Unipolar Experiments

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ABSTRACT Novel experiments on the relative motion of conductors and magnets are described. In contradiction of the currently accepted interpretation, it is shown that the field of a magnet rotates with the magnet about its North-South axis. Faraday's Law is shown to be a particular case of a more general rule. The 'seat' of the emf is shown to be in the magnet.

KEY WORDS : Unipolar Induction, Magnetism & Electricity, Faraday's Law, Relative Motion, Faraday Generator; Magnetic Field; Lines of Force.

1 Introduction

This paper gives a description of a series of novel experiments on the relative motion of conductors and magnets. Tests not covered in earlier papers by this author are included.

The word 'Unipolar' is used to describe the behaviour of a pole of a magnet; it is the behaviour of one pole of a magnet in relation to a conductor that is the phenomenon being investigated here.

Nobody has ever isolated a North or a South pole of a magnet. No sooner is a magnet cut in half than each half becomes a new magnet, complete with its own North and South pole.

The experiments were undertaken because there was distinct evidence in the literature that moving the magnet did not, in all circumstances, give the same result as moving the conductor. This is in direct contradiction of the Special Theory of Relativity, where relative motion should give the same result, whether it is the magnet or the conductor that is moved. The results of the new experiments, ironically, fit relativity theory, but disprove another basic theory of physics.

Faraday showed in 1832 that a current was generated in a conductor when :

- the pole of a magnet is moved laterally near a stationary conductor
- a conductor is moved laterally near the pole of a stationary magnet
- a conductor is rotated upon the North-South axis of a nearby stationary magnet

But, he also showed that when :

- a magnet and conductor are rotated in unison upon the North-South axis of the magnet, a current is generated in the conductor
- a magnet is rotated about its North-South axis, no current is caused in a nearby stationary conductor. This result is astonishing, and is not mentioned in many textbooks; it could lead to embarrassing questions from students.

He concluded that "rotating the magnet causes no difference in the results; for a rotating and a stationary magnet produce the same effect upon the moving copper". In 1852 he said "No mere rotation of a bar magnet on its axis, produces any induction effect on circuits exterior to it" and, "The system of power in a magnet must not be considered as revolving with the magnet".

Wesley (1991) stated that Faraday had changed his mind in 1851 and decided that the lines of force actually rotated with the magnet. But this is not so; Faraday in his lecture in November/December 1851 (test no 3090) stated *"The system of power about the magnet must not be considered as revolving with the magnet"* and *"the magnet may even, in certain cases, be considered revolving amongst its own forces".* He was, in the latter statement, referring to the Faraday Generator case.

The following tests have been identified, which reproduced Faraday's results: Lecher 1895; Barnett 1912 & 1918; Fehrle 1913; Pegram 1917; Kennard 1917; Cramp & Norgrove 1936; Then 1962; Das Gupta 1963.

The apparent anomaly, where the rotation of a conductor and a magnet, about the North-South axis of the magnet, do not produce reciprocal results, has been the subject of much controversy over the intervening years. The present experiments were carried out to further investigate this phenomenon.

2. Tests with Spinning Disc

In this section are described a preliminary series of experiments, which reproduce the results of those earlier authors.

The apparatus (see Figures 1 & 2) comprises two concentric shafts. On one shaft is mounted an aluminium disc, which forms the conductor, and on the other shaft is mounted a magnet (for ‘magnet’ read ‘solenoid’ as appropriate). The magnet and the disc could be rotated independently, or in unison. A galvanometer is connected between carbon brushes rubbing on the rim and the axis of the disc. The galvanometer sensitivity is 1.42 microvolt and 0.066 microamp/mm.

The apparatus using a permanent magnet is shown in Figure 1, with the North-South axis of the magnet on the axis of the driving shaft. The magnet is in the centre and the disc on the left. The distance between the disc and the magnet can be adjusted. The magnet has a head-and-shoulders shape and is 35 mm in length; the central portion (22 mm long in the North-South direction) is of ceramic material, and the two side portions (each 8.5 mm long) of ferrous material. The diameter of the ceramic portion is 166 mm, and that of the ferrous parts 148.5 mm. The disc is 155 mm diameter and 5 mm wide. There is an annular hole through the magnet, of diameter 47 mm.

The apparatus using a solenoid is in Figure 2. The aluminium disc (191 mm diameter, the same as the outer surface of the coil; 7.5 mm wide) is on the left. The solenoid is wound on a spool and consists of 1250 turns of copper wire, of total resistance 2.09 W; it is 225 mm long and 220 mm in diameter. The centre line of the disc is at a distance of 57 mm from the end plate of the solenoid. A 12 volt battery supplies the current to the solenoid. The driving of the solenoid or the disc is via the pulleys on the right.

The two drive pulleys make it possible to rotate the magnet alone, or the disc alone, or, by bolting the two together, the two in unison. By twisting the drive belt, the disc can rotate in one direction and the magnet in the opposing direction.

