeth, 1844 Apr 29 and May 1, in support of Wheatstone's claim to have invented the electric clock, mentioning John Martin (1789-1854), artist, also present at a demonstration, [1844], page 1.

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph

Royal Observatory
Greenwich
1844 May 1st

I have twice gone to King's College to see Mr Wheatstone's Telegraph, and on one occasion only I was accompanied by my sister.

Of the date of one of these visits I have no record. The other was in 1840 May 23; it is recorded in the Observatory Journal. I do not know whether it was on this occasion or on the other that I was accompanied by my sister.

At the first of these visits, the indicator used by Mr Wheatstone consisted of a number of needles, each of which was acted upon by a coil of wire through which the galvanic current passed. At the second, there was also an indicator formed by causing a piece of iron alternately to become magnetic and to lose its

Manuscript copy of letters from George Biddell Airy (1801-1892), mathematician and Astronomer Royal, and his sister Elizabeth, 1844 Apr 29 and May 1, in support of Wheatstone's claim to have invented the electric clock, mentioning John Martin (1789-1854), artist, also present at a demonstration, [1844], page 2.

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph

magnetism (by passing a galvanic current through a coil of wire surrounding it and interrupting the current), and causing this magnetised iron and an antagonist spring to act alternately upon a wheel with escapement.

At one of these visits I heard some conversation on the practicability of causing one clock to move the indicating part of many other clocks, by means of a galvanic current. I had heard of this proposal before the visit to King's College at which allusion was made to it. I gave no particular attention to the contrivance, as I considered it to be a mere application of the principles of the telegraph, containing no new principle whatever.

G. B. Airy

K/PP107/1/1/57

Manuscript copy of letters from George Biddell Airy (1801-1892), mathematician and Astronomer Royal, and his sister Elizabeth, 1844 Apr 29 and May 1, in support of Wheatstone's claim to have invented the electric clock, mentioning John Martin (1789-1854), artist, also present at a demonstration, [1844], page 3.

The Papers of Charles Wheatstone

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58

The Rotary Charger & Discharger

One charge and one discharge for each rotation of the small wheel.

Contact with the battery lasts during one quarter of the rotation, contact with the earth during another quarter; during the intermediate quarters the wire line is insulated

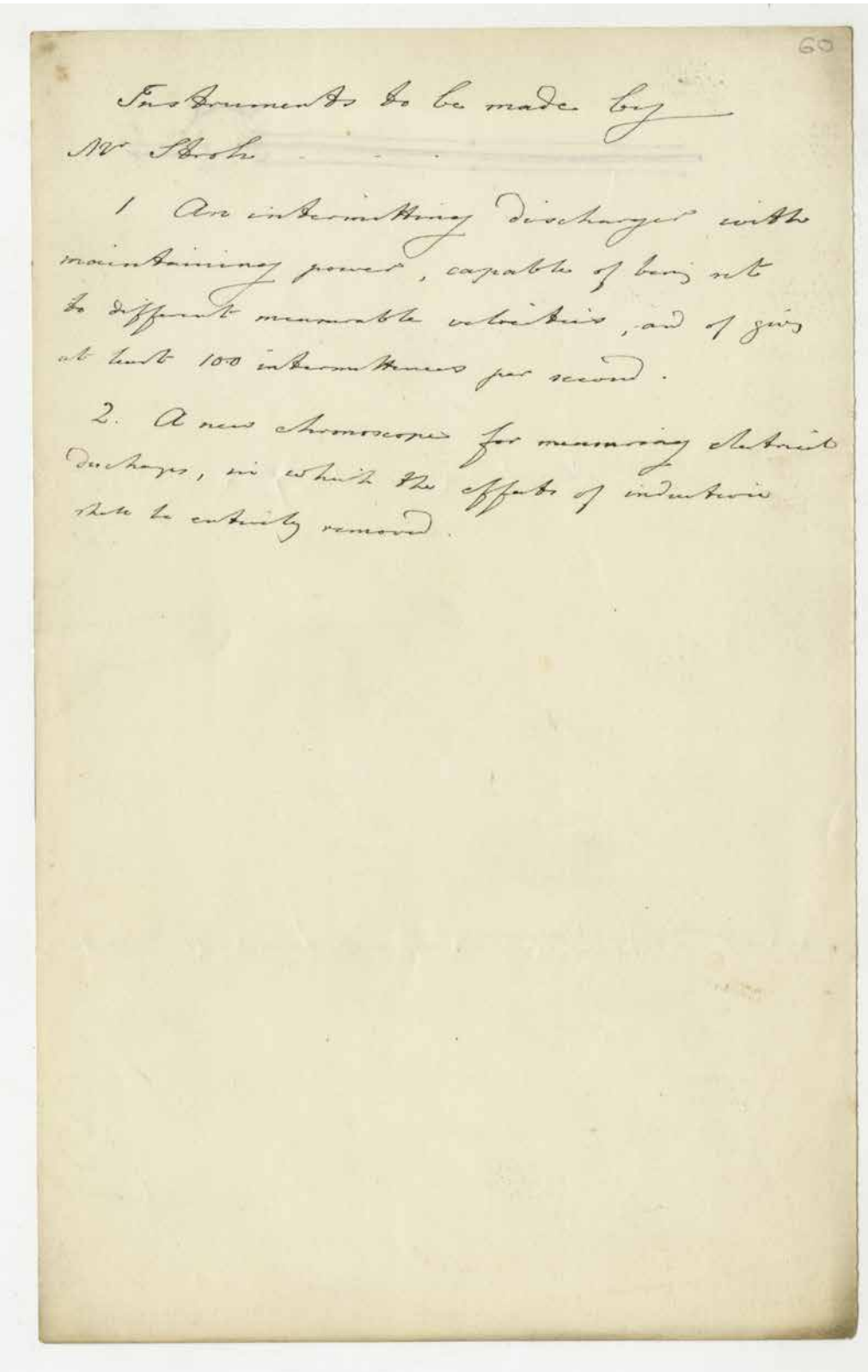
The small wheel makes 17 rotations during one rotation of the large wheel

The large can be turned by the hand 6 times in a second, corresponding with 600 rotations of the small wheel.

As the discharge of 512 elements from 1 mile of wire only occupies 1/1000 of a second, and as the contact with the greatest velocity with which the motion may be driven by the hand lasts much longer than this; the permanent effect on the galvanometer will increase with the number of charges.

