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THE FARADAY DISK

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I. THE FARADAY DISK

This problem, according to some, violates the conservation of the angular momentum; others will explain it using the relativistic transformation, as Professor SERRA-VALLS[1] does. Many will remain satisfied applying to it the denomination of exceptional case.

Here the results of a *"New Dynamics (ND) of Irreversible Mechanical Systems"*[2] which is isomorphic with the Electromagnetism of MAXWELL-LORENTZ, will be used. We will study the case of a spiral in the symmetrical field of a magnet, located in the normal axis to the same by its centre. (see fig 1).

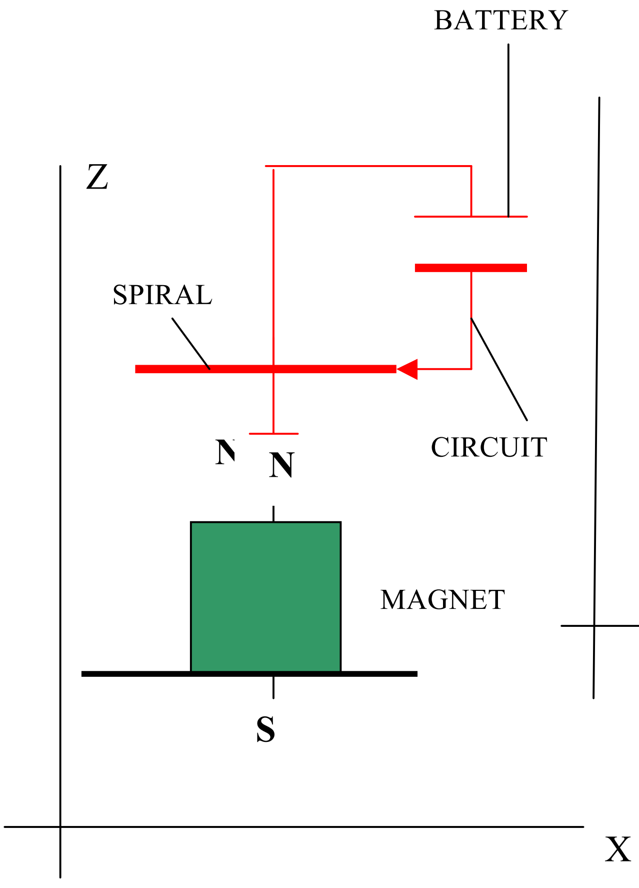

FIG. 1

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[1] A SERRA–VALLS. *El motor turbo electrodinámico.* Ed. IVIC. Caracas. 2009.
[2] JOHN RIUS-CAMPS. *Los Fundamentos Cosmológicos de la Mecánica y las Leyes Fundamentales de la Dinámica*. Anuario Filosófico. Vol. IX. 1976. Universidad de Navarra.

In order to study the present problem we will apply the expression of the "LORENTZ Force" of Electromagnetism:

$$\boldsymbol{F_L} = q(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B}) \qquad (1)$$

Considering that does not exist the electric field and is only present the magnetic field $\boldsymbol{B}$ (external to the system), created by the cylindrical magnet. The force $\boldsymbol{F}$ that acts on a charge q , in an element of current of the conductor in spiral, is ***external to the system*** like $\boldsymbol{B}$, and will be normal to it in this point (see fig 1); the expression (1) is

$$\boldsymbol{F} = q(\boldsymbol{v} \times \boldsymbol{B}) \qquad (2)$$

The result of the addition of all forces $\boldsymbol{F}$, on a spiral conductor, will be an external pair that will cause its rotation. One reaches the immediate conclusion that the *angular momentum* in the turn of the FARADAY disc (spiral) *is not conserved.*

Classical Dynamics (CD) demands the conservation of the angular momentum and it is not possible to be applied to the present study. In the New Dynamics (ND) the same force $\boldsymbol{F}$, on a mass m and charge q , is given by the expression,

$$\boldsymbol{F} = m(\boldsymbol{v} \times \boldsymbol{\omega}*) \qquad (3)$$

With $\boldsymbol{\omega}* = (dv/dt)/(d\rho/dt)\boldsymbol{b}$ ($\boldsymbol{b}$ is the *versor* according to the *binormal* in the FRENET's frame). Since the referred rotations only have sense to a referential of inertia like the one of our system, and it is *external* to the same; it results that $\boldsymbol{\omega}*$, as the field $\boldsymbol{B}$, is *external* also. In addition, the force (2) changes sign with $\boldsymbol{v}$, that is to say, when the current sense is reversed; the same happens to the force (3) of the ND. Consequently, force $\boldsymbol{F}$, expressed mechanically (3) , must agree with. its electromagnetic expression (2). Obviously the *angular momentum* is ***not conserved*** either here.

On the other hand the expression of the total force over the mass m in the ND is

$$\boldsymbol{F}_{total} = m(\boldsymbol{a} + \boldsymbol{v} \times \boldsymbol{\omega*}) \qquad (4)$$

being $\boldsymbol{a}$ the acceleration of m ; therefore, the "LORENTZ force" (1) is the electromagnetic expression of (4) . It is evident, also, the *isomorphism* between the **Electrodynamics** and the **ND**.

