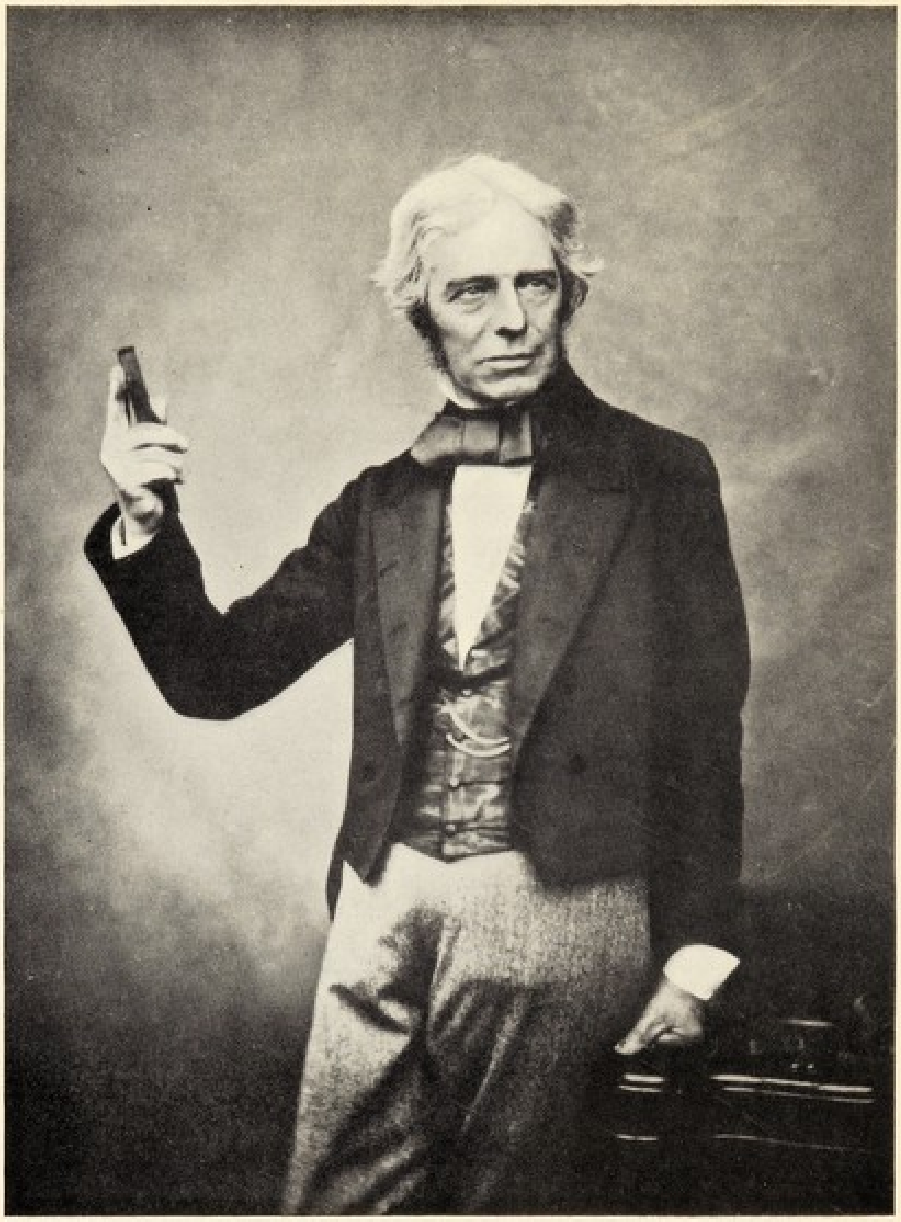
FARADAY CELEBRATIONS

SEPTEMBER
1931



MICHAEL FARADAY

A Reproduction of Some Portions of

FARADAY'S DIARY

presented by the Managers of

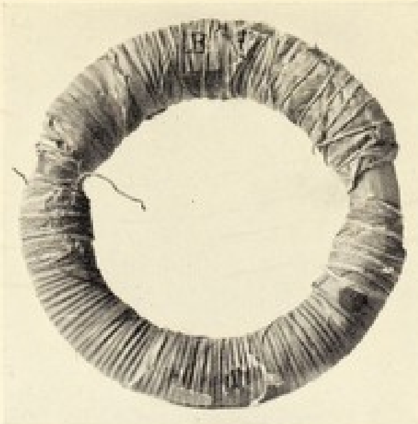
THE ROYAL INSTITUTION
OF GREAT BRITAIN

to

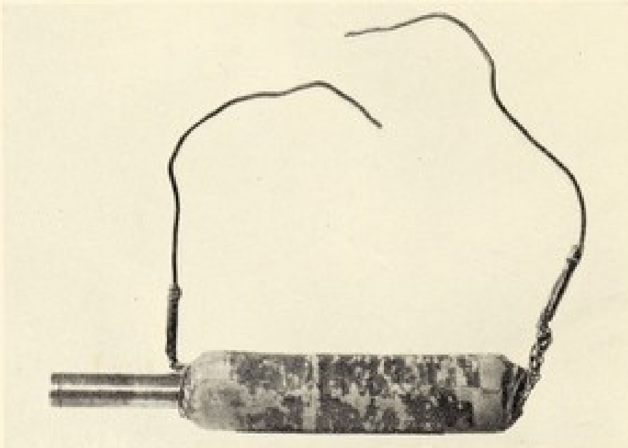
Dr. H. H. Dale.