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph



60

Instruments to be made by
Mr Stroh

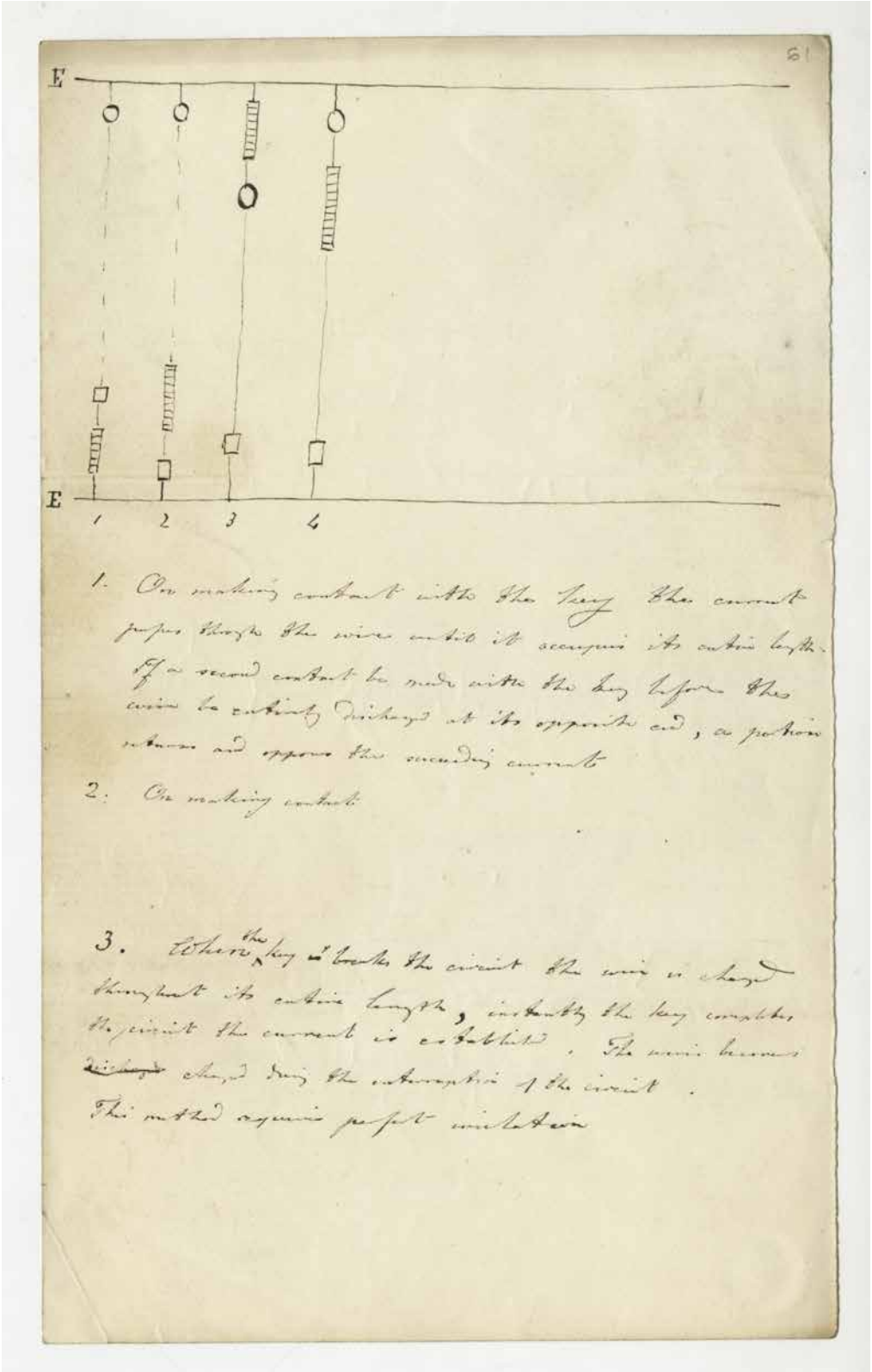
1 An intermitting discharger with maintaining power, capable of being set to different measurable velocities, and of giving at least 100 intermittences per second.

2. A new chronoscope for measuring electric discharges, in which the effects of induction shall be entirely removed.

K/PP107/1/1/60
Outline list of instruments to be made by John Matthias Augustus Stroh (1828-1914), telegraph engineer and inventor, [1852-1872].

The Papers of Charles Wheatstone

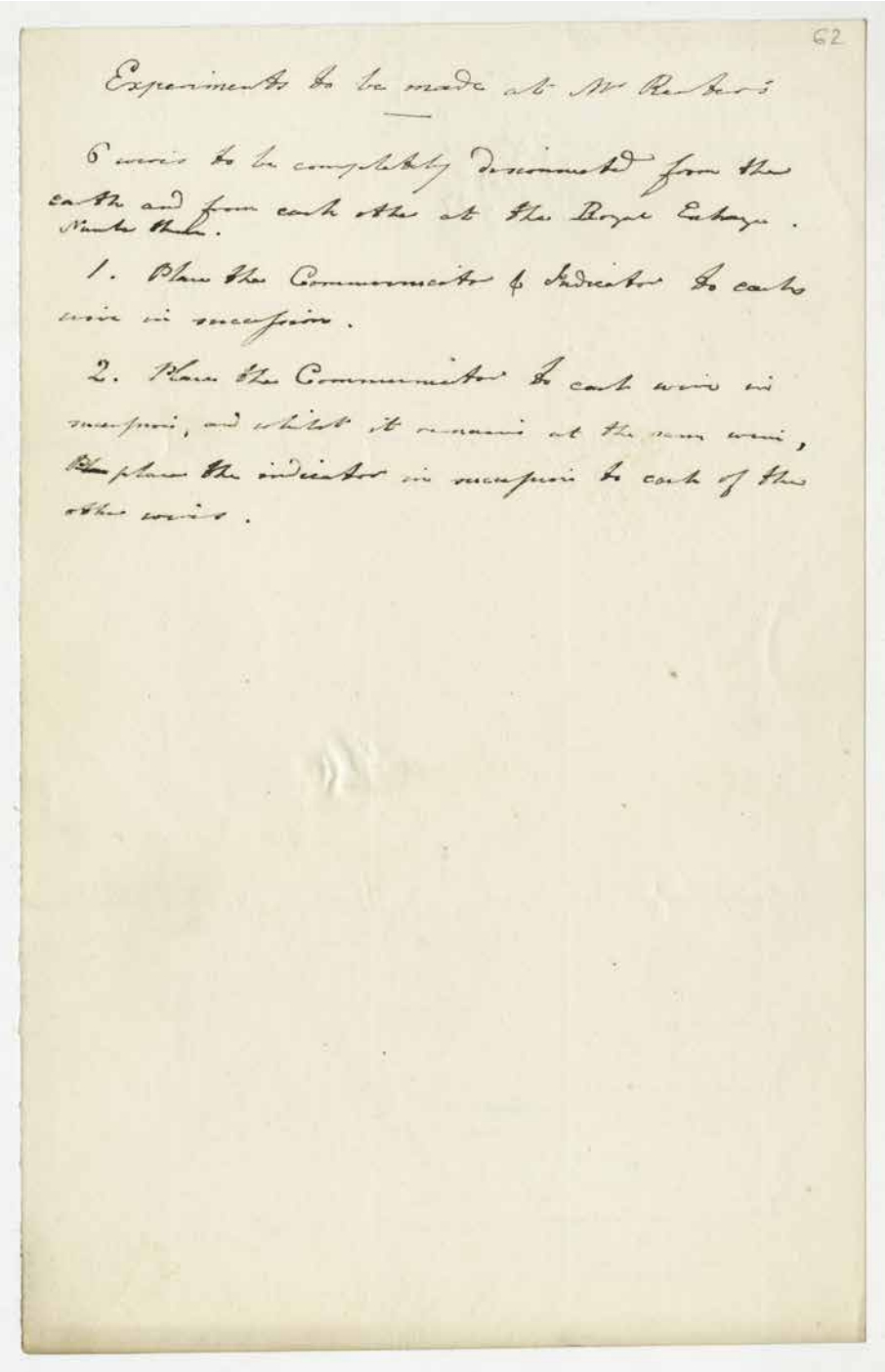
K/PP107/1/1 - Papers relating to the development of the electric telegraph



K/PP107/1/1/61
Note on telegraph keys with sketch diagram, [1836-1872].