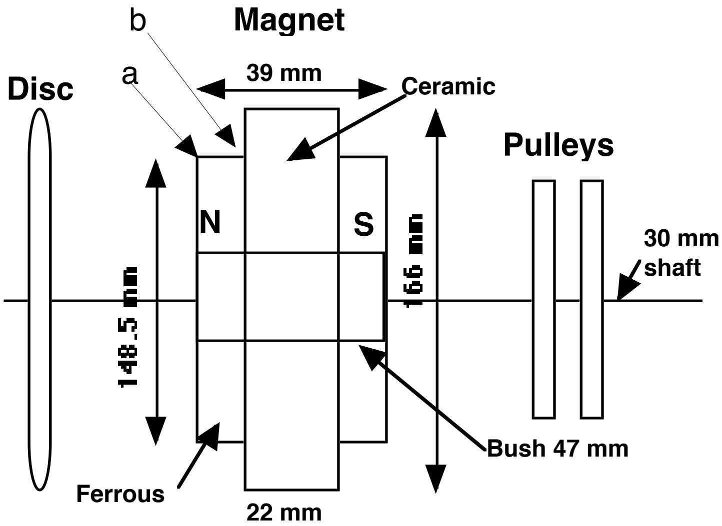

Figure 1 - Magnet Apparatus

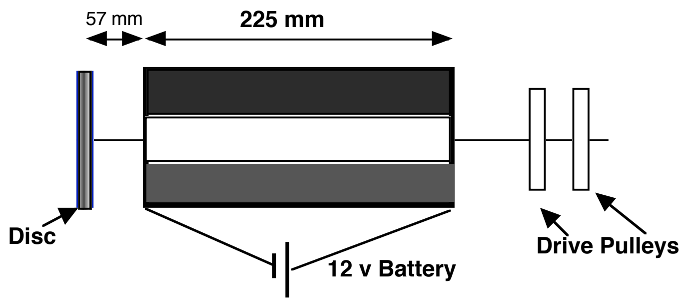

Figure 2 - Solenoid Apparatus

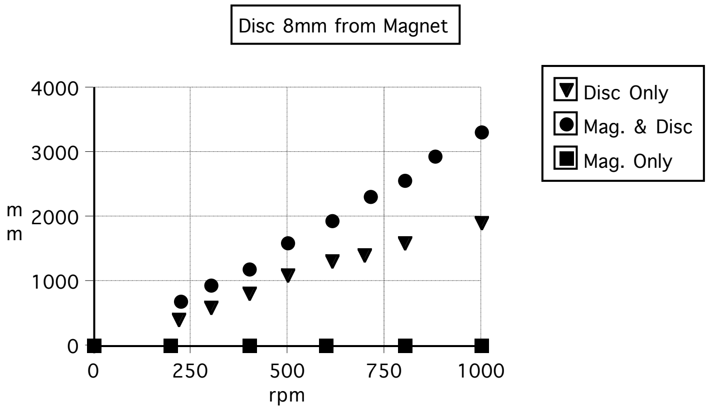

Figure 3 - Magnet Tests

The results of the experiments are shown in Figures 3 and 4.

Figure 3 gives the results of the magnet tests; this shows that when the disc alone is rotating, or when the disc and magnet rotate together, the galvanometer deflection varies directly with speed. The fact that these results differ from each other will be discussed later. When the magnet alone is rotating, no effect is recorded. The fact that spinning the magnet gives no voltage on the conductor, while spinning the conductor (or both together) gives a voltage, is the strange phenomenon being investigated in this paper.

Figure 4 shows similar results using the solenoid.

Moving the galvanometer or the leads to any positions, or shielding them with mu metal, while the disc alone was spinning, makes no difference in the readings. Cramp & Norgrove similarly altered the length and positioning of the leads in such a test, and obtained no difference in the results.

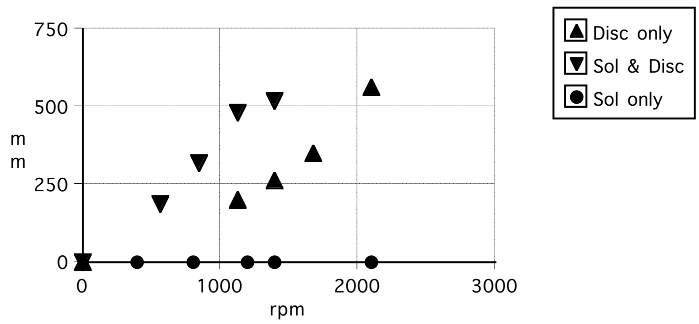

Figure 4 - Solenoid Tests

In the present experiments a permanent magnet or a pure solenoid (devoid of a core or any ferrous parts) is used. Only Kennard, Pegram and Cramp & Norgrove previously used a solenoid devoid of a ferrous core on spinning disc tests. Using a pure solenoid dispels the idea that, at microscopic level, the small magnets behave in a different way from a large magnet, and might explain the fact that no effect was evident when rotating the magnet alone (as proposed by Then). Cramp & Norgrove said that "A cylindrical magnet spins as freely about its tubes as does a solenoid". As a solenoid has no miniature magnets at microscopic level, this dispels the idea proposed by Then.

Since Faraday's original work, the accepted explanation of the results given in Figures 3 and 4 is that the lines of force do not rotate with a rotation of the magnet about its North-South axis.

There are different proposed explanations for the fact that the effect is not reciprocal for the movement of the magnet or the conductor. Preston said that "*it may be that the magnetic field partly partakes of the motion of the revolving magnet"*. Panofsky & Phillips said that *"In particular, the important conclusion is retained that motion (rotation in this case) of the source of magnetic field does not affect any physical process"*. They also said that *"many paradoxes result if one assumes that such phenomena should be reciprocal in the rotating frame and that of the earth"*. The term 'paradox' is often used whenever there is no explanation that makes sense. Moon & Spencer described how authors *"exchanged rapier thrusts"* in 1949 and 1950 in Electrical Engineering, on the (unsolved) subject of unipolar induction. Valone gave a useful list of references on the subject. Cullwick said that *the e.m.f. is due, not to a motion of the circuit as a whole, or to a changing magnetic field, but to relative motion between two parts of the circuit (e.g. between the rotating disc and the connecting leads)".* Shadowitz, discussing why the rotating magnet causes no effect, said that the lines are *"not defined with respect to the magnets but are defined with respect to the stationary observer".* Mencherini said that the fact that rotating the magnet gives a different result from rotating the nearby conductor causes no problem for Relativity Theory; he excuses the result as being *"explained exactly within the cybernetic approach to relativity by the fact that the rotation of the source of **B** does not have any influence on the computation of the emf because of the symmetry of the problem".* None of these strange convoluted ideas is correct, as will be later explained.

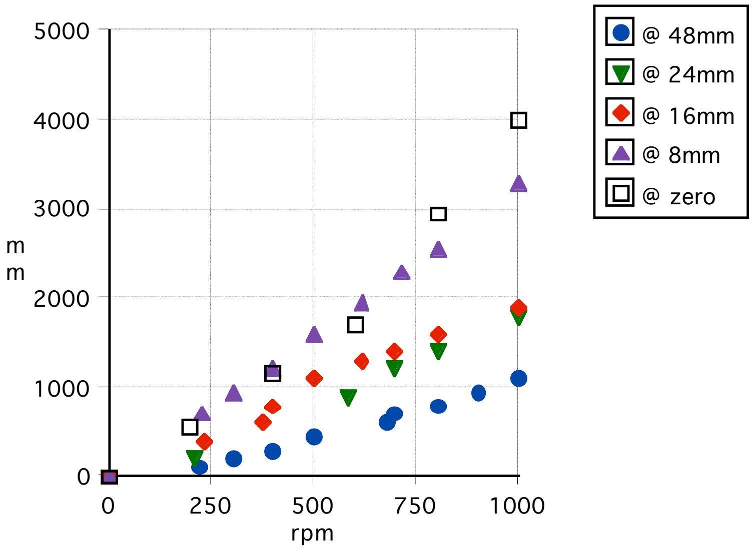

Figure 5 - Variation of Distance from Disc to Magnet

Figure 5 shows the effect of varying the distance between the disc and the permanent magnet. As would be expected, the nearer the disc to the magnet, the greater the voltages. Increasing the gap from 8 mm to 16 mm appreciably decreases the voltages. There is very little difference between the results for the 16 mm and 24 mm spacing. Increasing the gap from 24 mm to 48 mm appreciably decreases the voltages. A test of the magnetic field strength at the various distances from the magnet shows the reason for this phenomenon.

