The Relativistic Electrodynamics Turbine.
Experimentum Crucis of New Induction Law.

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ABSTRACT

Easy experiments carried out in the dawn of electromagnetism are still being a reason for scientific articles, because its functioning contradicts some laws and rules of electromagnetic theory. Although these experiments led Einstein to discover the relativistic electrodynamics and explained its working, the scientific community had not understood this. They see in these experiments a proof against relativity and prefer to look for the solution in the electromagnetics' theory or accept that their are an exception.

By means of a long and detailed experimental study with a new design in electromagnetic engines and improvements of these experiments that we call relativistic electrodynamics turbine, we managed to explain its working using relativistic electrodynamics. The revision of these experiments had taken us to discover the real law of induction, which does not have any exceptions.

The explanation of the relativistic electrodynamics turbine led us to discard the Faraday induction law and argue that the true law of induction is a consequence of the conservation of the angular momentum of the charges as the conservation of the angular momentum of the mass. Thus Einstein's idea to unify electromagnetism and mechanics is now clear and also opens the way for new research in science.

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1. Introduction

In this article we explain and confirm some concepts, which were expressed a long time ago by François Arago (1786-1853), Michael Faraday (1791-1867), Henry Poincaré (1854-1912) and Albert Einstein (1879-1955) about electrodynamics and unipolar machines in the description of Faraday's law of induction using some simple experiments.

The first and the most representative of unipolar machines is the Faraday Disk. Despite being discovered by Michael Faraday in 1831, the description of the Faraday disk remains a problem in electromagnetism. The problem of unipolar induction begins from Faraday's experiments in his investigation of electromagnetic induction when some experiments do not obey his law, the Faraday law of induction. In his conclusion, the magnetic field lines do not rotate with the magnet. In these experiments of rotating magnets begins the concept of relative motion, and of course, the relative velocity.

The lack of an absolute velocity in mechanics and in Faraday's experiments, which just depends on the relative velocity between a magnet and a coil, sets up an analogy between the mechanics and the electromagnetism. This analogy led Einstein to reject the existence of the ether, which made him create the theory of relativity.

The theory of relativity (1905) allowed us to understand that the absolute velocity does not exist in mechanics, neither in Faraday's experiments, which only depend on relative velocity between a coil and one magnet. This sets up an analogy between mechanics and electromagnetism. When Einstein came up with this analogy, it drove him to refuse the existence of the ether and he then created the theory of relativity through this.

The main concept we develop in this article is another analogy between mechanics and electromagnetism: The hypothesis that every moving particle conserves its own energy and momentum, as we know of course by the mass of a particle. But we extended this hypothesis to the charge of a particle.

Immediately, we realized there is a parallelism between Kepler's second law and Faraday's induction law. Kepler discovered the second law, which has his name, because he did not know the conservation of angular momentum of the mass flux law. Faraday also discovered the induction law because he did not know the conservation of angular momentum of the electrical charges flux law. This is the main law that shows the equivalence between mechanics and electromagnetism.

Everybody knows the work that forces do in mechanics, which takes place through the variation and conservation in the flux mass momentum. We are going to demonstrate in this article that the work or "electromotive forces" (watt/ampere) made by electric forces, which is attributed to the flux's magnetic rate of change, is in fact a consequence of the conservation of the momentum of electric current.

When in an electric circuit the intensity current varies, the magnetic flux in the circuit also varies as well as the magnetic and the angular momentum of the flow of charges. We know that the induction is attributed to the rate of change magnetic flux. The unipolar induction (Faraday Disk) is an exception to this law because there is not a variation in magnetic flux but induction does exist.

If we attribute the induction and torques in the electrodynamics of rotation to the variation and conservation of the angular momentum flux of electric charges, the unipolar induction exception disappears. Thereby, there are three possible ways to vary the angular momentum of the current in a circuit, which results in various forms of electromagnetic induction that everybody knows. In addition, we can observe that the three different ways of varying the angular momentum of the current in a circuit causes different forms of electromagnetic induction.

In this new interpretation, some magnetic flux exceptions and paradoxes disappear, like Faraday's paradox, spiral paradox and the supposed rule that every circuit increases its surface when a current increases the flux enclosed in it. In 1923, Hering C. [1] demonstrated with a simple experiment that this rule is false. However, it is still mentioned in some texts of electromagnetism as a valid rule.

Our new interpretation is of great interest in a conceptual and educational way when teaching physics. Because of this, by its analogy with respect to mechanics, this is the best intuitive and mnemonics rule to display the direction and sense of forces in electrodynamics.