NOTES:

1. When the tangential acceleration dv/dt on m is *null,* and then $\boldsymbol{\omega*} = \boldsymbol{0}$ with $\boldsymbol{F} = \boldsymbol{0}$. This does not happen in our case, being variable the *moment of inertia* of the mass m that runs along the spiral. Also is $\boldsymbol{F} = \boldsymbol{0}$ when the spiral is reduced to a circumference.

Like has proved professor SERRA-VALLS[3], the logarithmic spiral, of constant 1 , is the most efficient.

2. In order to explain the conservation of the *angular momentum* some authors maintain that the *outer circuit,* formed by the battery and the conductors that connect with the axis and the periphery of the disc, constitutes the *stator,* whereas the *disc* would be the *rotor*[4]. The same doctor SERRA-VALLS has tested that after *blinding* the external circuit, the *disc* continues turning, and thus it would be necessary to affirm the *non-conservation of the angular momentum*, but this fact results incredible to him, and goes to the relativistic solution of the phenomenon. In the final section: **II. STUDY OF THE "FARADAY DISK**, is clearly expressed this blindage possibility.

3. In order to facilitate the understanding, see the study of the *Normal Supplementary Acceleration* (NSA), departure point of the ND, that is included in the next section.

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[3] Doctor ALBERTO SERRA-VALLS, in his book *El Motor Turbo Electrodinámico y la Nueva Ley de Inducción* (Venezolan Institute of Scientific researches. 2009), presents the substitution of the disc by a conductor in the form of logarithmic spiral located in the same plane and centre. Also the magnet can be replaced by the magnetic field created by the current in the spiral.

[4] *Ibidem.*

II. ESTUDY OF THE "FARADAY DISK"

The problem can be simplified replacing the FARADAY DISK by a horizontal *radial rotating bar* around a vertical *conductor axis*. This would be the *rotor*. The *stator* is formed by a *circular conductor* and a second *radial bar*, both fixed to an inertial frame **XYZ**. The *battery* is in contact with the *vertical axis-conductor*. A *contact–brush mechanism* at the end of the first bar, closes the circuit with the *circular conductor* (see the figures **A** and **B**)