Figure 6 shows the field strength at different distances from the face of the permanent magnet. The Gaussmeter used was a Bell Model 600AV. On the y axis is given the gauss reading; on the x axis is the distance measured radially inwards from the outer rim of the magnet towards the axis; the zero reading is at the outer rim. With the disc at 8 mm from the magnet, the strongest field was at the outer rim of the magnet. With the disc situated at 48 mm distance, the strongest field was at the inner edge of the magnet. With the disc at the in-between distances (16 mm and 24 mm) the strongest field was at the mid section of the magnet. The readings were taken at the face of the disc nearer to the magnet. As an indication of the difference across the disc, with the disc at the 8 mm distance, the readings at the face furthest from the magnet were about 75% of those at the nearer face (the readings were, at distances of zero, 27 mm and 49 mm in from the rim, 73%, 75% and 81% respectively). These results indicate the rapid fall-off of the magnetic field with distance from the magnet, and also shows the drop across the disc.

From the pattern, it is clear why the voltages upon the spinning disc (Figure 6) were almost the same at distances of 16 mm and 24 mm. The field results for the 16 mm distance are slightly greater than those at the 24 mm distance. The difference is greater between the results at the 8 mm and 16 mm distances, as well as between the 24 mm and 48 mm results. The field strength figures conform with the voltages produced with the various spacings of the magnet and disc.

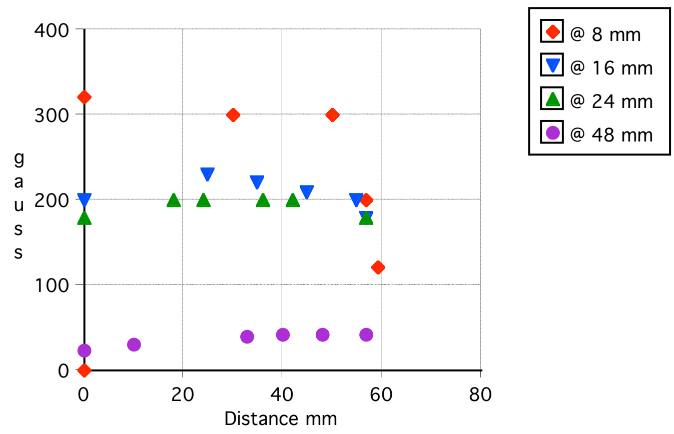

Figure 6 - Magnet Field Readings

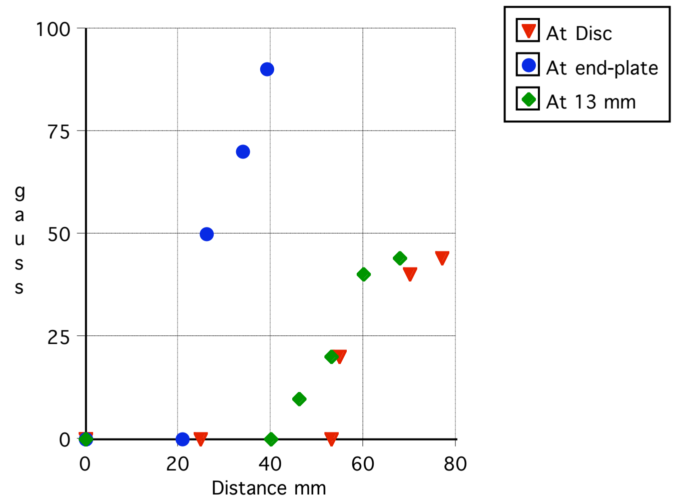

Figure 7 - Solenoid Field Readings

The strength of the permanent magnet can be appreciated from the pattern of the field at the face of the magnet nearer to the disc. The field read, at distances of zero, 15 mm, 25 mm, 50.75 mm (at the brass bush, Figure 1), and 59.25 mm (at the shaft) from the outer rim, 1200, 500, 350, 600, and minus 30 gausses respectively; these latter readings are not shown on Figure 6, as they would expand the scale inordinately.

Figure 7 shows a similar set of readings for the solenoid; in this case the disc was at a fixed distance. Field strength readings are given at the end-plate of the solenoid, at a distance of 13 mm (where there was no disc), and at the disc. The field at the disc was much less than in the case of the magnet tests.

The distance on the x axis was measured from the outer rim of the disc inwards towards the shaft; 78 mm is at the shaft. The field was concentrated near the shaft, and there was no measurable field at the outer 55 mm of the disc; even at the end-plate of the solenoid, the field was not measurable for the outer 20 mm. The field could not be measured all the way to the shaft at the end-plate, because the slipring for delivering the current to the solenoid was situated there.

3. Faraday Generator

A ‘Faraday Generator’ is a rotating magnet of conducting material (such as the two side portions of the magnet in Figure 1), on which a voltage is produced between the rim and the axis; in effect it dispenses with the spinning disc and, instead, uses the body of the magnet as a conducting disc. Faraday’s statement that rotation of the magnet, about its North-South axis, had no inductive effect did not refer to the Faraday Generator. Hence this phenomenon is here discussed separately.

The ceramic non-conducting central portion of the permanent magnet is a non-performing Faraday Generator, in that there is no voltage generated between the rim and the axis of the magnet. The performance of the conducting and the non-conducting portions of the magnet were confirmed in the present experiments. The voltages generated on the side portion of the magnet, between the rim and the shaft, are shown as the ‘zero’ distance results in Figure 6.

Vigier described the separate character of the ‘field’ and the source of that field. He concluded ”that a magnet moving in free space is really influenced by its own self-B field" in the case of a Faraday Generator, and that "Faraday's one-piece generator is an absolute space-time detector". This reflects the currently accepted interpretation that, in the case of a Faraday Generator, the magnet cuts its own field, and in this way generates the effect. This idea will be later shown to be incorrect.

4. Electromagnetic Induction

'Faraday's Law" of electromagnetic induction is commonly written as (see Young)

$$\varepsilon = -d\Phi_B / dt \tag{1}$$

where e is the emf, FB is the magnetic flux in a magnetic field B, and t denotes time. In words "the induced emf in a circuit equals the negative of the time rate of change of magnetic flux through the circuit".

However, it is accepted that there are two forms of electromagnetic induction, a 'transformer' form (given by Faraday's Law) and a 'motional' form (see Cohn, Moon & Spencer, Vigier and Young).

The Motional Electromagnetic force is:-

$$\varepsilon = vBL \tag{2}$$

where B is a uniform magnetic field, v the velocity of a moving portion of conductor, and L its length.

A disc, such as utilised in the experiments described earlier, rotating on the axis of a magnet, is a case of pure motional induction, because during the experiment there is no alteration in the magnetic flux over the area of the disc; there is also no alteration in the area concerned; in this case, the transformer form is not applicable because there is no change in flux.

In some cases, the two Laws give the same result; an example is where a rectangle is formed by three fixed sides and one moving side; the moving side slides along, while keeping contact with the two adjacent sides, and alters the area over which a constant magnetic field operates (see Young). In such a case the two are equal.