2. The Faraday Disk and the Faraday Paradox

When Faraday discovered the induction law, he performed an experiment that did not obey his own law. This experiment (1831-1832) is known as the Faraday Disk in his honour. Its simplicity and beauty captivated the entire physicist world of that time such as Ampere, Helmholtz, Poincaré, but they could not explain its functioning as Poincaré admitted.

In 1958, when we built a Faraday's disk in Salvador Velayo's laboratory at Madrid Complutense University, we did not understand how it worked, and it was the first problem we encountered, as we did not know it was an unsolved experiment called Faraday's Paradox. Despite its simplicity, it continues been a problem in the electromagnetism description, a controversial experiment and what physicists such as Aragó, Faraday, Poincare and Einstein said about it was ignored.

They are not aware of San Juan de la Cruz's advice: ¨Buscad leyendo y hallareis meditando¨ which means we need to know what others have said and done. As Einstein once said we learn by plagiarising. In experimental sciences, meditation is not enough, you also have to experiment in order to understand. Albert Einstein said [2]:

"In my old age I am developing a passion for experimentation"

Some physicists believe that Faraday's Disk and the Rotary Magnet, better known as "Faraday Paradox", should not be mentioned in the textbooks, since they are an exception to the law of induction. Because of this exception Richard Feynman[3] called it "Flux Rule" in his book. Galili and Kaplan [4] said

"Faraday's Disk should not be confused with the case of unipolar induction. In the latter the rotating disk is a magnet itself. This case is much more complicated conceptually and never touched on in introductory physics courses."

We will show that there are no conceptual differences between Faraday's disk and the rotary magnet.

Unfortunately, this dogmatic attitude has prevailed and these controversial experiments with a high historical and scientific value have been eliminated from textbooks. Otherwise, some physicists have considered this a big mistake and they have shown their dissatisfaction. For example: the physicist G.C. Scorgie [5] in his posthumous publication said

"Of course no discussion of the fundamentals of electromagnetic induction is complete without a reference to the

pons asinorum, the Faraday disk experiment, and Galili and Kaplan find a curious situation where Faraday's law does not account for Faraday's generator".

(Pons asinorum= Pont aux ânes, fig. et fam. Difficulté qui n'arrête que les ignorants. According to the Larousse dictionary.

We must not forget that science has progressed thanks to these experiments, which do not agree with theories, such as Henry Poincare mentioned in page 231 of his book La Science et l'Hipothèse [6]

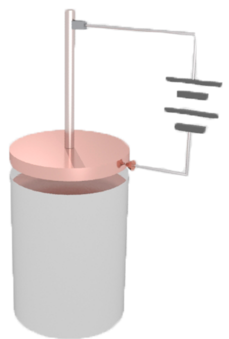
"Rôle de l' hypothèse.

Toute généralisation est une hypothèse; l'hypothèse a donc un rôle nécessaire que personne n'a jamais contesté. Seulement elle doit toujours être, le plus tôt possible et le plus souvent possible, soumise à la vérification. Il va sans dire que, si elle ne supporte pas cette épreuve, on doit l'abandonner sans arrière pensée. C'est bien ce qu'on fait en général, mais quelquefois avec une certaine mauvaise humeur.

Eh bien, cette mauvaise humeur même n'est pas justifiée; le physicien qui bien de renoncer à une de ses hypothèses devrait être, au contraire, plein de joie, car il vient de trouver une occasion inespérée de découverte".

These words are textually written because they encourage us to refuse the hypothesis of the law of induction or flux rule, and continue working on Faraday's disk by making many more experiments to understand its functioning.

If we want to understand and discuss everything about Faraday's disk, first we have to explain its functioning. If we set a copper disk that can rotate around its axis, over an equal-diameter cylindrical magnet with the same axis, when a radial stationary current circulates through it using sliding contacts, the disk rotates indefinitely. Reciprocally, when the disk rotates a stationary current is generated.



1. Faraday Disk

This experiment suggests that current and its momentum are a consequence of the disk rotation with respect to the magnet. The magnet is the stator of the generator as it happens with another unipolar machine: the Barlow Wheel.

However, we can demonstrate experimentally that the cylindrical magnet is not the stator, because if we link the magnet to the disk, they rotate together. This is just the Faraday's Paradox and it is easy to think that this rotation together is irrelevant, because there is not a relative movement between them. However, when the cylindrical magnet rotates around its symmetry axis, a radial electric field is generated and a radial force to the charges of the magnet and the disk is produced.