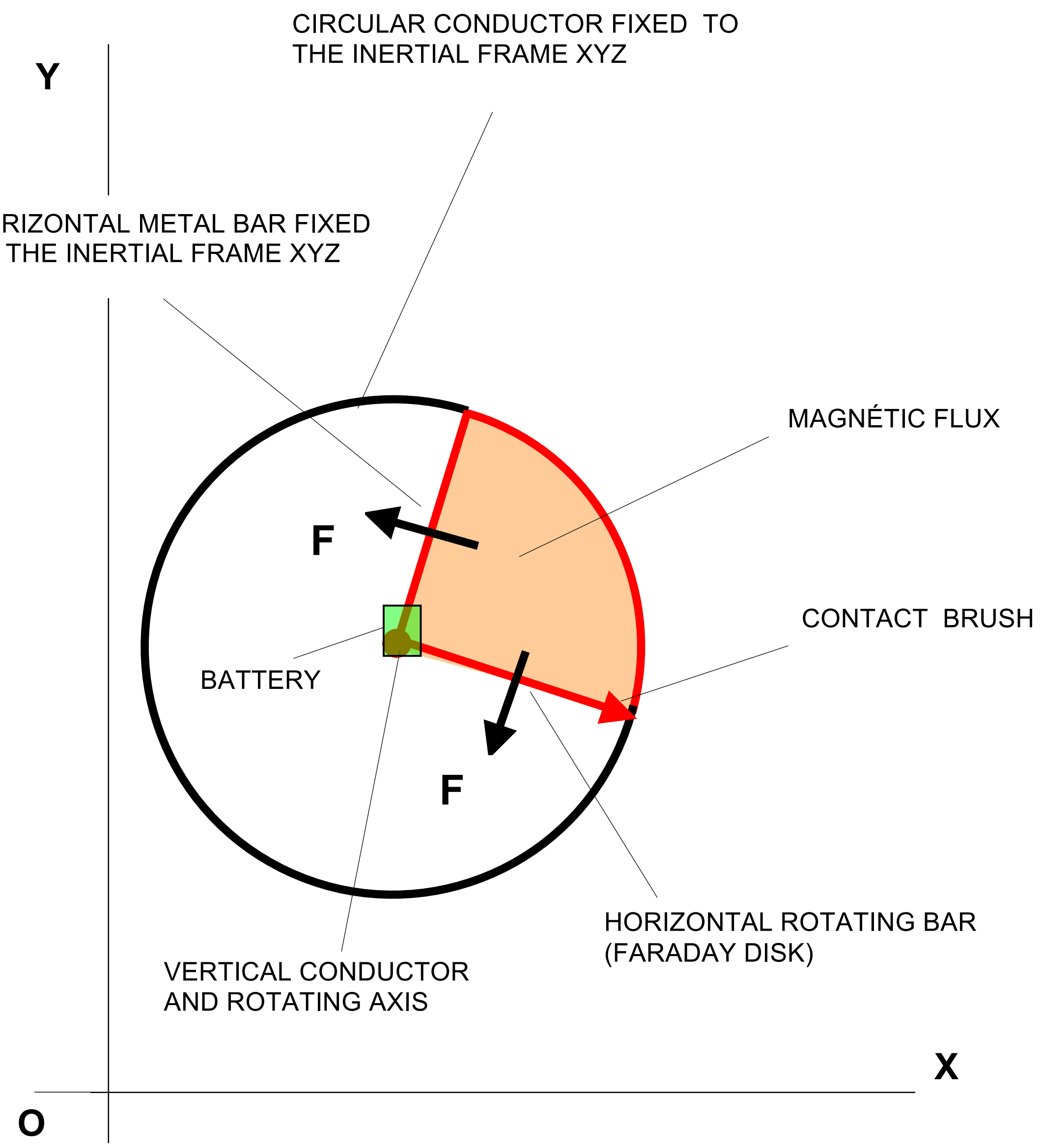

FIG. A (horizontal projection)

The magnet is a vertical and symmetrical cylinder, fixed with respect to the inertial frame **XYZ.**

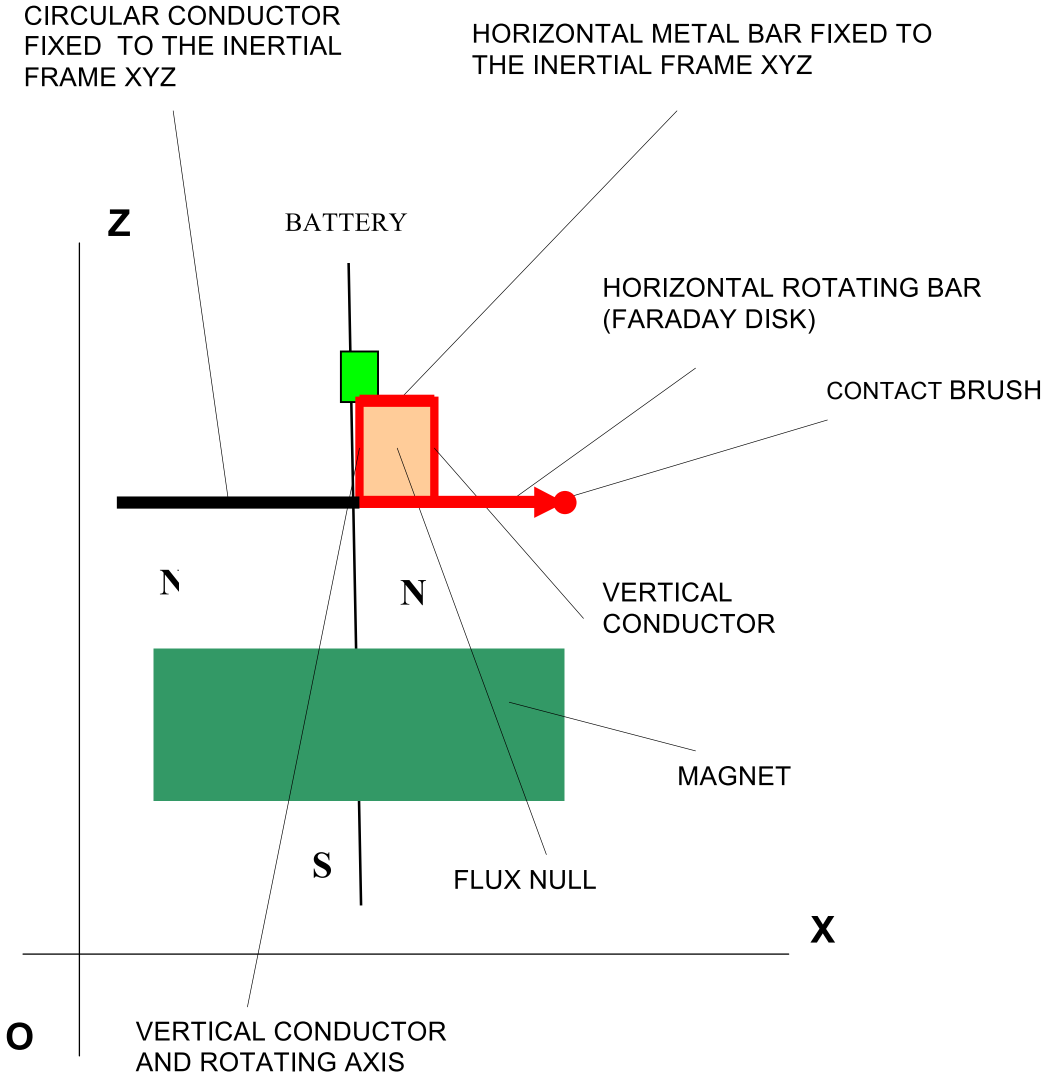

FIG. B (vertical projection)