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph



62

Experiments to be made at Mr Reuter's

6 wires to be completely disconnected from the earth and from each other at the Rope Entrance.

1. Place the Commutator & Indicator to each wire in succession.

2. Place the Commutator to each wire in succession, and whilst it remains at the same wire, place the indicator in succession to each of the other wires.

K/PP107/1/1/62

Note on experiments to be made at 'Mr Reuter's', [Julius (Paul) de Reuter (1816-1899), news agency founder], [1851-1868].

The Papers of Charles Wheatstone

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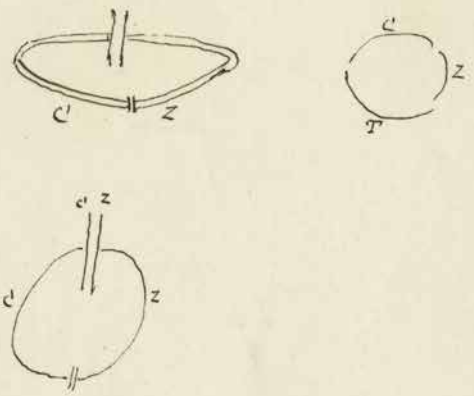
64

Charge a large Leyden jar by means of the rotary reversor from a wire of zinc and copper; if this needs also from a wire of zinc and platinum.

~~Enter with charge~~ If the surface of the jar be large and the wire short the deflection of the needle will be as the electromotive force



K/PP107/1/1/64

Notes and diagrams of experiments using a Leyden jar, [1836-1872].

The Papers of Charles Wheatstone

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65

1

Description of an instrument to measure the reciprocal action of two conducting wires.

The instruments which Ampère himself employed in his electro-dynamic researches are not of the kind that the verification of accurate measures can be ascribed to them. The reason of this lies in the friction, which frequently counts the whole or a great part of the electrodynamic power to be observed and vitiates the observation. With such instruments, even under favorable circumstances, no more can be attained than just to overcome this injurious friction by such electro-dynamic forces, whilst by such more accurate measure it must be assumed that in comparison with the measuring power the friction must be a very small fraction.

Twelve years ago I had, for the purpose of excluding friction and obtaining actual measures, provided a wire wound round a thin wooden frame through which a galvanic current was transmitted and which by means of the electro-dynamic attraction and repulsion of a multiplier might be set in motion with bifilar suspension from two fine metal wires (I will call this bifilar suspended wire-helix the bifilar-coil) and have employed one of these suspension wires to conduct the galvanic current to and the other from. But the whole importance of this arrangement for the purpose of measuring I have more recently learnt from Gauß' bifilar magnetometer from whom I also have learned the application of a mirror fixed to the bifilar coil. In the summer of 1837 I put together such an instrument and performed a series of experiments therewith which all prove that the greatest delicacy can be attained in the

K/PP107/1/1/65

Manuscript transcription of a translated extract from Wilhelm Eduard Weber (1804-1891), German physicist, *Determinations of Electrodynamic Measure*, 1846, [1846-1868], page 1.

The Papers of Charles Wheatstone

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observation of electro-dynamic phenomena with ~~very~~ such feeble currents, with it had never previously succeeded in producing these phenomena.

The instrument next described was constructed in 1841 by M. Meyerstein, I have however first found in Leipzig opportunity to give suitable presentation for a greater series of measures with it.

This instrument consists essentially of two parts: of the bifilar coil with mirror, and of the multiplier.

The bifilar coil which is represented in vertical section by fig 2 consists of two thin brass plates aa and a'a' of 88.0 mm diameter, which is maintained by a 3mm thick brass axis bb' in an opposite distance of 30 mm. Upon this axis between these plates, a copper wire cc of 1/10 of a millimeter diameter covered with silk is wound round nearly 5000 times, and entirely fills the interval between the two plates. Fig 3 represents the same coil in a vertical section perpendicular to the preceding

K/PP107/1/1/65

Manuscript transcription of a translated extract from Wilhelm Eduard Weber (1804-1891), German physicist, *Determinations of Electrodynamic Measure,* 1846, [1846-1868], page 2.

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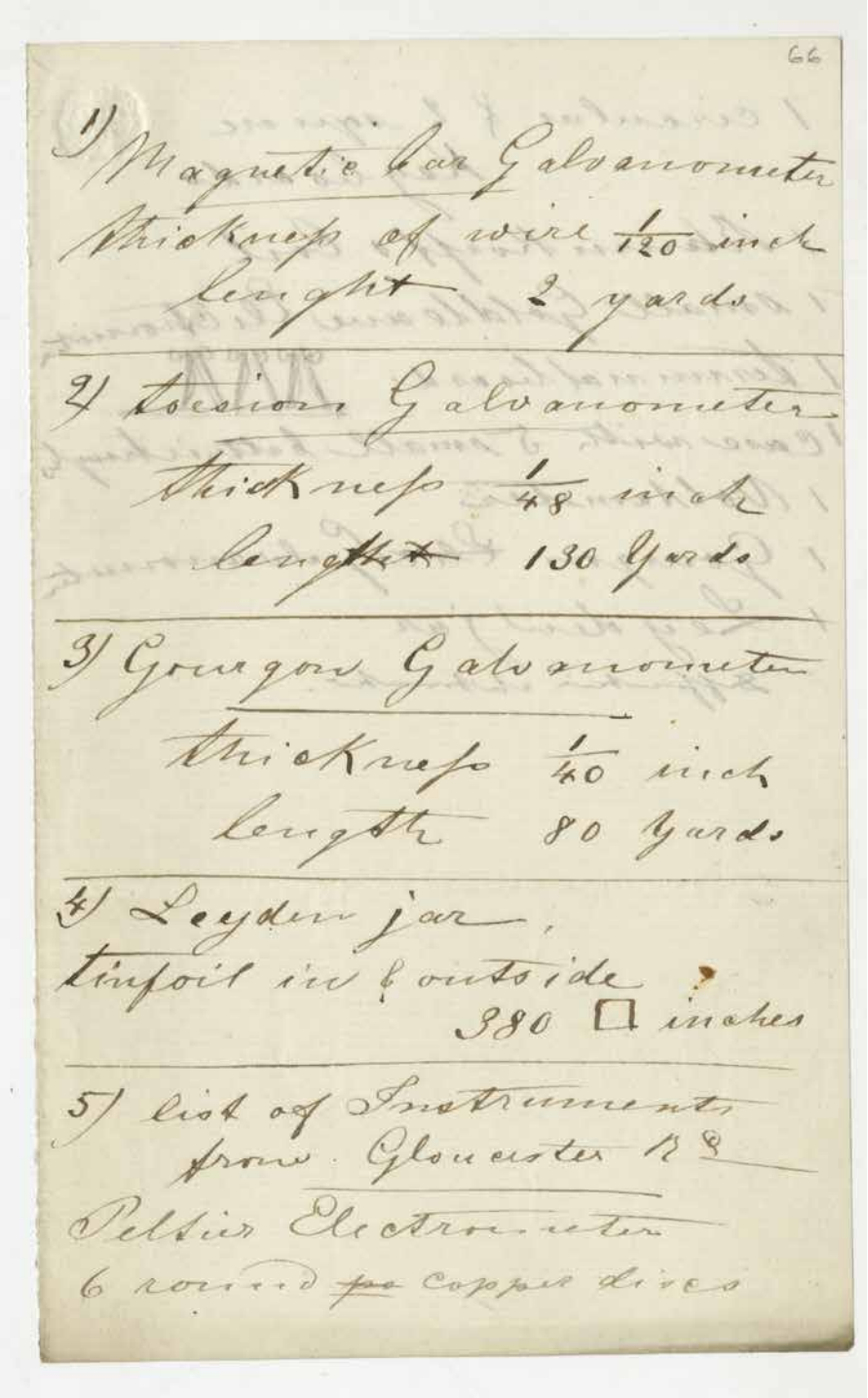