A cylindrical magnet that is magnetized around its symmetry axis has a magnetic field with rotation symmetry, like a circular current loop. This field does not change if magnet or current loops rotate around their axis. According to the theory of relativity, the magnetic field is due to the relative speed of rotation of opposite charges and this relative velocity does not change when the magnet or current loop rotates around its axis of symmetry. Any rotation around this axis occurs on this field, including the magnet. The fact that an observer rotates with the magnet and is also subjected to a radial electric field, can not detect or produce a current.

According to the Special Theory of Relativity, an observer who rotates around the symmetry axis of a magnetic field will observe a radial electric field [7], regardless of the magnet rotation around its axis. That is to say, the magnetic field does not rotate with it.

Twenty years after his discovery, Faraday carried out some experiments and reached to the conclusion that the magnetic field did not rotate with the magnet. This effect is a consequence of relativistic electrodynamics, which becomes more evident when we change the magnet by a current loop.

We can see the existence of this radial electric field rotating the disk around a parallel axis with respect to the magnet axis. In this case, the circular trajectories that describe the charges of the conductor disk are not concentric with the magnet and observe a variable electric field, which is not radial in all of its trajectories. These trajectories become rotational and generate Eddy currents. The mechanical energy transforms into electric energy and slows down the disk (Aragó disk, Barlow wheel). Arago and Faraday had suspected the existence of Eddy currents in the Aragó disk, and this motivated the discovery of electromagnetic induction.[8]

It is not the same to generate an electric field and an electromotive force over the charges as to generate electromotive energy. It is common to confuse the electromotive force with electromotive energy and this makes it difficult to understand Faraday's experiment. To generate a force over the charges, a relative movement between the two parts of the circuit (estator and rotor) is not required. On the other hand, to generate an electromotive energy, it is necessary to close the circuit and generate an electric current and mechanical work by the relative rotation between the two parts of the circuit (stator and rotor), as the law of conservation of energy requires. The measurement of the force is caused by the work it makes.

In some physics textbooks the Michelson-Morley experiment is cited as the crucial experiment which Albert Einstein used to develope the special theory of relativity. However, the inspiration "On the Electrodynamics of Moving Bodies"[9] came from Faraday's paradox.

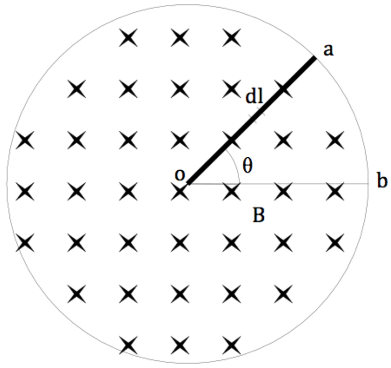
"It is known that Maxwell's electrodynamics -as usually understood at the present time, when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena."

Faraday's disk is the only electrodynamics experiment that quotes:

"Furthermore it is clear that the asymmetry mentioned in the introduction as arising when we consider the currents produced by the relative motion of a magnet and a conductor, now disappears. Moreover, questions as to the ¨seat¨ of electrodynamics electromotive forces (unipolar machines) now have no point."

However, this is not a problem for physicists who are still calculating the emf on the Faraday disk. We demonstrate experimentally that the calculation of the emf is false and has no physical meaning. Let's see how the calculation is made on the Faraday disc in the physic's book of D. Halliday and R. Resnick.[10]

We calculate the emf along a Faraday disk of radious L or a bar of the same length in a uniform rotating magnetic field, with an angular frequency ω.



2. Calculation of the emf in a Faraday Disk

Each dl element of the radial rod of the disk is kept perpendicular to the v velocity of the disk as well as to the B uniform magnetic field.

In each dl element, a dε of the emf due to the motion is generated.

$$d\varepsilon = vBdl$$

The rod or the radius of the disk can be divided into elements of dl length, the ωl being the v linear velocity of each element. Each element is perpendicular to B and also moves perpendicularly to B, so that when we integrate we have:

$$\varepsilon = \int d\varepsilon = \int Bvdl = \int B\left(\omega l\right)dl = \frac{1}{2}B\omega L^2$$

According to this calculation, any disk path trajectory is irrelevant to the emf. Whereas, the normal path components to the radio do not contribute to the emf. And therefore it only depends on the radius of the disk.

