JOHN RIUS–CAMPS

IRREVERSIBILITY AND CHAOS

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CHAPTER I

THE COSMOLOGICAL FOUNDATIONS OF MECHANICS
AND THE FUNDAMENTAL LAWS OF DYNAMICS

INTRODUCTION

This study was published for the first time in Vol. IX of the PHILOSOPHICAL YEARBOOK for 1976[1]. After 17 years we thought opportune to revise it at the light of more recent theoretical and experimental discoveries to improve some obscure points and others that were inadequately or even erroneously expounded. The *cosmological-philosophical* aspects are practically unchanged, but the physical-mathematical developments have been substantially modified, because initially we had only surmised the formulation of the foundations of a New Dynamics (ND), of which the Classic or Newtonian (CD) should be a particular and restricted case. We have not suspected its subsequent mathematical development. We have replaced the unsatisfactory formulations by a more elaborated ones which are, in our opinion, accurate and coherent with the starting points. Nevertheless, *the conclusion* remains basically the same. As we will expound later, the more important result of this ND is the ***dynamical irreversibility of a material point trajectory***. The ***CHAOS presence in the dynamical world,*** developed in **Chapter V,** is an immediate consequence.

MATTER AND FORM.

1. The co-principles of *matter* and *form*, the foundations of Metaphysics of Nature or Cosmology, might be considered by some people as mere historical lucubration passed down from ARISTOTLE's times to our own, which no longer require -and still less in scientific study- this infrastructure. It is nonetheless surprising that the greatest thinkers in contemporary physics cannot do without Metaphysics unless it is with a

[1] JOHN RIUS-CAMPS. *Anuario Filosófico*. Universidad de Navarra. 1976. pp.

certain intellectual violence; first, with themselves; then, once they are convinced and accustomed to the new, self-composed ideological dogma, believed and received, sometimes without the least criticism, they set out to impose it on everyone else. Others, intellectually more honourable, end up admitting the equal rights of the opinions they received through education and those that they surmise as other possibilities and which, not infrequently, are actually the inalterable foundations of Metaphysics. It seems appropriate here to try, by giving ideas a name, to set out some of these antimetaphysical assays together with examples of the rediscovery of the perennial truth which lies in the very structure of physical reality and man's thought. It is the expression of the failure of modern *mechanicism*, pioneered by DESCARTES, and of OCKHAM's "sharp knife "which does not penetrate as far as the intimate being of things nor the profundity, which cannot be analytically formulated, of man's soul, seat of intelligence -limited by matter and temporality- which goes beyond experimentable reality. The law of *causality*, the centre of Cosmology, is the point at which the debate begins. Whilst LAPLACE affirmed that "we must consider the present state of the Universe as the effect of its former state and as the cause of that which will follow.", MACH can be found at the opposite pole: "there is neither cause nor effect in nature; nature simply is, since the link between cause and effect only exists in the abstraction that we create in order to reproduce, mentally, the facts". MAX PLANCK is more moderate: "it can be said that the law of causality is, above all, a hypothesis... but although it may be a hypothesis, it is a fundamental hypothesis, which represents the requirement which is necessary to give sense and meaning to the application of all hypotheses in scientific research".

The principle of causality goes hand in hand with the concept of *determinism*. For some, "science, in the past, is a description and, in the future, a belief "(KARL PEARSON); it is a mere *probability* of coincidence. LOUIS DE BROGLIE would say, "the wall of determinism has a fissure the breadth of which is expressed by PLANCK's constant". But this indetermination is not metaphysical but purely experimental; nevertheless, there are many who have given it a transcendental nature, even taking it out of the framework of physics in order to apply it to the spirit -the existence of which they naturally refute- and then the truth no longer stands as universal, it is reduced to a pure "argument for plausibility": it is positivism taken to the very core of thought: GUSTAVE JUVET[2] puts the indeterminist position in its exclusively experimental

[2] G. JUVET, *La Structure des Nouvelles Théories Physiques*. p. 141. Ed. Alcan. Paris. 1933.

place: "observation and experience cannot express physical phenomena in the language of space and time with indefinitely perfectible accuracy; the successive approximation of experience and theory have a limit in their accuracy; they cannot catch reality in ever smaller nets, because it is impossible that it should be made more tenuous than that measured by the number *h* . HEISENBERG formulated his famous *"Principle of Indetermination"* and did not intend its scope to extend beyond the purely experimental; "with *indetermination,* all causality is not denied, just as EINSTEIN does not refute the relativity of classical mechanics. Both suggest that we should subject our conceptions to a more severe criticism and refinement"[3].

Another idea which is repellent, physically speaking, is that this causality which is necessary between the agent and its effect, may occur without *contact*, without *nexus* between them both. Nexus which must be real, physical; a merely notional relationship is not enough; nonetheless, this possibility depends on the conception of cause which is accepted. Previously, it was a question of whether the idea of cause existed; now that this has been accepted, it is a question of how it acts: this is where opinions are once again divided: some accept *material causality*, the Cartesian *"res extensa";* others go further, adopting the purely phenomenological and the space-temporal apriority of IMMANUEL KANT. Some will base themselves on the *formal aspect* eliminating physical reality: everything which is experimental is imponderable: *energy;* they follow more or less closely the ideas of LEIBNIZ and the founders of *energetism* which tries to be an anti-mechanical tendency. When physicists want to escape this ideological trap, they then fall into the *positivism* of AUGUST COMPTE: let us limit ourselves to study the relationship between phenomena, we might hear, and let us leave speculative tirades for the philosophers. It is not unusual to find, even in physics manuals, such expressions as "this manner of speaking is somewhat metaphysical, since the affirmation that fixed stars are not accelerated goes beyond our present experimental knowledge"[4].

For the first group, the *nexus* would be purely material, mechanical, and matter would be purely measurable, *quantifiable*; for followers of MACH it would be implicit in energetic transformations, energy is the only thing which is experimental: it gives rise to a kind of imponderable material nature which is equivalent to a physical formalism. *Energetism,* founded by LEIBNIZ, was generally accepted in 1855 with

[3] P. F. SCHURMANN, *Luz y Calor*. p. 148. Ed. Espasa-Calpe. Madrid. 1948.
[4] C. KITTEL, and others, *Mechanics Berkeley Physics Course*, vol. 1. p. 60.

RANKINE: it results from a negative criticism of *mechanicism,* starting from the assumption that all physical phenomena are nothing more than manifestations and transformations of energy and accuses it of giving too little importance to experimental fact and too much to the hypothesis that in the physicist's mind, it replaces reality itself. RANKINE's energetics was not idealistic, as LEIBNIZ suggested, but rather "experimental, empiric, determinist, deductive and mathematical"[5]. The physics of energetics had already begun to be developed by MAYER, although he did not go so far as to deny matter; MACH was the foremost driving force behind this doctrine in his famous *Mechanics*[6], in which he developed these ideas under the title of an "animated kinetic explanation of an anti-metaphysical spirit" and added that the "mechanical explanation of all natural phenomena is nothing more than a historical prejudice".

Basically, neither RANKINE nor MACH are very far from DESCARTES, neither were COPERNICUS, KEPLER, GALILEO, NEWTON or HUYGHENS. For over two centuries the mechanical doctrine was engaged in trying to construct a mathematical model of nature, by studying matter and its movements, following the Newtonian laws applying to the invisible mass and movement of atoms. It was a purely *quantitative* theory: first a geometrical analysis of nature, followed by analytical Mechanics which when completed with the concepts of *mass, inertia, action equal to reaction* (introduced by GALILEO, NEWTON, HUYGHENS) led to the mechanics whose findings, in part, are still valid. However, around the middle of the nineteenth century, this great edifice was on the verge of collapse when SADI CARNOT described and formulated the "Second Principle of Thermodynamics": natural phenomena are not only quantifiable but also display an *asymmetry*, a *one way direction* in their evolution: there exists a quality which cannot be explained by the all-powerful equations of Newtonian mechanics: the *irreversibility* of natural processes. This is an aspect which although merely formal is difficult to quantify. Matter, on its own, does not explain either this aspect or the reason why energy dissipates in order to transform itself into another kind of energy: MAYER enunciated the "First Principle of Thermodynamics", which historically came after the second (but which, as was discovered years after SADI CARNOT's death, he had actually discovered a great deal earlier, as is proved by his manuscripts, which his brother gave to the French Academy of Science –forty-six years later– in 1878). The supporters of energetics try to find a solution by means of energetic formalism; however, its Cosmology, without matter, is based on

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[5] P. F. SCHURMANN, *op.cit.* p. 208.
[6] E. MACH, *Mechanics*, published in 1903.

the continuity of energy and on determinism. But at the end of the nineteenth century there was no convincing experimental proof that the atom existed, as had been claimed since LEUCIPO and DEMOCRITUS, and later by GASSENDI; thus MACH could continue to consider the atomic hypothesis superfluous.

Continuous and *discontinuous* have constituted a constant polarity since the dawn of physics and philosophy. PLANCK inclines the experimental balance definitively in favour of the latter: *Quantum Mechanics* was born and energetics was abandoned. EINSTEIN, affirming the equivalence between mass and energy: $E=mc^2$, eliminates the alleged difference between mechanicism and the theories of energetics. Finally, beginning in 1925 with DE BROGLIE and WERNER HEISENBERG, and later with ERWIN SCHRÖDINGER and DIRAC, *Wave Mechanics* was born; it attempted something which is mentally contradictory: to unite the physical, corpuscular, discontinuous aspect with the ondulatory, energetic, continuous vision (based on the *substratum* or continuous ether). We come back once more to positivism and to experimental fact; all intuition, whether sensorial or relating to the old physical conceptions which sought a model which could be imagined, is disregarded in order to give a totally abstract description -based on values which could easily be measured- thus providing us with a mathematical model of a reality which vanishes -in a microcosmic analysis- behind the Principle of Indetermination. The causal nexus is solely logico-mathematical: concepts like "direct action at a distance", are perfectly admissible in a model of this kind.

2. Finally, after the arduous diatribe between mechanicists and energetists, modern Quantum Mechanics seeks more profound support; it cannot remain at the level of the positive facts, measured in the laboratory and synthesized in a mathematical model. Kantian systematics go well with this positivist-indeterminist vision of reality; CARL F. VON WEIZSÄCKER[7] says: "The insufficiency of ingenuously realist and positivist opinions, which clash today with KANT's system, embodies the approach in the direction taken by KANT. The solutions which KANT found for the basic problems he was considering do not appear, in the light of modern physics to be either true or false, but rather ambivalent. As we try to test here, hand-in-hand with present-day knowledge, a discernment between a sound interpretation and a false one of Kantian thesis, we establish a principle of criticism for KANT's philosophy and, at the same

[7] C.F. VON WEIZSÄCKER, *La Imagen Física del Mundo*. pp. 76 & c. Ed. B.A.C. Madrid. 1974.

time, a starting point for further philosophical elaboration of modern physics". P. F. SCHURMANN[8] casts somewhat more light on this tendency, a compromise between DESCARTES and LEIBNIZ: "In KANT's opinion experience provides us with the necessary information about *things in themselves* which really exist, but whose only intervention in our knowledge is to stimulate our senses and to remain inaccessible. It is on these impressions that our faculty of knowledge, with its intellect-sensorial organization constructs our image of the world. In order to do this it takes the notions of *time* and *space*, which are *forms* of our sensitivity, as fundamental bases of all perception. With understanding, which also has its own forms or *categories*, we give shape and relate to impressions of sensitivity..." In this Cosmology certain ideas are "a priori", stemming from sensitivity and understanding; the concepts of *space*, *time* and *causality* are to be found here. This vision of the world was pioneered in the last century by such eminent physicists as HERTZ who, agreeing with MACH in some aspects, coincides with KANT in declaring that "the images which our intellect constructs must satisfy conditions of admissibility, correctness and expediency. While correctness is established by experience, admissibility is released to our intellect as an *a priori* condition"[9].

The supporters of energetics defended a position based on the bastion of the thermodynamic "Second Principle", which was introduced with difficulty into mechanics; however, with MAXWELL, BOLTZMANN and GIBBS' kinetic theory of gases and the statistical concept of entropy, these difficulties disappeared. As if that were not enough, the triumph of atomism, definitively proclaimed by OSWALD[10] as opposed to continuity, knocked energetic Cosmology out of the running. The advocates of mechanicism had triumphed definitively... The quantification of matter and the powerful laws of determinism –even if they were statistical– gave sufficient explanation of our Cosmos. This was the accepted view, until the Thirties when another vision of the Microcosmos opened up as the result of HEISENBERG's "Uncertainty Principle". Mechanicism is also incapable of comprising all the "raison d'étre" of the real world. Modern Quantum Mechanics maintains a merely positive attitude which should not fall into such an awkward *crystallization* as the preceding ones Nevertheless, the scientist is constantly tempted to seek the *unity* of things; this is what E. POINCARÉ said on the matter: "science draws near to unity, one of the conditions which make it possible". Man

[8] P. F. SCHURMANN, *op. cit.* p. 205.
[9] P. F. SCHURMANN, *op. cit.* p. 211.
[10] To his great regret, as he was the author of *The Defeat of Atomism.*

often forgets where the driving force for his investigations comes from, that which really makes them possible: the search for *something*, which at the same time we understand to be desirable: something which is *good;* but one cannot draw near to reality without any law, with merely experimental data; a *unity* must exist, endowed by laws which distinguish the *true* behaviour of things and which exclude falseness and error. We thus arrive at *what it is* in its various manifestations: and it leads us to the essence of things comprised in the five *transcendentals*, foundations of the authentic Metaphysics of nature.

Aristotelic-Thomist Metaphysics, since OCKHAM and DESCARTES, was harshly attacked; not for its inadequacy, which has never been proved, since its foundations are so strong that its opposers –if they are consistent– deny its very starting points in order to destroy it. Perhaps it was attacked because of a desire for novelty, in an attempt to avoid the existence of *a sole* platform for all thinkers; arrogantly denying a "perennial philosophy", as a basis for all good thinking. Moreover, men often reject the *truth* if they do not live by it: they have often sought a "set of false teachers to flatter their base passions"[11] and because of the sophisms of his slanderers SOCRATES had to drink hemlock for his wisdom.

Physicists, and scientists in general, are actually closer to the perennial truth, in Metaphysics, than many philosophers. They do not usually ponder such problems until the end of their lives, as the result of profound reflection about their own physical knowledge: they include C. VON WEIZSÄCKER, BONDI, LEMAITRE, W. HEISENBERG. However, they are men of their time and were influenced by contemporary ideas, as were PARMENIDES and PLATO, ST. AUGUSTIN and his Manichean friend FAUST. Some manage to unmask fundamental errors thus giving rise to a new vision which replaces the former one (in the field of physics for example), but these changes often mean that a philosophical stand is taken, as seen in the preceding study. Present-day physicists are no exception and avidly seek an infrastructure which gives unity to their knowledge. In the environment in which they were born and had lived, in most cases, Metaphysics has not only been brought into "disrepute" or is viewed with suspicion, but it is not even well-known. ARISTOTLE, PLATO, PARMENIDES, surmised and even came to know the *five transcendentals*, *causality* and the co-principles of *matter-form*, which explain the unity and multiplicity of beings... They arrived at these conclusions by paying "a great price", in the midst of a world full of *myths*

[11] 2. *Tim*. 4, 3-4.

and *sophists* whose most outstanding intellectual characteristic was their zeal for novelty[12]. With the advent of CHRIST the Truth came into the world and that which previously had only been achieved at "a great price" was from that time on "held by birth".

Today, in an environment where science is evolving while Metaphysics has lost its place, it is hardly surprising that *ambivalence* is spoken of and *relativism*, and that a disconnection from reality occurs. Kantian philosophy has all the characteristics of pseudo-metaphysics in which the essence of things can no longer be objective: reality itself is disconnected. That is why many important contemporary physicists really prefer this cosmological vision which provides the Ontology which they were lacking.

The four Aristotelian causes: *causa materialis, formalis, efficiens, finalis,* have lost a lot of ground: the first is inaccessible and the formal one and the last one are identified with the agent which, based on its "categories", is the only cause and, moreover, is found outside physical reality. C.F. VON WEIZSÄCKER[13] expresses it thus: "The Modern Age knows no cause other than that which is found outside the thing. So, to start with, the two first causes, which are to be found within the thing itself, are eliminated; in this manner of speaking, matter and form designate the essence, but not the cause of the object. With these modifications, controversy broke out among the scientists of nature at the beginning of the Modern Age, distorting the original meaning of ARISTOTLE and going against the scholastic thesis that substantial forms, or qualities, could be causes... If knowledge is power, the first thing it must know, above all, is the means of producing things and phenomena, or at least it must influence them. The *causa efficiens* of each one must be known. The criterion by which we may know if the *causa efficiens* is really understood is being able to predict correctly the action which it causes. In this way the concept of cause was transformed so much that in modern natural science the principle of causality came to be identified with complete predictability of natural phenomena. The mathematical expression of this concept of causality is the representation of natural phenomena by means of differential equations which set forth the differential temporal quotient of magnitudes, which characterize the state of the thing, by means of these same magnitudes; this state even determines, from one time to another, its temporal variation". Modern mathematics claims that there is no difference between efficient and final determination of a process. The last redoubt of the old

[12] 2. *Tim.* 4, 3.
[13] C.F. VON WEIZSÄCKER, *op. cit.* p. 165.

metaphysical causality is the mathematical form on which physics is based: a kind of extra-material *causa formalis;* but Metaphysics has been mutilated to such an extent that rather it is pseudo-metaphysics, as stated earlier. Basically, all the formal value of physics, leaving aside the nebulous contact with reality through phenomena and the space-temporal "categories" of sensitivity, is found in mathematical science (we must not forget that KANT was a mathematician and that his errors arise from applying to philosophy methods which are valid for purely mathematical objects). Thus we can understand HILBERT's attempt[14] to reduce logic to *meta-mathematics*, (a phrase which he coined himself), a *consistent* and *complete* formal system: a complete foundation for mathematical methods and theorems. Nonetheless, GÖDEL's theorem implies that this system is not simultaneously consistent and complete. Contemporary physics took refuge in KANT; for a time it seemed to be a secure position; the mechanicists were ousted by the "Uncertainty Principle". What other Principle could discredit that ancient philosophical attitude, which was the very shortcoming of the afore-mentioned meta-mathematics? A. DOU[15] expresses it thus: "GÖDEL's theorem has been generalized in various directions and, in general, mathematical logic is at present undergoing a period of extraordinary development. From the point of view of the foundations of mathematics, the importance of the theorem is evidently extraordinary and it basically means that HILBERT's optimism must in principle be renounced... It also seems obvious that GÖDEL's theorem implies a certain limitation in the deductive power of logic. Something like HEISENBERG's Indetermination Principle in Quantum Mechanics, but here, it seems, at the much more abstract and profound level of mathematics or pure logic... Sometimes it seems that the fact that we know that the interpretation of *wdf (well done formula)* is true, in spite of being independent in the (system) S , is interpreted as if human intelligence, and consequently the capacity of the human brain, were superior to the very best of artificial calculators; since it is accepted that a computer's functions of calculation are identified as recurrent functions and these are precisely the ones which can be represented in S . It may therefore be concluded that man in his cognitive or intellectual function cannot, even in the realms of theory, be totally replaced by machines or robots. For the moment it appears that all this is effectively true".