Cramp & Norgrove said that “The question is whether a variation of flux enclosed by, or linked with, an electric circuit creates an e.m.f or whether the e.m.f. requires an actual cutting of magnetic lines or tubes of induction. The view is widely held that the two are practically identical, but that the former covers the latter case”.

5. New Experiments

Further novel experiments, which were carried out, are now described. These were done to test the postulate here proposed that, in contradiction of previous evidence, the lines of force rotate with the magnet upon its North-South axis. In considering the results of the following experiments, the reader should continuously bear in mind that the lines are assumed to rotate with the magnet, when that magnet rotates about its North-South axis. In this way the reader can decide whether the experimental results fit this theory.

The utilised terms ‘lines of force’ or ‘field’ are idealised simplified concepts (see Feynman). In all cases, cutting of a line of force has to be at right angles to that line to have the full effect; movement of a conductor parallel to the direction of a line produces no effect.

As far as was determined, the following analysis was not previously proposed.

In Figure 8, lines of force are depicted in the usual fashion. ‘G’ indicates the measuring galvanometer. The circuit G-A-B-C-D-G has opposing effects generated in the parts A-B and C-D, if that conductor moves near the magnet, or vice versa (laterally or in rotation). In the usual manner, we shall refer to the voltage that results from that effect. The lines which cross A-B from right to left, next cross C-D from left to right, as we follow the circuit around from A to B to C to D. The voltage on C-D is in the opposite direction to that generated on A-B. There should thus be no resulting voltage in the circuit. Conductor E-F has a voltage generated when moved near the magnet. However, to measure the result, we need to connect E and F to a galvanometer. In doing so, if the leads to a galvanometer were arranged as in the former case, an opposing voltage would be generated. To avoid or minimise the cancelling voltage, the leads would have to be brought to the galvanometer on such a route that there would be no (or minimum) cancellation.

A simple test with a magnet from a reject loudspeaker, a piece of conductor and a voltmeter (a multimeter with a resolution of 100 microvolts on a scale of 200 millivolts) can reproduce these results. If the conductor is doubled back tightly upon itself, and moved near the pole of the magnet, no voltage results; however, if the conductor has a straight single piece moving near the pole, a voltage will result.

In Figure 9 are shown two different arrangements of a circuit that is totally external to the magnet, and which is cut (a net) twice by the lines. The apparatus is constructed so that the complete circuit back to the galvanometer (but not the galvanometer itself, which is situated on the axis of the magnet and at a distance of 1 m) can be rotated. The connections to and from the galvanometer are via two sliprings on the end of the driving shaft, which are on the extreme left of the drive shaft in Figure 1. In this way, connections to the disc rim and to the shaft can be brought out to the galvanometer, as the apparatus is rotated.

Similarly, in the case of a Faraday Generator, a connection can be brought out to the galvanometer from the rim of the magnet; this connection is to be seen at A in Figure 10.

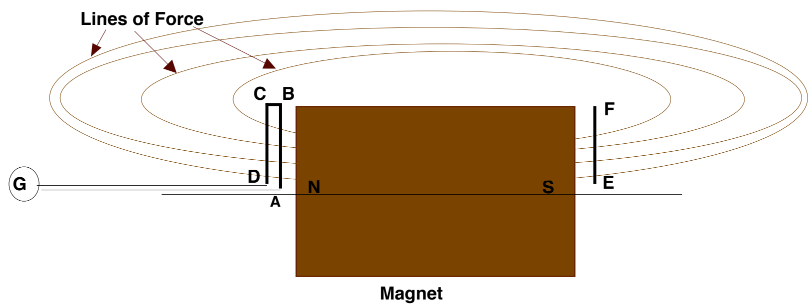

Figure 8 - Effect Produced on a Conductor near a Magnet

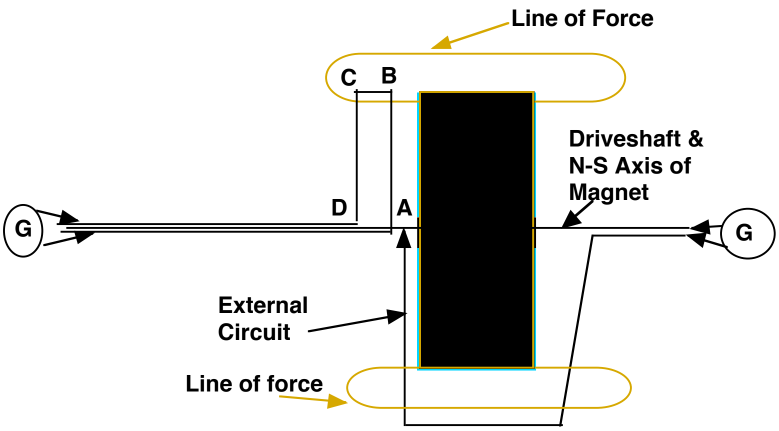

Figure 9 - Circuit Cut Twice by Lines

TABLE 1 - RÉSUMÉ OF TEST RESULTS

ARRANGEMENT	GALVANOMETER READING	COMMENTS
Circuit external to Magnet		
(a) Whole circuit spin	**0**	**Lines cut circuit twice**
(b) Magnet only spin	**0**	**Lines cut circuit twice**
(c) Magnet & whole circuit spin	**0**	**No relative motion**
Fardaday Generator		
(d) Magnet spin	**Yes**	**Lines cut leads once**
(e) Circuit spin	**Yes**	**Lines cut leads once**
(f) Magnet et circuit spin	**0**	**No relative motion**
Disc Tests		
(g) Disc only spin	**Yes**	**Some lines cut disc once**
(h) Disc & Magnet spin	**Yes**	**Lines cut leads once**
(j) Magnet only spin	**0**	**Lines cut circuit twice**
(k) Disc & Circuit spin	**0**	**Lines cut circuit twice**
(l) Magnet, Disc & leads spin	**0**	**No relative motion**
(m) Magnet & circuit spin	**Yes**	**Lines cut disc only**
(n) Circuit only spin	**Yes**	**Circuit cuts lines once**

Note: Neither tests (g) and (h), nor tests (m) and (n) necessarily yield equal voltages.

In Table I are shown the test results. Firstly we discuss the cases where the circuit is totally external to the magnet.

No voltage is generated where

(a) the circuit alone is rotated; this is the total circuit comprising the disc and the leads to and from the galvanometer; note that this is different from the earlier experiments where rotation of the disc alone yielded a voltage; the difference between the two cases will be later explained.

(b) the magnet alone is rotated; this gives the same result as in the earlier tests.

(c) both the magnet and the whole circuit are rotated in unison; again this result is different from the earlier case, where only the magnet and the disc (but not the connections to and from the galvanometer) were rotated in unison; the difference will be explained below.

In (a) and (b) the circuit is cut twice by the lines, and there should be no effect. In (c) there is no relative motion between the magnet and circuit, so there should be no effect; this particular test does not seem to have been repeated since done by Faraday.