as a token of their appreciation
of his presence at the

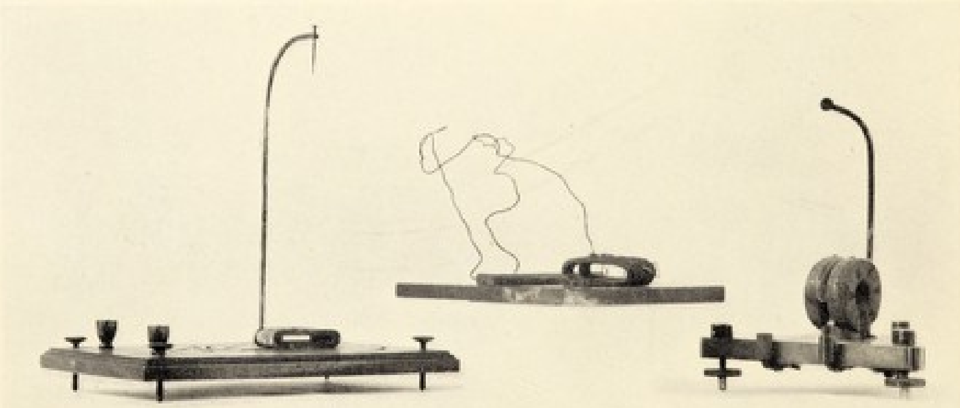
FARADAY CELEBRATIONS
SEPTEMBER 1931



Historic ring of soft iron, wound with separate coils of copper wire connected to battery and galvanometer respectively, used by Faraday in his first successful experiment in electro-magnetic induction



Helix of copper wire and bar magnet used by Faraday. It was with this apparatus that he first induced an electric current by plunging the magnet into the coil



Early galvanometers made and used by Faraday

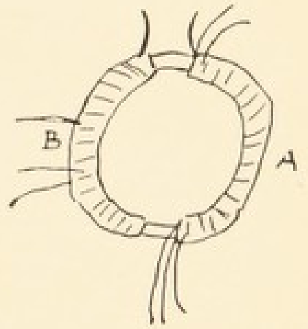
THE TWO PORTIONS OF FARADAY'S DIARY *here reproduced relate to experiments which were made in the year 1831. The first begins with the entries describing his work on Aug. 29. On that day he demonstrated for the first time and for a particular case the principle that electromotive force is generated by a changing magnetic field. The succeeding entries on Sept. 12, 24, 29 and Oct. 1 show him pressing on with the investigation of the new effect. The suggestion in the seventeenth paragraph, that the transient effects he had found might be connected with Arago's experiment was tested and verified by a research which he began on Oct. 28. The entries on this day form the second portion of the present reproduction.*

AUG. 29TH—OCT. 1ST, 1831.

AUG. 29TH, 1831.

1. Expts. on the production of Electricity from Magnetism, etc. etc.

2. Have had an iron ring made (soft iron), iron round and $\frac{7}{8}$ inches thick and ring 6 inches in external diameter. Wound many coils of copper wire round one half, the coils being separated by twine and calico—there were 3 lengths of wire each about 24 feet long and they could be connected as one length or used as separate lengths. By trial with a trough each was insulated from the other. Will call this side of the ring A. On the other side but separated by an interval was wound wire in two pieces together amounting to about 60 feet in length, the direction being as with the former coils; this side call B.

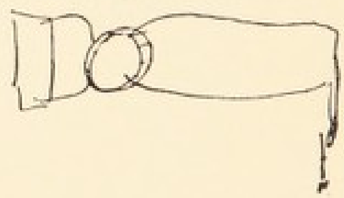


3. Charged a battery of 10 pr. plates 4 inches square. Made the coil on B side one coil and connected its extremities by a copper wire passing to a distance and just over a magnetic needle (3 feet from iron ring). Then connected the ends of one of the pieces on A side with battery; immediately a sensible effect on needle. It oscillated and settled at last in original position. On *breaking* connection of A side with Battery again a disturbance of the needle.

4. Made all the wires on A side one coil and sent current from battery through the whole. Effect on needle much stronger than before.

5. The effect on the needle then but a very small part of that which the wire communicating directly with the battery could produce.