3. Neither mechanicists, nor energeticists, nor this last attitude of Kantian following which has just been analysed can adequately explain the

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[14] A. DOU, *Fundamentos de la Matemática*. p. 105. Ed. Labor. Barcelona. 1970.
[15] *Ibidem,* pp. 109 and 110.

material reality which eludes them or, what is even more serious, even though accessibility to it is disregarded, what then vanishes is thinking reality itself. ARISTOTLE began and SAINT THOMAS completed the most powerful and congruent Cosmology with the brilliant intuition of the doctrine of *actus* and *potentia*, which can be applied to both levels of being: the purely entitative, which includes the most general form of being, and applies to all beings -both physical and spiritual- with a clear distinction of the co-principles of *essence* and *existence (actus essendi)*; and the purely material, composed of *matter* and *form*, which constitute the co-principles of the corporeal being. God goes beyond both levels, while man goes beyond matter: the thinking super-machine, as some would like to reduce it to, eludes matter, including formal logic: its substantial form is *spiritual*; it is a reality with certain qualities which are not contained in any quantifiable experience nor any attempt at "consistent and complete" formulation".

In the mechanicism, dispensing with the formal cause, the qualities of corporeal beings are elusive; they may only be approached in quantifiable form indirectly, through the Laws of Nature. Yet experience shows us that what we know "primo et per se" are, in fact, these very qualities. In formulations from energetics and phenomenalism, these qualities, which are on the lines of formal cause, are disconnected from physical reality; which is then no longer accessible reality, which may be objective, with objective qualities, that is to say, they are the "hallmark of the artist" who created them. The Laws of Nature, which we know and are able to formulate, are not sufficient to provide understanding of *all* the qualities of beings: there is an *excess of being* which cannot be formulated by any theory, even resorting to probabilistic processes, which some of us scientists are so accustomed to, and which require millions of years (or even billions in order to be exact) to be completed and which remind us of the fabulous numbers of the Hindustani cosmogonies.

There are ideas which were regarded for years as ascientific, and which are expressed by this "excess of being", as well as the insufficiencies pointed out in this study. The most important is the *"ex nihilo"* Creation by a transcendent Being. Another idea is the existence of a transcendent soul in man. With regard to the former, there are an increasing number of scientists who do not reject the existential hypothesis of a time t = 0, that is, "the beginning of time", and at least consider it as scientific as non-existence at the beginning. BONDI[16] has this to say on the subject:

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[16] H. BONDI, *Cosmología,* p. 17. Ed. Labor. Barcelona. 1970.

"Speaking in general terms, three answers have been given to the question of the beginning, and opinions of the relative merits of each one are strongly divided:

a) The beginning was a singular point in the frontier of physical science. Any question regarding its nature or antecedents cannot be answered by physics and it therefore bears no relation to the same.

b) The beginning was a very simple state; the most simple, harmonious and permanent that can be imagined. Nonetheless, it contained the origens of growth and evolution which at some undefined moment initiated the chain of complicated processes which have turned it into the Universe as we know it.

c) There was no beginning. On a large scale the Universe probably remains unchanged or perhaps undergoes cyclical changes. In either case, its age is infinite.

Further on we shall look at how these three different explanations are reached. For the moment suffice it to say that a theory must, at least, lead to the problem of creation and that opinions differ with regard to the nature of the actual explanation".

In order to identify the present disparity of opinion referring to the idea of Creation, the following anecdote related by C.F. VON WEIZSÄCKER[17] may be helpful: "In 1938, when I was a young theoretical physicist in Berlin I passed a report to the *Physikalische Colloquium* of that university on the subject of transmutation of the elements in the Sun... I was very proud of my discovery, and in order to demonstrate its plausibility I underlined the point stating that the Sun could be assigned an age very similar to that of the Universe, obtained by interpreting the spectrums of the nebulae, an idea which was very new at that time. But on this point I ran up against the violent opposition of the famous chemical physicist WALTHER NERNST, who belonged to an earlier generation and was then professor of physics at this University. NERNST said that the idea of the Universe having an age was not scientific. He then explained that the infinite duration of time was a basic element of all scientific thought, and

[17] C.F. VON WEIZSÄCKER, *La importancia de la Ciencia.* p. 140. Ed. Labor. Barcelona. 1968.

that to deny it would be to deny the very foundations of science. This idea greatly surprised me, and I ventured to object that it was scientific to form hypotheses in accordance with the insinuations of experience and that the idea of the Universe's age was one of these hypotheses. He argued that it is not possible to form scientific hypotheses which contradict the very foundations of science. He was very annoyed... What impressed me about NERNST was not his line of argument, which I am afraid I still believe to be lacking in substance; what impressed me was his annoyance. Why was he so irritated? What vital interests of the man WALTHER NERNST, born at the end of the nineteenth century and sure to die in the twentieth, what vital interests of this man could be violated by the possibility that the Universe had not existed since infinity, but that it had begun to exist some five thousand million years ago?...Neither the platonic, believing in the immortality of the soul, nor the Christian, believing in resurrection to a new land under a new sky, would feel disturbed by the discovery that this material world could be of finite duration for immanent reasons. I think that I am not mistaken in believing that NERNST, along with most scientists of his generation, was not a positively religious man, and it seemed natural to me (and it still does) to conclude that he had mentally adopted the infinite and everlasting Universe in place of an eternal God and an immortal soul".

We have seen that one of the strongest hypotheses of present-day physics is the *First Fundamental Law* of Mechanics: the conservation of energy, or rather of mass-energy, according to Einstein's identification of $E = mc^2$, equally strongly accepted; with the exception of theories which, in order to maintain the density of matter-energy constant in a Universe in expansion, suggest that it is constantly being created; such as BONDI and GOLD's "fixed state theory" (1948)[18] and that of HOYLE, which begins with conveniently modified equations of General Relativity. However, no experimental confirmation of this constant creation appears to exist and, in any case, it is not a question of an *"ex nihilo"* creation, but rather of a hypothesis. It is nevertheless clear that all Cosmologies run up against this problem of creation, as BONDI himself warns.

In our opinion, although we believe that this *First Law* is fundamental to Mechanics, we do not accept it in this absolute sense of "ex nihilo" creation, because in actual fact this observation applies to that which can be quantified, which can be measured in a laboratory. We find more appropriate the creational hypothesis of a cosmological *substratum*,

[18] *Cf.* H. BONDI, *op.cit.* p. 159.

of a *continuum*, which serves as a necessary basis for all cosmological theory: the basis of inertia which is implicitly accepted by all cosmological formulations, where to set up the "fundamental observers" which none of them can do without. We postulate this continuum in opposition to the quantum discontinuous, which is the object of all experimental measurement. Moreover, as expounded in an earlier study[19], the claims defining the properties of this continuum are the following:

a) "The continuous exists" (as a last extreme created "ex nihilo" by God). Really it is the only matter in existence. The cosmological substratum is its physical interpretation.

b) "The continuous admits discontinuities". These constitute what we know as matter-energy.

c) "The continuous is meta-empiric". What is experimented or measured are merely relationships between discontinuities.

d) "The continuous is indestructible". Perishability and local movement are characteristic of the discontinuous. It could only perish by decree of its Creator. When discontinuities intervene in the heart of the continuous it marks the beginning of the observable Cosmos. Time, understood since ARISTOTLE as a "measure of movement", is pure, successive dynamic discontinuity; it is the experimental, measurable time of physicists. The "beginning of time" and the "end of time" refer to this discontinuous time, different from the "duration", permanence in being, characteristic of the cosmological substratum. This duration, because it is continuous, does not allow physical measurement, it is meta-empiric. It is not contradictory that the cosmological, or continuous, substratum did not begin simultaneously with time; the reason for this lies in the domain of Theology. NERNST's annoyance, as mentioned earlier, was physically out of place. Time $t = 0$ refers to the beginning of matter-energy, it is necessarily finite, as it is the measurement of a number of identical dynamic discontinuities which follow one after another, and it does not make sense that this number should be infinite. On the other hand, the substratum, being continuous, could have an infinite duration, that is to say,

[19] J. RIUS–CAMPS, *La afirmación del Principio de Mach y sus consecuencias dinámicas*. pp. 10 & c. E.T.S.A. Pamplona. 1975.

it might not require a beginning and an end. Christians know from the Revelation of God[20] that it had a beginning, but there is no reason why it should have an end; they know, however, that the "end of time" will occur.

e) "The continuous does not flow". Movement, understood as a topological variation, pertains to the discontinuous, that which is quantifiable. In this sense, the continuous cannot admit spatial discontinuities which are infinitely and immediately divisible; matter-energy is quantifiable, as has been known since PLANCK; we may say that the same is true of time.

We may conclude from all this that the question of the Cosmological Foundation in terms of Physics, and in particular of Mechanics, is not something meta-scientific, as has been affirmed by more than a few, but that it is in fact of major importance. That is why we believe that these digressions on the subject of *Cosmological Foundations* of physics are of interest. We will now expound, along generic lines, the *Three Fundamental Laws* of Mechanics according to the same Cosmological vision.

The *First Fundamental Law*, which refers directly to the quantifiable aspect of matter-energy, has already been dealt with; it is based on the most material aspect of the essence of things; *quantity*, the primary expression of *matter*, which DESCARTES called *"res extensa"* and confused with *substance*, giving birth to modern mechanicism. However, still following faithfully in accordance with ARISTOTLE and SAINT THOMAS, corporeal beings also possess objective qualities, directly related to *substantial form* and cannot be reduced to simple quantifiable aspects. As we stated at the beginning, they are what is known "primo et per se". These qualities *are* of the material object, not a creation derived from the "a priori" forms of sensitivity and understanding based on a strict phenomenalism.

If this second qualitative aspect is neglected, denying it objectivability, it would hardly be surprising if physical science were to lose some possibilities in its development, that is to say, in its capacity to discover the profundities of Nature. In the following section, we will endeavour to give a cosmological foundation to what we shall call the *Second and Third Fundamental Laws* of Mechanics, based on the preceding ideas and criticism of the Newtonian Principles from the point of

[20] *Genesis*, 1, 1. "In the beginning GOD created the heavens and the earth".

view of the Philosophy of Nature. The exposition will be completed in the following chapters.

4. In addition to the conservation of matter-energy, the following basic aspect of the physical world is the corporeal quality of *inertia*; which is as disconcerting for physicists as it is for philosophers[21]. Is inertia a quality which is inherent in each body or is it relative to the presence of others? And another question: is it a property of masses in mutual relation, or is it the relation which each one of them has with space, understood in physical terms as "substratum"? We read[22]: "in a coherent theory of Relativity, inertia may not exist in relation to space, but only as inertia of masses in relation to each other". NEWTON, on the other hand, claimed the existence of an absolute space, or substratum[23]. He could not accept the idea of a "direct action at a distance" which, nonetheless, underlies "MACH's Principle", accepted by EINSTEIN as one of the axioms of his theory of General Relativity which, on the other hand, gives an insufficient explanation of inertia as something real and existing in the Universe[24]: "Thus, inertia would be *influenced (beeinflusst)* surely, but it would not be *determined (bedingt)* by matter present in the finite", in the words of EINSTEIN himself. "Following progressive disinterest in the question of inertia, the cosmologists of the present generation have returned it once more to the order of the day: this points out the fact that, in this aspect, EINSTEIN's failure has not been rectified and that nobody has been able to give a perfectly satisfactory mathematical expression of the principle of relativity of inertia. And for this reason people like HOYLE feel inclined to conclude that this principle is not actually of great interest; and even if it were true its heuristic value and deductive fecundity are very limited"[25].

If the *continuous substratum* is accepted, inertia is nothing more than the *response* of the same to all acceleration; unlike gravity, it does not depend on the presence - either close or distant - of other masses, but is rather a property of physical space, *extrinsic* to any body. "The distant stars", from MACH's Principle, are not the cause of inertia by an "actio in distans" but something like the beacons which tell us the situation of the *substratum* -which cannot be directly experimented as we pointed out earlier- and the same must also be said of the frameworks of inertia in the

[21] *Cf.* J. MERLEAU-PONTY, *Cosmología del siglo XX* pp. 41 & c. Ed. Gredos. Madrid. 1971.
[22] *Ibidem*, p. 53.
[23] *Cf. Principia Matematica*, published for the first time in 1686.
[24] J. MERLEAU–PONTY, *op.cit.* pp. 44 & c.
[25] *Ibidem*, p. 53.

laboratory: the gyroscope, FOUCAULT's pendulum, etc., which concur with what was determined by the distant stars so accurately that any chance coincidence is excluded. This inertia might be different in another Cosmos different from our own (supposing that a procedure for comparison existed). It may also be thought that in our own Universe -on a large scale- it might well vary from one point to another, and even according to the direction which is considered; but on the scale known to us our Universe appears to be *homogeneous* and *isotropic*.

Faced with the question: what would happen if all matter were eliminated except for just one experimental body, would inertia still exist?: the "MACH school of thought" replies that it would not. However, those who believe that this is a *quality* of the substratum would answer in the affirmative. NEWTON is still right according to many present-day cosmologists. But his weakest point is the First Principle: "an isolated body moves with a rectilinear and uniform motion"; it refers to a material point and can be extended to the centre of masses (CM) if it is a question of an isolated system. This statement is nevertheless contradictory, since its movement is straight with regard to any framework of inertia, the only ones in which all three Newtonian principles are valid, and these references are *external* to the system, isolated by hypothesis, and consequently cannot be used to affirm that the movement will be rectilinear and uniform. If looked at in this light, *inertia* is a quality which is *external* to the system and the "forces of inertia" of Classical Mechanics (CM), instead of "apparent forces", are *real* and *external* to the system, an assumption referable to a framework of inertia. If there were not a framework of inertia, it is evident that apparent forces could appear, in the full sense of the word, as is well known. The MACH Principle's declaration that "the only accelerations which make sense are those which refer to movement in relation to the distant stars", that is to say, in relation to an framework of inertia, corroborates the preceding conclusions since the *"distant stars"* are evidently external to the system. We can call the affirmation that "inertially isolated systems do *not exist*" the *Third Fundamental Law* of Mechanics.

Some physicists have tried to prove the validity of MACH's Principle in ways which differ from the Einsteinian one (and other analogous Cosmologies), starting with a parallelism with MAXWELL's electromagnetic theory. One of these is D. W. SCIAMA[26], who has a precedent in FELIX TISSERAND (1872) who tried, on the basis of his

[26] D.W. SCIAMA, *"On the origin of inertia", Monthly notices of the Royal Astr. soc. (1953), nº 1.* pp. 34 – 39.

theory, to explain the abnormal behaviour of the perihelion of the planet Mercury, but he failed. in the attempt. More recently, the physicians BRANS and DICKE have tried to provide complete experimental confirmation for MACH's Principle. But for most physicists, if not for all of them, this principle will continue to be mere conjecture, neither proved nor disproved".

The *First Fundamental Law*: conservation of matter-energy, and the *Third Fundamental Law*: inertially isolated systems do not exist, have been expounded and justified; what, then, is the *Second Fundamental Law?* Evidently, the Second Axiom of Thermodynamics sheds some light on what it may be, but it is not applicable to problems which are strictly mechanical; the latter are always *reversible* in the framework of CM, while the former refers precisely to the *irreversibility* of thermodynamic processes. The forces which act on a mass in movement are explained in the Second Newtonian Principle: the fundamental equation of Dynamics, and the equations of movement derived from it are always reversible with regard to variable time. However, continuing with the metaphysical criticism of these Principles (and thereby with consequences which are significant in physics), it turns out that when there is no acceleration, the Second Principle sends us back to the First: the movement is rectilinear and uniform; yet we know that this is not exact, then the other one will not necessarily always be so either. In general, the expression of force does not have to be so simple: the *acceleration* vector multiplied by a constant of proportionality which we call *mass*. As is shown in many studies, chronologically later than the first publication of this one in 1976, mass can vary with time when it is submitted to a Potential in function of position and time, and in the general expression of *force,* in the New Dynamics (ND) which emerges there appear new terms which, in addition to mass and acceleration, include the intervention of the velocity vector of the particle and the variation of the mass with time. It is surprising and gratifying at the same time that this expression should be isomorphic with "LORENTZ's force" of Electromagnetism; the equations which govern this ND are also isomorphic with *"MAXWELL's equations";* moreover, the latter are a particular case of the former in their formal aspect. In the following chapters some further points of this matter will be explained.

Continuing with the exposition of the cosmological foundations of this ND, we can say that the *First Fundamental Law's* metaphysical starting-point is to be found in the co-principle, *matter,* of corporeal beings and the first of the *accidents* which determines it: *quantity*. That is the reason why this law is essentially quantitative and quantifiable. The *Third Fundamental Law* does not refer directly to the very essence of being of things, but to the fact that beings are not isolated, since they interact on account of their very *nature*. Furthermore, the fact that every material being occupies a "place", which is not exclusively its own but rather is determined by the presence of other bodies, is not a merely abstract question about distance relations, but concerns a physical and dynamic interaction (in the Microcosmos nothing is at rest, and in any case this rest would only have existed prior to the "beginning of time", when the continuous was in perfect "silence", and would return if everything regressed to that "primitive silence"[27] at the "end of time"). The only body which does not occupy a place is the Universe, the Cosmos taken as a whole, so that this is actually the only really isolated system, the most extensive object, studied by Cosmology.

Another *accident,* which inevitably goes hand in hand with the *quantity* which it *qualifies* is that which, since ARISTOTLE, has been called *quality*: its essence pertains rather to the *formal* line; it can only be quantified indirectly, but it is the most intelligible property that things possess. The *Second Fundamental Law* is the physical, quantified expression of the most fundamental quality that bodies have when they change; since at the bottom of all change lies the Aristotelian concept of *local movement,* and that is why this *Second Law* is directly related to *time,* the intellectual measurement of all movement which, when related to the measurement of space, between the initial place and the final one, gives rise to the concept of *velocity.* This *Law* states first of all: "things move" (it would be the *panta rei* of HERACLITES of EPHESUS), and adds: "according to certain conditions". Things move because they are not isolated as a result of inertia *(Third Law),* and moreover they conserve their mass-energy *(First Law),* yet this interaction, this movement, is in the *direction* indicated by the *Second Law*. The "Second Principle of Thermodynamics" partly expresses this *Second Fundamental Law,* when it concerns the interaction of a very large number of particles; this is a statistical law. It is quite enlightening that this *Second* Principle was discovered before the *First*, as mentioned earlier; from the point of view of the Metaphysics of Nature, the following must be true: that the first thing the intellect understands are qualities; quantification comes afterwards.

As we will explain further on, in this ND the paths taken by material particles in a system are generally *not reversible* as is the case in Classical Dynamics (CD). Thermodynamic irreversibility –which considers a quasi-infinite number of interacting particles– is the statistical consequence of the irreversibility of each one of these trajectories. Thus, paradoxically, the

[27] *IV Liber Esdrae,* 6, 39 and 7, 30.

problem of a system of infinite bodies was resolved, whilst the "simple" one of three remained unsolved. On the other hand, the fundamental incompatibility of CD and the second Principle of Thermodynamics is well known. Further on, in the next chapter, we will try to provide a mathematical formulation for the *Second Fundamental Law,* by defining the *mechanical entropy* of a system made up of a finite number of particles. It is also possible to reformulate mechanically the classical entropy of a thermodynamic system, without turning directly to the concepts of heat and temperature, or BOLTZMANN's statistical expression[28].

5. As you will see, the possibility of mathematically formulating this concept of *mechanical entropy*, for systems with a *finite* number of interacting bodies, rests on the fact that the kinetic energy of a system may vary not only *quantitatively* but also *qualitatively,* even if it remains constant. This point, as we understand it, had been unknown until now and even more so its formal expression. However, apart from the incomplete light shed on it by the Second Thermodynamic Principle, it did not pass unnoticed by such ancient thinkers as ARISTOTLE and SAINT THOMAS AQUINAS. Obviously their knowledge was a response to an intuitive, and esthetico-hierarchical vision of the Cosmos, yet no less real for all that; one cannot expect more from the scientific knowledge of those times. In our own age, however, it is somewhat surprising that this fact should, as we affirmed, have arrived so belatedly; perhaps as a result of our positivistic and anti-metaphysical education. We think that some of the texts of these two great thinkers deserve to be quoted, thus concluding this first chapter.

