II. "On an Electro-Magnetic Gyroscope." By M. Wilfrid de Fonvielle. Communicated by the President. Received April 15, 1880.

I have the honour to submit to the Royal Society of London an apparatus which I have invented, after having witnessed an experiment by M. Dieudonné Lontin.

The original Lontin experiment consists in the rapid and continuous rotation of a magnetised steel needle, placed under the influence of the currents of a peculiar induction machine.

The object of my apparatus is to give a movement of rotation in a horizontal plane, not only to a needle, but to any moveable piece of iron which is symmetrical in reference to its axis of rotation. It is consequently composed of (1) a vertical coil, which I have made rectangular, but is susceptible of receiving any form; (2) a Ruhmkorff coil of a peculiar construction; and (3) the axis of suspension. This piece can be removed at pleasure, and another substituted, thus demonstrating the form to be indifferent, if it is placed in equilibrium. The coil may however be horizontal, and in that case the moveable piece will rotate in a vertical plane.

The apparatus has been constructed in order to work easily with one Bunsen cell of 20 centims. height, or with one or two bichromate of potassium cells.

Above the frame is placed a horseshoe-magnet, supported by a vertical axis, round which it can be placed in any particular azimuth that may be required for the experiments. This axis can be taken away, and the horseshoe-magnet can be replaced by one or two or a large number of bar-magnets, laid flat upon the frame. It is possible also to place other bar-magnets underneath the frame, in a space arranged for this purpose. It is possible also to place four magnets laterally, two on each side of the frame, or to replace them by a number of electro-magnets.

To produce a continuous movement of rotation, the magnets do not appear to be absolutely necessary, although they greatly increase the velocity, and outweigh every chance of perturbation and uncertainty.

But the motion without magnets presents peculiarities, which are of great interest, and have led to an explanation, accepted by M. Lontin, and which will be developed more fully hereafter.

Under ordinary circumstances the moveable piece does not start by itself, but requires an external impulse.

Another peculiarity of this movement is that the direction of the current can be altered without altering, in any respect, the direction of the rotation, although sometimes it diminishes or increases the velocity. But owing to the necessity of giving an impulse to the moveable
piece, these experiments are rather tedious, as it is necessary to wait for some minutes before knowing with certainty whether the rotation is due to electro-magnetic reactions or to the mechanical impulse.

All the effects exhibited with magnets and moveable pieces of iron have the advantage of being produced without the help of any external force other than magnetical attraction working at a distance. This it is, I venture to think, what renders them so really effective.

When the moveable pieces are star-shaped, or composed of a number of iron pieces insulated magnetically, they are not moved by themselves, except when they occupy certain positions in relation to the position of equilibrium of a magnetic needle under the action of a continuous voltaic current flowing through the coil.

Under the same circumstances, the more arms the star possesses the more easily it revolves. An even number of arms appears to be less favourable to rotation than an uneven number.

But the difference of the phenomena exhibited when there is no magnet in operation is very striking, as there is then a definite direction of rotation, and if the moveable piece should be propelled in the wrong direction, its velocity quickly diminishes, and the piece soon rotates in the right direction. If the magnet is placed in a direction perpendicular to the frame the rotation is stopped.

A very small moveable piece has also been constructed so that it can be placed in different positions in the interior of the frame. The position of the axis within the frame involves no difference in the direction of the rotation, although the velocity can be in some degree altered, but it is not very easy to ascertain the fact, the velocity being so great that very often the motion seems to be imperceptible to the eye. These phenomena, which can be varied to any extent, as will be shown hereafter, appear to be capable of a very simple explanation, by an application of the laws of induction discovered by Faraday.

The possibility of producing the same movement by means of moveables of any form whatever, and notably of two spirals constructed of a flat wire and wound in an opposite direction, appears to demonstrate that the rotatory action is exercised individually on each molecule of iron, and that the total impulse must be regarded as the integral of the individual impulsive actions. This remarkable property appears to furnish a very simple means of completely explaining all the circumstances of these curious phenomena by means of the known laws of induction, and to dispense with having recourse to any new hypothesis. It is sufficient, in fact, to remark that the molecule of iron acts in its movement of rotation in two different ways in each of the two nearly equal currents of induction which successively traverse the spirals, but the alternate appearances of which are separated by very feeble intervals of time. In fact, during the whole continuance of the two phases of rotatory movement which the galvanometric frame
When we bring the pole of a magnet into action, it is clear that its influence determines in each of the molecules of the moveable object a transient magnetisation which strengthens the induction currents produced in the spires in the cases in which it is concordant, and which paralyses them in the opposite case. It hence results that, in presence of a permanent magnetic centre, the movement is possible only in a direction determined by its position and its nature. The author believes that this principle applies even to the action of the earth.