66

1/ Magnetic bar Galvanometer
thickness of wire 1/120 inch
length 2 yards

2/ torsion Galvanometer
thickness 1/48 inch
length 130 yards

3/ Gourgon Galvanometer
thickness 1/40 inch
length 80 yards

4/ Leyden jar,
tinfoil in & outside ?
380 □ inches

5/ list of Instruments
from Gloucester R.R.
Peltier Electrometer
6 round ~~po~~ copper discs

K/PP107/1/1/66

List by John Matthias Augustus Stroh (1828-1914), telegraph engineer and inventory, of various pieces of apparatus including galvanometers and a Leyden jar, [1852-1872], page 1.

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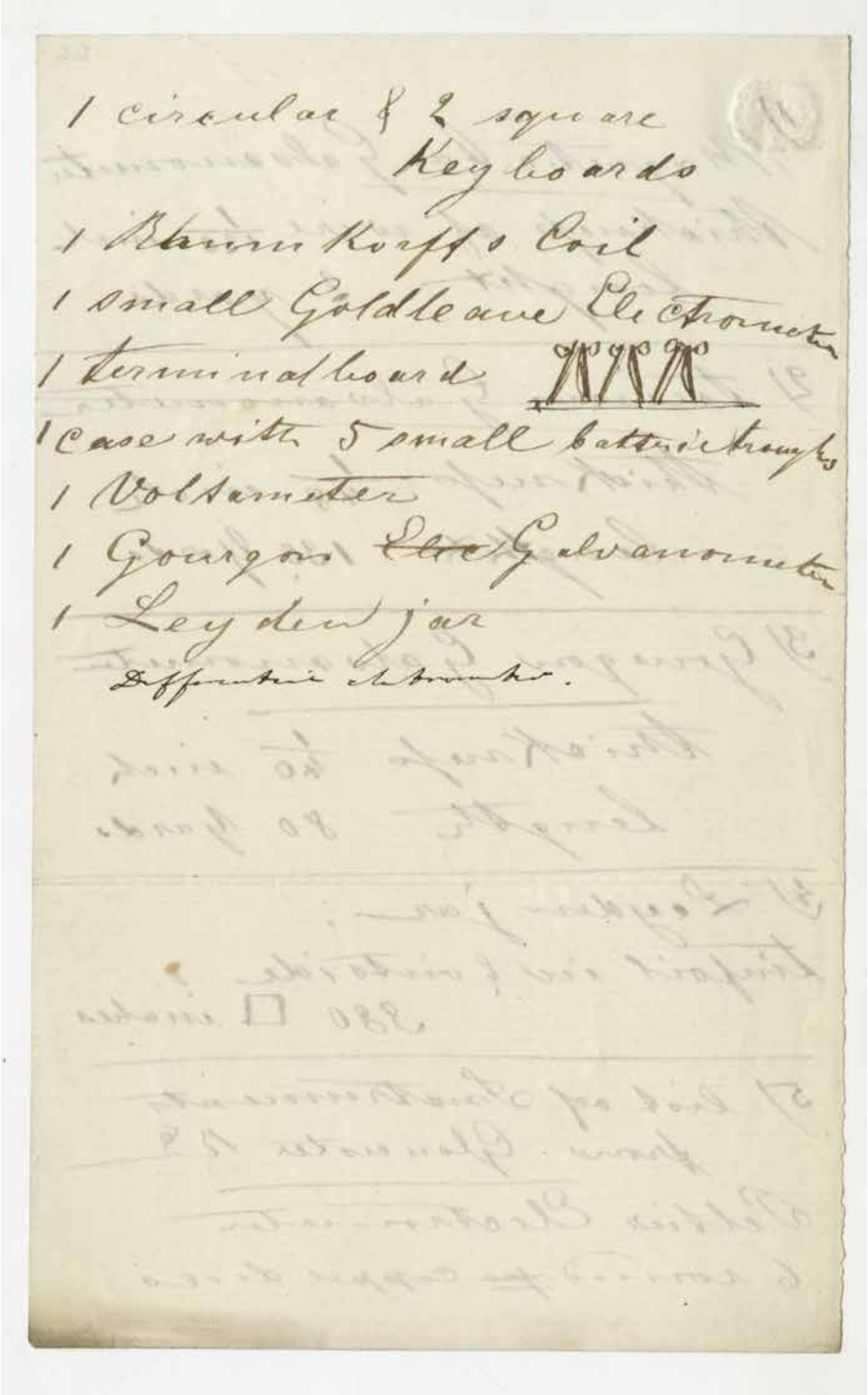

1 circular & 2 square
Keyboards
1 Ruhmkorff's Coil
1 small Goldleaf Electrometer
1 terminal board
1 Case with 5 small battery troughs
1 Voltameter
1 Gourgon ~~Elec~~ Galvanometer
1 Leyden jar
Differential Galvanometer.

K/PP107/1/1/66

List by John Matthias Augustus Stroh (1828-1914), telegraph engineer and inventory, of various pieces of apparatus including galvanometers and a Leyden jar, [1852-1872], page 2.