ARISTOTLE insists on an *active power*, found in the *medium* which surrounds the isolated *moving body*, so that it remains in movement; this continual movement cannot be understood without this active cause, *external* to the moving object. It is not a question of air or water in immediate contact (as claimed by other Greek thinkers, including PLATO). The Stagirite does not fall into the trap of this "challenge to common sense"[29], as misunderstood by DUHEM; instead it is an *active* property of *all* the medium, not of the particles in immediate contact: something along

[28] J. RIUS–CAMPS, *Formulación Mecánica de la Entropía de un Sistema* registered in Barcelona, 1992. This study aims to give strictly mechanical expression to the entropy of a thermodynamic system from the mechanical concepts of potential energy and kinetic energy of the same.

[29] DUHEM, *Etudes sur Léonard de Vinci,* I. pp. 109 & c. *Le systéme du monde. Histoire des doctrines Cosmologiques de Platon a Copernic.* pp. 321 & c.

the lines of LORENTZ's ether?[30] A *cause* is required and, moreover, in *contact*: *"actio in distans"* is not admissible; the modern "theory of fields" is nothing more than the negation of this direct action at a distance. In this active power of the medium we find the cause of inertia: it is the intuition of the *Third Fundamental Law*.

ARISTOTLE noticed that not all bodily movements are equivalent in perfection, not even in the simplest of them: *local movement*, which only directly affects the accident *Ubi,* (but, in the last analysis, is what all the other actual *proper* movements amount to). In present-day thought we would say that not all kinetic energy is equivalent from the qualitative point of view although quantitatively they might be so, as has already been pointed out and will be expounded later on. Continuing with the ideas of the Philosopher, we read in Physics[31]: "Might someone wonder if all movement is comparable with all other movement or not? If all movement is comparable, and if all bodies of equal velocity move in the same time along an equal quantity, then we could find a line equal to a straight line, either bigger or smaller... However, what can be said about the circle and the straight line? It would be absurd to compare them if the circular movement and that of the straight line were not alike... And yet, if they are comparable, we come back to the same conclusion that we expressed a short time ago: the equality of the straight line and the circle. Nevertheless, these lines are not comparable, then neither are their movements... Does that not mean, then, that velocity does not have the same meaning in these two cases?" He then goes on to consider the movements of alteration which are only comparable when they pertain to the same kind of thing and concludes: "The same thing happens with movement: there is equality of velocity when two movements equal in magnitude and in quality have occurred at the same time. But if during this time part of the magnitude has been altered and the other has been moved, would this alteration be equal to the movement and of the same velocity? This is absurd, because movement varies. Therefore, if things moved in an equal magnitude during an equal time have the same velocity then the straight line and the circle are equal. Why then is the movement of one kind or the line of one kind? In fact, time can never be divided into different kinds. So movement and trajectories have correlatively different types, since movement must have different types if the place where the movement takes place has them... Therefore, things moved across the magnitude for the same length of time will have the same velocity, and I understand by "the same" that it is

[30] *Cf.* P. HOENEN, *Filosofia della natura inorganica.* pp. 128 & c. Ed. La Scuola. Brescia. 1949.
[31] ARISTOTLE, *Fisica*, lib. VII, ch. 4.

indistinct in type and also in relation to movement. Thus it is necessary to study the differentiation of movement... But we call equal velocity that of the alteration of the being whose change is the same in an equal time. What must be compared, then: the receptacle of modification or the modification itself? In this case, since the health is the same, one has the right to admit that there is nothing more or less in it than simple similarity. If, on the other hand, the alteration is different, for instance, when the alterations are a whitening and a healing, none of this can be called identical nor more equal than similar, since there are so many different kinds and because they do not form a united group in themselves, even less so than rectilinear and circular movements". ARISTOTLE qualifies rectilinear and circular movement as being specifically different. Circular movement may have a constant velocity, but this is not the case with rectilinear movement, which must begin to decrease at some moment until it stops and then, in any case, increase once more; he does not believe that an infinite rectilinear movement is possible: "the increase and decrease cannot be continuous, but they must have an intermediate state in which they stop".

ARISTOTLE thus perceives that there exists something, a *quality*, which differentiates movements in themselves; specifically in the two extreme cases of circular and rectilinear movement. The *Second Fundamental Law* formulates this quality, as we stated before while on the subject of *mechanical entropy*.

SAINT THOMAS AQUINAS[32] would remark to the Stagirite: "The circular movement of heavenly bodies can only go in one direction, and therefore there is no violence between them; on the other hand, the lower bodies can go in different directions, such as up and down movements. So the heavenly bodies have a more universal virtue than the lower bodies. That is how the universal virtues are the driving force for the individual ones, as is clear from what has already been said. Therefore, the heavenly bodies move and direct the lower bodies". This is an outline of what we would now call *irreversibility* of a process. Further on in the same chapter, he continues: "because circular movement is also the first kind of local movement: regarding time, for it can only be perfect in that, as is proved in Book VIII of the Physics; as for nature, because it is the simplest and has the greatest unity, since no beginning nor middle nor end can be distinguished in it, but rather everything is the middle. And also with regard to perfection, because it reverts to its beginning. In the third place, as only heavenly movement is always regular and uniform; while in the

[32] T. of AQUINO, *Summa contra gentes*, Lib. 3, ch. 82.

natural movements of both heavy and light bodies the velocity increases at the end, and in the violent ones it decreases. This means, therefore, that all heavenly movement is the cause of all other movement".

SAINT THOMAS AQUINAS perceives, from a different approach, the same thing that the Philosopher saw centuries earlier. We think that the quotations from these two thinkers, and the preceding exposition, can be illuminating and may help to penetrate into the essence of the chapters which follow.

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CHAPTER II

THE DYNAMICS OF IRREVERSIBLE MECHANICAL SYSTEMS

INTRODUCTION

1. The following study corresponds to the largest and most complete of a series of studies begun in 1974 on the *Foundations of Dynamics*[33]. It was published for the first time and with the same title in 1985. Now it has been reprinted, with the opportune corrections and additions, in the light of the most up-to-date theoretical and experimental investigation. The first chapter, and the section which deals with the foundations, contain a summary of the ideas expounded in more detail and

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[33] These studies were commenced during the Seventies; the most significant officially registered ones are:

Algunas consideraciones acerca de las Ecuaciones Cardinales de la Dinámica y el Segundo Principio de la Termodinámica. Pamplona. 1974.

La afirmación del "Principio de MACH" y sus consecuencias Dinámicas. Ed. ETSA, University of Navarre. Pamplona. 1975.

Los Fundamentos Cosmológicos de la Mecánica y las Leyes Fundamentales de la Dinámica, Ed. Anuario filosófico, University of Navarre. Pamplona. 1976.

Sustentación no aerodinámica de determinados Insectos. Barcelona. 1977.

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Dinámica del Punto Material. Barcelona. 1981.

Dinámica de Sistemas Mecánicos Irreversibles. Barcelona. First edition 1985. p. 41. This study –which is now being reprinted in a revised and amplified edition– gathers together the most essential and valid points of the preceding works from the exclusively physical point of view.

El Vuelo del Abejorro. "Investigación y Ciencia", Barcelona. February 1986. This article expounds the experimental tests carried out on hymenoptera: *Bombus terrestris* ("Bumblebee") and on Diptera: *Calliphora vomitoria.* They fly perfectly well in a very thin atmosphere (*13 mb* , equivalent to *98.7%* of normal atmospheric pressure: *1013 mb* , and at a temperature of $15^o\,C$) with only the partial pressure of water vapour, at room temperature, so that the insect does not become deformed. The insect maintains its flight, even when hovering, for a maximum of *2 minutes* ; the test can often be repeated after it has recovered from anoxia.

Formulación Mecánica de la Entropía de un Sistema, Barcelona, 1992. This investigation studies thermodynamic entropy starting out from the concepts of kinetic energy and potential energy in which the internal energy of a closed system is definitively transformed.

at greater length in earlier investigations, in which at first by intuition and later more systematically, a *metaphysical* criticism was made of the "Newtonian Principles" of Classical Dynamics (CD)[34]. These led us to formulate the Fundamental Laws which form the basis of a New Dynamics (ND) of which the former is is a particular and restricted case. Problems of high velocities, which correspond to the Special Theory of Relativity (STR), are not tackled, and neither are those pertaining to Quantum Dynamics.
Starting out from the *Three Fundamental Laws* and the expression of kinetic energy: $U_c = (1/2)mv^2$, of a particle (or a system of material points), which are accepted axiomatically, we come to the formulation of *force* in this ND which turns out to be *isomorphic* with "LORENTZ's force" in electromagnetism. The need for an *inertial framework* for reference, at rest in relation to the centre of mass (CM) of the system which is being studied (energetically closed and unbound to the rest of the Universe except for the inertia), forms part of the essence of the *Third Fundamental Law* of the ND.

2. From the formal point of view it is remarkable and surprising to be able to deduce "MAXWELL's equations" of Electromagnetics as a special and limit case of the ND, instead of postulating them with regard to experimental laws which were discovered earlier (FARADAY, AMPÈRE, etc.). Analogous laws govern the behaviour of other "fields of force" (for instance, gravitational) and other dynamic interactions. The basic incompatibility between Dynamics and Electrodynamics ceases to exist.

Likewise, it is clearly possible to bridge Dynamics and Quantum Dynamics: DE BROGLIE's "waves of matter" fall within the sphere of the ND; "particle" and "wave" are aspects of the same formulation.

Irreversibility, which is the essence of the Second Principle of Thermodynamics, is the statistical consequence of the fact that the trajectories of the material points are irreversible in the ND, apart from singular cases.

Logically, this ND takes us back to the CD in particular cases and in those which, although not exact, it is sufficiently approximate: small

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[34] *Los Fundamentos Cosmológicos de la Mecánica y las Leyes Fundamentales de la Dinámica,* Pamplona, Anuario filosófico, Universitdad de Navarra, 1976, Vol. IX, pp. 325-378. This study was reprinted in 1993, with some obscure and even erroneous expositions rectified, owing to subsequent discoveries, both theoretical and experimental; nevertheless, the conclusions remain essentially the same.

accelerations and speeds, fields which are slowly variable with time, etc.

SYSTEM OF MATERIAL POINTS.

A. FOUNDATIONS.

1. Until now the First Newtonian Principle postulated the existence of physically isolated systems; but although the idea of isolation in relation to external influences is feasible, a separation of this kind is not in actual fact possible. The existence of a property of matter *–inertia–* makes it impossible, since inertia is nothing other than the response of "the rest of the Universe" to the presence of matter in the system in question. Thus inertia is partly an *internal* property and partly *external* to the system; the "forces of inertia" which until now were described as "fictitious" or "pseudo forces", are *real, external* forces acting on the system. In this exposition it is of course assumed that we are using a frame of inertia in the afore-mentioned conditions as reference for the system (in the first approximation in a rectilinear, uniform movement in relation to COPERNICUS' axes), otherwise it would not make sense to speak of accelerations; this clearly reveals the essence of "MACH's Principle". If the frame or basis for reference is not inertial, then it is possible that "fictitious" or "apparent" forces may appear owing to the fact that the coordinated axes of reference are not specific ones. The axes which correspond to a reference for inertia are, then, very specific; they are determined at least from a constant velocity vector, from the dynamic point of view.

Up until now, *attempts to determine an absolute referential have failed* if we look at the results of MICHELSON-MORLEY, TROUTON-NOBLE, etc.; nonetheless, the homogeneity and isotropy which correspond to the "red shift" show that our solar system has, at most, a velocity of *300 km/s* in relation to the frame of inertia determined by the stars and galaxies taken as a whole. This velocity suggests the presence of a *cosmological substratum* –completely at rest, since there is nothing to indicate its movement– in which to place the "fundamental observers" and of which the stars and galaxies are like beacons telling us of its situation. This substratum is metaempiric, that is, it avoids direct experience, but this does not exclude its existence, which is required by considerations which existed before physical experimentation, that is, its necessity is metaphysical. Even if MACH were fundamentally antimetaphysical, his "Principle" is nothing other than the affirmation of the necessary physical presence of a substratum of this kind; he says: "The only accelerations which make sense are measured regarding the frame determined by the distant stars as a whole". However, according to what we said earlier about the "red shift", not only accelerations but even velocities require a privileged reference; in the first case it is enough that the velocity of the reference frame is constant, in the second an absolute reference which excludes all indetermination is required, even if it is only a constant vector.

2. The First Newtonian Principle must be rectified by affirming instead that *inertially isolated systems does not exist,* with the exception of the Cosmos considered as a whole. The success of CD based on NEWTON's "First Principle" is due to the fact that, at first sight, a large number of dynamic systems behave as if they were isolated; but this is actually a very strong restriction which should have been detected and rectified a long time ago. The postulation: "the CM of an isolated system moves with a constant velocity" incurs the contradiction of a metaphysical rather than physical nature, since this "constant velocity" is such with regard to an inertial frame (COPERNICUS' axes at least) and this frame is different, *external,* to the system in question. And when we postulate its "isolation" we cannot define this constant vector, nor even its direction which could be seen from the inertial frame, as we cannot refer to it if the system is "isolated"[35]. The declaration of the First Principle therefore implies a contradiction that we can express as: "an isolated system has the property of not being isolated". On the other hand a contradiction with a metaphysical basis must have physical consequences; this means that a theory of Dynamics, based on this Newtonian theory, must deviate from physical reality; and not only in those cases anticipated by the STR for high velocities, but also in those in which up until now it was considered perfectly valid[36].

3. If we replace the first Newtonian postulation by the statement: *there are no isolated systems,* we come to the essence of what we have called the *Third Fundamental Law* of ND. The *First Fundamental Law* of this ND is simply the conservation of energy in a closed system. What is

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35 P. HOENEN, *Filosofia della Natura Inorganica,* Brescia, Ed. La Scuola, 1949, p.124 &c.

36 For a detailed study of this aspect in relation to the metaphysical foundations of the ND, see our publication: *Los Fundamentos Cosmológicos de la Mecánica y las Leyes Fundamentales de la Dinámica,* Philosophical Yearbook, University of Navarre, Vol. IX, 1976. Reprinted, revised and updated, in 1993.

the *Second Fundamental Law*? It refers to the *irreversibility* of the dynamic processes considered by the ND, apart from exceptional cases; we shall look at it in detail in the following sections of this chapter. The ND must be structured on the basis of these starting points. The Second and Third Principles of the CD will only be partly valid, as they lead us to the laws of conservation of *lineal momentum* and *angular momentum* in an isolated system and, as we shall see, this is not always possible in the ND framework which we are putting forward here. We embarked on this investigation some years ago, especially from 1974 on, when the first officially registered studies were published; since then we have constantly penetrated more deeply in the investigation of the ND. In the work we undertook prior to 1981 we had maintained constant the mass m of a physical particle which was subject to non-consevative potential energy, that is, dependent on position and time (and both variable independents): $U_p = U_p(P, t)$; from then on it was clear that in this general case it had to be: $m = m(t)$. This will be seen in greater detail in the next section.

B. STUDY OF THE EXPRESSION OF FORCE IN NEW DYNAMICS (ND).

1. By way of introduction it must be said that in this ND we can no longer set out from the Newtonian "Fundamental Equation", which gave us the expression of force, as it would only be valid in singular cases, as a result of what we said before. However, in order to construct the ND we must set a starting point which enables us to elaborate the new theory; the CD is a particular case of this. This starting point, in the framework of the *Three Fundamental Laws*, is the assertion that kinetic energy in a system of particles can be expressed thus:

$$\boxed{U_c = (1/2)mv^2}$$

when m is the total mass of the system and v is its *average quadratic speed*. This energy is the sum of the kinetic energy in each one of the system's particles, which satisfy analogous expressions. We are not considering relativistic problems with high speeds here. As we shall see later on, the mass of the system in this ND is not necessarily a constant, but instead it generally depends on time. Normally, and while it is not particularly specified, we will assume that the system has an inertial Cartesian frame of coordinates for reference.

In Classical Dynamics the potential energy of a system is said to be conservative if it depends only on the position of the particles, that is, it is independent of time. This energy cannot generally be written as the sum of potential energy in each particle –as is the case with total kinetic energy–: its expression is *global*, as it depends on the position of all the masses in the system, and it is not possible to assign to each one of them a potential energy which depends exclusively on its position. It is nonetheless possible to give each particle a potential energy which depends on both position and time; this can be done by simply making the coordinates and the velocities of the other bodies in the expression of the total energy dependent on time. In an energetically closed system, for each particle m –if we call $U_{pi}(P_i ,t)$ its potential energy and $U_{ci}(P_i) = (1/2)m_i v_i^2$ its kinetic energy– we can write by virtue of the *First Fundamental Law*

$$\boxed{U_{ci}(P_i) + U_{pi}(P_i,t) = C_i} \qquad (i = 1,2,3,...,n) \qquad (1)$$

in which

$$U_{pi}(P_i, t) = \Sigma_j U_{cj}[P_j(t)] + U_p^{(i)}[P_i, P_1(t), P_2(t), P_{i-1}(t), P_{i+1}(t),...P_n(t)]$$

And the result when these are all put together extends to all the variables *except (i)*. For the system of n particles m_i the result when they are added together the expressions (1), will be

$$\sum_{i=1}^{n} U_{ci}(P_i) + U_{pi}(P_i,t) = U_c + \sum_{i=1}^{n} U_{pi}(P_i,t) = C$$

that is

$$U_c + U_p = C$$

which expresses the conservation of energy in the system, as was to be expected. It should be noted that in the expression: $U_{ci}(P_i) = (1/2)m_i v_i^2$ it is always $v_i = v(P_i)$, since velocity, by its very nature, implies a change of place and for this reason *depends on the position* of the particle, except for trivial cases where this functional relationship cannot be established. It is also always possible to make the position depend on time, but it must be stressed that here time is a simple parameter, by which the positional variables can be expressed, and *not an independent variable* as it is with non-conservative potential energy: $U_{pi}(P_i,\ t)$. In the light of these reflections we can write the (1) as follow:

$$U_{ci}(P_i) + U_{pi}(P_i, t) = C \Rightarrow \quad (1/2)m_i v_i^2 + U_{pi}(P_i, t) = C \qquad (2)$$

which gives the paradox that $U_{pi}(P_i,\ t)$ can be written as a function of the position P_i and independent of time. The only solution, generally, is that mass m_i cannot be considered constant in this ND but must rather be

$$\boxed{m_i = m_i(t)}$$

and thereby it is obviously $(1/2)m_i v_i^2 = U_{ci}(P_i,\ t)$. This conclusion is clearly of major importance.

2. We are already in a position to find an expression for the force that acts on a particle of mass m which follows a trajectory in relation to a frame of inertia; for the sake of simplicity and clarity we shall start with an idealized case in which the mass is constant and, as a result, the potential is conservative. Since it is a closed system, according to the *First Fundamental Law* it is true that

$$(1/2)m_o v^2 + U_p(P) = C$$

in which $v = v(P)$ and $m = m_o = constant$. The particle follows a determined trajectory and, since this is known, its kinetic energy depends on a unique variable which determines its position on the same; for instance: the arc travelled from the starting point, the radius of curvature at each point, etc., that is, we are dealing with *intrinsic variables*. Thus, our study of the *force* which acts on the particle when it travels along this trajectory, is *local*. Let us imagine a differential arc situated on the plane of osculation at point P ; in this way, still speaking in general terms, we can consider the trajectory as being locally plane and as a reference we shall use FRENET's trihedron, whose unitary vectors or *versors* are: $\boldsymbol{s}$, $\boldsymbol{n}$, $\boldsymbol{b}$, according to the *tangent*, *normal* and *binormal,* respectively. We choose as positive senses: that of the velocity of the particle for $\boldsymbol{s}$, that which goes towards the convexity of the trajectory for $\boldsymbol{n}$, and for $\boldsymbol{b}$ the dextroturn so that

$$\boldsymbol{b} = \boldsymbol{s} \times \boldsymbol{n} \tag{3}$$

In these conditions we define force according to a variable x on which *all the kinetic energy* U_c of the particle depends

$$\boxed{\boldsymbol{F}_x = (dU_c / dx)\boldsymbol{x}} \tag{4}$$

with $\boldsymbol{x}$ as the corresponding *versor*.