When we change the position of the active pole in relation to the axis of rotation, the rotation changes its direction; but the pole of the magnet may be placed above or below, to right or left, without the rotation changing its direction. The two poles of a bar or a horse-shoe-magnet combine to accelerate the movement when they are placed in the direction of the frame; but if we place the magnet in a perpendicular direction, all movement is, as a rule, rendered impossible. It is the same with near position; in proportion as we approach it to that limit of position, the rotation in general will be found to slacken. It is clear that a magnetisable body so strongly tempered as not to have the capacity of being magnetised and demagnetised to the given extent, will remain insensible to these successive dynamic reactions, and consequently immovable, and that it is necessary to employ the softest possible iron in the construction of the moveable objects. The same phenomena, especially with the spiral, may evidently be produced if we place it about the frame. They are accompanied, especially with the full disk, by a strident sound, arising from the alternate magnetisations and demagnetisations; and this fact seems to be a new confirmation of the theories which have been advanced.

I must not omit to mention also a number of other phenomena which at least, in some respects, can be quoted in support of that opinion which my friend, M. Lontin, considers also as being valid.
If we take two spirals made of a similar iron ribbon, but curved in an opposite direction, viz., the one to the left and the other to the right, the velocity and direction of rotation are precisely the same under similar circumstances. This proves the action to be really molecular.

This remarkable experiment may be made in a very striking form. If we place a left-handed spiral to the left of the frame, and a right-handed one to the right, or vice versa, at a distance sufficiently small from the frame, the influence is felt, and the rotation of the two spirals is obtained. But they rotate in the same direction. If the axis of the spirals be placed so near to the frame that a part of the solid is immersed in it, the rotation may be very rapid indeed. It seems impossible to witness that experiment without coming to the conclusion that it is not unreasonable to believe that a motive power comparable with that of other magneto-electrical machines may be obtained by taking advantage of these properties of the induction current.

This conviction receives some support from the following curious experiment.

If a spiral be placed on the top of the machine, after the removal of the horseshoe-magnet, it rotates under the influence of the two bar-magnets placed underneath. The direction of rotation is in reverse direction to the gyration of a moveable placed in the interior of the frame, but in the same as the moveable whose axis is placed outside.

A very pretty experiment can be made by placing a number of moveables in these various positions, and to see them changing their direction under the influence of active magnets, when the direction of primary current of the coil is altered.

Experiments have been tried to ascertain whether induced currents, or even interrupted currents, can work the machine. The results appear to have been affirmative, at least for the inducing current, although the phenomena are less easy to produce. It has been acknowledged also that the velocity is increased by placing the condenser in communication with the coil, and that the number of vibrations exerts also a great influence.

It is easy to show that a magnetised steel star will not move if it is magnetised up to saturation, and if incompletely magnetised it works like an ordinary star, but with a reduced velocity.

A magnetic bar placed perpendicularly to the frame and within it prevents the rotation of the moveable piece. But if an iron bar is placed in the same position, it seems to accelerate it; at all events, the motion seems to be a reversible one. Here the direction of the primary current is reversed and ceases almost to rotate or it stops entirely.

All these varied experiments appear to be in conformity with the theory already developed, but all these points, as well as many others, require more mature consideration.
Perhaps the best forms of the moveable piece are the spiral and the copper disk, surrounded by a continuous ribbon of iron.

No result was obtained with unmagnetisable substances, but the experiments were not made with a sufficient degree of accuracy to be deemed final.

No attempt has been made either to ascertain whether the rotation of the moveable pieces obtained by a motive power can produce alternate currents in the coil, which appears to be very dubious, as the motions produced by the destruction of the symmetry which exists generally between the two sides of a galvanometric frame.

It can be very easily proved that the frame is an excellent magnetising machine, and that the magnetisation takes place in the position of equilibrium of a magnetised needle under a continuous current. If a needle is placed horizontally within the frame, the end which is sent forward becomes magnetic, so that it is very easy to alter the magnetism in any way which might be required.

The induction machine which is presented has been reproduced from one which M. Lontin had constructed for some special purposes, described in a letter inserted in "Electricité" (5th April last), and the peculiarity of which is that inducing and induced wires have a similar resistance. But I understand that the resistance of the wire going round the frame may be enlarged to four times its present value without diminishing the velocity of the rotation in any sensible manner. So the actual conditions can be largely altered without interfering with the production of the phenomena under consideration; and it may be inferred that the motive power derived from them can be greatly increased by these obvious alterations, although it is quite impossible to state whether it can be made useful to any practical purposes.

In concluding this short preliminary notice, I would venture to add that the apparatus most nearly resembling mine is Faraday's disk, with this difference, that it is made of mica and worked by a frictional electrical machine. The mechanical work produced is very small in either instrument.

It may be stated to the credit of the gyroscope that the work done by a man in turning the glass disk, is executed under the actual condition by one Bunsen element of 20 centims. high; so that in certain respects the action may be said to be wonderfully great. But it must not be forgotten that it is really Faraday's disk which has paved the way in this new field of electrical researches; and that certainly I should not have taken advantage of the experiment shown to me by M. Lontin, if I had not been acquainted with all the circumstances of the disk rotation exhibited to me by your great natural philosopher so many years ago.