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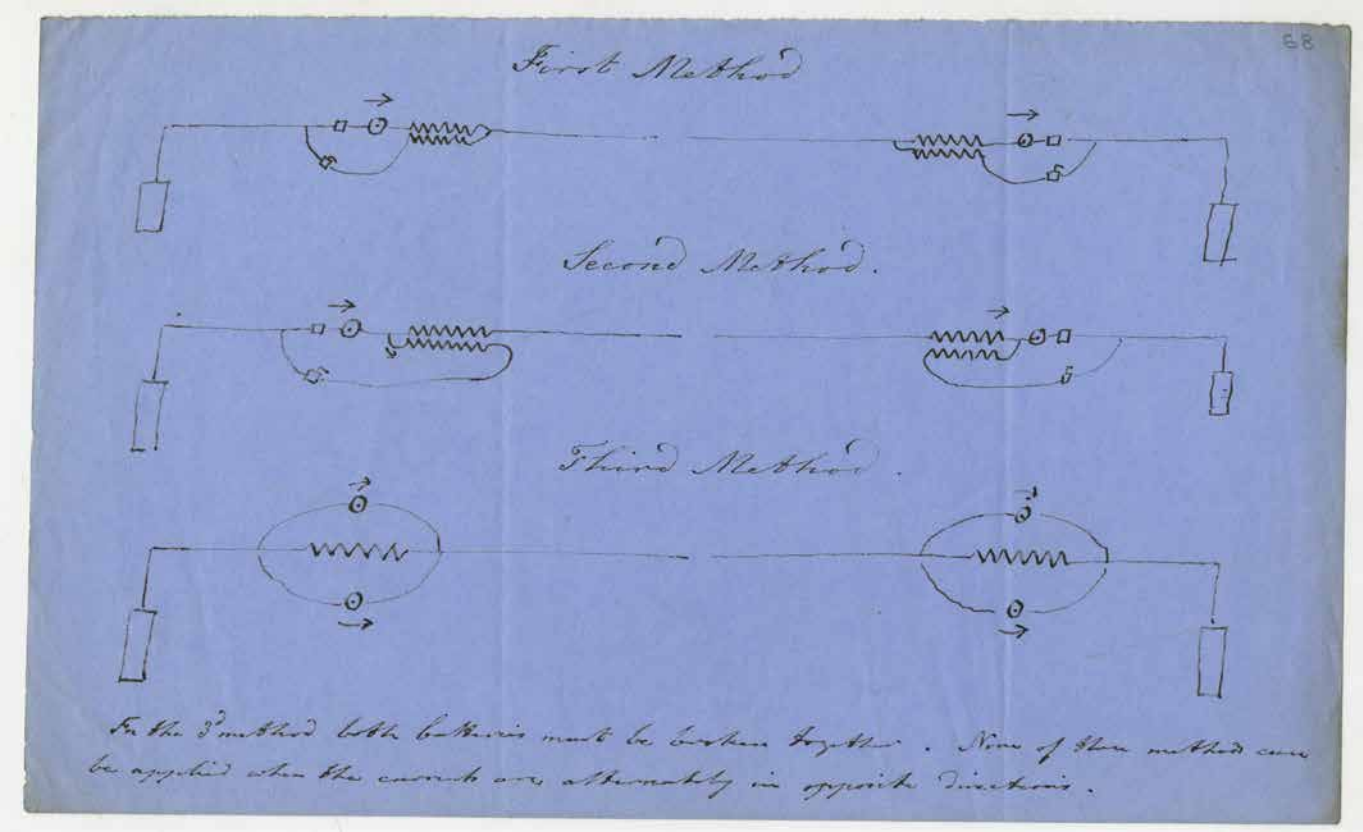

K/PP107/1/1/68

Notes and diagrams on various methods of arranging a circuit, [1836-1872].

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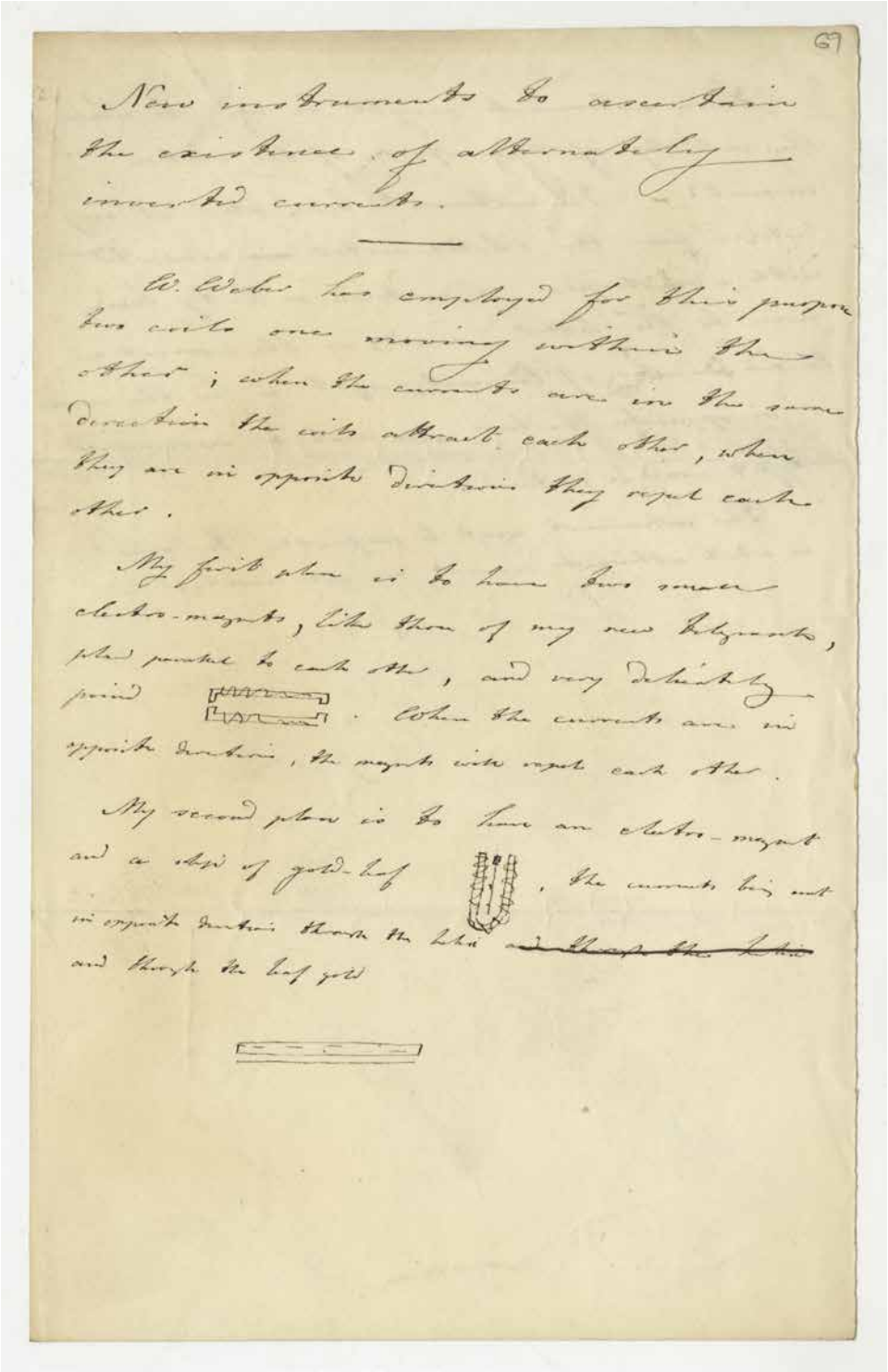

69

New instruments to ascertain the existence of alternately inverted currents.

Wd. Weber has employed for this purpose two coils one moving within the other; when the currents are in the same direction the coils attract each other, when they are in opposite directions they repel each other.

My first plan is to have two small electro-magnets, like those of my new telegraph, placed parallel to each other, and very delicately poised . When the currents are in opposite directions, the magnets will repel each other.

My second plan is to have an electro-magnet and a strip of gold-leaf , the currents being sent in opposite directions through the bar ~~in opposite directions~~ and through the leaf gold

The Papers of Charles Wheatstone

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These instruments might be used to measure the velocity of transmission of the electric current. The instrument being placed at any distance from the electro-motor — connected with a chronoscope; a certain velocity being given to the latter, according as the current in the two branches of the instrument is in the same or in opposite directions, a nul or maximum effect would be produced.