On the *fixed radial conductor* acts the LORENTZ force **F** , normal to the same; another identical force, acts on the *bar–disc of FARADAY*, producing two pair of forces, equal and opposed; only turns this last *bar,* because the *radial conductor* is fixed with respect to inertial frame **XYZ**. (see Fig. **A** and **B**). At first sight it seems that the angular momentum is conserved, as it demands the Classical Dynamics (CD), but if the *radial conductor* is *blinded* with respect to the magnetic field, stops existing the normal LORENTZ force, but the FARADAY disk will continue turning. Thus it is allowed to affirm that in this motor the *angular momentum is not conserved.*[5]. If both radial bars could turn freely, then we would have two FARADAY's disks, superposed, that turn in inverse sense[6]. There is no *action-reaction* between both.

Also, observing the Figures **A** and **B**, one concludes that the circuit, to apply the *Induction Law of FARADAY or rule of the flow*, consists of a *horizontal sector* (fig. **A**) and a *vertical rectangle* (fig. **B**), and in the last one the flow is null by the symmetry of the system, forming both a *dihedron;* in addition, the *rectangle* surface can be reduced to zero when both radial conductors were practically coplanar. Obvious the result would be the same one obtained applying the "LORENTZ's force"[7]. Consequently the FARADAY disk *does not constitute an exception to the "flow rule".*

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[5] Professor ALBERTO SERRA-VALLS in his book, *El Motor Turbo Electrodinámico y la Nueva Ley de Inducción,* after *blinding* the external conductor, reaches the same conclusion, but does not accept it because it seems to him "impossible". Textually writes: "Cuando el año 61me percaté que el conductor que conecta el borde del disco de FRADAY constituye el estator me pregunté si era posible blindar dicho comductor del campo magnético del imán. En caso afirmativo, no podría funcionar sin violar la Ley de la Conservación del Momento Angular. Por más intentos que hice de blindar el conductor, el disco no dejó de funcionar. No pudiendo medir la fuerza de la reacción sobre el conductor y no creyendo en la violación de la ley; (...)"

[6] *Vid. ibidem.* pp, 47–49 y pp. 55–56 .

[7] *Ibidem*. pp. 44–47 .

SUPPLEMENTARY NORMAL ACCELERATION a_n*

KINEMATIC A ND DYNAMIC MEANING OF ANGULAR VELOCITY ω*

1. At first, we begin with the study of the trajectory of a material point *m* from the kinematical point of view exclusively. In classical kinematics a differential ***ds*** of arc in the trajectory is substituted by the corresponding in the osculating circle in order to calculate the acceleration vector. For this purpose a FRENET's referential frame is used. The acceleration components in this circle are

$$\boldsymbol{a}_s = (dv/dt)\boldsymbol{s} \qquad \text{and} \qquad \boldsymbol{a}_\rho = -(v^2/\rho)\boldsymbol{n} \qquad (1)$$

Where ***s*** and ***n*** are the *versors*. In this frame whose *versors* are ***s , n , b*** the *positive sense* is determined by the velocity sense, by the sense towards convexity and by the vector product: $\boldsymbol{b} = \boldsymbol{s} \times \boldsymbol{n}$, respectively. The angular velocity is

$$\boldsymbol{\omega} = (v/\rho)\boldsymbol{b}$$

A definite trajectory has a well defined *evolute,* and in the calculation of the normal component in the expressions (1) the differentials dv and $d\rho$ are obviously not taken into account. But, as we will demonstrate, when $dv \neq 0$ and $d\rho \neq 0$, the *arc* of the *evolute* does not correspond with the real one: it turns locally at an angular velocity

$$\boldsymbol{\omega}* = (dv/d\rho))\boldsymbol{b}$$

and the same thing occurs with the corresponding *arc* of *trajectory* in the osculating circle.

In order to explain the kinematics meaning of this angular velocity $\boldsymbol{\omega *}$, we shall study an element $\boldsymbol{ds}$ of trajectory which corresponds to the $\boldsymbol{d\rho}$ of the *evolute;* they are both located on the plane of osculation (see Fig.1 when $dv/dt > 0$; and Fig. 2 when $dv/dt < 0$). Thus we can consider the trajectory as being locally plane and referred to an intrinsic frame with *versors* $\boldsymbol{s}$, $\boldsymbol{n}$, $\boldsymbol{b}$, formed by the *tangent, normal* and the *binormal.* The *arc* $\boldsymbol{ds}$ of the trajectory is determined by the points A , B , and the $\boldsymbol{d\rho}$, of the *evolute,* on account of its equivalent points A , B