If we apply this definition to the intrinsic variables: trajectory arc s and curvature radius ρ, we shall have respectively

$$\begin{aligned} \boldsymbol{f_s} &= (dU_c/ds)\boldsymbol{s} = (m_o v dv/ds)\boldsymbol{s} = (m_o dv/dt)\boldsymbol{s} \\ \boldsymbol{f_\rho} &= (dU_c/d\rho)\boldsymbol{n} = (m_o v dv/d\rho)\boldsymbol{n} \end{aligned} \tag{5}$$

since the variation in the radius of curvature is in accordance with $\boldsymbol{n}$. These two forces depend on how the kinetic energy varies, and in this sense no more variables exist, as we can only consider two intrinsic variables in a plane trajectory. However, we must also take into account the *centripetal force* of the CD, which is *not included* in $\boldsymbol{f_\rho}$ as it does not depend on the variation of kinetic energy but on its value

$$m_o \boldsymbol{a_n} = -m_o(v^2/\rho)\boldsymbol{n} = -(2U_c/\rho)\boldsymbol{n}$$

The *total force* acting on m will be the resultant of these three:

$$\boldsymbol{f_o} = m_o\boldsymbol{a} - \boldsymbol{f_\rho} = m_o\boldsymbol{a} - (m_o v dv/d\rho)\boldsymbol{n} \tag{6}$$

In which the sign, in accordance with $\boldsymbol{n}$, will be *(–)* if we have chosen as positive the sense towards the convexity (as in this case) and it will be *(+)* if this sense is towards the concavity. Another expression for the force $\boldsymbol{f}_\rho$ (5) can be given by writing

$$\boldsymbol{f}_\rho = (m_o v dv/d\rho)\boldsymbol{n} = (m_o dv/d\rho)\boldsymbol{b} \times v\boldsymbol{s} =$$
$$-\boldsymbol{v} \times (m_o dv/d\rho)\boldsymbol{b}$$

since, because of (3), it is $\boldsymbol{n} = \boldsymbol{b} \times \boldsymbol{s}$. As $dv/d\rho$ has the dimensions of an angular speed, we can define it as

$$\omega^* = \omega^*\boldsymbol{b} = (dv/d\rho)\boldsymbol{b} \tag{7}$$

so that

$$\boldsymbol{f}_\rho = -m_o\boldsymbol{v} \times \omega^*$$

and from (6) we get

$$\boxed{\begin{aligned}\boldsymbol{f_o} &= m_o\boldsymbol{a} + m_o\boldsymbol{v} \times \omega^* = \\ &\quad m_o(\boldsymbol{a} + \boldsymbol{v} \times \omega^*)\end{aligned}}$$

which is isomorphic with "LORENTZ's force" of electromagnetism. This analogy is made clearer if we put

$$\boldsymbol{E_o} = \boldsymbol{a} \qquad\qquad \boldsymbol{B_o} = \omega^*$$

and we are left with

$$\boxed{\boldsymbol{f_o} = m_o(\boldsymbol{E_o} \pm \boldsymbol{v} \times \boldsymbol{B_o})} \tag{8}$$

The result 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 and negative in the opposite sense. We know that while the moving body is following the trajectory, the centre of curvature at the corresponding point moves in the *evolute* and if we reverse the sense the particle is moving in, it also reverses in the e*volute;* we can therefore take this speed of the centre of curvature as positive if that of the moving body is so too, and negative if it is the other way round. This result is of major importance, since in (7) $\omega^* = dv/d\rho_{.}$ *change sign,* because when the sense in the trajectory is inverted dv *changes sign,* but the sign of $d\rho$ in the *evolute*. *does not changes* it. The consequence of this is that if a particle follows a certain trajectory (on account of the presence of a field of forces) according to CD the *trajectory is unchanged* even though the movement is in the opposite sense. This will not happen with our ND since the term $m_o\boldsymbol{v}\times\boldsymbol{\omega}^*$ *changes its sense,* because $\boldsymbol{s}$ and $\boldsymbol{b}$ are both reversed, but the *sign* of $\omega^* = dv/d\rho_{.}$ *is changed.* Consequently, the ***reversibility of the trajectory does not hold up***. The sign (±) in (8) is due to this ***irreversibility***.

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

3. We shall now study the case in which $m = m(t)$, in other words, in which (4) is verified

$$U_c(P, t) + U_p(P, t) = (1/2)mv^2 + U_p(P, t) = C \qquad (9)$$

We have kept the same definition as in (4) for the force depending on $U_c(P, t)$ which acts on m . We shall simply bear in mind that the kinetic energy will depend on position and time, as shown in (9). We shall now determine the forces acting on m following the preceding process. We shall have:

$$\boldsymbol{f}_s = (dU_c/ds)\boldsymbol{s} = (mvdv/ds)\boldsymbol{s} + (1/2)(dm/ds)v^2\boldsymbol{s} = (mdv/dt)\boldsymbol{s} + (1/2)(dm/dt)v\boldsymbol{s}$$

$$\boldsymbol{f}_\rho = (dU_c/d\rho)\boldsymbol{n} = (mvdv/d\rho)\boldsymbol{n} + (1/2)(dm/d\rho)v^2\boldsymbol{n}$$

and analogously the *total force* on m will now be

$$\boldsymbol{f} = m\boldsymbol{a} + (1/2)(dm/dt)v\boldsymbol{s} - \boldsymbol{f}_\rho = \tag{10}$$
$$m\boldsymbol{a} + (1/2)(dm/dt)v\boldsymbol{s} - (mvdv/d\rho)\boldsymbol{n} - (1/2)(dm/d\rho)v^2\boldsymbol{n}$$

and in the light of (8) we can write

$$\begin{aligned}
\boldsymbol{f} &= m(\boldsymbol{a} + \boldsymbol{v} \times \omega^*) + (1/2)(dm/dt)v\boldsymbol{s} - (1/2)(dm/d\rho)v^2\boldsymbol{n} = \\
&\boldsymbol{f_o} + (1/2)(dm/dt)v\boldsymbol{s} - (1/2)(dm/d\rho)v^2\boldsymbol{n} = \\
&\boldsymbol{f_o} + (1/2)(dm/dt)v\boldsymbol{s} + (1/2)(dm/d\rho)v^2\boldsymbol{s} \times \boldsymbol{b} = \\
&\boldsymbol{f_o} + (1/2)(dm/dt)v\boldsymbol{s} + \boldsymbol{v} \times (1/2)(dm/d\rho)v\boldsymbol{b}
\end{aligned}$$

Analogous to the preceding case in which $m = m_o = constant$, we can put:

$$\boldsymbol{E} = (1/m)[\boldsymbol{f_o} + (1/2)(dm/dt)v\boldsymbol{s}]$$
$$\boldsymbol{B} = (1/m)(1/2)(dm/d\rho)v\boldsymbol{b}$$

with the result

$$\boxed{\boldsymbol{f} = m(\boldsymbol{E} \pm \boldsymbol{v} \times \boldsymbol{B})} \tag{11}$$

Totally parallel to (8). (*dm changes sign* when de movement is *inverted).* Starting out from this, and with some complementary hypotheses, equations are deduced for this ND which are isomorphic with those of MAXWELL that govern the electromagnetism, and will be expounded in the next chapter. In this ND the forces (11) are no longer *invariant* with regard to "GALILEO's transformations", parallel to what happens with electromagnetic forces.

In the next section another, completely different method will be expounded for studying the *irreversibility* of mechanical systems in general which, as we have seen, is in the essence of this ND and which we have called the *Second Fundamental Law*. It is a question of establishing a function of state for the mechanical system, which we shall call *mechanical entropy* of the same, which enables us to study the possible situations of *steady* equilibrium which can be obtained.

C. MECHANICAL ENTROPY: *SECOND FUNDAMENTAL LAW.*

1. We shall be looking at *closed* mechanical systems, that is, systems which satisfy the *First Fundamental Law*; we shall define in them a *function of state,* a *mechanical entropy* of the system, which we shall call S , parallel to the entropy which is studied in Thermodynamics. It expresses a *qualitative* characteristic of the system, different from its energetic situation which is governed, from the *quantitative* point of view, by the *First Fundamental Law:* conservation of energy. Mechanical entropy is the quantitative formulation of the energetic qualities of a closed system. With the existence of this function S , clearly expressed and defined, we have a useful instrument which no doubt could be called the *Second Fundamental Law* of Mechanics. This Law, together with the *First,* defines the *evolution* of mechanical processes in systems that are *"isolated"* from the energetic point of view and which we shall call *closed.* Nonetheless, a system which is closed and unbound to the rest of the Universe cannot properly be called *"isolated"* since, as we have already seen, there is a quality, the omnipresent *inertia,* which binds together all the systems in the Cosmos: we can thus confirm: *"there are no inertially isolated systems".* This proposition coincides basically with "MACH's Principle" which we cited earlier (which was already known though less clearly by NEWTON), and can be formulated as: "the only accelerations which make sense are those which refer to movement in relation to the distant stars"; from this arises the necessity of using "inertial frames" in order to construct the theory of Mechanics. As we explained earlier, an assertion of this kind is in the essence of the *Third Fundamental Law.*

The ND is built on these *Three Fundamental Laws* and on the definition of force given in the previous chapter. The First and Second Newtonian "Principles" are generally invalidated and are only true in certain particular cases. What will happen to the "Third Principle"? Will it still be universally valid? Given the new expression of force in this ND, in which the mass of each particle in a system is, generally speaking, a function of time, the *angular momentum* of the same will obviously not be conserved even if it is *isolated*.[37] However, the other aspect of the "Third Principle" which requires that the *lineal momentum* be conserved in an isolated system, is also satisfied in this ND : in this case the resultant of all the forces dealt with in this ND is null; the CM (centre of masses in a

[37] *isolated system* = energetically *closed* plus *unbound* (without any kind of link).

system) will move in a rectilinear, uniform motion. We say this on the basis of experiments carried out in recent years, without further justification: there exists what we have called *"coupling"* of the forces which act on the masses in the system, which causes the nullity of the resultant. It is nevertheless possible to *"uncouple"* these forces if, as a result of their reciprocal movements, there occurs amongst the masses which make up the system a *dissipation* of energy towards the rest of the Universe, and the only way possible since it is *unbound*, is for this dissipation to occur by means of *radiation*; in this case the system ceases to be *closed* and becomes *open*. Thus in an unbound system the linear momentum may be not conserved, against the requirements of CD in parallel circumstances. We have confirmed this point experimentally and will cite some examples in the last chapter.

2. Since S is a *function of state* of the system, it must be independent of the path taken in the system's evolution from one state of equilibrium to another. In order to reach a formulation for it, we shall start out from the customary requirements, adapted to this case, and in axiomatic form:

- it must be *defined positive.*
- it must be *additive* or *extensive*
- it must be *continuous* and *able to be differentiated*.

The kinetic energy U_c of the closed system we are considering, is additive and expressed: $U_c = (1/2)mv^2$, with m as the total mass and v the average quadratic speed. The simplest function for S to satisfy the preceding requirements is

$$\boxed{S = \sum m_i v_i \geq 0}$$

when v_i is the speed of the particle m_i taken at its absolute value. If we introduce the *average speed* v^* of the system we can then write

$$S = mv^* \geq 0 \tag{12}$$

and as a result of CAUCHY-SCHWARZ's inequality it is

$$S \leq S_{max} = mv$$

In the possible states of steady equilibrium in the system, it must be constant the cinetic energy, that is

$$\boxed{dU_c = 0} \qquad (13)$$

Thus U_c, according (13), must be *constant* (or: *max., min., horitz. inflex.*). but this condition (13) is not generally sufficient. As well there may be systems whose kinetic energy is constant but nonetheless are not in steady equilibrium, they are oscillating; for example, four masses bound together by four rigid bars, in the form of a rhombus, and lain out symmetrically on the same plane; the opposite sides are equal[38] . The rhombus is articulated, so that the masses can oscillate, without colliding, and rotate around an axis which is perpendicular to the plane and which passes through the centre of mass and symmetry. It is clear that, with an initial impetus, they will keep their kinetic energy constant, but it will not be so for each one of the masses. CD solves the problem of their movement by conserving the angular momentum in relation to the axis of rotation, but this requirement does not exist in the ND. What are the possible states of steady equilibrium, if they exist? It is clear that condition (13) is only *necessary* but *insufficient* for situations of steady equilibrium. Since the entropy, defined by (12), will be variable during the evolution of the system (even if the kinetic energy remains constant), we shall insist on a second condition for steady equilibrium:

$$\boxed{dS = 0} \qquad (14)$$

We must remember that now in this ND it will generally be $m = m(t)$. Thus, the two requirements for the equilibrium to be steady are (13) and

[38] This mechanism, which is only schematic here, can be constructed in such a way that the four masses can slide along their respective guides without colliding. The real mechanism is somewhat more complicated but it is perfectly feasible. As usual, all the elements of the system apart from the four masses: $2m$, $2M$, are considered to be valueless mass.

(14), which when expanded give

$$mvdv + (1/2)dmv^2 = 0$$
$$mdv^* + dmv^* = 0$$

and by simplifying the first

$$mdv + (1/2)dmv = 0$$
$$mdv^* + dmv^* = 0$$

homogeneous equations –considering the independent variables *m, dm*– which in order to be compatible require

$$\begin{vmatrix} dv & \frac{1}{2}v \\ dv^* & v^* \end{vmatrix} = 0$$

in other words:

$$v^*dv = (1/2)vdv^*$$

which when integrated gives us

$$ln\ v^2 = ln\ v^* + ln\ A^2 \qquad \text{(when } A \text{ is a } \textit{constant}\text{)}$$

that is

$$v^2 = A^2v^*$$

In the general case which we are dealing with here, this last condition requires them to be

$$v = constant$$
$$v^* = constant$$

and being now m necessarily constant, also will be $U_c = constant$; we have steady equilibrium. In short, conditions (13) and (14) are *necessary* and *sufficient* for steady equilibrium in the general case with which we are dealing. If only the first is satisfied, (U_c = *constant* , *max.* , *min.* or *horizontal inflexion*) the equilibrium will be *unsteady*. If there are identical states of unsteady equilibrium the system will *oscillate*; but it may also happen that it *evolves irreversibly* towards steady equilibrium passing through a finite, or infinite, number of unsteady situations, all different but tending to steadiness in a finite, or infinite time; in the latter case the system's evolution will be *asymptotic*[39] .

In this ND we know, as we have expounded in another study, that when the different trajectories of the physical points m_i which make up the closed system are not circumferences (as it is impossible for them to be rectilinear and for their movement to have a constant velocity except in the case of a single particle) then it is generally true that

$$m_i = m_i(t) \qquad \text{and} \qquad m = \sum m_i(t) = m(t)$$

and there is no steady equilibrium.

However, there may be states of steady equilibrium, with non-circular trajectories for the $m_i\,(t)$, in which m = *constant* and likewise v = *constant*; for example: a symmetric spinning top with mass m_1 , with a point of the rotational axis fixed on another mass $m_2 >> m_1$, and which has a *steady precession* because of the reciprocal gravitational attraction which we assume is constant. We can observe that in this case the system remains identical to itself.

In the example mentioned earlier of the symmetrical system comprised of four equal masses, two by two, in the form of a rhombus; this ND anticipates two possible forms of evolution: it will either be a system with identical oscillations and equal periods, or it will evolve in such a way that the trajectories of the four masses come closer, asymptotically, to the circular form (as an singular case: two immobile masses at the axis of rotation and the other two, those with greater mass, on the circular orbit). Thus the *irreversibility* of the process is clearly shown.

[39] The *particular* case can be cited in which, when Uc = *constant* , S nonetheless is not, but at certain points, and during a dt , it is proved that $dS = 0$ (*max., min.* or *horizontal inflexion*): we shall have *unsteady* equilibrium at these particular points.

In the above mentioned example of the symmetric spinning top, if the precession is *not steady*, in other words, if there is *nutation*, the ND anticipates the possibility of this practically disappearing after a certain time; in fact, this is what happens in reality. CD cannot account for this phenomenon unless it resorts to loss of rotational energy owing to friction at the point of support; in our opinion this explanation is not very convincing, since for the same reason that it disappeared it could also reappear, if the friction were to continue.

3. It is well known that in the framework of the Three "Newtonian principles" the problem of movement of two interacting bodies is solved, and yet no general solution has been found for the "simple problem of three bodies". Only approximate solutions have been established, by the *"perturbations"* method, when one of the particles has a superior mass to the other two (for example, the Sun in the solar system). In 1912, SUNDMANN, having overcome serious difficulties, managed to solve this problem by means of this method; but there is no simultaneous solution for the whole system and it is impossible for the general case of three particles with identical masses[40] .

Circular trajectories are the limit to which the closed system tends when it evolves irreversibly towards steady equilibrium; whether they are of each one of the m_i , or of the centres of mass of various groups of them (as in the above-mentioned case of the spinning top). As we said earlier, it may be that steady equilibrium is unobtainable. Obviously we are studying the system with reference to a basis of inertia at rest in relation to the centre of mass of the same.

This incapacity of CD to solve the problem of systems formed of three or more interacting bodies is surprising. And yet, Thermodynamics solves the problem of an infinite number of analogous particles (atoms and molecules). The irreversibility which is generally characteristic of systems, according to ND, is generally closely related to the "second Principle" of Thermodynamics, which many scientists consider to be "extremely troublesome and strange"[41]. In our ND the problem is clear and simple: thermodynamic irreversibility is the statistical consequence of the irreversibility of each and every one of the trajectories followed by the particles which make up the system.

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[40] B. FINZI *Meccanica Razionale*, vol. II. p. 89.
[41] J. MERLEAU–PONTY, *Cosmología del siglo XX,* Madrid, Ed. Gredos. p. 84.

Finally, since generally $m = m(t)$, the kinetic energy of a physical particle depends on position and time; it is thus easy to imagine a "wave particle" and to bridge the gap between ND and many of the problems studied by Quantum Mechanics.

The isomorphism between ND and electromagnetism that we have proposed likewise solves the basic incompatibilities of CD with electrodynamics.

D. KINEMATIC MEANING OF ANGULAR VELOCITY ω^*

1. At first, we begin with the study of the trajectory of a material point from the kinematic 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 refferential frame is used. The acceleration components in this circle are

$$\mathbf{a}_s = (dv/dt)\mathbf{s} \qquad \text{and} \qquad \mathbf{a}_\rho = -(v^2/\rho)\mathbf{n} \qquad (15)$$

And where ***s*** and ***n*** are the *versors,* in this frame: ***s*** , ***n*** , ***b*** , whose positive sense in the *tangent, normal* and *binormal,* is determined by the velocity sense, by the sense towards convexity and by the vectorial product: $\mathbf{b} = \mathbf{s} \times \mathbf{n}$, respectively. The angular velocity is

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

A definite trajectory has a well defined *evolute,* and in the calculation of the normal component in the expressions (15) 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

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

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

In order to explain the kinematic meaning of this angular velocity ω^*, we shall study an element ***ds*** of trajectory which corresponds to the ***dρ*** 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* **s** , **n** , **b** , formed by the *tangent, normal* and the *binormal.* The *arc* ***ds*** of the trajectory is determined by the points A , B , and the ***dρ*** , 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

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

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 expression (15) in the form

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

in which the increases dv , $d\rho$, are not considered, as they do not affect it. It is the consequence of replacing the ***ds*** of *trajectory* by 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 must also be said of its equivalent centre of curvature: A is located in the *evolute,* as it is the starting point, but A' lay outside of the *real evolute* (see Fig.1 and 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 *opposite sense* (when $dv/dt > 0$) and in the *same 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

$$B'B'' = -ds d\theta^* \qquad \text{(when } dv/dt > 0\text{)}$$

and

$$B'B'' = ds d\theta^* \qquad \text{(when } dv/dt < 0\text{)}$$

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

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

superimposed to the *normal acceleration* a_ρ (15). So the *total normal acceleration* is

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

$$a_\rho + a_\rho^* = -(v\omega - v\omega^*) = -v(\omega - \omega^*) \qquad (16)$$

in the two possible cases.