This instrument would be preferable to one in which alternate currents are not employed.

P. 72

The phenomena exhibited in the large spindle shaped vessel where the series of metallic shocks is employed are very peculiar. A system of stratifications occupies the axis of the vessel. On approaching the hand towards the vessel, on any side whatever the luminous system of stratifications is repelled so as convert the straight into a curved line. If the vessel be placed horizontally not far above the table the luminous system will not occupy the axis of the vessel but will approach much nearer its upper part. The mobility of this system is very great.

Admitting this repulsion to be the effect of static induction, i.e. of the electricity of the luminous column upon the hand, a great difficulty occurs. The effect of such induction from the ~~luminous~~ column would be to produce an opposite state in that part of the body which is opposed to it; and, in consequence thereof mutual attraction ~~would~~ ought to take place, whereas we have the most unmistakable repulsion. How is this to be

The Papers of Charles Wheatstone

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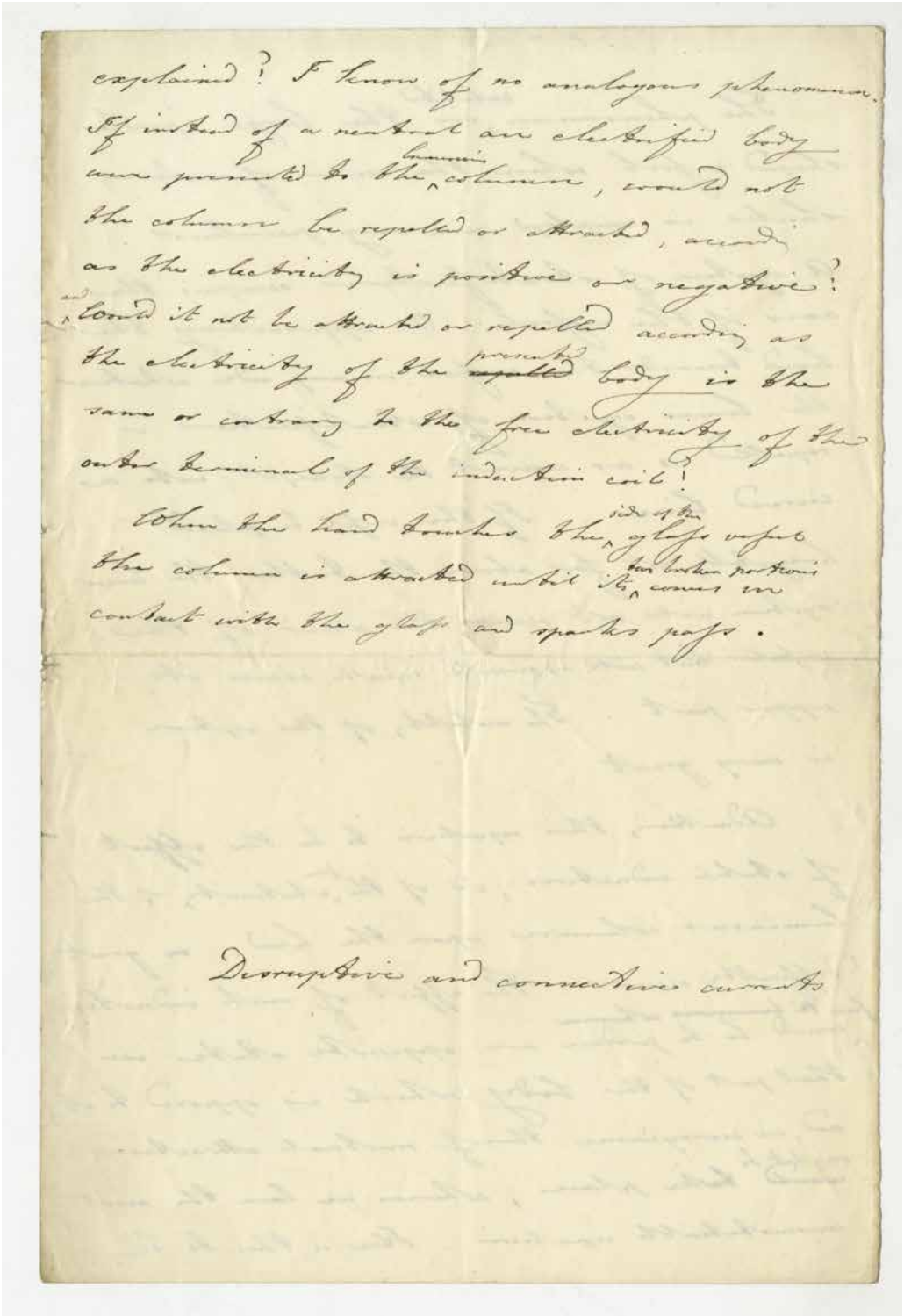


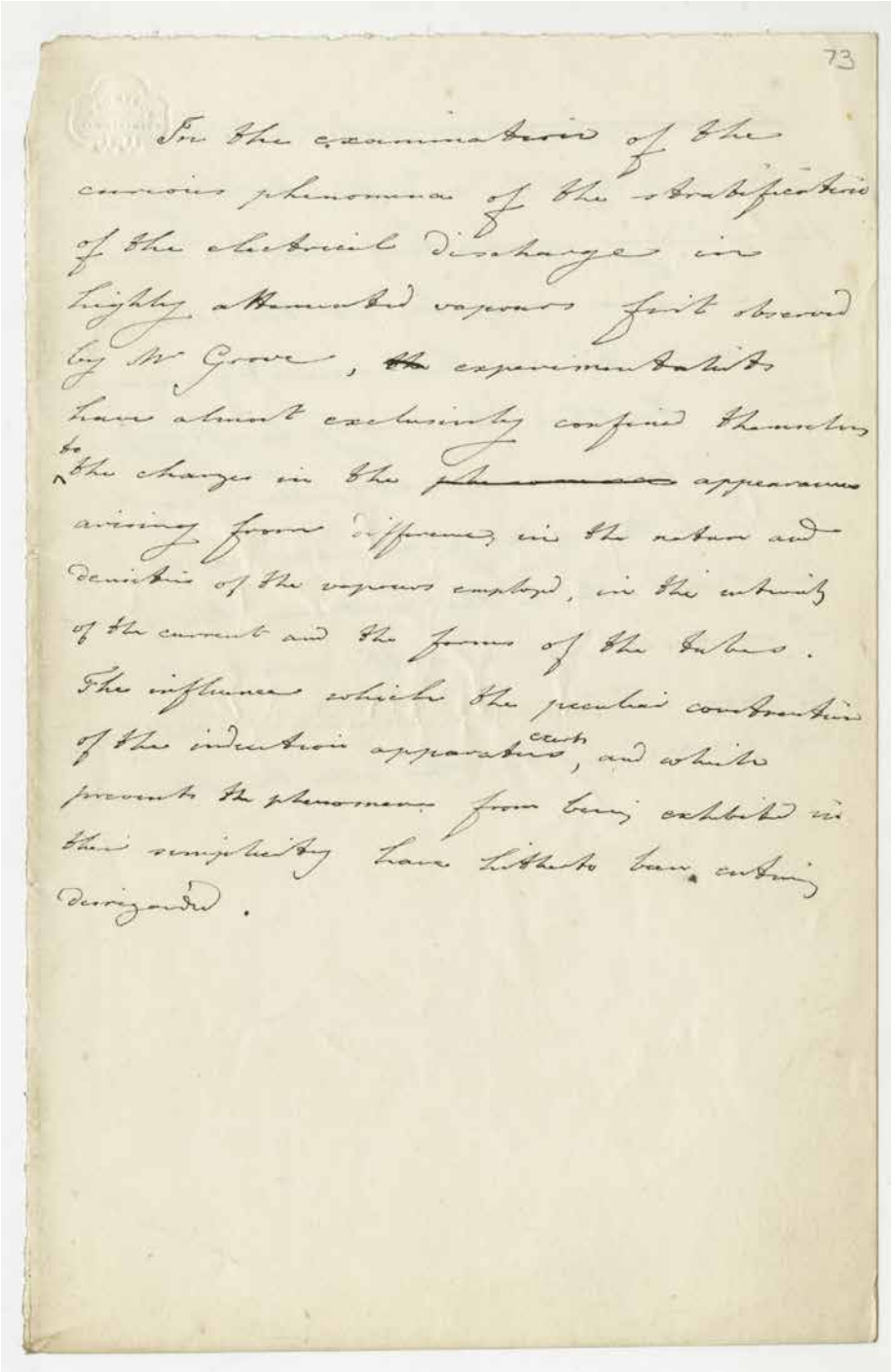
explained? I know of no analogous phenomena. If instead of a neutral an electrified body were presented to the lower column, would not the column be repelled or attracted, according as the electricity is positive or negative? and would it not be attracted or repelled according as the electricity of the ~~repelled~~ presented body is the same or contrary to the free electricity of the outer terminal of the induction coil!