These results are all in conformity with the proposal that the lines rotate with the magnet.

In Figure 10, the lines cut the circuit but once (net). This is the ‘Faraday Generator’, a device that was extensively investigated by Faraday. The body of the magnet forms part of the conducting circuit. The circuit is G-B-[through the body of the conducting magnet]-A-G. The spinning disc used in the earlier experiments is replaced by the spinning conducting magnet body. The same effect could be got by attaching the disc to the face of the magnet and rotating the two together, as in the earlier tests using a rotating disc; the voltage would be measured from the rim of the disc to the axle. In Figure 10, the nearer the connection A is to the middle of the magnet, the greater the effect.

Tests (d), (e) and (f) in Table I are on the Faraday Generator. The standard explanation of this phenomenon has been that the magnet cuts its own lines, as it rotates. It is a phenomenon that has heretofore never been satisfactorily explained. In case (d) spinning the magnet generates a voltage in the stationary lead from the rim of the magnet to the galvanometer, because the rotating lines cut that lead mainly once (see Figure 10). In case

(e) spinning the leads alone produces the same result. Faraday commented that the conductor crossed the lines once in this particular test, but did not continue with this distinction in his other tests. Rotating the magnet and the whole circuit (the magnet and the leads to and from the galvanometer) in unison (case f) gives a zero result, because there is no relative motion between the magnet and the circuit; this test does not seem to have been done before, even by Faraday. Again, these results are also in conformity with the proposal that the lines rotate with the magnet.

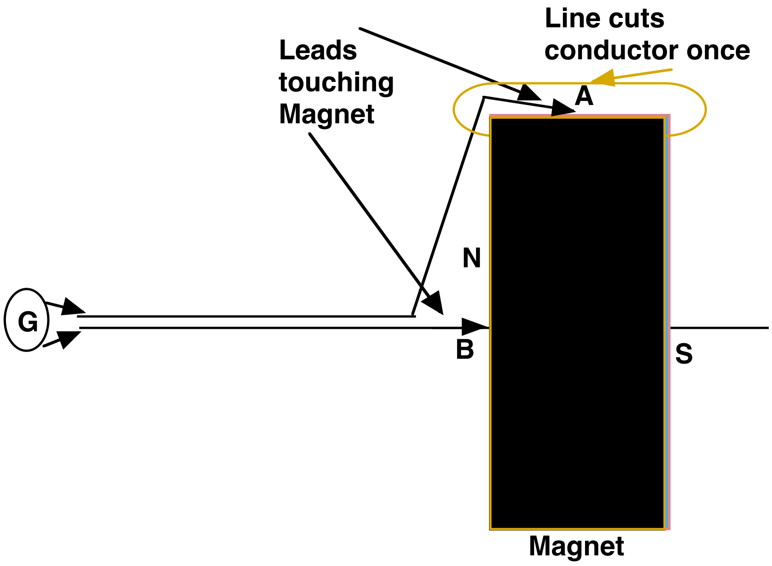

Figure 10 - Circuit Partially Internal to the Magnet; The Faraday Generator

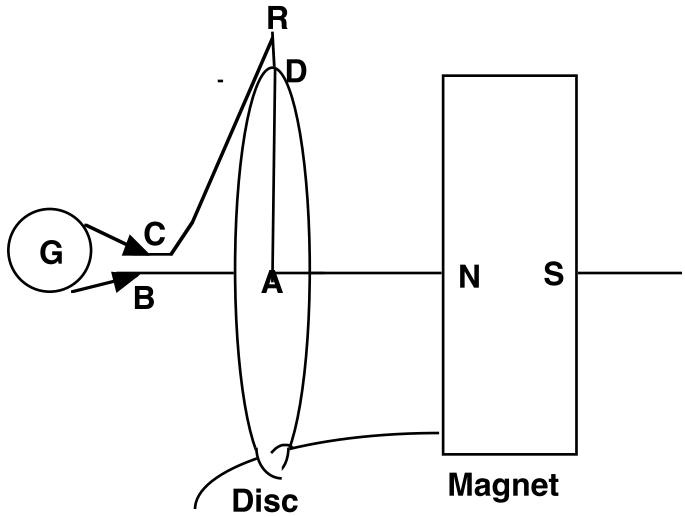

Figure 11 - Lines Cutting Disc

No voltage occurs in a rectangular circuit crossing a uniform magnetic field, with two opposing sides cutting the lines at right angles. This is because opposing voltages are generated in the two sides that are cutting the lines. however, on entering or leaving the field, a voltage is produced only in the side that is alone in cutting the lines.

Why are the results given in the first part of this paper different from tests (a), (b) and (c) in Table I? An explanation will now be proffered.

A disc comprises only part of the circuit that is subject to the effect of the movements (see Figure 11). In this arrangement, the disc and the circuit C-R-D-A-B can be rotated as a unit. Alternatively, the disc alone can be rotated, leaving the leads stationary; here a carbon brush rubs at D on the rim of the disc and at B on the axle axis. The whole circuit includes the disc and the leads to and from the galvanometer, and the galvanometer itself. Leaving the galvanometer stationary does not affect the results; it was on the axis, 1 m from the magnet.

As shown, most of the lines (excepting those that double back and cut the disc twice) cut the disc only once when the disc alone rotates; in this case there is an effect (case g, Table I).

When the disc and the magnet rotate together, there is also a result (case h), because the lines cut the leads to the galvanometer mostly once. There is no relative motion between the disc and the lines, and thus there is no resulting effect from the rotation of the disc. The effect results from the rotating lines cutting the remainder of the circuit (except the disc).

In case (j), where the magnet alone rotates, the lines cut the stationary circuit G-B-A-D-R-C-G twice, with zero result; this test is the one which deceived previous experimenters into concluding that the lines did not rotate with the magnet. None of the previous experimenters, including Faraday, depicted the leads to, or the position of, the galvanometer. This was, presumably, because they thought that the leads could not possibly have an effect on the results; these leads play a critical role in the resulting voltages.

When the disc and the leads to and from the galvanometer spin in unison (case k), there is a zero result because the circuit G -C - R - D - A - B -G is cut twice by the lines; the remainder of the disc does not come into play, because the voltage generated on any radius is the same as that on A-D, and which is being cancelled.

When the magnet, the disc and the leads all rotate together, there is no relative motion and thus no effect (case l).

In case (m), when the magnet and the circuit (to and from the disc to the galvanometer), but not the disc, rotate in unison, a voltage is generated across the disc. This result, like most of the tests, could be explained by either a moving lines theory or by assuming the lines of the magnet were stationary.

In case (n) rotation of the circuit (but not the disc, or the magnet) generates a voltage, because the circuit is cutting the stationary lines once.