We will demonstrate that this is false, because, if we replace the disk with a radial conductor, we can verify that, when the current path varies, doubling the radial conductor, the electromotive force and torque vary. The most compelling evidence for this, as it will be seen later, is to show that the conductor can be rotated without the magnet.

This is a typical example of a mathematical calculation applied to a false interpretation of an experiment. As Einstein said

"With maths you can prove anything"

The Faraday disk is the simplest and worst described experiment in electromagnetism books; it is the only generator where only half of the generator is shown, making it even more difficult to understand its functioning. Everyone believes that the disk and magnet constitute the generator. They ignore or forget that the fixed conductor connecting the edge of the disk is the stator.

Any good experimenter can see that by bending the conductor connected to the Faraday disk edge also varies the torque and emf. This shows that it makes no sense to calculate the emf or torque on the disk regardless of the rest of the circuit.

If the great Faraday had given a turn around the disk to the conductor that connects its edge, he would have seen that, by using a higher current, the disk rotateds without the magnet and that its circuit was an electrodynamics turbine.

In order for a turbine (without a magnet) to work as a generator it must be excited by a current, such as a demagnetized dynamo. The calculation of the electromotive force or torque is completely equivalent. When the turbine operates as a motor, it generates (like all motors) a counter-electromotive force that opposes the passage of current as a result of energy conservation.

We will demonstrate experimentally that the Faraday disk is a deformable circuit that can operate as a motor without a magnet, due to the normal components of the conductor which defines the path of the charges, unlike the calculation results.

3. Metamorphosis of the Faraday Disk

To understand how the Faraday Disk works, we will make a metamorphosis of the Disk. As a result, an electrodynamics turbine arises and becomes the crucial experiment of the law of induction. For this law, the Faraday Disc no longer is an exception and a paradox. Unipolar or homopolar machines are in fact electrodynamic turbines as they are the only machines that can work with a stationary current.

If we consider that the magnetic field generated by a cylindrical magnet has rotational symmetry like a coil with the same diameter, then we can replace the magnet of the Faraday disk with a coil. On the other hand, considering that the disk and the magnet can be rotated together and that the radial current of the disk is equivalent to a radial conductor, we can then replace the disk with a radial conductor and the magnet with a coil. Because they can be rotated together we can connect them in series and they become a spiral with a G shape.

3. Spiral G and logarithmic spiral.

If we assemble the spiral G so that it rotates around its centre, it continually rotates with the passage of the stationary current like the Faraday Disk. That's how we discovered the electrodynamics turbine, which works with universal current, unlike the Faraday disk which only works with direct current.

The reason is very simple. By reversing the direction of the current, the radial flow and the angular momentum (magnetic field) generated by the current of the coil are simultaneously reversed.[11]

4. First circuit that was successfully rotated

In the Spiral with a G shape it is not important if the coil is connected to the radius and it rotates with it, or with the stator or neither of them. That is to say, the current of the coil can be independent from the rest of the circuit, like the magnet of the Faraday disk. The field of a cylindrical magnet does not change when rotating around its symmetry axes, the same as a coil, since its angular momentum or magnetic moment of the current (according to relativity) is due to the rotation of the charges with respect to those of the opposite sign, and its relative speed does not vary when the coil rotates. In the classical description, we can say that the electric field generated by the current of the coil does not vary nor is it “dragged” by the rotation of the coil and that the charges of the radius of the spiral G rotate in that field. Therefore, when a cylindrical magnet rotates around its symmetry axes, a radial electric field is generated (according to relativity and the Lorentz force, but we cannot measure it without closing the circuit and producing a rotation between the two parts of the circuit). This is opposite to intuition and it constitutes the biggest paradox of the disk and the rotating magnet of Faraday. We can see why there is no conceptual difference between the disk and the Faraday’s rotating magnet. This turbine also constitutes a special relativity experiment.

If the G coil is closed with another radial conductor (stator), we would expect a direct interaction between the radius, the rotor and the stator. In that case, due to reasons of symmetry, its torque would not be constant.

The interaction takes place between the current of the radius and the angular momentum of the circular current loop, but not directly between the radius. That is why the torque and the emf are fully constant.

Due to symmetry reasons, it is impossible to generate a constant torque with respect to its centre by the direct interaction of the two radios.

The electric field generated by the mechanical force or torque is perpendicular to the conductor, whereas the electric field generated by the electric power per unit time (power) or "emf" is in the direction of the conductor and depends on the relative speed of the rotation of the two radius, as the mechanical power.

Therefore, the location of the electrical energy or "emf" generated makes no sense, as Einstein deduced in the theory of relativity.