. The speed of the particle in A is v and in B it is $v + dv$. The radii of curvature at these points are: $\rho + d\rho$ and ρ . The angle turned by the radius of curvature when it passes from A to B is

$$d\theta = ds/\rho$$

and the corresponding angular speed will be as we have seen

$$\omega = d\theta/dt \qquad (\text{with} \quad \boldsymbol{\omega} = \omega\, \boldsymbol{b})$$

We can also write: $\omega = v/\rho$, which evidently does not depend on dv and $d\rho$. When we calculate the centripetal acceleration we get the last expression (1):

$$\boldsymbol{a}_{\rho} = -(v^2/\rho)\boldsymbol{n}$$

in which the increases dv , $d\rho$, are not considered, as they do not affect it. It is the consequence of replacing the $\boldsymbol{ds}$ of *trajectory* by the corresponding one in the *osculating circle* at the same point. However, if we observe the real trajectory carefully, we see that is characterized by having a well determined *evolute* (see Fig. 1, when $dv/dt > 0$, and Fig. 2, when $dv/dt < 0$). When dv is dispensed with, in the study of centripetal acceleration, it means that starting out from point A we arrive at B' but not at the real point B ; and the same should occur to the centre of curvature: A is located in the *evolute,* as it is the starting point, but B' lays outside of the *real evolute* (see Fig. 1 and Fig. 2), whose point is B . It is evident that the centripetal acceleration is correctly determined, but it is also clear that the *arc* of the *evolute* must coincide with what is determined by points A and B in the figure, and not by the A and B', as happens when dv and $d\rho$ are omitted. In order to rectify this deficiency it is necessary to rotate AB' an angle

$$d\theta^* = BB'/d\rho$$

so that it coincides with the $\boldsymbol{d\rho}$ in the *evolute,* with a *finite* angular velocity (see Fig. 1 and Fig. 2) whose module is expressed by

$$(BB'/d\rho)/dt = (d^2s/d\rho)/dt = dv/d\rho = d\theta^*/dt = \omega^*$$

This angular velocity shows that the simplification of replacing the trajectory with the osculating circle in each point means that it is necessary to turn locally the *arc* of the *evolute*, with angular velocity $\boldsymbol{\omega^*}$, so that it coincides with the real one. But this *arc* AB' of the *evolute* must be *normal* to the corresponding AB'' of the *trajectory,* rotated also $d\theta^*$, with respect to the initial AB (see Fig. 1 and Fig. 2). It will be necessary to turn AB' this angle, in the *same sense* (when $dv/dt > 0$) and in the *opposite sense* (when $dv/dt < 0$), so that it coincides with the *real* one . As a result, the *radius* ρ has increased in a second order infinitesimal amount:

$$B'B'' = dsd\theta \qquad \text{(when } dv/dt > 0\text{)}$$

and

$$B'B'' = -dsd\theta \qquad \text{(when } dv/dt < 0\text{)}$$

and the immediate result is a *supplementary normal acceleration:*

$$\alpha_\rho^* \;=\; B'B''/dt^2 \;=\; ds\, d\theta^*/dt^2 \;=\; v\omega^* \quad (\text{when } dv/dt > 0)$$

$$\alpha_\rho^* \;=\; B'B''/dt^2 = -\,ds\, d\theta^*/dt^2 = -\,v\omega^* \quad (\text{when } dv/dt < 0)$$

superimposed to the *normal acceleration* a_ρ (1). So the *total normal acceleration* is

$$a_\rho + a_\rho^* \;=\; -(v\omega + v\omega^*) \;=\; -v(\omega - \omega^*)$$

$$a_\rho + a_\rho^* \;=\; -(v\omega \;-\; v\omega^*) \;=\; -v(\omega + \omega^*) \tag{2}$$

in the two possible cases.

Obviously the *tangential acceleration* $a_s = dv/dt$ remains unchanged. Taking in account (2)we get in vector form the *total acceleration:*

$$a_s\boldsymbol{s} + a_\rho\boldsymbol{n} + a_\rho^*\boldsymbol{n} \;=\; \boldsymbol{a} + v\omega^*\boldsymbol{n} \;=\; \boldsymbol{a} - \boldsymbol{v}\times\boldsymbol{\omega}^*$$

$$a_s\boldsymbol{s} + a_\rho\boldsymbol{n} + a_\rho^*\boldsymbol{n} \;=\; \boldsymbol{a} - v\omega^*\boldsymbol{n} \;=\; \boldsymbol{a} + \boldsymbol{v}\times\boldsymbol{\omega}^* \tag{3}$$

respectively.

2. From the dynamical point of view, if we want to calculate the *total normal force* correctly, the *total normal acceleration* (2) must be taken into account. So the expression of this *normal force* will be

$$\boldsymbol{f_n} = -mv\,(\omega \;-\; \omega^*)\boldsymbol{n} \;=\; m\boldsymbol{v} \times (\boldsymbol{\omega} \;-\; \boldsymbol{\omega}^*)$$

and

$$\boldsymbol{f_n} = -mv\,(\omega \;+\; \omega^*)\boldsymbol{n} \;=\; m\boldsymbol{v} \times (\boldsymbol{\omega} \;+\; \boldsymbol{\omega}^*)$$

in both possible cases.