It is significant that, as mentioned previously (see Figures 3 & 4), the voltage generated when the disc alone rotates is different from that when the disc and magnet rotate in unison. In several tests the distinction between the two cases was not great and was firstly thought to be due to experimental scatter. The variation from one experiment to another was often greater than the difference indicated between the two cases; variation with time as the experiment proceeded due to alteration of bearing friction, heating of the coils in the solenoid, and of the contact resistance of the brushes rubbing on the rotating disc and shaft, tended to occlude this important difference. However, by careful control of the experiment, when the difference was suspected to exist, a sizable and consistent difference, as depicted in Figures 3 & 4, was found.

The cause is different in the two cases (with the disc alone spinning, versus with the disc & magnet spinning in unison). In the case of the disc alone spinning, the voltage is generated across the radii of the disc, by the disc's cutting of the stationary lines of the stationary magnet. However, in the case where the magnet and disc rotate in unison, the cause is the cutting of the leads to the galvanometer by the rotating lines of the rotating magnet. As the profile offered to the lines can be greater for the lead (R-C in Figure 11) than that offered by the radius of the disc (A-D), the voltage can be greater; this will be explained in further detail below. The two cases can yield substantially the same voltage when the lead to the galvanometer emerges horizontally from point D on the rim of the disc.

A test, in which the disc and the leads were rotated in unison, while the orientation of the leads was altered, was not previously done. It can now be appreciated why the voltages in Figure 3 and 4 are greater when both the disc and solenoid/magnet rotate than when the disc alone rotates. By varying the route taken by the small section of conductor between the rim of the disc D and point R (Figure 11), it was shown that :

- when R-D is radially out to the maximum distance, the voltage generated is at a maximum, and
- when the conductor is aligned to emerge axially from D parallel to the axis of rotation, and directly from the rim of the disc, without any radial component, the voltage is at a minimum.

Kennard and Das Gupta commented that the two tests (with the disc alone rotating or with both the magnet and the disc rotating in unison) gave about the same result; they assumed that any difference was due to experimental scatter.

Then recorded a 20% difference in 1960, but none in 1962, when he retracted his 1960 statement that "the galvanometer deflection is greater than when the disc only rotates". He refers to this situation as paradoxical; we again have this word as a panacea for inexplicable results. Then said that "if the field and the rotor rotate as a single unit, an emf is developed that is as large as that when the field is stationary and the conductor rotates". This left the possibility that his earlier results might some time in the future be replicated; they were in the present tests.

He proposed that, when using a stationary solenoid with a ferrous core that could rotate,"since the solenoid did not rotate, it is conceivable that even though the magnetized core was rotated the external magnetic field did not rotate". He said "it is impossible to measure or detect the rotation of a uniform or symmetrical magnetic field". The present tests positively identify the rotation of such a magnetic field. Then also maintained that "the stationary parts of the circuit develop no emf", when the magnet was rotated.

It is shown in the present experiments that, when both the disc and magnet rotate, there is an emf generated in the stationary leads. The magnet used by Then was totally of ceramic material; he did not have the advantage of working with a magnet of conducting material. Then, like Faraday, appreciated that the cutting of a circuit in two opposing directions gave a zero result, but neither of them proceeded to the conclusions in this paper. Then said "if one could go to the micro structure of the discrete magnetized particles in the ceramic magnet, surely it would seem reasonable that a microscopic conductor would experience the same effect as one visualises " in an experiment where he had the poles of a horseshoe permanent magnet moving in a circle around the circumference of a conductor; the poles chased each other around the conductor. This arrangement is quite different from the cases where the magnet rotates about its North-South axis near a conductor. This test was, in effect, a lateral movement of the magnet poles in relation to the conductor. Then suggested that, at the macroscopic level, one cannot discern the rotation of the field, even though he suspected that it did exist.

Faraday did not do test (k) where the disc and the leads to the galvanometer rotate in unison. He did not notice any difference in the magnitude of the resulting voltage between cases (g) and (h). In 1832 he said "Taking, then, a mass of metal or an endless wire, and referring to the pole as a centre of action, if all parts move in the same direction, and with the same angular velocity, and through magnetic curves of constant intensity, then no electric currents are produced". So, Faraday was aware of the effect of rotating all parts of a circuit in unison, but did not draw the conclusions given in the present paper.

Assis & Thober gave a theoretical analysis of the behaviour of spinning the various combinations of a magnet, a disc and a galvanometer. They utilised Weber's Electrodynamic theory in this analysis. Their predictions agree with the results of the present tests.

The external circuit has to be compact to achieve the above effects. The return portion (C-D in Figure 8) has to be near the portion A-B of the circuit that is near the magnet. The distances between B and C and between A and D have to be short. As those are lengthened, the cancelling of the effect gradually disappears, because at the further distance the magnetic field is weaker. With the permanent magnet used in the present series, the distance C-B had to be 100 mm or less; above that figure the cancellation effect gradually diminished, and the residual voltage gradually increased.

Another test was done to test the veracity of the proposal that the lines rotate with the magnet. If this proposal is correct, there should be a variation in the voltage produced, with both magnet and disc rotating, if the route taken by the connecting leads between the galvanometer and the disc are altered. In fact, rerouting the lead from the rim of the disc to the galvanometer on a zig zag route (A-C-D-G), somewhat as shown in Figure 12, causes a significant reduction in the galvanometer reading.

By experimenting with the routing of the leads the recorded voltage could be varied down to a reading of close to zero on the galvanometer. This test was done with the solenoid and also with the magnet. In the case of the solenoid the leads came roughly out as depicted in Figure 12.

In the case of the test with the magnet (see Figure 1) the leads had to pass by the magnet to get to the normal position of the galvanometer; the galvanometer was at the magnet end of the apparatus and at shaft level.

The reason for the variation in the net voltage that is generated can be appreciated, by considering the net number of times that a line of force is intersected by the connecting lead to the galvanometer. With the magnet and the leads rotating, the lines cut the lead A-B-G but once (except for a small portion A-B-X in Figure 12). This single cutting gives a voltage, as discussed earlier. The two magnetic lines of force depicted in Figure 12 cut the lead B-G but once. If the lead is changed to take a zig-zag route, somewhat like A-C-D-G, the lines cut more of the lead twice, than in the case A-B-G. The part that is cut twice will reduce the voltage that is produced.

The lower of the two lines depicted in Figure 12 cuts the lead A-C-D-G three times; there is a portion from A to C and back level with A which will have the voltage cancelled out, giving a smaller net result.

There is also a small triangle near the apex of C-D-G where lines, which will not have previously crossed the conductor, will cut the conductor twice and cancel out.

When the lead A-B is routed vertically from the rim of the disc at Point A, as depicted in Figure 12, the voltage will be at a maximum, because a greater portion of the lead is cut but once (the portion X-G), than when that lead comes out horizontally from the Point A. The lead portion X-G offers a greater radius to the magnetic lines than the radius of the disc; thus, the greater voltages in the former case can be appreciated. By moving the leads to different positions, the voltage could be reduced close to zero (to the accuracy of the galvanometer). This is to be contrasted with the case where the disc alone is rotated and no difference occurs in the voltage produced, no matter what the configuration of the leads.