6. Changed the simple wire from B side for one carrying a flat helix and put the helix in the plane of the Mag. Meridian to the west of the S pole of the needle, so as to shew best its influence when a current passed through it—the helix and needle were about 3 feet from the iron ring and the ring about a foot from the battery.



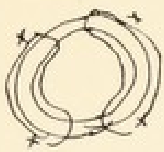
7. When all was ready, the moment the battery was communicated with both ends of wire at A side, the helix strongly *attracted* the needle; after a few vibrations it came to a state of rest in its original and natural position; and then on *breaking* the battery connection the needle was as strongly *repelled*, and after a few oscillations came to rest in the same place as before.

8. Hence effect evident but transient; but its recurrence on breaking the connection shews an equilibrium somewhere that must be capable of being rendered more distinct.

9. The direction of the pole towards the helix was, when the contact was first made, as if the helix round B was a part of that at A, i.e. the electric currents in both were in the same direction; but when the contact with the battery was broken the motion of the needle was as if a current in the opposite direction existed for a moment.

10. Had a short cylinder of iron $\frac{7}{8}$ thick, 4 inches long, and coiled round with 4 pieces of wire each about 14 feet long: made these coils into one and substituted this in place of the flat helix. The needle was affected as before, but not at all as if the iron had helped to develope magnetic power—not more than helices round it would probably have done without the iron. It was the same transient and inverted states as before.

11. Removed the iron and helices and substituted two platina poles to ends of B coil; put these into solution of copper, lead, etc. etc., but could get no evidence of chemical action. Put solution of copper on to one pole and then touched the drop with the other; then connected the battery, then broke connection at drop, and then at battery, and so went on in succession so as to avoid the recurrence of the return or opposite current on the drop: but got no evidence of chemical action.



12. On making *all* the wire round the iron ring one helix and sending current from battery through it, and also hanging a magnetic needle over the ring, one pole being in the middle at the point of suspension, the needle darted about irregularly and shewed poles—two N and two S. On putting paper over the ring and sprinkling filings over it also see the 4 poles, but were irregularly placed. Iron probably not soft but evidently not a perfect conductor, for the parts between the ends of the two general helices of A and B were of very different magnetic power to the ends of the helices.

13. Put a helix (of brass brace spring) round a glass jar and brought a needle within it in various positions, but it behaved merely as a single ring of wire would have done.

14. Repeated (6): continued the contact of A side with battery but broke and closed alternately contact of B side with flat helix. No effect at such times on the needle—depends upon the change at battery side. Hence is no permanent or peculiar state of wire from B but effect due to a wave of electricity caused at moments of breaking and completing contacts at A side.
15. Tried to perceive a spark with charcoal at flat helix junction B side but could find none. Wave apparently very short and sudden. No use trying platina wire. Not sure large battery would not produce spark.
15*a*. Then disjoined the three portions of wire on A side—made two into one helix and sent battery current through that—and connected the third portion with the flat spiral and needle, etc. so as to represent B side. Effects on needle stronger than before but same in character, occurring inversely, etc. on breaking battery connection, etc. etc.
16. A large bar magnet brought in contact with the ring caused no change at the flat helix.
17. May not these transient effects be connected with causes of difference between power of metals in rest and in motion in Arago's expts.?
18. Took the iron cylinder (10) and connecting two of the wires into one Helix and the other two into another, connected one of these Helices with the flat spiral and needle and the other with the battery—immediately a sharp short pull upon the needle, the effects being exactly as before but not so strong. Hence a ring magnet is not wanted.
19. Brought the poles of strong magnets in contact with ends of the iron cylinder, but found no difference upon the needle at the flat spiral—all the effects seem due to the Electrical current only.

SEPT. 12, 1831.

20. Have prepared several coils, helices, etc. etc. etc. Coil A consists of various lengths (as under) of copper wire, string being interposed between the turns of each coil and calico or linen between the different coils.

Coil B was composed of alternate copper and iron (see lengths beneath), the iron either covered with cotton or else separated as before.

A	B
20—6	C—26—6
20—5	I—30—6
21—4	C—31—5
24—3	I—31—5
25—2	C—36—4
26—1	I—38—4
27—6	C—38—3
28—5	I—37—3
28—4	C—39—2
29—3	I—37—2
31—2	C—38—1
31—1	I—41—1
310	422
	C—208
	I—214

These lengths are the lengths of coil (not including the projecting ends), and the core in each is of wood.

C a flat spiral of covered iron wire containing about 6 feet.

D a double flat do. do. 19 feet.

E a do. copper wire uncovered do. 14 feet.

F a cylindrical round solid helix of covered iron wire containing about 12 feet.

G do. of 31 feet.

H a double flat spiral of covered iron wire of 18 feet.

I a coil of covered iron wire 35 feet about and 2$\frac{1}{2}$ inches mean diameter, forming a thick ring; this then covered by a helix at right angles to it of two lengths of copper wire 40 feet each or 80 feet together, these being separated by string and calico from each other as in former cases.