This electrodynamic turbine constitutes a simple proof of Einstein’s special relativity.

4. The paradox of the conductive coil.

Since all coils work like a turbine, we initially believed that the torque of an Archimedes spiral coil would grow with the number of turns while keeping its diameter. That is to say, making it more compact and reducing its path.

When we intended to improve a turbine, we found that it was not true and what we call the paradox of a conductive spiral appeared.[12]

5. Two coils with same diameter and different number of turns

The magnetic flux increases when we decrease the path of the spiral, but the torque scarcely increases. Therefore, we wondered which spiral generated the highest torque per unit length with the same intensity of current. The result was the logarithmic spiral of constant 1, like a mechanical turbine whose torque is produced by the rate of change of the angular momentum of the stationary current. The Faraday Disk is also an electrodynamic turbine whose torque gets higher when the speed of the variation of the angular momentum of the electric current increases.

When we increase the number of turns in a spiral by decreasing its path, we increase the angular momentum of the current (magnetic flux) but to the detriment of radial current speed, which causes a variation in the angular momentum.

Therefore, the induction is not produced by the rate of change of the magnetic flux Φ, but by the rate of change of the angular momentum of the stationary current.

The spiral is an open-circuit and it has to be closed so that a stationary current can flow. As we have seen above the part of the circuit that closes the spiral is also an active part of it and can vary its torque and emf. We can increase or decrease the torque of the spiral and even reverse it depending on the shape and the length of the conductor that closes the circuit.

The torque of the two parts of the circuit depends on the total angular momentum generated by both parts. In fact, all circuit becomes an electrodynamic turbine when it is divided in two parts. Regardless of the shape and the length of the two divided parts of the circuit, their electrodynamic torques are always equal and opposite, due to the conservation of the angular momentum.

The fact that the torque of a spiral or part of a circuit can be increased or decreased depending on the shape of the rest of the circuit means that it can be closed without varying its torque. This is the case when a circuit is closed with a straight conductor that does not contribute to the angular momentum of the circuit current. In this case the torque is intrinsic and the action between the two parts is not reciprocal. The curved part of the circuit generates an equal and opposite torque to the straight part as required by conservation of the angular momentum. However, the curved part of the circuit is not affected by the straight part of the circuit. This intrinsic torque can be explained by the variation speed of the angular momentum of the charges in that part of the circuit, which in this case acts as a hydraulic turbine whose torque does not depend on the rest of the circuit. However, it depends on the permeability of the medium that separates the two parts of the circuit. (Later we will see later that the generation of an intrinsic torque in a part of a circuit is also the result of the theory of relativity).

It is easy to see the inviolability of the conservation of the angular momentum by selecting the shortest and the most symmetrical circuit.

If we cut a turn into two semicircles and we attach them from one extreme to a perpendicular axis to its plane so that they can rotate and the other extreme stays in contact with a circular mercury canal, through the passage of the current, then they rotate in opposite directions indefinitely.

If we cut the circumference into two arcs of different lengths, the torques will remain equal and opposite, but smaller. This constitutes a proof of the inviolability of the conservation of angular momentum.

All these experiments show that the Faraday disc is a turbine like all deformable circuits whose electromotive force (or rather power) depends on the relative velocity between the two parts of the circuit. Therefore, the location of the generation of the emf makes no sense, as Einstein showed in the relativistic electrodynamics.

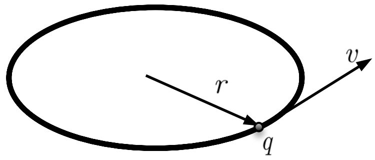
When connecting in series the current flow of the disk with the circular current, we realized that the Faraday disc is actually a deformable circuit as seen by Poincaré.

“Les rotations continues en sont donc possibles que si le circuit C' se compose de deux parties: l'une fixe, l'autre mobile autour d'un axe, comme cela a lieu dans l'expérience de Faraday”(La Science et L'Hypothese).

But Poincaré believed that this could be possible only with the presence of a magnet, as everyone still believes. The magnet facilitates the rotation of the disk but hides the real law of induction. If the great Poincaré had rotated the disc without the magnet, he would surely have discovered the law.

Every circuit is an electrodynamic turbine that can be endlessly deformed by rotating around an axis with the passage of a stationary current and without the presence of a magnet or a magnetic field. The normal circuit components generate the angular momentum of the current, that is the magnetic field. It’s equivalent to an external magnetic field such as the one generated by a magnet or any other circuit. What we call magnetic flux is actually the angular momentum $m = iS$ of the opposite charge flow.