When the hand touches the side of the glass before the column is attracted until the lower portion comes in contact with the glass and sparks pass.

Disruptive and connective currents

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph



73

For the examination of the curious phenomena of the stratification of the electrical discharge in highly attenuated vapours first observed by Mr Grove, ~~the~~ experimentalists have almost exclusively confined themselves to the changes in the ~~phenomena~~ appearance arising from differences in the nature and density of the vapours employed, in the intensity of the current and the forms of the tubes. The influence which the peculiar construction of the induction apparatus exerts, and which prevents the phenomena from being exhibited in their simplicity have hitherto been entirely disregarded.

K/PP107/1/1/73

Note describing the stratification of electrical discharge, [1836-1872].

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph

74

A new comparable Galvanometer

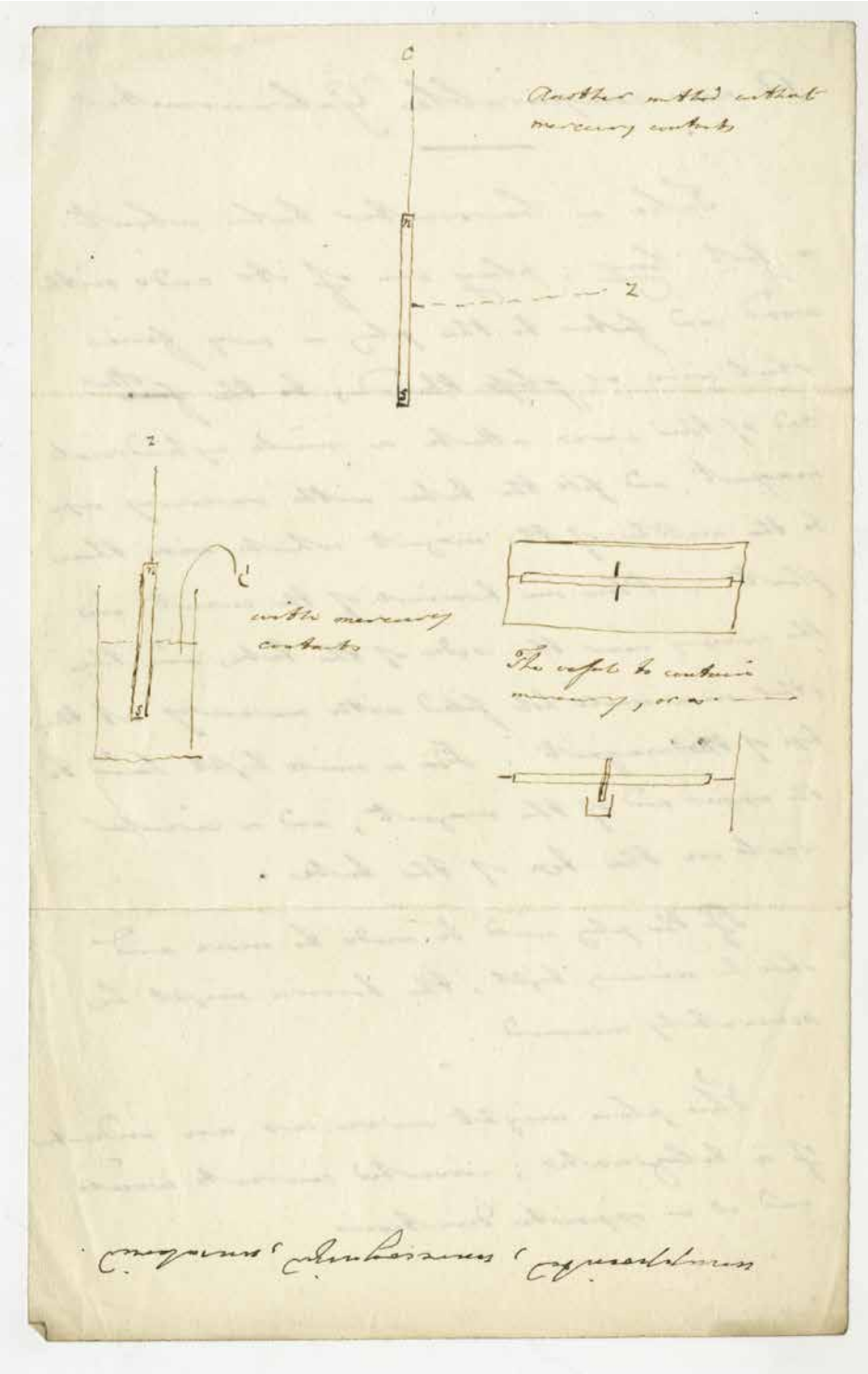
Take a barometer tube about a foot long; plug one of its ends with wood and fasten to the plug a very fine steel wire or glass thread; to the free end of this wire attach a small cylindrical magnet, and fill the tube with mercury up to the middle of the magnet which will then float. Place one terminal of the circuit in the mercury near the side of the tube, and the other in a small hole filled with mercury at the top of the magnet. Fix a small light hand to the upper end of the magnet, and a circular scale on the top of the tube.

If the plug could be made to move and still be mercury tight, the terminal might be accurately measured.

This plan might serve as an indicator of a telegraph; inverted currents would send it in opposite directions

The Papers of Charles Wheatstone

K/PP107/1/1 - Papers relating to the development of the electric telegraph



K/PP107/1/1/74
Notes with diagrams on a new comparable galvanometer, [1836-1872], page 2.

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Electro-magnetic Chronoscope.

The instantaneous deflection of the needle of a galvanometer might be employed as a measure, if any relation can be established between the duration of the current and the limit of deflection of the needle when a constant current is employed.