K The iron ring covered of (2).

L The covered iron cylinder of (10).

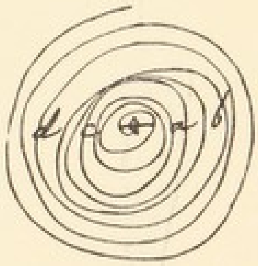
SEPTR. 24, 1831.

21. A tried–each length independant and right–half the lengths (i.e. 1, 3, 5, 7, 9, 11) made into one helix, the other half (i.e. 2, 4, 6, 8, 10, 12) into another helix by connection, so as to form two helices closely interposed, having the same direction, not touching anywhere and each 150 feet long. One helix connected

as in (6) with flat helix and the other with battery of 10 pr. plates 4 inches square. Not the slightest effect on needle at flat helix either at time of contact or disunion or any other way. No induction sensible—contacts all perfect.

22. Then B, the final copper helix containing 208 feet wire, the final Iron helix 214 feet, but no effect on needle, though sometimes the battery current was sent through the iron, sometimes the copper; the iron seemed to do no more than the copper.

23. Used H. When brought towards pole of needle concentric with it, the pole seemed to be repelled towards edge in any direction going from +. In fact the pole of needle in inducing magnetism on the wire could do it better at *a* than at +, and better at *b* than at *a*, opposite poles no doubt being formed at *c* or *d*. Would be it so also with a continuous plate as well as a flat helix. Evident therefore that magnetic action tends to arrange particles longitudinally in the direction of its own axis and is itself powerfully arranged by previous arrangement of iron particles—important influence thus exerted.



24. When H connected with the battery then the centers were the poles, and there was nothing particular in the magnetic action evolved. The moment the connection was broken the magnetism was lost.

25. The double flat iron helix H connected with wires leading away, as in (6), to flat copper helix and needle, and then pole of a powerful bar magnet brought flat against iron helix and suddenly removed to distance—but no effect produced at test helix beyond that of motion of magnet itself.

26. The flat helix H put between N and S poles of the two bar magnets, the lower ends of bars touching, and then the upper poles put close to or kept at distance from H—but still no effect at indicating helix at distance.

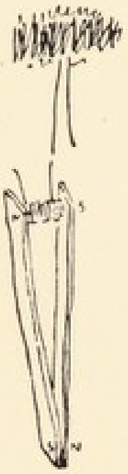
27. A flat copper helix E substituted for H and experimented with but still no effect.

28. Two double iron spirals such as H but side by side—one connected with indicating spiral at distance and a current from 10 pr. of plates and trough sent through the other. No sensible inductive effect.

29. I. Tried in various ways by currents through iron or copper

but no effect at indicating coil. Magnetic poles brought quickly to it and then removed, still no effect.

30. When copper of I carrying current no particular magnetism in the iron that was sensible to needle; those parts of iron wire ends nearest to rings were powerful poles for wire but not powerful for helix used and for battery.



31. Covered Iron wire bent to and fro like a cracker; when current through it no particular action.

32. The iron ring K and cylinder L acts as before and very well.

33. The iron cylinder and helix L. All the wires made into one helix and these connected with the indicating helix at distance by copper wire: then the iron placed between the poles of bar magnets as in former expt. and in fig. Every time the magnetic contact at N or S was made or broken there was magnetic motion at the indicating helix, the effect being as in former cases not permanent, but a mere momentary push or pull. But if the electric communication (i.e. by the copper wire) was broken then these disjunctions and contacts produced no effect whatever. Hence here distinct conversion of Magnetism into Electricity.

34. Perhaps might heat a wire red hot here–try with Marshes magnet.

SEPT. 29TH.

35. M. Put two coils of copper wire round block of wood, string intervening and the coils alternating. Each coil had 34 turns of 73 inches each–each was therefore 2432 [*sic*] inches or 202.8 feet in length. Each had one joint but bright and well twisted.

OCTR. 1, 1831.

36. A battery of 10 troughs each of 10 pr. of plates 4 inches square charged with good mixture of sulphuric and nitric acid, and the following experiments made with it in the following order. The discharge of the battery between charcoal points was very powerful at the first and very good at the conclusion.

37. One of the coils of M connected with the flat helix as in expt. (6), and the other with the poles of the battery (it having been found that there was no metallic contact between the two). The mag. needle at the indicating flat helix was affected but so little as to be hardly sensible.

38. In place of the indicating helix our Galvanometer was used and then a sudden jerk was perceived when the battery communication was *made* or *broken*, but it was so slight as to be scarcely visible—it was one way when made, the other when broken, and the needle took up its natural position at intermediate times.

39. Hence there is an inducing effect without the presence of iron, but it is either very weak or else so sudden as not to have time to move the needle. I rather suspect it is the latter. Use a hollow helix in place of indicating galvanometer and put needle in to magnetise. Compare with effect with Iron present also.