Obviusly the tangential acceleration $a_s = dv/dt$ remains unchanged. In vectorial form we get

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

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

respectively.

2. Now, from the dynamical point of view, if we want to calculate the *total centripetal force* correctly, the *total normal acceleration* (16) must be taken into account. So the expression of this force will be

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

and

$$\boldsymbol{f_n} = -mv(\omega - \omega^*)\boldsymbol{n} = m\boldsymbol{v}\times(\boldsymbol{\omega} - \boldsymbol{\omega}^*) \qquad (17)$$

in both possible cases.

In summary, taken in account the expression (2), the *total force* acting on the material point is

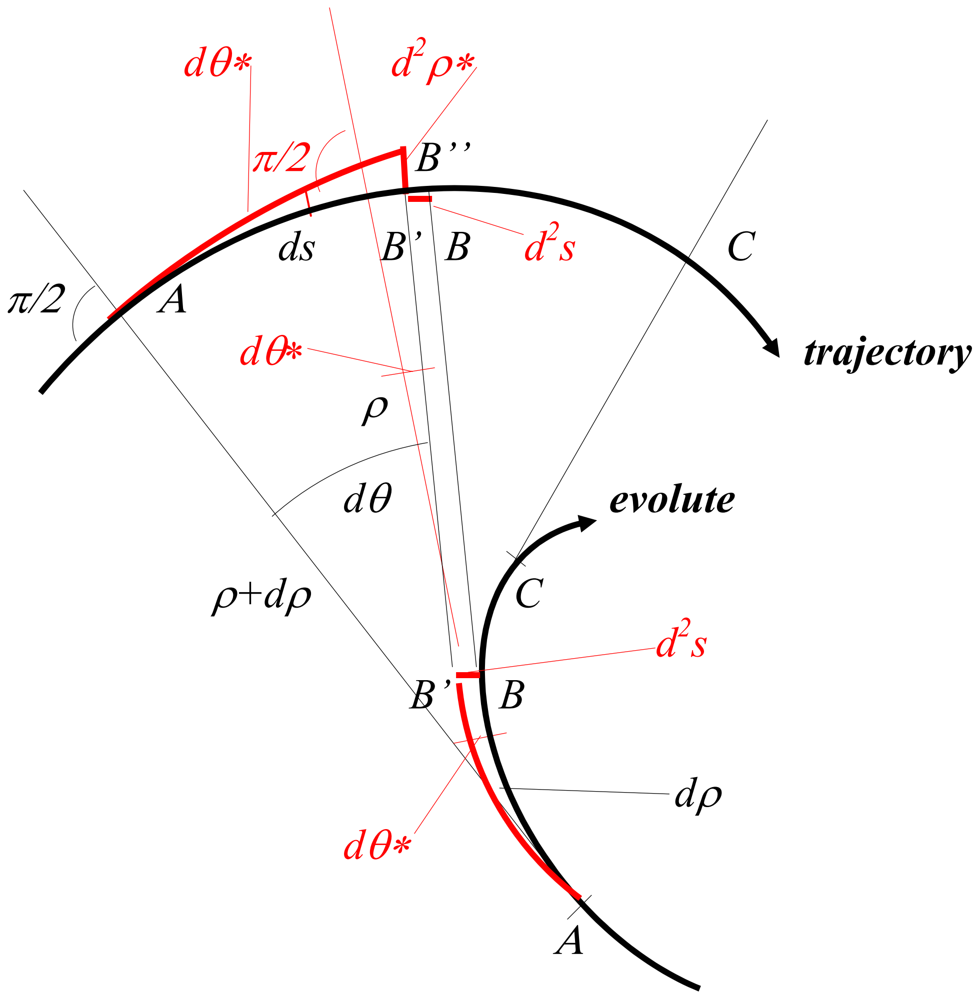
$$\boxed{\boldsymbol{f} = m(\boldsymbol{a} \pm \boldsymbol{v}\times\boldsymbol{\omega}^*} \qquad (18)$$

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

We insist that the *centripetal acceleration,* as a component of the *total velocity acceleration,* is perfectly correct: the acceleration vector expresses the variation with time of the velocity vector with regard to the frame of inertia, and there is no mistake there. As we have just seen, the insufficiency stems from the fact that the forces caused exclusively by velocity acceleration *are not the only ones* which act on the mass m , as the Newtonian "second Principle" postulates. Equation (17) expresses the dynamic formulation of the presence of the angular velocity $\boldsymbol{\omega}^*$, which entails the action of another force, which is also normal to the trajectory, and additional to the centripetal one of Classical Dynamics (CD). As it seen in the analytical study of this New Dynamics (ND) (and also in view of Fig. 1 and Fig. 2), it is clear that this angular velocity does change its sense according to whether the tangential acceleration dv/dt is *positive* or *negative*. When the *velocity sense* is *reversed* in a point of the trajectory (see Fig, 1' and Fig. 2'), the particle does not follows the initial path. Consequently, the trajectory of a particle m is ***ireversible*** in the frame of ND. .

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').

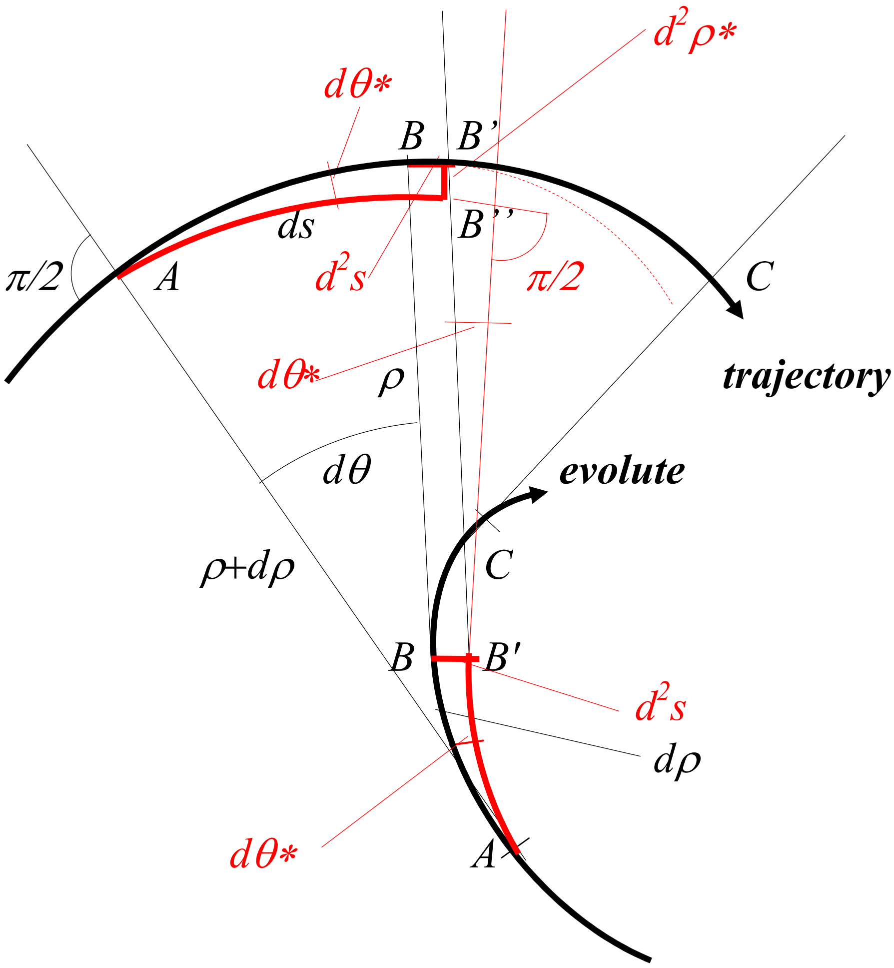
The result (4) is surprising: even more so when we remember that "LORENTZ's force" is exclusively experimental. Moreover, in FRENET's trihedron the value v of speed is always *positive* in the sense in which the particle is moving. We know that while the moving body follows the trajectory, the centre of curvature, at the corresponding point, moves in the *evolute* and if we reverse the sense the particle is moving in, it also reverses in the e*volute;* we can therefore take this speed of the centre of curvature as positive if that of the moving body is so too, and negative if it is the other way round. This result is of major importance, since $dv/d\rho$. *changes sign,* because when the sense in the trajectory is inverted dv changes sign*,* but the sign of $d\rho$ in the *evolute*. does not vary. As a consequence, when a particle follows a certain trajectory (on account of the presence of a field of forces) and the sense being travelled is reversed, according to CD the trajectory is *unchanged* even though the movement is in the opposite sense. In the ND the term $m_o\boldsymbol{v} \times \boldsymbol{\omega}^*$ *changes its sense,* because $\boldsymbol{v}$ and $\boldsymbol{\omega}^* = \omega\boldsymbol{b}$ are both *reversed,* but the *sign* $\omega^* = dv/d\rho$ is *inverted.* Consequently, being $m = constant$ in the present hypothesis, the ***reversibility*** of the trajectory ***does not hold up.*** The ***CHAOS*** presence in physical phenomena has its foundation in this ***irreversibility.***



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

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

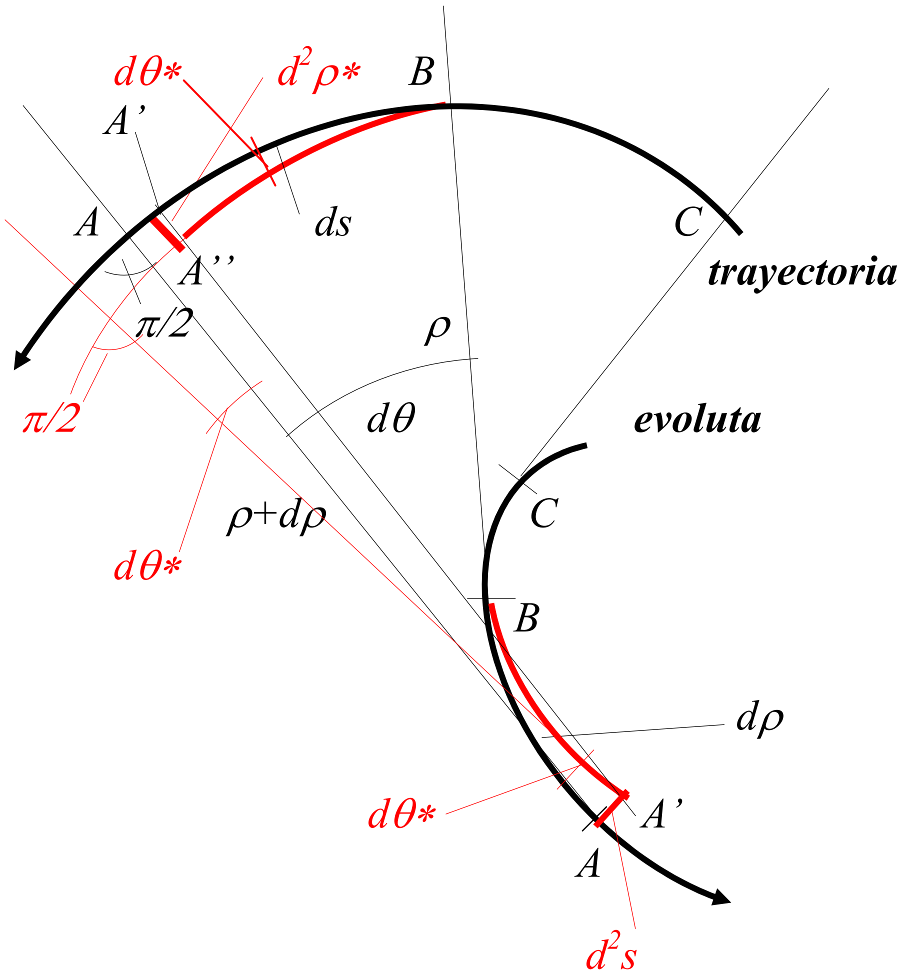
FIG. 1



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

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

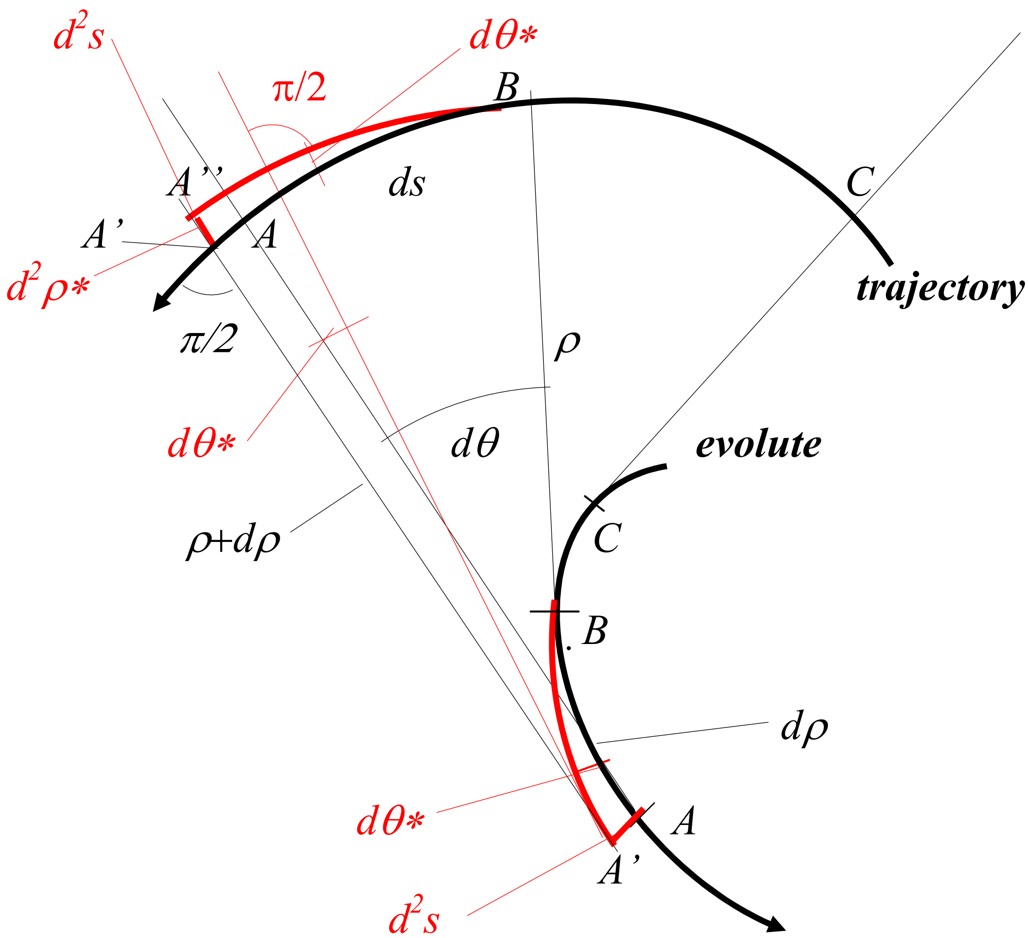
FIG. 2



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'

CHAPTER III

WAVE EQUATIONS AND "MAXWELL's EQUATIONS"

A. DETERMINATION OF THE WAVE EQUATION WHEN *$U = U(P, t)$*

1. Starting with the general expression of force in ND (10), we can arrive at conclusions which are parallel to those which govern electromagnetism. But if we are to proceed with our investigation some additional hypotheses must be made from the expression (9) whose derivative is

$$dU_c(P, t) + dU_p(P, t) = d[(1/2)mv^2] + dU_p(P, t) = 0$$

which we can put in the form

$$[\nabla U_c \cdot \boldsymbol{v} + \partial U_c/\partial t] + [\nabla U_p \cdot \boldsymbol{v} + \partial U_p/\partial t] = 0 \qquad (18)$$

And now we make the simplified hypothesis which is proved:

$$\boxed{\begin{aligned} \nabla U_c \cdot \boldsymbol{v} &= -\nabla U_p \cdot \boldsymbol{v} \\ \partial U_c/\partial t &= -\partial U_p/\partial t \end{aligned}} \qquad (19)$$

It is clear that, generally speaking, the correspondence between these two pairs of values which satisfy (18) could be more complicated, but the last one suits our purpose perfectly[42] . Generally speaking, it will also be

$$\nabla U_c \neq -\nabla U_p$$

and if we expand the gradient operator applied to the kinetic energy, we immediately get

$$\nabla U_c = m\boldsymbol{a}$$

On the other hand we can observe that force $\boldsymbol{f_o}$ is the component of $\boldsymbol{f}$ which does not depend on time and the same thing happens with the force defined by $-\nabla U_p$ at the moment when we calculate it, and thus we can write the equality

$$\nabla U_p = -\boldsymbol{f_o} = -m(\boldsymbol{a} + \boldsymbol{v} \times \omega^*) =$$

$$-m\dot{v}\boldsymbol{s} + m(v^2/\rho)\boldsymbol{n} + (mv\dot{v}/\dot{\rho})\boldsymbol{n} =$$

$$-m(\boldsymbol{E_o} + \boldsymbol{v} \times \boldsymbol{B_o}) \qquad (20)$$

On the other hand we had found in (10) the expressions for the vectors $\boldsymbol{E}$ and $\boldsymbol{B}$ given by

$$\boldsymbol{E} = (1/m)[\boldsymbol{f_o} + (1/2)(dm/dt)v\boldsymbol{s}]$$

$$\boldsymbol{B} = (1/m)(1/2)(dm/d\rho)v\boldsymbol{b}$$

when $\partial U_c/\partial t = (1/2)(dm/dt)v^2$ and with the result (20) the last two can be written as

42 In "slowly variable" phenomena it will be $|\partial U_c/\partial t| << |-\partial U_p/\partial t|$ and $|\nabla U_c \cdot \boldsymbol{v}| >> |-\nabla U_p \cdot \boldsymbol{v}|$. The faster the variation, the more exact those of (19) will be. This recalls the parallelism with electromagnetic phenomena.

$$\boldsymbol{E} = (1/m)[-\nabla U_p + (1/v)(\partial U_c/\partial t)\boldsymbol{s}]$$

$$\boldsymbol{B} = (1/m)(1/v)(\partial U_c/\partial t)(dt/d\rho)\boldsymbol{b}$$

and on account of hypothesis (19) it is equivalent to:

$$\boldsymbol{E} = (1/m)[-\nabla U_p - (1/v)(\partial U_p/\partial t)\boldsymbol{s}]$$

$$\boldsymbol{B} = -(1/m)(1/v)(\partial U_p/\partial t)(dt/d\rho)\boldsymbol{b}$$

These last two equations made us think that a "potential vector" could be defined in the following way:

$$\boxed{\boldsymbol{A} = (U_p(P\,,t)/v)\boldsymbol{s} + \boldsymbol{\Phi}(P)} \qquad (21)$$

when □(P) is an arbitrary vector, depending only on position, and thus we get

$$\boxed{\begin{aligned} \boldsymbol{E} &= (1/m)(-\nabla U_p - \partial \boldsymbol{A}/\partial t) \\ \boldsymbol{B} &= -(1/m)(\partial A/\partial t)(dt/d\rho)\boldsymbol{b} \end{aligned}} \qquad (22)$$

These equations are analogous to those which are deduced in electromagnetism starting from "LORENTZ's force". We can calculate the rotational of this potential vector in FRENET's trihedron:

$$\nabla \times \boldsymbol{A} = \begin{vmatrix} \boldsymbol{s} & \boldsymbol{b} & \boldsymbol{n} \\ \partial/\partial s & \partial/\partial b & \partial/\partial n \\ U_p/v & 0 & 0 \end{vmatrix} = \frac{\partial}{\partial n}\left(\frac{U_p}{v}\right)\boldsymbol{b} - \frac{\partial}{\partial b}\left(\frac{U_p}{v}\right)\boldsymbol{n} =$$

(23)

$$\frac{\partial}{\partial n}\left(\frac{U_p}{v}\right)\boldsymbol{b} = \frac{1}{v}\left(\frac{\partial U_p}{\partial n}\right)\boldsymbol{b}$$

since, as the movement is locally plane, U_p *cannot vary according to the binormal* and the velocity v will only vary according to the tangent. Moreover, $\Phi(P) = 0$ has been chosen.