To properly understand the new law of induction, we will express the magnetic moment of a charge “q”, which rotates in a coil of a radius “r” with a speed “v” respect to the opposite charges through these parameters**.**



The intensity in the loop is

$$i = \frac{qv}{2\pi r}$$

And the magnetic moment can be expressed in terms of velocity and intensity by

$$\vec{m} = \frac{1}{2}\vec{r} \times q\vec{v}$$

$$\vec{m} = \frac{1}{2}\vec{r} \times i\vec{l}$$

In the most basic expression, the integer form will be

$$\vec{m} = \frac{1}{2}i\oint \vec{r} \times d\vec{l}$$

Each circuit produces to a stationary current two equal and opposite variations of its angular momentum with respect to an axis passing through a point of a circuit and perpendicular to its plane. The only possible way for a stationary current to vary its angular momentum and to generate or induce a torque or an emf is by approaching or moving the charges away from the axis of rotation.

Therefore, it is impossible to make an electrodynamic turbine with the two moving contacts in the axis of rotation i.e. the electrodynamic turbine has to necessarily have one of the moving contacts as far away as possible from its axis of rotation. This is the biggest disadvantage of the electrodynamic turbines known as unipolar machines or acyclic machines. Repeated attempts to build a unipolar machine with two contacts in its axis have been made unsuccessfully due to the Faraday law, which does not show its impossibility. Otherwise, according to the new law, the impossibility is evident. This disadvantage reduces the advantages that turbines have to work with large stationary current intensities (superconductives) without generating losses by hysteresis nor by Eddy currents.

Turbines are the only machines that can run with a stationary current, but when the only existing magnetic field is the one generated by the current, the torque is proportional to the square of the current and can also run on AC.

The Faraday disk, wrongly called unipolar machines, is actually an electrodynamic turbine and it stops been an exception and becomes the crucial experiment of the true law of induction. With reference to the above expression of the angular momentum of a current in a circuit, we can see that three different ways to vary the rotation moment of the flow of charges exist, which determines the three ways of induction. Rigid circuits and deformable circuits can be distinguished:

a) *Interactions between rigid circuits*

1. We can vary the norm of the angular momentum of the current by changing the intensity. The direction of the momentum does not vary, the circuits are not moving and there is no transformation of the mechanical energy into electrical energy. This is the case of transformers.

2. We can vary the direction and the norm of the angular momentum by the rotation or displacement of the circuits. We will obtain the cyclical machines of ac or intermittent direct current.

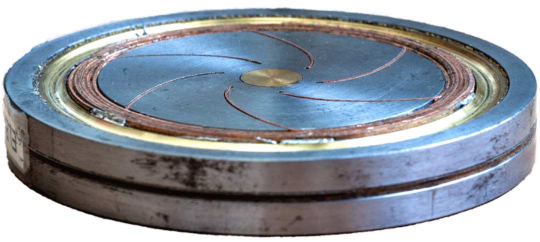
b) Interactions between two parts of a deformable circuit

3. Variation of the angular momentum in two parts of the circuit, due to the variation of the radio of gyration. Neither the current nor the total angular momentum vary. We obtain unipolar induction, acyclic or stationary current machines.

5. The variation of the angular momentum of the current and relativistic electrodynamics.

5.1. Calculation of the torque in a logarithmic spiral

Let's consider a circuit formed by a conductor with a logarithmic spiral shape of a constant unit, closed by a straight conductor, which coincides with the extreme radius vector of the spiral.



6: Relativistic turbine with logarithmic spiral conductor

In this case the torque generated in the coil is "intrinsic", i.e., the straight part of the circuit does not increase or decrease their torques with respect to the centre. However, these torques depend on the medium that separates the parts of the circuit (spiral and straight conductor) in which the equal and opposite variation of the angular momentum of the stationary current occurs.

These variations of the angular momentum of the stationary current generate equal and opposite torques in the spiral and the straight conductor, which rotate in the opposite direction when connected via a sliding concentric circular contact with the spiral.

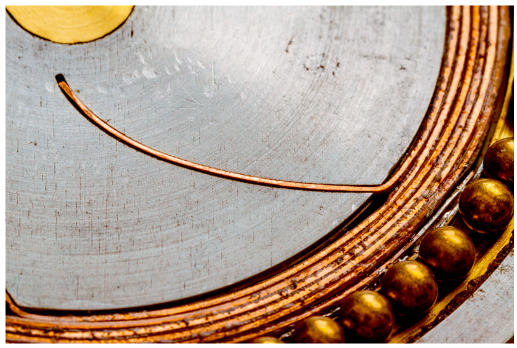
The velocity of relative rotation between the two parts of the circuit generates the power of transformation of electrical-mechanical energy.