40. The Galvanometer tells better than the flat helix.

41. Endeavoured to obtain evidence of Chemical action as in (11), but could not. Probably the interference of fluid conductors is enough to stop the wave.

42. Could get no heating effect with Platina wire or spark with charcoal with this arrangement at induced side.

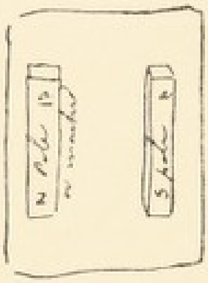
43. When a small battery was introduced on induction side so as to send a continual current through that helix and constantly deflect the galvanometer needle, the making and breaking of the contact on the other side was not more sensible if so sensible as with the helix alone. And as contact was made in opposite directions it would appear that when currents in both wires there was little effect or none beyond that with no first current.

44. Now used the Ring K instead of these large coils—all other things for induction, etc. remaining the same as in the former expt., and in (6). With index helix there was powerful effect, and with indicating galvanometer very powerful, pulling the needle quite round, but still it was only momentary. The needle settled as at first though contact continued, and when contact was broken the needle was pulled for the moment in the opposite direction with equal force.

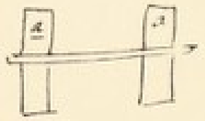
45. Decomposition as at (11)—could not perceive the least trace.

46. Got a spark with charcoal at the end of the inducing wires, very distinct though small—only at the moment of contact or disjunction. Tried to heat a platina wire but probably failed because of too great thickness of wire.

OCT. 28, 1831.



85. At. Mr Christie's to-day making many expts. with the great magnet of the Royal Society. a, a are the ends of the projecting poles of the magnets: each is 12 ? inches long and 3 ? inches wide and they are about 10 inches apart. A soft iron cylinder $\frac{3}{4}$ inch in diameter and 13 inches long was put through O–all the ends of O helices made into 2 bundles and these connected by long copper wires, bell wire, with the last galvanometer that I made in a jar. This Galvanometer was about 10 feet from the magnet and in about the position marked in the sketch*. In altitude it was rather above the middle of the poles.



86. By connecting the two poles (magnetic) by the soft iron cylinder, when connection between the galvanometer and wires was not made, the galvanometer was very slightly affected, so little as to be barely sensible. But when wires *were* connected, then on making or breaking the magnetic contact with the iron cylinder–a powerful pull *whirling the Galvanometer needle* round many times was given.

87. As the helix or cylinder were moved to or from the magnet, *not touching*, corresponding effects were exhibited by the galvanometer.

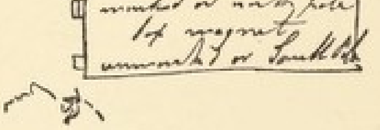
88. When the contact was continued–no permanent effect on the needle was produced. Even with this powerful magnet the effects were only for a moment as in former cases at home.

89. As the evidence of a strong current for the moment was visible we tried other actions. Easily made magnetic needles when a helix (hollow) was substituted for the galvanometer.

90. On bringing ends of short wires from the ends of the helices O to the tongue and gums could get no taste or flash.

91. Could get no spark by charcoal and wire–could not heat platina wire of the fineness I possessed, but I had none of Wollaston's Silver platina.

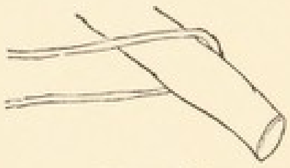
* [85] 



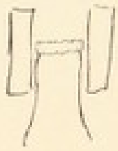
92. Could get no chemical action on Sul. copper though took care to repeat contact at proper times, etc. etc.

93. Re-arranged Galvanometer—tried a jacket like that of (61) but of thick copper plate—put with paper on the soft iron cylinder. Obtained a good effect at the Galvanometer. Put on three jackets and connected at projecting parts—somewhat more of effect but contact not good with wires—too hasty.

94. Put paper on iron cylinder and took 6 turns of copper wire on it. Very powerful effect at Magnetic contacts and disjunction.



95. Took only a half round of wire on iron cylinder—still excellent effect on needle.



96. Brought helix O up suddenly between the large poles of the magnet; it having no iron bar in its axis. The needle was strongly affected; and also upon its removal as in former cases. This of course a mere effect of approximation and that not very near—not subject to any objection founded on notion of the iron exerting a momentary peculiar action at time of becoming a magnet—is directly connected with Arago's expt.