Now, in summary, taken in account the expression (3), the *total force* acting on the material point is

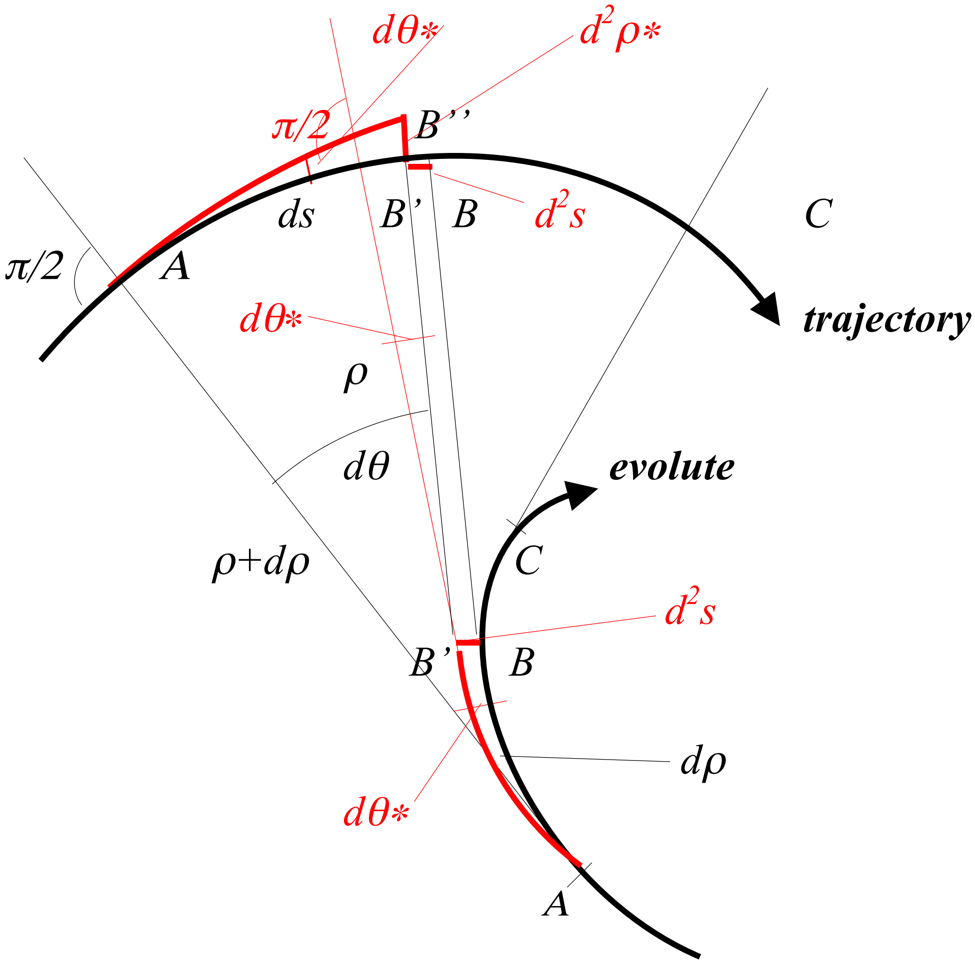
$$\boxed{\boldsymbol{f} = m(\boldsymbol{a} \pm \boldsymbol{v} \times \boldsymbol{\omega}*)} \qquad (4)$$

(which is *isomorphic* with the LORENTZ electromagnetic force).

The angular velocity $\boldsymbol{\omega}*$ will only cease to exist when the trajectory is a circumference or the speed v is constant, as it follows observing Fig.1 and Fig. 2 (see also the cases of Fig. 1' and Fig. 2').

The result (4) is surprising: even more so when we remember that "LORENTZ's force" is exclusively experimental. Moreover, in FRENET's trihedron the value v of speed is always *positive* in the sense in which the particle is moving . We know that while the moving point follows the trajectory, the *centre of curvature,* at the corresponding point, describes the *evolute*, and we can take the sign of $d\rho$ as *positive* because the sense of its movement follows the *changing sense* of the velocity $\boldsymbol{v}$. This result is of the major importance (see the two possible cases in Figs. 1, 2, and 1', 2') because $\omega = dv/d\rho$ *changes sign,* when the movement is inverted (*dv changes to $-dv$* whereas $d\rho$ *,* in the *evolute does not change).* When the *movement is inverted,* the *versor* $\mathbf{s}\times \boldsymbol{b} = -\boldsymbol{n}$ *maintains its sense,* because $\boldsymbol{s}$ and $\boldsymbol{b}$ simultaneously change sign; but the *supplementary normal acceleration* $\boldsymbol{a}* = \boldsymbol{v}\times \boldsymbol{\omega}* = \mathbf{s}\times \boldsymbol{b} v\omega*$ *changes sing* when $\omega*$ *changes to* $-\omega*$. Consequently, the ***reversibility*** of the trajectory in CD ***does not hold up*** in the ND,