But with the results (20) the component according to the normal of the gradient of U_p is

$$\partial U_p/\partial n = mv(v/\rho + dv/d\rho)$$

so that in the light of (37) we have definitively:

$$\nabla\times\boldsymbol{A} = m(v/\rho + dv/d\rho)\boldsymbol{b} = m(\omega^* + \omega) \qquad (24)$$

2. If we want it to be proved exactly

$$\boldsymbol{B} = (1/m)\,\nabla\times\boldsymbol{A}$$

we shall have to identify with members of this equality starting from the expressions (21), (22) and (24) and we shall have

$$-\frac{1}{m}\frac{\partial A}{\partial t}\frac{dt}{d\rho} = -\frac{1}{m}\frac{1}{v}\frac{\partial U_p}{\partial t}\frac{dt}{d\rho} = v/\rho + dv/d\rho$$

but in accordance with the hypothesis (31), $\partial U_p/\partial t = -(1/2)(dm/dt)v^2$ so that

$$-\frac{1}{m}\frac{1}{v}\left(-\tfrac{1}{2}\frac{dm}{dt}v^2\frac{dt}{d\rho}\right) = v/\rho \;+\; dv/d\rho$$

by simplifying and multiplying both members by $d\rho/vdt$ there remains

$$\tfrac{1}{2}\frac{1}{m}\frac{dm}{dt} \;=\; (d\rho/dt)/\rho \;+\; (dv/dt)/v \qquad \Rightarrow$$

$$(1/m)(dm/dt) \;=\; 2(d\rho/dt)/\rho \;+\; 2(dv/dt)/v \;=$$

$$2\frac{\dot{\rho}}{\rho}+2\frac{\dot{v}}{v}$$

which can immediately be integrated into

$$ln\, m \;=\; ln\, \rho^2 \;+\; ln\, v^2 \;+\; ln\, a^2$$

that is

$$m \;=\; a^2\, v^2\, \rho^2 \;\geq\; 0$$

which means that the mass cannot be negative.

The general equations in (22), in the particular case mentioned above, take the form

$$\boxed{\begin{aligned} \boldsymbol{E} &= (1/m)(-\nabla U_p - \partial \boldsymbol{A}/\partial t) \\ \boldsymbol{B} &= (1/m)\, \nabla\times\boldsymbol{A} \end{aligned}} \qquad (25)$$

Later on we shall consider the *limit case* in which

$$m \approx m_o \qquad\qquad v \approx v_o$$

and in which it is nonetheless

$$dm/dt \neq 0 \qquad\qquad dv/dt \neq 0$$

In this way, as a special conclusion of this ND, a group of equations are deduced which are *isomorphic* with MAXWELL's electromagnetic equations. Also it is clearly shown the *corpuscular-wave* nature of a particle of mass $m = m(t)$ when submitted to a not conservative potential $U_p = U_p(P, t)$.

3. In the expression of $\boldsymbol{E}$ found in (22) the divergence can be calculated, on the assumption that $U_p(P, t)$ is physically present around the particle whose mass depends on time: $m(t)$. In this case we can write

$$\nabla\cdot\boldsymbol{E} = (1/m)(-\nabla^2 U_p - \nabla\cdot(\partial\boldsymbol{A}/\partial t)) \qquad (26)$$

but

$$\partial\boldsymbol{A}/\partial t = (1/v)(\partial U_p/\partial t)\boldsymbol{s}$$

and when $\partial U_p/\partial t = -\partial U_c/\partial t = -(1/2)(dm/dt)v^2$ we get

$$\begin{aligned}\nabla\cdot(\partial\boldsymbol{A}/\partial t) &= (\partial/\partial s)[(1/v)(\partial U_p/\partial t)] = \\ &(\partial/\partial s)[-(1/2)(dm/dt)v] = \\ &-(1/2)(dm/dt)(dv/dt)/v \qquad (27)\end{aligned}$$

since it is only $v = v(s)$.

On the other hand, from the expression found for the gradient of the potential energy in (20), we immediately get

$$\partial U_p/\partial s \;=\; -m(dv/dt) \tag{28}$$

that together with the preceding one for $\partial U_p/\partial t$ (19) and (27) gives us

$$\nabla\cdot(\partial \boldsymbol{A}/\partial t) \;=\; -\tfrac{1}{2}\frac{dm}{dt}\frac{dv}{dt}\frac{1}{v} \;=\; -\tfrac{1}{2}\frac{dm}{dt}v^2 m\frac{dv}{dt}\frac{1}{v^3 m} \;=$$

$$-\frac{\partial U_p}{\partial t}\frac{\partial U_p}{\partial s}\frac{1}{v^3 m}$$

and we can then write the divergence of $\boldsymbol{E}$ (26) as:

$$\nabla\cdot\boldsymbol{E} \;=\; \frac{1}{m}\left(-\nabla^2 U_p + \frac{\partial U_p}{\partial t}\frac{\partial U_p}{\partial s}\frac{1}{v^3 m}\right)$$

and if we remember that we can easily find (in view of (28)):

$$\partial^2 U_p/\partial s\partial t \;=\; \partial^2 U_p/\partial t\partial s \;=\; -(dm/dt)(dv/dt)$$

starting from (27) we can also put

$$\nabla\cdot(\partial \boldsymbol{A}/\partial t) \;=\; (1/2v)(\partial^2 U_p/\partial s\partial t)$$

and finally it is:

$$\nabla\cdot\boldsymbol{E} \;=\; (1/m)[-\nabla^2 U_p \;-\; (1/2v)(\partial^2 U_p/\partial s\partial t)]$$

If we consider the surroundings of the physical point m , where there are no sources, whose meaning is $\nabla\cdot\boldsymbol{E} = 0$, we obtain the "wave equation"

$$\boxed{\nabla^2 U_p + \frac{1}{2v}\frac{\partial^2 U_p}{\partial s\,\partial t} = 0} \qquad (29)$$

which is completely general and is satisfied here.

4. Also demonstrated is the "particle-wave" structure which has a material point in movement when its potential energy is not conservative. This *dualism* is seen in the possibility of the wave aspect, which extends to all the space external to the particle and is expressed by the term $\nabla^2 U_p$, being made to correspond with the *corpuscula*r aspect, localized and expressed by

$$\frac{1}{2v}\frac{\partial^2 U_p}{\partial s\,\partial t} = -\tfrac{1}{2}\, v\frac{dm}{dt}\frac{dv}{dt} = -\tfrac{1}{2}\, v\dot{m}\dot{v}$$

so that the equation of waves of this "corpuscle-wave" takes the form

$$\boxed{\nabla^2 U_p - \tfrac{1}{2}\frac{1}{v}\dot{m}\dot{v} = 0}$$

thereby unifying these aspects of the question. Obviously a wave structure of this kind will not exist when $m = constant$ or when $v = constant$.

5. We shall now study a special case in which we want the lineal momentum of the particle to be conserved:

$$\boldsymbol{p} = m\boldsymbol{v} = constant$$

by deriving its module with regard to time it is

$$(dm/dt)v \; + \; m(dv/dt) \; = \; 0$$

and by using the expressions found earlier:

$$\partial U_p/\partial s \; = \; -m(dv/dt) \; = \; -m\dot{v}$$

$$\partial U_p/\partial t \; = \; -(1/2)(dm/dt)v^2 \; = \; -\tfrac{1}{2}\dot{m}v^2$$

we shall have

$$-(dm/dt)v \; - \; m(dv/dt) \; \equiv -\frac{2}{v}\tfrac{1}{2}\dot{m}v^2 \; - \; m\dot{v} \; =$$

$$(2/v)\partial U_p/\partial t \; + \; \partial U_p/\partial s \; = \; 0$$

and if we derive it partially with regard to time we shall get

$$(2/v)(\partial^2 U_p/\partial t^2) \; = \; -\partial^2 U_p/\partial s \partial t$$

with this result the general wave equation (29) in this special case becomes

$$\boxed{\nabla^2 U_p - \frac{1}{v^2}\frac{\partial^2 U_p}{\partial t^2} \; = \; 0} \qquad (30)$$

which is isomorphic with D'ALEMBERT's wave equation, except that here the velocity is not constant; if it were, the wave aspect would disappear, but we can come closer, as an extreme result, so that: dv/dt and dm/dt are not null and yet we can consider: $v \approx constant = v_o$ and $m \approx constant = m_o$, which are perfectly compatible (for example, it is enough to imagine very brief durations of these variations of speed and mass).

Also, and in the light of expression (26), it is possible to write

$$-m\,\nabla\cdot\boldsymbol{E} \;=\; \nabla^2 U_p \;+\; \nabla\cdot(\partial\boldsymbol{A}/\partial t) \;=$$

$$\nabla^2 U_p \;+\; (\partial/\partial t)\,\nabla\cdot\boldsymbol{A} \;=\; 0$$

and from the last wave equation (30) we get

$$(\partial/\partial t)\,\nabla\cdot\boldsymbol{A} \;=\; -(1/v^2)(\partial^2 U_p/\partial t^2)$$

and definitively:

$$\boxed{\nabla\cdot\boldsymbol{A} \;=\; -(1/v^2)(\partial U_p/\partial t) \;+\; \phi(P)}$$

where $\phi(P)$ is arbitrary and independent of time; it is also isomorphic with "LORENTZ's condition" of electromagnetism, except that here the velocity is not constant.

B. DEDUCTION OF "MAXWELL'S EQUATIONS"

1. In the general expression for vector $\boldsymbol{B}$ (22) we can calculate the divergence

$$\nabla\cdot\boldsymbol{B} \;=\; \nabla\cdot\Big(-\frac{1}{m}\frac{\partial A}{\partial t}\frac{dt}{d\rho}\boldsymbol{b}\Big) \;=\; -\frac{1}{m}\frac{dt}{d\rho}\,\nabla\cdot(U_p/v)\boldsymbol{b} \;=$$

$$-\frac{1}{m}\frac{dt}{d\rho}\,\frac{1}{v}\,\frac{\partial U_p}{\partial b} \;=\; 0$$

since $\partial U_p/\partial b = 0$, as the movement of the particle is on the osculating plane to the trajectory and ∇U_p has no component according to the *binormal* $\boldsymbol{b}$ (see (20)). Thus, it is always proved true that

$$\boxed{\nabla \cdot \boldsymbol{B} = 0}$$

so that $\boldsymbol{B}$ must be the *rot.* of a vector.

2. We are now going to look at the limit case, cited previously, in which the following conditions are satisfied:

$$dm/dt \neq 0 \quad \text{but} \quad m \approx m_o = constant$$

$$dv/dt \neq 0 \quad \text{but} \quad v \approx v_o = constant$$

and consequently the kinetic energy of the particle will also be approximately constant[43]. Continuing with our study, we shall start by complying with:

$$\boldsymbol{B} = (1/m)\, \nabla \times \boldsymbol{A}$$

which, as we saw earlier, requires that: $m = a^2 v^2 \rho^2 \approx m_o$. And, since the speed is nearly constant, the radius of curvature should also be so; in other words, the trajectory is practically circular, or a straight line as a limit case. Thus, starting from the first equation in (22), we can write

$$\nabla \times m_o \boldsymbol{E} \approx -(\partial/\partial t)\, \nabla \times \boldsymbol{A}$$

since it is permissible to permute the derivation order (on the assumption that the conditions of SCHWARZ's theorem are satisfied). From this we get

[43] There are other particular cases in which $U_c = constant$ and yet the preceding requisites are also satisfied.

$$\boxed{\nabla\times\boldsymbol{E} \approx -\frac{\partial}{\partial t}\frac{1}{m_0}\nabla\times\boldsymbol{A} = -\partial\boldsymbol{B}/\partial t} \qquad (31)$$

The equation for this limit case that we are considering and which is isomorphic with MAXWELL-FARADAY's equation.

3. Let us now suppose that "LORENTZ's condition" is satisfied:

$$\nabla\cdot\boldsymbol{A} = -(1/v^2)(\partial U_p/\partial t)$$

in the same conditions as the preceding section. In addition to the general expression for $\boldsymbol{E}$ (25) it is

$$\partial\boldsymbol{E}/\partial t = \frac{1}{m}\frac{\partial}{\partial t}(-\nabla U_p - \partial\boldsymbol{A}/\partial t) =$$

$$\frac{1}{m}[-\nabla(\partial U_p/\partial t) - \partial^2\boldsymbol{A}/\partial t^2]$$

and in the hypothesis that "LORENTZ's condition" is satisfied, we can write

$$\partial\boldsymbol{E}/\partial t \approx \frac{1}{m}[\nabla(v_o^2\,\nabla\cdot\boldsymbol{A}) - \partial^2\boldsymbol{A}/\partial t^2] =$$

$$\frac{1}{m}[v_o^2(\nabla\times\nabla\times\boldsymbol{A} + \nabla^2\boldsymbol{A}) - \partial^2\boldsymbol{A}/\partial t^2]$$

since in this case $\nabla v_o^2 = 0$. And starting from $\boldsymbol{B} = \frac{1}{m}\nabla\times\boldsymbol{A}$ then it is

$$\partial \boldsymbol{E}/\partial t \approx \frac{1}{m} v_o{}^2 [\nabla \times m\boldsymbol{B} + \nabla^2 \boldsymbol{A} - \frac{1}{v_0^2} \frac{\partial^2 \boldsymbol{A}}{\partial t^2}]$$

by grouping terms and when $m \approx m_o$ in our case we get

$$\nabla \times \boldsymbol{B} \approx \frac{1}{v_0^2} \partial \boldsymbol{E}/\partial t + \frac{1}{m_0}[-\nabla^2 \boldsymbol{A} + \frac{1}{v_0^2} \frac{\partial^2 \boldsymbol{A}}{\partial t^2}]$$

but if we consider the definition given by the potential vector $\boldsymbol{A}$ in (21) and the wave equation (29) we immediately get

$$\boxed{\nabla^2 \boldsymbol{A} - \frac{1}{v_0^2} \frac{\partial^2 \boldsymbol{A}}{\partial t^2} = 0}$$

and this together with the preceding one give

$$\boxed{\nabla \times \boldsymbol{B} \approx \frac{1}{v_0^2} \frac{\partial \boldsymbol{E}}{\partial t}} \qquad (32)$$

isomorphic with MAXWELL-AMPERE's equation.

4. From equation (31) and with identical hypotheses we can write

$$\nabla \times \nabla \times \boldsymbol{E} = \nabla \nabla \cdot \boldsymbol{E} - \nabla^2 \boldsymbol{E} \approx -\frac{\partial}{\partial t} \nabla \times \boldsymbol{B}$$

but, since $\nabla \cdot \boldsymbol{E} = 0$ it is then also

$$\nabla^2 \boldsymbol{E} \;-\; \frac{\partial}{\partial t}\,\nabla\times\boldsymbol{B} \;\approx\; 0$$

which if we remember (32) gives us

$$\nabla^2 \boldsymbol{E} \;-\; \frac{\partial}{\partial t}\,\frac{1}{v_0^2}\,\frac{\partial \boldsymbol{E}}{\partial t} \;=\; 0 \qquad\qquad \Rightarrow$$

$$\boxed{\nabla^2 \boldsymbol{E} \;-\; \frac{1}{v_0^2}\,\frac{\partial^2 \boldsymbol{E}}{\partial t^2} \;=\; 0}$$

From the last expression (32) for $\nabla\times\boldsymbol{B}$ it can be deduced that

$$\nabla\times\nabla\times\boldsymbol{B} \;\approx\; \frac{1}{v_0^2}\,\frac{\partial}{\partial t}\,\nabla\times\boldsymbol{E}$$

and in the light of (31) we immediately get

$$\nabla\times\nabla\times\boldsymbol{B} \;=\; \nabla\nabla\boldsymbol{B} \;-\; \nabla^2\boldsymbol{B} \;\approx\; \frac{1}{v_0^2}\,\frac{\partial}{\partial t}(-\partial\boldsymbol{B}/\partial t)$$

and as $\nabla\cdot\boldsymbol{B} = 0$ always, we finally have

$$\boxed{\nabla^2 \boldsymbol{B} \;-\; \frac{1}{v_0^2}\,\frac{\partial^2 \boldsymbol{B}}{\partial t^2} \;\approx\; 0}$$

5. Still on the subject of the limit problem which we have been dealing with in the preceding sections, it is clear that when the kinetic energy U_c is approximately constant, it can be derived with regard to time and we shall have the relation

$$mv(dv/dt) + (1/2)(dm/dt)v^2 \approx 0$$

And we can expand the equations (10) for $\boldsymbol{E}$ and $\boldsymbol{B}$ to:

$$\boldsymbol{E} = \frac{1}{m}[m\boldsymbol{a} - mv(dv/dt)(dt/d\rho)\boldsymbol{n} + \tfrac{1}{2}(dm/dt)v\boldsymbol{s}]$$

$$\boldsymbol{B} = \frac{1}{mv}(dt/d\rho)\tfrac{1}{2}(dm/dt)v^2\boldsymbol{b}$$

If we now set the condition that $\boldsymbol{E}$ is normal to $\boldsymbol{v}$, the component, according to $\boldsymbol{s}$, in the previous equation, must be null:

$$mdv/dt + \tfrac{1}{2}(dm/dt)v = 0$$

whose meaning is precisely $U_c = constant$. And then, in this limit case, the equations will be

$$\boldsymbol{E} \approx [-v_o^2/\rho_o - v_o(dv/dt)(dt/d\rho)]\boldsymbol{n}$$

$$\boldsymbol{B} \approx (1/m_O)\,\nabla\times\boldsymbol{A} = (v_o/\rho_o + dv/d\rho)\boldsymbol{b}$$

If we wish for an analogy with the electromagnetic case of "plane wave", this means that the radius of curvature must tend towards infinite or else must be very large in comparison with the other magnitudes, and thus it must be

$$v_o/\rho_o \approx 0$$

and then the vectors $\boldsymbol{E}$ and $\boldsymbol{B}$ will be

$$\boldsymbol{E} \approx -v_o(dv/d\rho)\boldsymbol{n} \qquad \boldsymbol{B} \approx (dv/d\rho)\boldsymbol{b} = \boldsymbol{\omega}^*$$

so that $E/B \approx -v_o$. Therefore, the force that acts on the particle in this limit case is

$$\boxed{\boldsymbol{f} = m_o(\boldsymbol{E} + \boldsymbol{v_o}\times\boldsymbol{B}) \approx 0}$$

and in addition to this we shall have: $\boldsymbol{v_o}\times\boldsymbol{B} = \boldsymbol{E}$, and since $\boldsymbol{E}$ is transverse, this relation tells us that the direction of propagation $\boldsymbol{v}$, $\boldsymbol{E}$ and $\boldsymbol{B}$ form a direct trihedron. In this limit case the following is also proved:

$$\boldsymbol{B} = (1/v_o)\boldsymbol{s} \times \boldsymbol{E}$$

and from this can be seen, in this special case, the existence of a progressive *plane wave* with a velocity of propagation of $v = v_o$.