This test, where the routing of the leads was altered, with both the disc and the magnet rotating, was not carried out by previous experimenters, who all tested with the disc alone rotating.

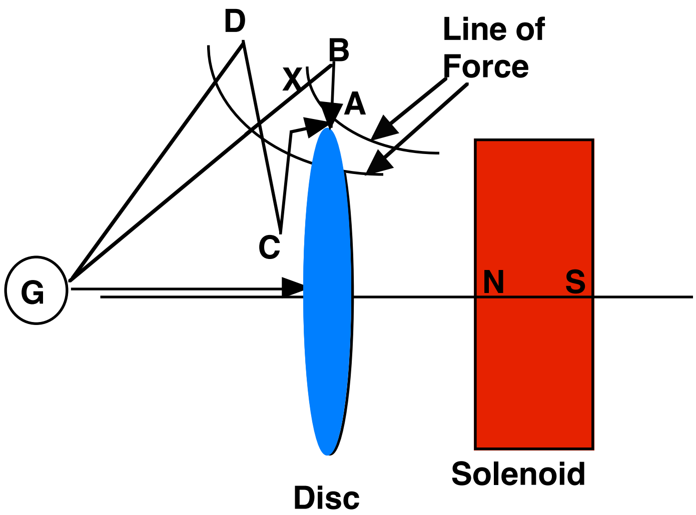

Figure 12 - Effect of Changing Routing of Leads

Consider the difference between two tests, one where the disc alone rotates, and the second where the disc-cum-magnet rotate in unison. In the first case there is no alteration in the result when the leads are moved around; in the second there is a radial alteration in the result.

The only difference between the two cases is that, in the second case, the rotation of the magnet is added. In both cases the disc is rotating. Therefore, any alteration in the result must be due to that added rotation of the magnet. The new effect that appears is that the movement of the leads alters the result. Consequently, the rotation of the magnet (and that alone) causes the change in the result which appears, and is evidenced when the leads are moved. Therefore, there can be no doubt but that the lines must rotate with the magnet upon its North-South axis.

No other explanation is possible. If the lines did not rotate with the magnet then, there would not be any such result, because there would be no relative motion between the lead to the galvanometer and the lines, to add this new phenomenon to the case where the disc alone rotates.

Further confirmation that this is the case was provided by another test. A Faraday Generator is provided by utilising the conducting portion of the permanent magnet in Figure 1. A galvanometer reading between (a) and (b) while the magnet was rotating provides the answer. In effect this is a case where the 'disc' in Figure 12 is replaced by the magnet body itself; the disc can be considered as right tight to the magnet and welded to it forming part of the Faraday Generator itself.

A reading taken while the magnet is spinning between (a) and (b) shows that when the conducting connection to and from the galvanometer are moved in a similar manner to that depicted in Figure 12 the reading on the galvanometer alters.

Another positive confirmation of this phenomenon is as follows. In the case of the Faraday Generator (Figure 10) when the leads to and from the galvanometer (A-G and A-B) are altered significantly in routing to the magnet, there is a distinct alteration in the effect as measured upon the galvanometer.

6. Seat of the emf?

A debate has also raged over the years, as to where was the ‘seat’ of the electromagnetic force; was it in the magnet, or was it in the disc/conductor?

Müller in 1990 described how measurements “cannot discriminate between one theory or the other”. Barnett, Pegram and Kennard said that the seat of the force was not in the magnet. No publication has been located where the seat of the electromotive force was proven to be in the magnet.

Wesley (2001, in press) when discussing the co-rotation of the magnet and the disc, quoted Müller as proving that the ‘seat’ of the emf is in the disc.

Let us consider this matter further. If the rotating combination of disc and magnet are separated by ever smaller distances as shown in Figure 5, the emf becomes ever larger. Eventually, when the disc is tight up against the magnet the voltage is at a maximum for a separate disc. Then we can (as Faraday found) discard the disc altogether and just rotate the magnet and measure the voltage from a point near the end of the magnet to the axis of rotation. Here we have no disc at all, so the ‘seat’ of the emf cannot be in the non-existent disc. To continue, moving the measurement of the voltage nearer to the mid point of the magnet, the voltage increases still further and reaches a maximum between the axis of rotation and the mid-point of the magnet.

The voltage was also measured between two points (a) and (b) on the conducting ferrous side portion of the magnet as shown in Figure 1. In this case, the ‘seat’ of the emf has to be either in the magnet or the connections to and from the glavanometer. No disc exists and the measurement is between two points on the rotating magnet; the connections are to and from the galvanometer, which is situated upon the axis of rotation.

Müller tests were all on totally ceramic non-conducting magnets (unlike those in Figure 1) and the voltages described in the Faraday Generator tests above and in the test just described would not show up.

Müller, as reproduced in Wesley (2001), using ceramic magnets devised an ingenious method of detecting the voltage in different parts of a circuit. Unfortunately, he could not detect voltages across parts of the body of the magnet because he used only magnets made of non-conducting material.

Any test that merely 'wiggles' or 'oscillates' different parts of the circuits (as was done by Müller) will not be definitive. This is because, as we know, any lateral movement (however tiny) of any conductor near the pole of a magnet will produce an effect. The puzzle being investigated here is the behaviour of magnets and conductors which rotate about a common axis. The tests must therefore be purely on rotating magnets and conductors with no semblance whatever of lateral movement.

None of Müller's tests constitutes a rotation of even one revolution; there is no control to ensure that the tiny movement is purely on a perfectly circumferential path at a constant radius from the common axis of magnet and conductor. These tests must therefore be discarded as providing any evidence in the matter of rotating magnets and conductors.

Valone mounted a voltage measuring device attached to and rotating with the rotating Faraday Generator. No voltage was detected. This is in conformity with the foregoing because the lines of force are rotating with the generator and are not cutting the connections to and from the measuring device. This test was not covered in earlier papers by Kelly.

The word 'seat' is ambiguous. In the sense that the seat is 'where the power resides which is causing the effect', then the magnet must be the seat of the emf. There can be no effect if there is no magnet (or solenoid) present.

7. Flux linking or Flux Cutting?

Cohn described the difficulty of forecasting a correct result, if either a 'flux-cutting' theory or a 'flux-linking' theory is used.