A constant deflection of the needle be established by means of a rheostat.

The rise of a column in the microvoltameter might be employed, but in consequence of the great resistance in the circuit the intensity of the current would not be sufficient to produce a marked effect in so short a time.

By means of a rheotrope wheel the correspondence of small intervals of time with the deflection of a needle might be empirically determined. Or better by means of a bullet falling through different distances.

An apparatus should be made for the fall of a bullet through vacuo.

The deflection of the needle could not be employed unless the line were perfectly insulated.

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Note describing an 'electromagnetic chronoscope', [1836-1872].

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To make an Electric Telegraph act with double the power actually transmitted.

Place in the circuit of the Telegraph and near it a battery having an electro-motive force ~~slightly~~ greater than that of the transmitted portion of the current, and make it regulatable to any less amount by a rheostat in a derived circuit. (or which is rather better, for then no current will exist in the behind circuit, a many of plates a greater or less number of shunts in the circuit).

Then the circuit ~~[illegible]~~ is a closed one with the two batteries in opposite directions the Telegraph does not act, but on inverting the current of the distant battery. the Telegraph acts under the joint influence of the near and distant battery which are then in the same direction.

The compensating battery is not required to be of equal electromotive force with the original battery except in the case of perfect insulation; in other cases it is only the residual portion of the current which requires to be compensated

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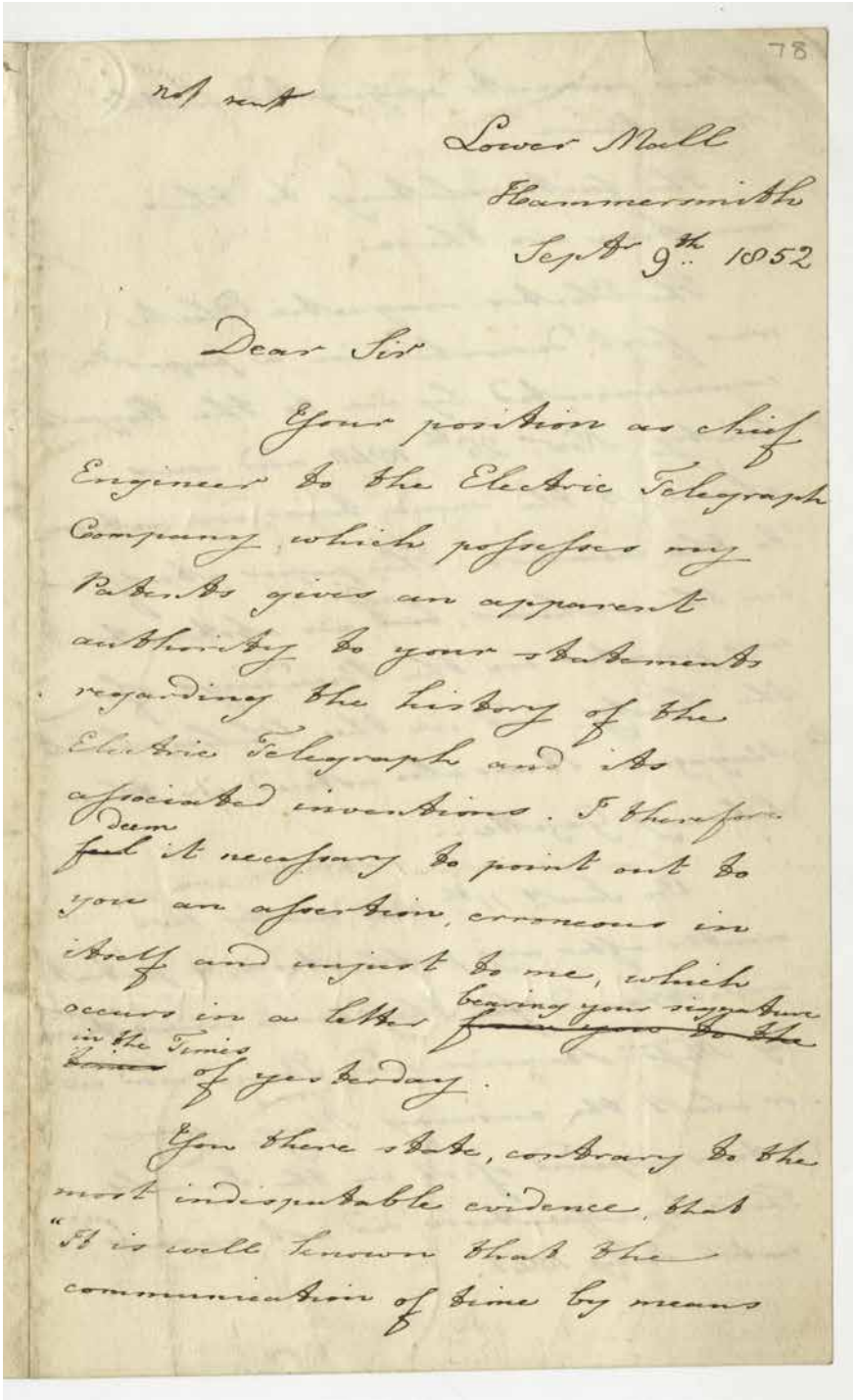

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not sent

Lower Mall
Hammersmith
Sept 9th 1852

Dear Sir

Your position as chief Engineer to the Electric Telegraph Company, which possesses my Patents gives an apparent authority to your statements regarding the history of the Electric Telegraph and its associated inventions. I therefore deem it necessary to point out to you an assertion, erroneous in itself and unjust to me, which occurs in a letter bearing your signature ~~from you to the~~ in the Times of yesterday.

You there state, contrary to the most indisputable evidence, that "It is well known that the communication of time by means

K/PP107/1/1/78
Draft letter to Edwin Clark (1814-1894), civil engineer, Electric and International Telegraph Company, regarding his letter in *The Times* in which he states that Alexander Bain (1810-1877), Scottish inventor, invented the electro-magnetic clock, 1852 Sep 9, page 1.

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voltaic currents originated with Mr A. Bain"

The facts relating to this invention are these:

The Electro-magnetic Clock was first described in a paper communicated by me to the Royal Society Nov.r 26th 1840 and was shown, at the same time, in action to the members. The paper itself is in the archives, ~~but~~ and an abstract was printed in the Proceedings of the Society and in the Philosophical Magazine. It was also noticed in the Literary Gazette.

On Jan.y 11th 1841, nearly two months after my publication, a patent was obtained for the same invention by Mess.rs Barwise and Bain, and in or about the ensuing May some notices appeared of it in the Journals. Their specification did not appear until July 1841.

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So far then as the original publication and exhibition of the electro-magnetic clock goes there can be no question whatever of my priority.

Bain, to justify his proceedings and assert a claim to the invention, subsequently asserted that he had communicated the idea to me in August 1840. Fortunately I had ~~developed~~ explained my plans ~~long~~ to a great number of friends long before this time

K/PP107/1/1/78

Draft letter to Edwin Clark (1814-1894), civil engineer, Electric and International Telegraph Company, regarding his letter in *The Times* in which he states that Alexander Bain (1810-1877), Scottish inventor, invented the electro-magnetic clock, 1852 Sep 9, page 3.