Evidently, as in electromagnetism, the relation is proved:

$$|E| \,/\, |B| = v_o$$

6. We shall end our comparison with electromagnetism here. Any field in which the potential energy $U_p = U_p(P, t)$ and cannot be reduced to trivial cases, to which we have already referred throughout this study, has this structure. For example, this theory should be applied to those cases in which CD is insufficient, as in the famous problem of the "three bodies" ("Trojan" asteroïds, etc.).

CHAPTER IV

IRREVERSIBILITY AND CHAOS

The irreversibility of the trajectories of material points causes its mathematical irresolution although they continue being determinist; in fact the chaos does not exist, it is only a form to indicate this irresolution.

1. In which it precedes we have presented a New Dynamics (ND) of Irreversible Mechanical Systems, requisite previous for the development of the present section dedicated to one of the most important conclusions of this ND. It seems to us interesting to mention a summary of the Chaos Theory; to this aim we transcribe in the following pages a complete study on this particular.[44]

TEORÍA DEL CAOS

En el presente ensayo sobre la "Teoría del Caos" se realiza un análisis partiendo de las diferencias surgidas entre la Ciencia del siglo XIX y XX, es decir, la posición determinista y la "Nueva Física". Hasta principios del siglo XX, la Física se sitúa en la certeza de la predicción de los fenómenos, a pesar de los antecedentes de Poincaré en el siglo XIX sobre el problema de los tres cuerpos, donde se expresa que sólo podemos tener una "aproximación" y que la predicción se vuelve imposible. Sin embargo, se ignora tal postura y se continúa en la misma línea hasta el fin de la "Revolución de la Física"; es entonces que se retoman las consecuencias del descubrimiento de Poincaré y se observa que las variables pueden desarrollar un comportamiento caótico, complicado e impredecible pero dentro de un orden geométrico observable. Es así que, a partir de este enfoque, se desarrolla la "Teoría de Caos" , aportando un paradigma donde los problemas científicos pueden resolverse desde esta nueva óptica.

Desde hace algunos años oímos mencionar vagamente una "Teoría" a la que se dio por llamar "del Caos". No obstante, pocas de las referencias han sido claras. Para comprender el significado de la Teoría del Caos es conveniente analizar las diferencias entre la Ciencia del siglo XIX y la del XX.

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[44] La dirección es: http://hverdugo.tripod.cl/cuenta_medio.htm donde no se cita el nombre del autor.

Durante el siglo XIX, la Ciencia llegó a un triunfalismo determinista. Se creía que la Física, la más rigurosa e importante de las Ciencias, estaba a punto de cerrarse, ya que casi estaba todo concluido. Las leyes se expresaban en la Física de manera estrictamente determinista. Aunque ninguna otra Ciencia (excluiremos a las Matemáticas por ser otra su naturaleza y metodología) podía jactarse de lo mismo, se suponía que como la Física expresaba las leyes fundamentales del Universo, éstas eran igualmente aplicables en Química, Biología, Psicología, etc. sólo que en éstas, los temas de estudio se presentaban con mayor complejidad (una bacteria es mucho más compleja que el Sol mismo).

Pierre Simon de Laplace, el gran matemático, ya desde el siglo XVIII había expresado la idea dominante: "El estado presente del sistema de la Naturaleza es evidentemente una consecuencia de lo que fue en el momento precedente, y si concebimos una inteligencia tal que a un instante dado conociera todas las fuerzas que animan la Naturaleza y las posiciones de los seres que las forman, podría condensar en una única fórmula el movimiento de los objetos más grandes del Universo y de los átomos más ligeros: nada sería incierto para dicho ser, y tanto el futuro como el pasado estarían presentes ante sus ojos". Ese era el anhelo de la Ciencia: ser capaz de predecirlo todo.

Pero en la misma Física, hacia finales del siglo XIX, aparecieron unos problemas que no parecían encontrar solución dentro del marco científico existente: eran llamados "el problema del éter" y la "catástrofe ultravioleta". Estos problemas llevaron a la Física a una revolución que desembocó en la Teoría de la Relatividad por un lado, y la Mecánica Cuántica, por el otro. Ambas teorías parecen desafiar el sentido común al proponer que el tiempo es relativo o que existen partículas virtuales llenando el Universo. La Mecánica Cuántica, en particular, postuló un principio devastador para la fe del científico en la posibilidad de hacer predicciones de todo; en pocas palabras, el Principio de Incertidumbre de Heisenberg afirma que nunca es posible tener mediciones exactas: sólo se podrán hacer aproximaciones. Nunca podremos conocer con exactitud la magnitud de lo ancho de esta hoja, sólo podremos decir, realmente que está entre 21.55 y 21.65, por ejemplo.

Muchos científicos se resistían a aceptar este principio, entre ellos Albert Einstein, quien trató de demostrar su inconsistencia, pero lo único que logró fue fortalecerlo aún más.

Los físicos se hallaban extremadamente atareados en desarrollar estas nuevas ideas. Algunos químicos se interesaban por el efecto de la Mecánica Cuántica en su disciplina. Los demás científicos, en tanto, se encontraban ocupados en sus propias disciplinas, menos maduras. Ninguno de ellos veían efectos importantes de las nuevas teorías de la Física sobre sus áreas. En efecto, la Teoría de la Relatividad se aplica a lo muy grande (del tamaño del Sol o mayor) o lo muy veloz (a velocidades cercanas a las de la luz); mientras que la Mecánica Cuántica se ocupa de lo muy pequeño (de tamaño menor que el átomo).

Mientras esto ocurría, pocos reparaban en un tercer problema insoluble de la Física que traería consecuencias insospechadas en el examen científico de los fenómenos cotidianos: el problema de los tres cuerpos.

El problema de los tres cuerpos era más que nada astronómico: si se tienen dos cuerpos en el espacio, es fácil deducir las ecuaciones del movimiento: se moverán en elipses, por ejemplo. Pero si se tienen tres cuerpos, ya no hay manera de encontrar tales ecuaciones exactas, solamente aproximaciones válidas para un intervalo. Al salir de ese intervalo de validez, se debe hacer otras aproximaciones.

Henri Poincaré decidió atacar el problema de los tres cuerpos a finales del siglo XIX, con motivo de un concurso de Matemáticas organizado en Suecia. Al estudiarlo, encontró algo que le sorprendió: un sistema tan sencillo de plantear como el de los tres cuerpos podría dar un comportamiento extremadamente complicado, tanto que imposibilitaba hacer predicciones a largo plazo en el mismo.

Poincaré mismo lo expresa de esta manera: "Una pequeña causa que nos pasa desapercibida determina un considerable efecto que es imposible de ignorar, y entonces decimos que el efecto es debido al azar. Si conocemos exactamente las leyes de la Naturaleza y la situación del Universo en el momento inicial, podemos predecir exactamente la situación de este mismo Universo en un momento posterior. Pero aun si fuera el caso que las leyes de la Naturaleza no nos guardasen ningún secreto, todavía nosotros conoceríamos la situación inicial sólo aproximadamente. Si esto nos permitiera predecir la situación posterior con la misma aproximación, que es todo lo que necesitamos, podríamos afirmar que el fenómeno ha sido predicho, que es gobernado por leyes conocidas. Pero esto no es siempre así; puede pasar que pequeñas diferencias en las condiciones iniciales produzcan grandes diferencias en el fenómeno final. Un pequeño error al principio produce un error enorme al final. La predicción se vuelve imposible, y tenemos un fenómeno fortuito".

Los físicos y demás científicos hicieron poco caso de este descubrimiento matemático (de hecho sólo los matemáticos continuaron trabajando en ello). Hasta el último cuarto del siglo XX donde, una vez apaciguada la llama de la Revolución de la Física, se observaron las consecuencias del descubrimiento de Poincaré. Y sobre todo por la ayuda de los ordenadores.

Se pretendía hacer predicciones a medio plazo del clima apoyándose en cálculo computacional intensivo. Pero se vio que era imposible porque simplemente tres variables podían desarrollar un comportamiento "caótico", es decir, muy complicado e impredecible (cambios no periódicos y crecimiento del efecto de las pequeñas diferencias en el inicio). Sin embargo, este caos es distinto del comportamiento al azar. Existe un orden dentro del caos que puede observarse geométricamente.

Imaginemos una curva en el espacio. La curva nunca se cruza, pero es infinita. Se construyó con unas determinadas condiciones iniciales (es decir, a partir de un punto determinado en el espacio). Si hubiésemos iniciado desde otro punto, por muy cercano que estuviera al punto original, la trayectoria hubiera sido distinta en el sentido de que si en la primera dio 4 vueltas alrededor del un lóbulo antes de pasarse al otro, en la segunda trayectoria daría, digamos 17 vueltas antes de pasar al otro lóbulo. Pero ¡las dos trayectorias, en conjunto se verían como la curva imaginada. Siempre la misma figura. Ninguna trayectoria puede alejarse de los lóbulos ni entrar dentro de ellos, no son trayectorias al azar, aunque no sean predictibles.

Ahora, ¿qué importancia tenía para las Ciencias? Si tres variables generan un comportamiento complicado, no aleatorio, ¿qué no harán más variables? Aquí acaba la posibilidad de predicción a largo plazo de la Ciencia. Sin embargo, visto al revés, un comportamiento complejo, en lugar de ser causado por un enorme número de variables, la mayoría indeterminadas, ¿no será en realidad manejado por un puñado de variables en comportamiento caótico?

La teoría del Caos aporta un nuevo enfoque a la complejidad que es la característica común en la inmensa mayoría de los problemas de la Ciencia: reacciones químicas en el suelo, el comportamiento humano... todo eso rebosa complejidad. Y el caos no es desorden simplemente, sino un orden diferente, que debe verse de otro modo. Más aún, muchas variables no necesariamente han de generar un comportamiento tan complicado que parezca al azar. Muchas veces, de sus interacciones emerge un orden diferente. Por ejemplo, de la interacción de muchos seres humanos puede surgir una sociedad, que contiene un orden evidente. No es predecible a largo plazo, pero el orden existe, como en el atractor de Lorentz.

Así, la teoría del Caos puede aplicarse a toda Ciencia, pero hay que entender el enfoque nuevo que aporta, una especie de paradigma que no descarta ni el desorden aparente ni lo que parece ser "ruido de fondo" de un comportamiento lineal perfecto. Muchos problemas científicos podrían resolverse con una nueva óptica.

El caos es impredecible, pero determinable. O dicho de otro modo, el caos no es aleatorio, tiene un orden subyacente. En un principio, la teoría del caos se aplicaba al análisis de circuitos electrónicos, encontrando resultados tales como el aumento de la potencia de láseres (Ditto y Pecora) y la sincronización de circuitos. Se demostró entonces, que era posible sincronizar dos sistemas caóticos, siempre y cuando fuesen excitados por la misma señal, independientemente del estado inicial de cada sistema (Neff y Carroll). O sea, que al perturbar adecuadamente un sistema caótico, se le está forzando a tomar uno de los muchos comportamientos posibles. Lo que ocurre es que el caos es sensible a las condiciones iniciales. Sin sincronismo, dos sistemas caóticos virtualmente idénticos, evolucionarán hacia estados finales distintos.

Más tarde, pudo aplicarse al análisis de oscilaciones en reacciones químicas, y al seguimiento del latido cardíaco. En los últimos años, la Biología se hace cargo de este nuevo tipo de procesos, modelizando comportamientos enzimáticos (Hess y Markus). Los sistemas naturales son, en su gran mayoría, no lineales, y justamente el caos es un comportamiento no lineal.

Un ejemplo introductorio: entendemos perfectamente lo que significa que alguien afirme que pesa 80.5 Kg. También es razonable que aceptemos que un boxeador pesa 75,125 Kg (sabemos que este peso sólo es válido en el momento del pesaje). Pero ¿ que opinaríamos de una persona que afirmara pesar 78,12456897355568793 Kg?. No parece razonable. Con cada exhalación eliminamos vapor de agua y dióxido de carbono en cantidades mayores a 0,0000001 Kg, con lo cual dejamos sin valor las últimas 10 cifras del peso mencionado. Y en este punto es donde empiezan algunos conceptos fundamentales.

Observación Fundamental: si empleamos un peso de 80,5 Kg en nuestras cuentas, en realidad, matemáticamente estamos empleando el número 80,5000000000000000000000000...... y ahí es donde conviene comenzar a replantearse el empleo de las Matemáticas para describir la realidad física. Porque si no especificamos 100, 200 o un millón de cifras significativas, y hacemos cuentas con números redondos, en realidad estamos empleando ceros para completar las cifras significativas que no conocemos.

Por supuesto que toda persona que trabaja con datos experimentales sabe que no puede obtener resultados con mayor cantidad de cifras significativas que las que le permiten sus mediciones experimentales. Pero la pregunta vuelve a ser la misma: aunque no dispongamos de 100 cifras significativas (y en ninguna medición real se superan las 10 cifras significativas), ¿éstas cifras existen?.

Para ser más específico: si dos cuerpos chocan entre sí, aunque no podamos medir su masa con mayor exactitud que 6 cifras significativas, ¿podemos afirmar que las leyes que rigen la colisión responden a valores de masa expresados con 50 cifras significativas? (o con un millón de cifras)? ¿O para la Naturaleza existe un grado máximo de exactitud, a partir del cual la respuesta es indeterminada?.

De modo que ahora se puede formular la PREGUNTA (para la que no se tiene respuesta): ¿Con cuántas cifras significativas trabaja la Naturaleza? ¿Tiene sentido la pregunta anterior?

Todo esto no pasaría de ser un juego intelectual si no hubiera aparecido en escena la Teoría del Caos. Porque después de todo: ¿qué nos importan las cifras significativas que no podemos medir ni en los datos ni en los resultados experimentales?. Pero resulta que la Teoría del Caos puso de manifiesto que existen numerosos sistemas reales donde la respuesta a un estímulo varía en forma manifiesta con cambios minúsculos en las condiciones iniciales.

El primer experimentador del caos fue un meteorólogo llamado Edward Lorentz. En 1960 estaba trabajando en el problema de predecir el tiempo. Tenía un ordenador que calculaba el tiempo con 12 ecuaciones. La máquina no predijo el tiempo, pero en principio predijo cómo sería el tiempo probablemente. Un día, en 1961, Lorentz quiso ver unos datos de nuevo. Introdujo los números de nuevo en el ordenador, pero para ahorrar con el papel y el tiempo, solo calculó con 3 números decimales en vez de 6. Le salieron resultados totalmente diferentes. Lorentz intentó encontrar una explicación. Así surgió la Teoría que está tan de moda en nuestros días: la Teoría del Caos.

Según las ideas convencionales, los resultados habrían tenido que ser prácticamente los mismos. Lorentz ejecutó el mismo programa, y los datos de inicio casi fueron iguales ("esas diferencias muy pequeñas no pueden tener efecto verdadero en los resultados finales"). Lorentz demostró que esa idea era falsa. Al efecto que tienen las diferencias pequeñas e iniciales, después se le dio el nombre del 'efecto mariposa':
"El movimiento de una simple ala de mariposa hoy, produce un diminuto cambio en el estado de la atmósfera. Después de un cierto período de tiempo, el comportamiento de la atmósfera diverge del que debería haber tenido. Así que, en un período de un mes, un tornado que habría devastado la costa de Indonesia no se forma. O quizás, uno que no se iba a formar, se forma."

Este fenómeno, y toda la Teoría del Caos es también conocido como dependencia sensitiva de las condiciones iniciales. Un cambio pequeño puede cambiar drásticamente el comportamiento a largas distancias de un sistema. Al medir, una diferencia tan pequeña puede ser considerada 'ruido experimental' o impuntualidad del equipo. Esas cosas son imposibles de evitar, incluso en el laboratorio más moderno. Con un número inicial 1,001 el resultado puede ser totalmente diferente que con 1,000543.

Es simplemente imposible alcanzar este nivel de eficacia al medir. De esta idea, Lorentz concluyó que era imposible predecir exactamente el tiempo. Pero esto llevó a Lorentz a otros aspectos de lo que viene llamándose Teoría del Caos. Lorentz intentó encontrar un sistema menos complejo que dependiera sensitivamente de las condiciones iniciales. Estudió las ecuaciones de convección y las simplificó. El sistema ya no tuvo que ver con la convección, pero sí dependía mucho de los datos iniciales, y esta vez solo había 3 ecuaciones. Después se vio que sus ecuaciones describen precisamente una "rueda de agua".

En 1963 Lorentz publicó lo que había descubierto, pero como lo publicó en un periódico meteorológico, nadie le lo tomó en consideración. Su descubrimiento solo fue reconocido más tarde, cuando fueron redescubiertos por otros científicos. Lorentz descubrió algo revolucionario, pero tuvo que esperar a alguien que le descubriera a él.

Así surgió la nueva Ciencia que todavía en nuestros día también es muy joven. Hay muchas ideas falsas sobre el caos, según las cuales la Teoría del Caos es un tratado del desorden. Nada más lejos de la verdad. Es cierto que la Teoría dice que cambios pequeños pueden causar cambios enormes, pero no dice que no hay orden absolutamente. Una de las ideas más principales es que mientras es casi imposible predecir exactamente el estado futuro de un sistema, es posible, y aún más, muchas veces fácil, modelar el comportamiento general del sistema. Eso es lo que se muestra en el "atractor" de Lorentz. O sea, el Caos no se trata del desorden, incluso en cierto sentido podemos decir que es determinista.

¿Qué es un atractor? Consta de múltiples órbitas periódicas, representa un sistema cuya velocidad y posición cambian a lo largo de una sola dirección. Consta de dos ejes; uno representa la posición, el otro la velocidad. Los atractores pueden ser multidimensionales, pues los sistemas pueden tener muchas variables, que equivalen a otras tantas dimensiones en el espacio de estados: por ejemplo, posiciones y velocidades que varíen en tres dimensiones. Pero veamos un ejemplo.

"La rueda de agua" de Lorentz, antes mencionada, es parecida a la rueda en el parque de atracciones. Tiene cajitas (generalmente más de siete), que están colgadas a la rueda, o sea, su 'boca' siempre mira para arriba. Abajo todas tienen un hueco pequeño. Y todo eso está dispuesto bajo un flujo de agua. Si le echamos agua a velocidad pequeña, el agua después de entrar en el cajón, sale inmediatamente por el hueco. Así que no pasa nada. Si aumentamos la corriente del agua un poco, la rueda empieza a rotar, porque el agua entra más rápido a las cajitas que sale. Así, las cajas pesadas por el agua descienden dejando el agua, y cuando están vacías y ligeras, ascienden para ser llenadas de nuevo. El sistema está en un estado fijo, y va a continuar rotando a una velocidad prácticamente constante. Pero si aumentamos la corriente más, van a pasar cosas extrañas. La rueda va a seguir rotando en la misma dirección, pero su velocidad va a decrecer, se para y luego gira en la dirección contraria. Las condiciones de las cajitas ya no están suficientemente sincronizadas como para facilitar solamente una rotación simple, el caos ha conseguido el mando en este sistema aparentemente tan sencillo.

Ahora no podemos decir nada del estado de la rueda en concreto, porque el movimiento nos parece hecho totalmente al azar.

Los sistemas caóticos están presentes todos los días. Y en vez de mirarlos cada uno, investigamos los comportamientos de los sistemas parecidos. Por ejemplo, si cambiamos un poco los números iniciales del atractor, siempre nos dará números distintos que en el caso anterior, y la diferencia con el tiempo va a ser cada vez más grande, de tal forma que después de un tiempo, los dos casos aparentemente ya no tendrán que ver, pero sus gráficas serán iguales.