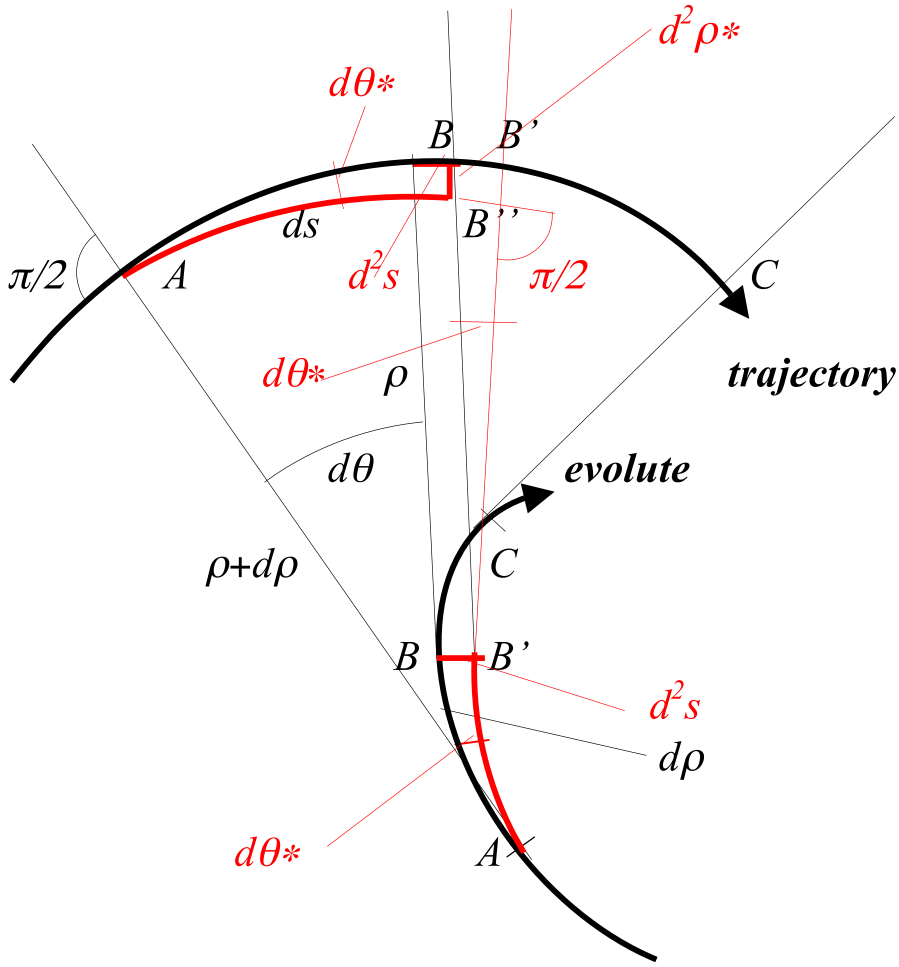
The ***CHAOS*** presence in physical phenomena has its foundation in this ***irreversibility.***



Supplementary Normal Acceleration (when $dv/dt < 0$)