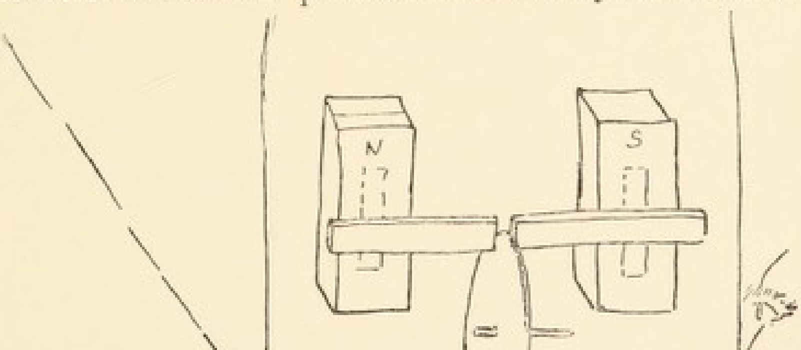
97. A copper bolt $\frac{3}{4}$ inch in diameter put through helix O: not more action than without.

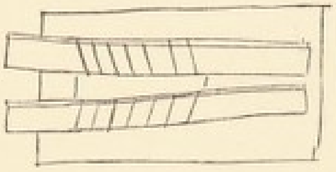
98. A thick iron wire put through helped to increase the action.

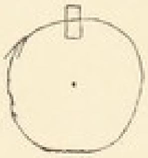
99*. Made many expts. with a copper revolving plate, about 12 inches in diameter and about $\frac{1}{5}$ of inch thick, mounted on a brass axle. To concentrate the polar action two small magnets 6 or 7 inches long, about 1 inch wide and half an inch thick were put against the front of the large poles, transverse to them and with their flat sides against them, and the ends pushed forward until sufficiently near; the bars were prevented from slipping down by jars and shakes by means of string tied round them.

100. The edge of the plate was inserted more or less between the two concentrated poles thus formed. It was also well amalgamated, and then contact was made with this edge in different places by conductors formed from equally thick copper plate and with the extreme end edges grooved and amalgamated so as to fit on to and have contact with the edges of the plate. Two of these were attached to a piece of card board by thread at such

* [99]







distances that they might come in contact with two near parts of the edge of the plate at once; these conductors being connected by wires with the Galvanometer.

101. The circular plate was in all the expts. nearly in the plane of the magnetic meridian, the Galvanometer in the same place as before. In the following notes and diagrams the plate will be represented by a circle looked at from the west or from the eye ( ) in the above sketch; the direction of its motion will be represented by arrow heads. The place of the poles (magnetic) by a red area thus [1], and the place of the conductors by black sketches thus .

102*. The Galvanometer had two needles put north and south, one between the helix the other above, but the upper one gave by its stronger power direction to the whole, and the observations were always made upon its south or unmarked pole (that pointing south).

103†. When conductors were on edge of plate equidistant from place of poles, and plate raised up till edge level with middle of each pole and then turned as in the figure (from right to left above), then galvanometer gave indications and the S pole of the upper needle passed towards the *East*. But when plate turned the other way, all other things being the same, the S pole went *West*.

104. The direction of the Galvanometer wires from the conductor is evident above[2]. The effects were very distinct and constant.

105‡. Next held the conductors against the edge as if they were fixed to it, and moved them with the circle by the Magnetic poles. When the motion was in the same direction as in the last expt., the S pole went west as before.

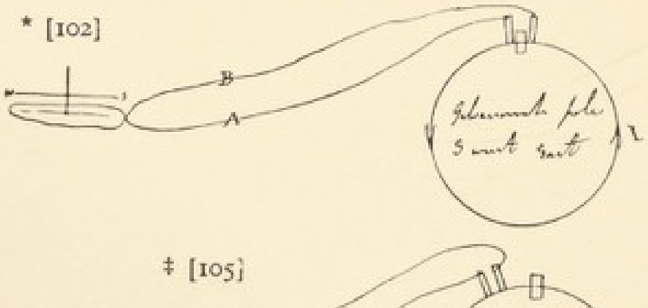
106§. But when the motion was reversed and therefore in the same direction as in the first expt. the S pole went east, i.e. the contrary of the last and the same as the first.

107. All these effects were constant in direction but difficult to obtain regularly, because of the difficulty of holding both con-

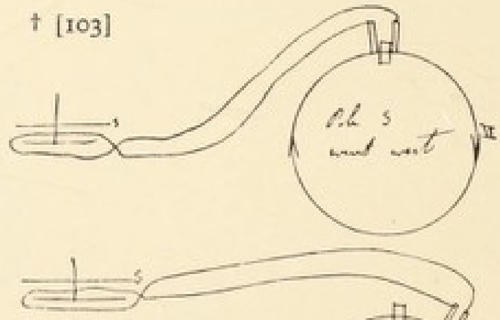
[1] The small rectangles here referred to, which were drawn in red ink in the manuscript, will be seen in diagrams to pars. 101 to 167 inclusive.

[2] See diagrams.