All the stationary current charge in the logarithmic spiral has a velocity composed of two equal velocities, one in the direction of the radius and the other perpendicular to it. When these velocities are the same, the speed of variation of the angular momentum of the charges is at its maximum and produces the maximum torque per unit length.

Every current element of the spiral "ids" can also be considered as made up of two elements of current, one in the direction of the radius and the other perpendicular to it.

According to the theory of relativity a force is generated in these perpendicular elements of the current, with the results being perpendicular to the path.[5]

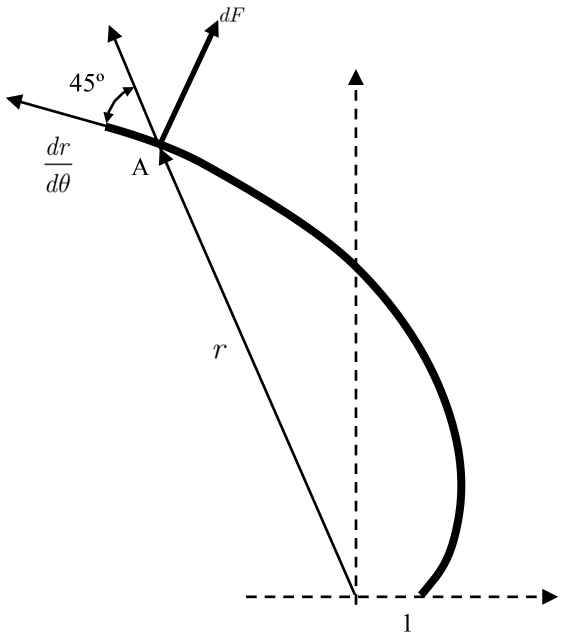
In every point of the logarithmic spiral the charges undergo an equal and maximum variation of its angular momentum and individually contribute to a torque, which depends on its radius of gyration, i.e. the distance of the charge to the rotation axis.



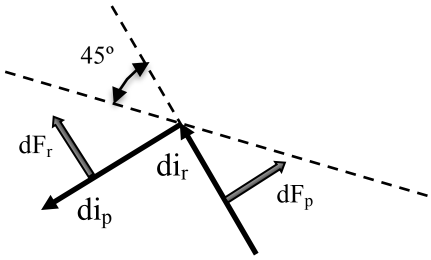
7: Detail of the logarithmic spiral

The equations for the logarithmic spiral are

$$\left.\begin{array}{l} r = e^{\theta} \\ \dfrac{dr}{d\theta} = e^{\theta} \end{array}\right\} \rightarrow tan\,\psi = \frac{r}{\dfrac{dr}{d\theta}} = \frac{e^{\theta}}{e^{\theta}} = 1 \Rightarrow \psi = 45^{0}$$



Separating in differential current elements at point A



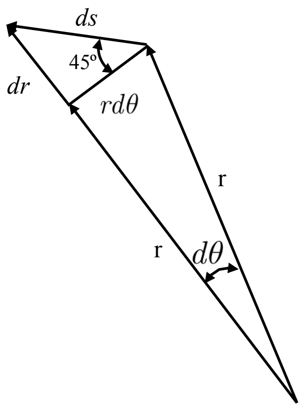
The only element that contributes to the torque is the perpendicular dF_p. Then the torque is

$$d\tau = rdF_p$$

How we calculate the force in the spiral is very easy. We consider that the force between two parallel wires is proportional to the square of intensity. If we are opening the wires the relation remains the same, then we can *say* that the element of the diferencial force dF is

$$dF = ki^2 ds$$

In the spiral they are all the same and they form the same angle with the radius vector "r".



$$dr = sin\,45 ds \Rightarrow ds = \frac{1}{sin\,45}dr = \frac{2}{\sqrt{2}}dr = \sqrt{2}dr$$

The component perpendicular to the radius "r" of the differential force is

The constant "k" depends on the units and the medium.