$$a_n{}^* = d^2\rho{*}/dt^2$$

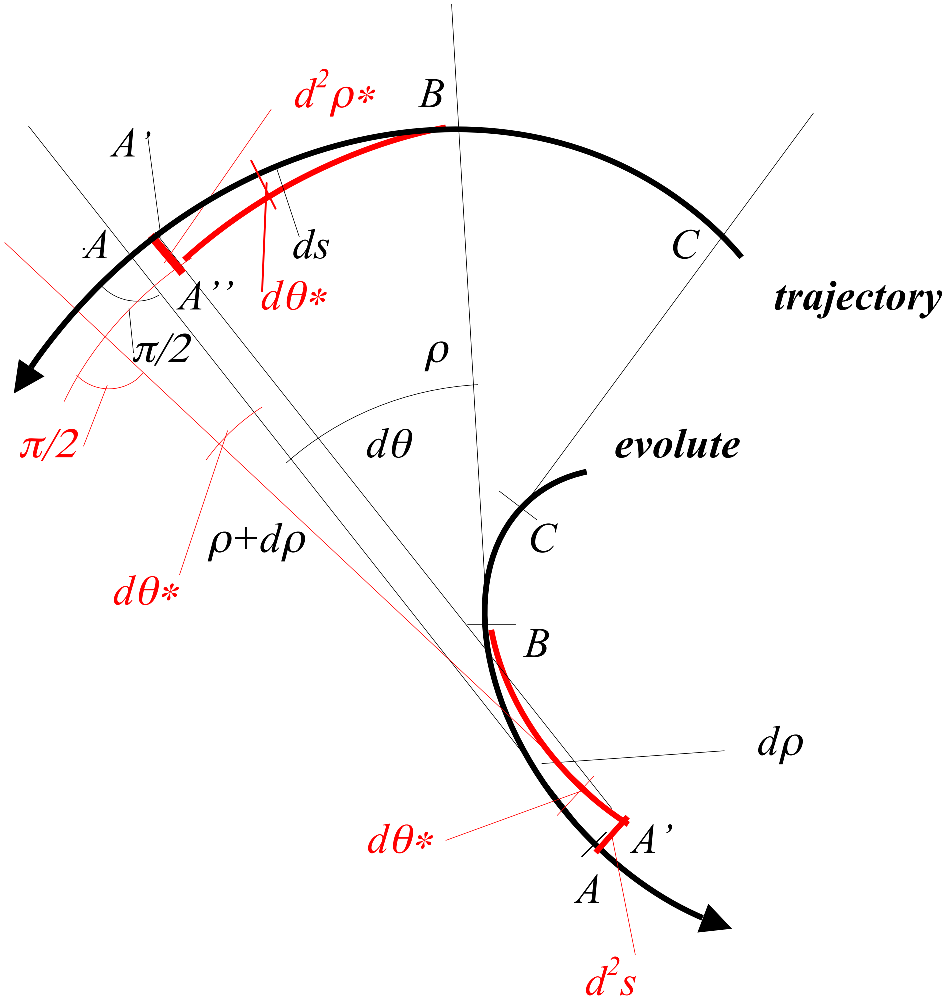
FIG. 1



Supplementary Normal Acceleration (when $dv/dt > 0$)

$$a_n* = d^2\rho*/dt^2$$

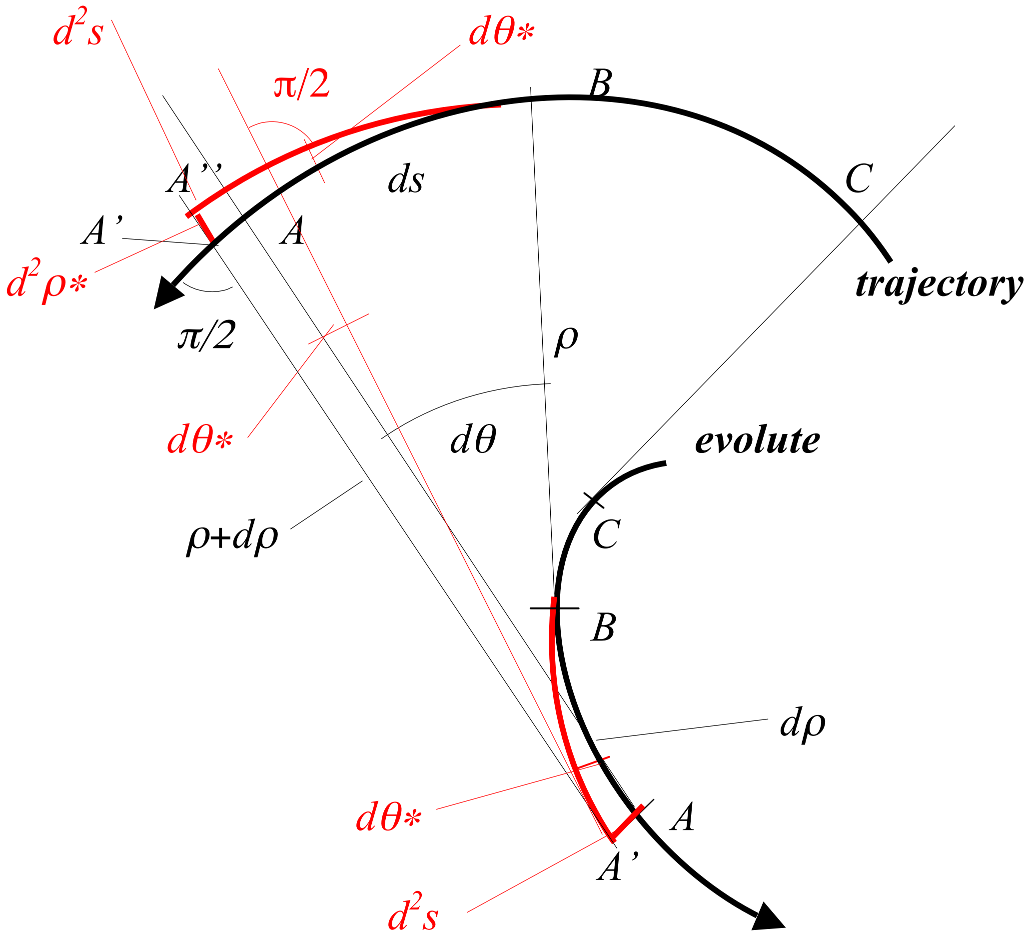
FIG. 2



Supplementary Normal Acceleration
(running in *inverse direction*, with $dv/dt < 0$)

$$a_n* = d^2\rho*/dt^2$$

FIG. 1'



Supplementary Normal Acceleration
(running in *inverse direction*, with *dv/dt > 0)*

$$a_n{}^* \;=\; d^2\rho{*}/dt^2$$

FIG. 2'

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