* [102]

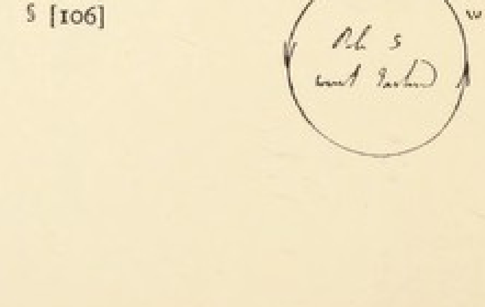


† [103]



‡ [105]

§ [106]



ductors in contact at once—both for that the edge of the plate was not perfectly regular and also that the stand was not steady.

108*. Then suspecting terrestrial action, especially as plate was revolving nearly in Magnetic meridian, the latter was raised until the magnetic poles were in the plane of the magnetic equator of the revolving plate, but the effect was the same, i.e. the south pole went west when the plate moved from left to right above. By depressing the place of magnetic poles still lower still the same deflection was produced when the plate revolved the same way.

109. Hence the earth's effect either null or too small to confuse the experiment.

110†. Then endeavoured to examine effect more minutely. Put conductors as in the figure, i.e. the left hand one between the poles and the other at one side on the right; then revolving the plate as the arrows point out the S pole went *east*.

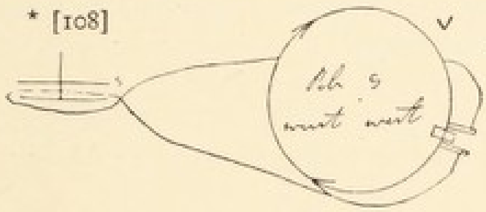
111‡. But on making the motion and every thing else the same, except that the right hand conductor was between the pole and the left a little to the left of it (which did not require more than an inch of displacement), now the S pole went *west*, i.e. the reverse of the last expt.

112§. Hence it was evident there ought to be a nearly neutral position, and on examining the position of equidistance more carefully it was found that the power though westerly was very weak and depended more upon irregularity of contact than constant action. This had every appearance of a neutral position.

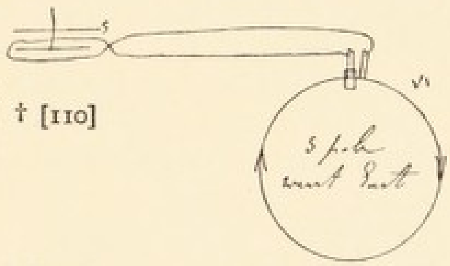
113‖. Now the experiment was repeated except that the motion of the plate was reversed. The conductors being placed as in vi, south pole went west instead of east.

114¶. On placing conductors as in vii the south pole went east instead of west.

* [108]



† [110]



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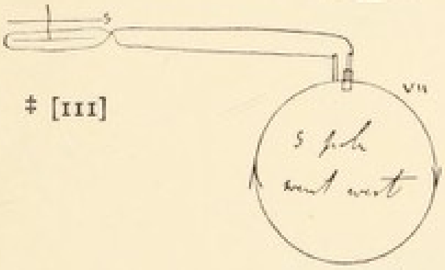
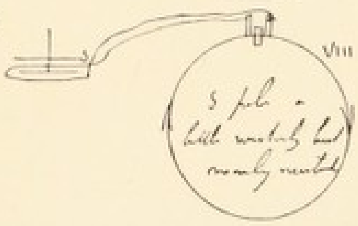
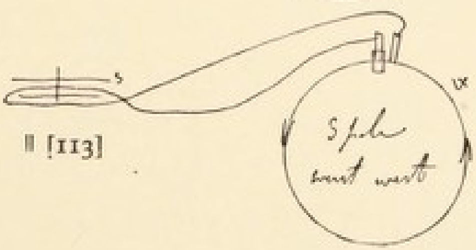


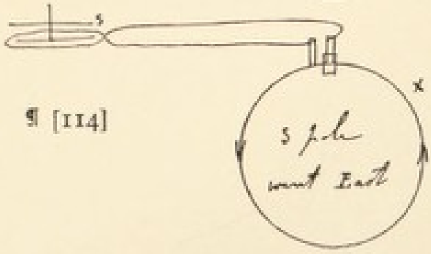
§ [112]



‖ [113]



¶ [114]



115. Hence changing the direction of the motion of the plate changes the current, and also changing the conductors to the right or left reverses the current.

116. Suspected from all this that a single conductor would do more than two, and that the condensed imaginary bisected vortex was not so definite as supposed, if existing at all. The wire coming from the upper coils of the Galvanometer was therefore fastened round the brass axis of the plate as the most neutral part of it, and the conductor from the other wire end applied to the edge of the wheel.

117*. When the wheel was revolved from left to right above and the conductor placed between the magnets the S pole of galvanometer went powerfully *west*, and when the conductor was placed either right or left of that still the S pole went west, but with less force. Even when a good way removed the S pole went westward.

118†. On the contrary, when the wheel revolved in the opposite direction the south pole went *east* most strongly when the conductor was directly at the magnets—less strongly when removed right or left as in the faint figures.