Blondel in 1915 had shown that a circuit could be altered by winding on or off coils from a spool without altering the voltage produced. Bewley had shown a similar effect; he stated that "the turns linking the flux may be changed in such a way as not to cut through the flux, as by winding on turns or substitution of circuits, thus effecting a change in interlinkages without introducing a voltage". Tilley described an experiment (Figure 13), similar to that of Blondel and Bewley, as follows: "when the switch on the left is closed and that on the right is opened, the galvanometer circuit experiences a large flux change but there is no induced electromagnetic force". He commented that "Faraday's 'flux rule' the statement that the electromotive force induced in a circuit is proportional to the rate of change of magnetic flux through the circuit, cannot be applied indiscriminately". There was, he commented, "a large rate of change of flux but no induced electromagnetic force". He described this test as "a gross violation of the 'flux law'". He offered no alternative explanation. Neither of the latter two referenced Blondell's work.

Tilley's result was reproduced in the present series.

This enigma can be explained by assuming that the basic cause of the effect is not due to the rate of change in 'flux', but to the actual cutting of the conductor circuit by the lines of force. In Tilley's test, where there is no alteration in the position or direction of the lines in relation to the stationary but altering circuit, there is no effect.

There are cases where there is no change in flux or area, but there is an effect (the spinning disc tests).

There are cases where there is a change in flux or area, but no effect generated (Tilley test).

The traditional 'Faraday's Law' is a particular case, which applies only when the flux change through a circuit is simultaneously associated with either :

- a locational change of a circuit or magnet/solenoid, or
- a change in the strength of the field of a solenoid

In these circumstances, the changing of flux through a circuit will be proportional to the cutting of the conductor by the lines. Any alteration in the flux intensity, by altering the current through the coils of a solenoid, must also cause a cutting of the circuit by the lines, because of the altered positioning of the lines in space. It is suggested that Faraday's Law is not the general law, and that it is not the rate of change of flux that is the basic cause of the emf.

Feynman says "We know of no other place in physics where such a simple and accurate general principle requires for its real understanding an analysis in terms of two different phenomena. Usually such a beautiful generalisation is found to stem from a single deep underlying principle. Nevertheless in this case there does not appear to be any such profound implication".

It is proposed that the single underlying principle is the requirement that the circuit must be cut by the lines of force.

The adding together of the two different phenomena "rate of change of flux" and "physical movement" (as discussed earlier, and referred to by Feynmann) cannot give the correct answer in all cases, because the flux rule is incorrect in some situations.

The age-old problem as to the 'seat' of the emf is now solved; it is shown to be in the magnet. It is also shown that the field rotates with the magnet. We also have an answer to the problem as to the what is the cause of the emf.

The emf is produced by the magnet, through the cutting of the circuit by the lines of force of that magnet. It is not produced unless there is cutting of the circuit by lines of force; additionally, the cutting must be in one direction (net), or be by unequal force lines if cut in two directions (net).

The apparent non-reciprocity, when rotating a magnet or a nearby short piece of conductor, is now explained as being due to the different parts of the circuit that comprise the 'conductor' in those particular tests. There is no longer a problem in relation to reciprocal relative motions of magnet and conductor.

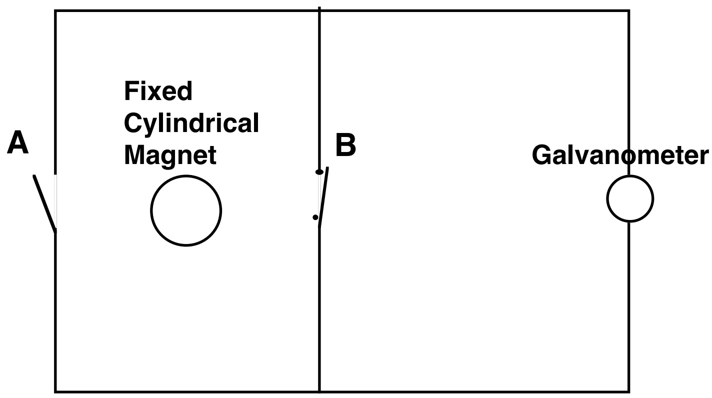

Figure 13 - Tilley Test

When either an electric or a magnetic field is changing with time, a field of the other kind is induced in nearby regions of space. Such an electromagnetic disturbance results in the generation of an electromagnetic wave. The speed of emission of such a wave, at the speed of light, in relation to surrounding space is independent of any motion of the source of that wave. Because of this fact, it has been assumed that the idea that a magnetic field does not rotate with a magnet upon its North-South axis is in conformity with the behaviour of electromagnetic waves. The proposal that the magnetic field rotates with the physical material of the magnet in no way clashes with the theory of electromagnetic radiation.

When a magnet is moved from one place to another, the field of that magnet moves with the magnet at the speed v at which the magnet is moved. This movement of the field at that velocity v in a straight line in no way conflicts with the behaviour of electromagnetic waves. There is no reason to suppose that a rotary motion of the magnet would behave in a different manner from a lateral motion, as far as the movement of the lines at the speed of v is concerned.

Consider a small very thin wedge of North-South material removed from near the perimeter of a circular annular magnet such as used in these tests. Movement of such a lozenge near a conductor will cause a voltage upon that conductor. When the magnet is rotated, that small wedge (replaced in its original position) passing by a nearby stationary conductor, would behave just like a bar magnet passing laterally by such a conductor. Because the lines must move, and thus rotate with that small thin wedge, the related lines will similarly rotate with all of the remaining portions of the circular magnet. A large annular shaped magnet would approach the case of a bar magnet passing laterally by a conductor. This effect was reproduced in the present tests.

Thus, the field rotates with the magnet in toto. Faraday's Law applies to cases where a change in flux is taking place. In the experiments carried out here, where the disc or the magnet-cum-disc were at steady rotational speed, there was no alternation with time in the magnetic field, or of the area concerned in the test. In such cases, the voltage produced has nothing to do with a changing magnetic field or flux. This fact reinforces the proposal that it is the cutting of the conductor by the lines that is the critical factor.

The theoretical implications of these experiments are outside the scope of this paper. A mathematical representation would have to describe the movement of the lines in space and the physical cutting of the conductor by those lines. The extant laws (Faraday's Law and the Motional Law of electromagnetic induction) are not sufficient, but are particular cases of the more general rule.

8. Conclusions

The lines of force rotate with a magnet upon its North-South axis.

The emf, that is produced in a nearby circuit by a magnet, is caused by the cutting of the circuit by the lines of force of that magnet. It is not produced unless there is cutting of the circuit by those lines of force; additionally the cutting must be in one direction (net), or be by unequal force lines, if cut in two directions (net).

The Faraday Generator phenomenon is caused by the cutting of the stationary circuit by the lines of force of the magnet, as the magnet rotates. It has previously been supposed that the magnet is cutting its own lines of force.

When a disc is set rotating near the pole of the magnet, the results are anomalous. The results are fully explained as being due to involvement of only a portion of the whole circuit.

'Faraday's Law' of electromagnetic induction is true only in particular circumstances. As is known, a separate analysis is required for Motional Electromotive Force. One single general rule is missing. This paper provides the basis for such a general rule.

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