The differentials "ds" of the logarithmic spiral are proportional to the differential "dr" of the radius vector of the spiral. The tangent of the spiral is a constant angle of 45 ° with the radius vector.

$$\left.\begin{array}{l} dF = ki^2 ds \\ dF_p = dF\,cos\,45 = \dfrac{\sqrt{2}}{2}dF \\ ds = \sqrt{2}dr \end{array}\right\} \Rightarrow dF_p = ki^2 dr$$

We obtain for the torque

$$d\tau = ki^2 rdr$$

And the torque " τ " or rate of change or the momentum of the spiral arm, whose radius vector varies from zero to L, is:

$$\tau = \int_1^r ki^2 rdr = \frac{1}{2}ki^2\left(r^2 - 1\right)$$

For very large values of "r" with respect to 1 we can make the following approximation:

$$\boxed{\tau \approx \frac{1}{2}ki^2 r^2}$$

As mentioned above, the part of the circuit that closes the spiral can increase or decrease its torque depending on the direction of the normal components. If these do not exist or are cancelled, the torque is "intrinsic" of the spiral. However, in the conductor which closes the spiral, an equal and opposite torque is generated due to the normal components of the spiral. The radial components of the entire circuit make the conservation of angular momentum possible.

The generation of an intrinsic torque in the electrodynamics of rotation due to the speed of variation of the angular momentum of the stationary current can also be explained through the relativistic electrodynamics or the Lorentz force .

The intrinsic torque in the logarithmic spiral allows us to make a definition of the Ampère which does not depend on the distance between two parallel currents.

To summarize and demonstrate experimentally what we have expressed, a very simple and symmetrical turbine has been built with a patent number P201430376.

5.2. Calculation of the momentum variation

As a curiosity we obtain the variation of momentum

$$dA = \frac{1}{2}r\left(rd\theta\right) = \frac{1}{2}r^2 d\theta \Rightarrow r^2 d\theta = 2dA$$

$$d\tau = ki^2 rdr = ki^2 e^\theta e^\theta d\theta = ki^2 r^2 d\theta = ki^2 2dA$$

$$\boxed{\frac{d\tau}{dA} = 2ki^2 = cte}$$

We observe that is a constant.

5.3. Single blade turbine

Another important question about the electrodynamic turbine is that, if n is the number of blades, the current that passes trough each blade is i/n and the torque made on it is $\left(i/n\right)^2$, which multiplies by the number of blades

$$\tau = n\left(\frac{i}{n}\right)^2 = \frac{i^2}{n}$$

Then a single blade, with only one turn, forms the best relativistic turbine. The torque of an electrodynamic turbine is proportional to the square of the intensity of the current and inversely proportional to the number of blades

9. Last Electrodynamic Turbine

6. Conclusions

The "unipolar" machines are electrodynamic turbines formed by a single and deformable circuit, which it requires distant moving contacts from the axis of rotation. The relative rotation between the two parts of the circuit generates the transformation of mechanical $\leftrightarrow$ electrical energy.

The location of the energy or "electromotive force" generated in them makes no sense, as Einstein showed in the theory of relativity, but in each of the two parts of the circuit, an equal and opposite torque is located. These torques are due to the variation of the angular momentum of the stationary current in the circuit.

The variations of the angular momentum are always equal and opposite as required by the angular momentum conservation law.

In the electrodynamics turbine there is no independent magnetic field of the current, and its torque is proportional to the square of the current and inversely proportional to the number of blades, i.e. they are single-blades and their operation is not predictable in the classic description of electromagnetism.

It is the only machine that can work with a stationary current as well as with alternating currents of a wide range of frequencies.

Its work as a generator is even more unpredictable. Its capacity to amplify an oscillation or transient at any rotation speed can cause resonances.

Electrodynamics turbine is a crucial experiment of the law of induction to show that the law is the expression of Variation and Conservation of the angular momentum of the current.

I.e., the torques and the electromotive forces are proportional to the rate of change of the angular momentum of the stationary current.

The three possible ways to vary the angular momentum of the current generates three ways of induction.

This law is also fulfilled when the intensity of the current varies and the charges are accelerated (alternating current) regardless of the fact that in this case, the Special Relativity is not applicable.

The theory of relativity shows that the magnetic field is a mathematical device that transforms the electrodynamics of rotation into electrodynamics of translation. This facilitates the calculation, but makes its interpretation difficult.

The transformation of the electrical $\leftrightarrow$ mechanical energy takes place by the flux of the angular momentum of the mass and the flux of the angular momentum of the charges, which are perpendicular and simultaneous.

When we apply the Lorentz force and the relativistic electrodynamics to calculate the force between two perpendicular conductors, they express the rate of change of the angular momentum of the stationary current.

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