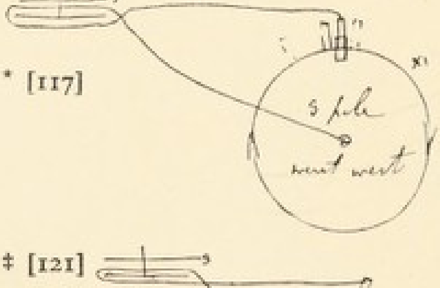
119. Hence it is easy to see how two conductors acted. They only shewed the difference of intensity of the two currents setting into them, and consequently by changing the conductors with relation to the strongest part of the plate the direction of the current in the wires and galvanometer was changed and therefore the direction of the needle. The neutral position was that in which each conductor tended to receive a current of equal intensity and in the same direction, consequently there was no circulation.

120. When the conductor was fixed on the plate, and with the plate itself moved forward from left to right above, the S pole went west first as if the plate had moved without the conductor.

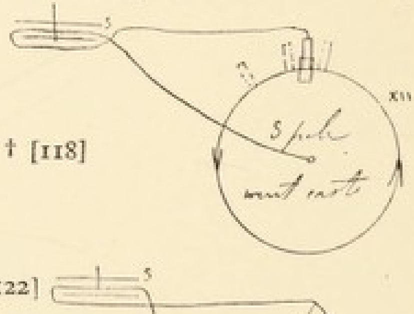
121‡. When the plate and conductor moved together by the Magnetic poles in the opposite direction the S pole went east—again as if plate had moved without the conductor.

122§. When the two conductors were placed as in the neutral position viii, but connected as one as in figure, then revolving

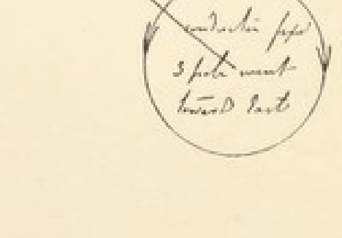
* [117]



† [118]



‡ [121]



§ [122]

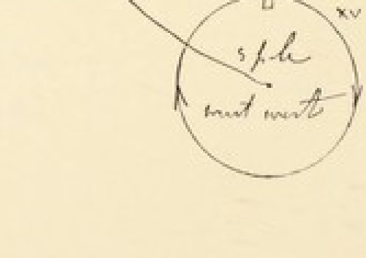


plate made S pole of needle go *powerfully* west. On reversing motion of the plate it went as powerfully east.

123*. Now raised the plate so that the projection of the Magnetic pole should be quite within the edge of the former.

124†. But although supposed vortex thus nearly included, effects were as before, i.e. a current of the same kind set off from all the parts of the edge of the plate near the pole whilst the rotation one way. But on reversing the rotation the deflection of the needle at the Galvanometer was reversed.

125. As now the edge could be seen and the contact better preserved, it was found that whilst the plate continued to revolve the Galvanometer needle was permanently deflected.

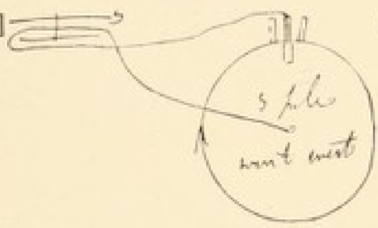
126‡. On raising the plate so that the magnetic poles were much nearer the center still effect was the same and the deflection was very sensible. It was reversed with the reversal of the rotation of the plate. Hence if any vortex it must be very diffuse.

127. To ascertain effect of vicinity to one pole or the other, one pole was quite taken away from plate and only the other left. The effects were exactly of the same kind, though not so strong as the former.

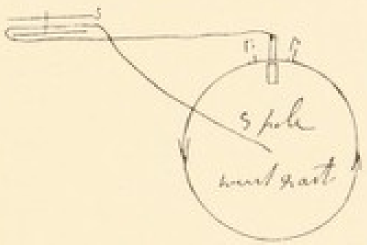
128. None of all these effects took place when the plate was made to revolve away from the magnet. They occurred very feeble when the plate was placed between the large magnetic poles, each being then several inches from it.

129. No electric effect from friction, mercury, etc. etc. could have therefore led to mistakes.

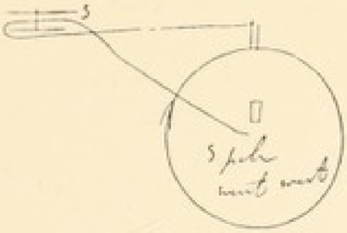
* [123]

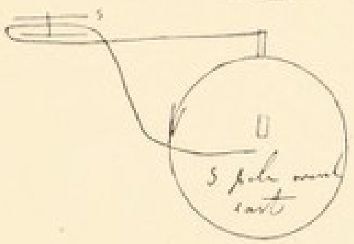


† [124]



‡ [126]





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