¿Y por qué no se desarrolló esta Ciencia hasta ahora? El 'padre' del conjunto Mandelbrot fue un libro publicado por Gaston Maurice Julia, y aunque recibió el 'Grand Prix de l'Academie des Sciences', sin visualizar sus funciones nadie le dio mucha importancia. La respuesta es simple: ordenadores. Para poner un conjunto Mandelbrot en la pantalla se necesitan 6 millones de cálculos (operaciones), que son mucho para ser calculados por científicos, pero para los ordenadores actuales es una tarea de todos los días. Y de verdad, la Teoría surgió cuando los matemáticos empezaron a introducir números al ordenador y miraron lo que éste hacía con ellos. Después trataron de visualizarlo todo de alguna forma.

Pasado un tiempo, las imágenes se veían como la naturaleza. Nubes, montañas y bacterias. Así indicaron por qué no podemos predecir el tiempo. Parecían ser iguales al comportamiento de la bolsa y de las reacciones químicas a la vez. Sus investigaciones dieron respuestas a preguntas puestas hace 100 años sobre el flujo de fluidos, cómo pasaban de un flujo suave hacia un flujo caótico, o sobre el comportamiento del corazón, o las formaciones de rocas. Los sistemas caóticos no son hechos al azar, y se conocen por unos rasgos muy simples.

Los sistemas caóticos son deterministas, o sea hay algo que determina su comportamiento.

Los sistemas caóticos son muy sensitivos a las condiciones iniciales. Un cambio muy pequeño en los datos de inicio producen resultados totalmente diferentes.

Los sistemas caóticos parecen desordenados, o hechos al azar. Pero no lo son. Hay reglas que determinan su comportamiento. Sistemas de verdad hechos al azar no son caóticos. Los sistemas regulares, descritos por la Física clásica, son las excepciones. En este mundo de orden, reglas caóticas...

Las nuevas investigaciones muestran que sí hay esperanzas de 'domesticar' el caos. Edward Ott, Ceslo Grebogi (físicos) y James A. Yorke (matemático) elaboraron un algoritmo matemático con el que un caos puede ser transformado en procesos periódicos sencillos. Y ya superaron experimentos, de los que probablemente el más importante es el experimento de A. Garfinkel de la Universidad de California. Logró transformar el movimiento caótico de un corazón sacado de un conejo en un movimiento regular. Obviamente el uso de esto en la medicina significaría un avance enorme.

La idea nueva es que no hace falta comprenderlo todo sobre el movimiento caótico para regularlo. El algoritmo Ott-Grebogi-Yorke mira continuamente a qué 'dirección' tiende el proceso, y variarlo con perturbaciones pequeñas para lograr que esté de nuevo en el 'camino' antes deseado. Naturalmente aquí no se termina de vigilar el sistema, porque después el caos aparecerá de nuevo. Yorke dice que el método es como "ayudar a andar a un elefante con un palito".

Parece que habrá más avances en el regulamiento del caos, lo cual nos daría respuesta a muchas preguntas, nos ayudaría evitar catástrofes, y daría un avance enorme a toda la Ciencia, todo el saber logrado hasta ahora.

Los sistemas caóticos son muy flexibles. Si tiramos una piedra al río, su choque con las partículas del agua no cambia el cauce del río, sino que el caos se adapta al cambio. Sin embargo, si el río hubiese sido creado por nosotros con un orden artificial, donde cada partícula de agua tuviera una trayectoria determinada, el orden se hubiera derrumbado completamente. El caos en realidad es mucho más perfecto que nuestro orden artificial; hemos de comprender el caos y no intentar crear un orden rígido, que no sea flexible ni abierto a la interacción con el medio.

Siempre hemos estado obsesionados por el control, creemos que cuantas más técnicas creemos, más control tendremos sobre el mundo. Pero con cada tecnología nueva que introducimos se nos echan encima muchos problemas, para cada uno de los cuales hemos de inventar nuevas tecnologías. Volvamos al ejemplo del río: si tiramos una piedra el cauce no cambia, pero si tiramos una roca gigante la flexibilidad del sistema caótico no será suficiente. Es lo que ocurre en la Tierra: es un sistema caótico, siempre cambiante y adaptándose, pero si nos pasamos de la raya el sistema se puede romper. De hecho lo está haciendo y por eso tenemos problemas con la capa de ozono, el aumento de la temperatura global y el deshielo, problemas con los recursos como el petróleo, etc.

Aprender a vivir en el caos no significaría aprender a controlarlo, ni a predecirlo. Al contrario: hemos de enfocar la cuestión desde el punto de vista de que nosotros también somos parte del caos, no nos podemos considerar como elementos aparte. Desde esa perspectiva lo que podemos hacer es vivir de la creatividad del caos, sin intentar imponernos: si conseguimos realmente formar parte del sistema, el concepto de sujeto y objeto desaparecerán, con lo cual el problema del control también[45].

Veamos unos ejemplos donde se ve claramente que la Tierra es una unidad caótica: un bosque, por citar algo, puede llegar a ser muy flexible y adaptable debido a su rica red de rizos retroalimentadores que interactúan con el medio constantemente. Algunos bosques, incluso, se han ajustado a cambios drásticos. Pero cuando este sistema caótico se desestabiliza (porque empezamos a talar bosques, por ejemplo), la conducta no lineal puede hacer que su dinámica cambie abruptamente o que incluso se colapse. Ya tenemos el ejemplo de tierras sobre las que hace años hubo ricos bosques que creaban su propio microclima y ellos mismos hacían que las condiciones les fueran favorables; sin embargo, ahora no se puede plantar ni una sola planta ahí. Cortar un árbol puede significar que el bosque se quede con un árbol menos. Cortar diez árboles también. Pero cortar mil árboles puede no significar que el bosque se quede con mil menos, sino que a partir de ahí se extingan todos. Los procesos naturales de la Tierra son indivisibles y constituyen un holismo capaz de mantenerse y alimentarse, al menos que en el sistema caótico intervenga algún factor que lo desestabilice.

En la atmósfera de nuestro planeta hay considerables cantidades de metano. Por lógica, todo el metano y el oxígeno libres deberían haber entrado en una reacción de combustión. Como Lovelock remarcó, metano, oxígeno, sulfuro, amoníaco y cloruro de metilo están en la atmósfera en diferentes niveles de concentración de lo que podríamos esperar que ocurriera en una probeta. Lo mismo ocurre con el porcentaje de sal del mar. Estas concentraciones aparentemente extrañas resultan ser las óptimas para la supervivencia de la vida sobre la Tierra, es decir, la Tierra se comporta como un ser vivo, con los bosques, los océanos y la atmósfera como sus órganos.

Cuando un automóvil (fruto de la visión mecanicista) se avería, buscamos la parte averiada. Es una parte la que hace que todo el coche deje de comportarse como una unidad (porque por mucho que metamos la llave no arranca). Pero en los sistemas caóticos, como son las familias, las sociedades o los sistemas ecológicos, el problema se desarrolla siempre a partir de todo el sistema, nunca a partir de una "parte" defectuosa. Siempre es necesario tener en cuenta todo el contexto en el que se manifiesta un problema.

El cuerpo humano también es un sistema caótico. Está claro que es imposible predecir el recorrido que una partícula cualquiera tendrá dentro de nuestro cuerpo. También está claro que la medicina todavía no puede hacer una predicción acerca de la evolución del cuerpo de determinado individuo. Sin embargo, el cuerpo humano, a pesar de las

[45] Este último párrafo responde a una visión antropológica que no compartimos, pues el hombre trasciende lo puramente material como es bien sabido.

muy diferentes condiciones externas a que puede estar expuesto (clima, alimento, esfuerzo físico, etc.), siempre mantiene una forma general. Es tan resistente a cambios (dentro de lo que cabe) porque los sistemas caóticos son muy flexibles. Una enfermedad es algo impredecible, pero si el cuerpo no tuviera la libertad de ponerse enfermo, con cualquier cambio producido el sistema se desmoronaría.
Hasta tal punto es flexible dicho sistema, que mantiene una forma más o menos parecida durante más de 70 años, a pesar de que ningún átomo de los que hoy forman nuestro cuerpo era el mismo hace 7 años. La explicación de que un sistema tan impredecible como el cuerpo humano sea tan estable está en que es un atractor extraño y está lleno de atractores extraños. El sistema siempre es atraído hacia un determinado modelo de conducta; si cambiamos algo en el sistema éste vuelve cuanto antes hacia el atractor extraño. Esto no significa que la conducta sea mecánica, todo lo contrario: es impredecible. Sólo sabemos hacia dónde va a tender.

Por ejemplo, en el corazón la conducta atractora es el disparo de una secuencia de neuronas. Conocemos aproximadamente el ritmo que debería tener el corazón, pero éste siempre tiene pequeñas irregularidades. Estas pequeñas alteraciones son una señal de salud del corazón, una muestra del vigor del sistema caótico, que es flexible a los cambios. El caos permite al corazón un abanico de comportamientos (grados de libertad) que le permiten volver a su ritmo normal después de un cambio.

Un organismo sano, animal o vegetal, es un atractor extraño, cada uno con su particular grado de libertad y grado de regularidad.

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2. This excellent article, or assay as their author titles it, can serve for to present the *new vision of* ***CHAOS*** that it is given here:

For simplicity we refer, as we have already exposed, to the trajectory of an only *material point m* . The fact that in general their trajectory is *irreversible* in the frame of the ND, doesn't mean that it is *undetermined* or *uncertain*. Certainly it is very complicated (it is enough to take in consideration that its mass *is no longer constant* as in the CD) because it will be time dependent, $m = m(t)$. To determine and to quantify this variation is impossible because it depends in each instant of the *velocity, acceleration* and *position* of the other bodies interacting with this point mass $m(t)$. This *indetermination* is due to the impossibility of getting information in each instant and position of the particle, but the reality is perfectly *determinist* We don't consider here phenomena that belong to the Relativity or to the Quantum Mechanics that would add bigger complexity to the problem. If we conceive, as it was made by PIERRE SIMON DE LAPLACE, "such an *Intelligence* knowing all the forces that embodies the Nature and the positions an velocities of all the beings that form them, in a given instant", (and we add: the *irreversibility* in the frame of the ND*);* in this case there should be not *indetermination.* This *Being* of such an *Intelligence* the believers call it GOD.

3. In order to continue our exposition we can do a short parenthesis::

As we already saw, the dynamic paradigm of the ND involves the possible ***non conservation*** of the ***angular momentum*** and of the ***linear momentum*** in ***isolated systems,*** impossible thing within the framework of the CD. In this line, the more powerful experimental fact is the flight of the insects in a vacuum of 98.7% equivalent to 10 mb. The ***energy conservation,*** that we have denominated ***First Fundamental Law,*** also is fulfilled in the ND, but it is not as absolute as in DC in those processes in which is created or is destroyed linear momentum. We will explain it with a simple example:

Let us suppose an insect (for example the "Bombus terrestris" as is described in the test) that, departing from the rest, flies in the absence of air and gravity; the movement is with respect to a *referential of inertia* until acquiring a certain speed and kinetic energy, with a straight trajectory in respect to this referential, and stops propulsion after a time interval; its movement will continue rectilinear and uniform, because the insect is isolated and do not act external forces. In this situation we change the *referential* to another one in rest with respect to the insect that reasumes the propulsion in opposed sense, on the same straight line, until reaching the same speed and kinetic energy, and stops the propulsion. Now its movement is rectilinear and uniform with respect to this *second referential* but it is again in rest with respect to *first one;* on the same straight line but not necessarily in the same departure point, although obviously it can reaches this situation. This means that the kinetic energy of going and coming back has disappeared, in evident contradiction with the energy conservation. This fact, although surprising, iit is not so if we thought that we do not know the actual kinetic energy in the Universe, since all the inertial frames are equivalent. An *absolute referential* does not exist (failure of the experience of MICHELSON–MORLEY, etc). Thus this *disappearance of kinetic energy* is not so strange since we do not know its *totality.*

The ND, with the ***irreversibility*** and its capacity to give real sense to the *non conservation* of the *Three Fundamental Laws*–based on the axioms of the CD–, opens a new chapter in the understanding of the Nature. The mathematical expression of the physical phenomena is much more complex, even impossible, notwithstanding with the powerful aid of the modern computers. The **CHAOS** presence in the Cosmos is consequence of this scientific weakness: of mathematical physics that, with its great and undeniable achievements, cannot reach a suitable explanation.

4. ***The order within the chaos,*** that describes very well the preceding study, is not a consequence of the determinism lack but only ignorance. It is caused by the enormous complexity of the problem of a *single body* trajectory, because it is no isolated of external forces. If *two bodies* are interacting the problem is more difficult than in CD; and in the *"simple one of three",* or the case of practically infinite corpses –like in fluids–, then the magnitude of the problem is absolutely inaccessible. Approximate predictions only will be done for a short time interval; it is the case discovered by LORENTZ in meteorology. Order exists, for instance the annual cycles of winter, spring, summer and autumn, but never will be equally repeated; surprising similar phenomena can happen as the presence of new freezing or unpredictable climatic changes, similar to which already happened at past times as it is point out by fossil registries, geologic studies, etc., but never will be repeated as it happens with *"atractors"*; we could affirm the same thing about tides regularity and other natural facts. The presence of *"bifurcations"* in the chaotic phenomena indicates *order* in the middle of **CHAOS** andit is a manifestation that in ND are possible two senses of motion with two different trajectories when the movement is reversed. Only coincide at the return point under the same acting forces. This dual **IRREVERSIBILITY** appear also in many *"atractors"* like the LORENTZ one, the spherical pendulum, etc. The order presence indicates that ***absolute CHAOS does not exist.***.

We mention here, as a complement, other works about the **CHAOS** in Nature whose last cause remains unknown. At the light of the ND it is an immediate result of the appointed dynamic **IRREVERSIBILITY.** We expose them, total or partially, to give direct information about the actual ideas on this important subject.

a) "CAN ORDER COME OUT OF CHAOS?"[46]

"For God is not the author of confusion . . " (I Corinthians 14:33).

"There is a new science abroad in the land-the science of *chaos!* It has spawned a new vocabulary: "fractals," "bifurcation," "the butterfly effect," "strange attractors," and "dissipative structures," among others. Its advocates are even claiming it to be as important as relativity and quantum mechanics in twentieth-century physics. It is also being extended into many scientific fields and even into social studies, economics, and human behavior problems. But as a widely read popularization of chaos studies puts it:

[46] CAN ORDER COME OUT OF CHAOS? by Henry M. Morris and John D. Morris. Institute for Creation Research, PO Box 2667, El Cajon, CA 92021
Voice: (619) 448-0900 FAX: (619) 448-3469 "Vital Articles on Science/Creation" June 1997

Where chaos begins, classical science stops: 1) There are many phenomena which depend on so many variables as to defy description in terms of quantitative mathematics. Yet such systems—things like the turbulent hydraulics of a waterfall—do seem to exhibit some kind of order in their apparently chaotic tumbling, and chaos theory has been developed to try to quantify the order in this chaos. Even very regular linear relationships will eventually become irregular and disorderly, if left to themselves long enough. Thus, an apparently chaotic phenomenon may well represent a breakdown in an originally orderly system, even under the influence of very minute perturbations. This has become known as the "Butterfly Effect." Gleick defines this term as follows: Butterfly Effect: The notion that a butterfly stirring the air in Peking can transform storm systems next month in New York.

2) There is no doubt that small causes can combine with others and contribute to major effects—effects which typically seem to be chaotic. That is, order can easily degenerate into chaos. It is even conceivable that, if one could probe the chaotic milieu deeply enough, he could discern to some extent the previously ordered system from which it originated. Chaos theory is attempting to do just that, and also to find more complex patterns of order in the over-all chaos. These complex patterns are called "fractals," which are defined as "geometrical shapes whose structure is such that magnification by a given factor reproduces the original object. 3) If that definition doesn't adequately clarify the term, try this one: "spatial forms of fractional dimensions." 4) Regardless of how they are defined, examples cited of fractals are said to be numerous from snowflakes to coast lines to star clusters. The discovery that there may still be some underlying order —instead of complete randomness— in chaotic systems is, of course, still perfectly consistent with the laws of thermodynamics. The trouble is that many wishful thinkers in this field have started assuming that chaos can also somehow generate higher order—evolution in particular. This idea is being hailed as the solution to the problem of how the increasing complexity required by evolution could overcome the disorganizing process demanded by entropy. The famous second law of thermodynamics—also called the law of increasing entropy—notes that every system—whether closed or open—at least *tends* to decay. The universe itself is "running down," heading toward an ultimate "heat death," and this has heretofore been an intractable problem for evolutionists…"

b) " IMPLICACIONES DEL CAOS DETERMINISTA EN LA ECONOMÍA Y LA GESTIÓN EMPRESARIAL"[47]

"INTRODUCCIÓN "

"En este trabajo se abordan sobre las implicaciones filosóficas y metodológicas de la teoría del caos y la sensibilidad a las condiciones iniciales sobre el concepto de complejidad, el paradigma científico, el análisis económico y el enfoque para su estudio y la gestión empresarial. La posibilidad de generar comportamientos aparentemente erráticos a partir de sistemas deterministas sencillos ha influido en el desarrollo del significado del vocablo complejidad, pasando de una complejidad cuantitativa tradicional a una complejidad cualitativa, en la que resaltan la importancia de la globalidad, las relaciones no lineales de retroalimentación positiva y las propiedades emergentes. Por último, también se traduciría en las nuevas técnicas a aplicar en la gestión empresarial en un entorno complejo, basadas en la importancia de los conceptos de comportamiento cualitativo, retroalimentación, desorden, globalidad, adaptabilidad, flexibilidad, inestabilidad, endogeneidad, creatividad, aprendizaje, integración y fractalidad.

COMPLEJIDAD Y CAOS

La ciencia del caos y de lo complejo supone uno de los grandes avances en la investigación científica del siglo XX y representa un cambio de enfoque radical en la concepción que existe sobre el poder de la ciencia.

El caos termina con la dicotomía que existía bajo el enfoque determinista tradicional entre determinismo y aleatoriedad[1]. Según este enfoque la incertidumbre proviene de la ignorancia de las diversas causas involucradas en la realización de un evento así como de la complejidad del mismo. Henri Poincaré, ya en sus estudios pioneros en este campo, se dio cuenta de que no son necesarios sistemas

[47] " IMPLICACIONES DEL CAOS DETERMINISTA EN LA ECONOMÍA Y LA GESTIÓN EMPRESARIAL".
Ruth Mateos de Cabo Universidad San Pablo-CEU Elena Olmedo Fernández Universidad de Sevilla

complejos para producir aleatoriedad, según él, esto es debido a lo que se conoce como "sensibilidad a las condiciones iniciales" que origina que un error pequeño en la medición de éstas se convierte en un gran efecto el fenómeno final, de manera que la predicción se convierte en imposible[2].

Alrededor del cambio de siglo, los avances realizados en las ciencias naturales y las matemáticas sembraron serias dudas sobre la validez de la visión mecanicista. Así, mientras el desarrollo de la teoría de la relatividad o de la mecánica cuántica supusieron un desafío para la visión del mundo determinista, el descubrimiento de las propiedades matemáticas de diversos sistemas dinámicos supuso una amenaza para la teoría determinista en sí misma. Se demostró que podían surgir problemas a la hora de predecir la evolución de sistemas dinámicos que son completamente deterministas en el sentido de que en su definición no intervienen elementos estocásticos.

Una consecuencia inmediata de los resultados obtenidos en el estudio de los sistemas dinámicos no lineales consiste en la necesidad de una revisión de la distinción popperiana entre determinismo científico y teorías deterministas[3]. Este concepto de teoría determinista está basado en las propiedades matemáticas de sistemas dinámicos básicamente lineales. Cuando aparecen en escena sistemas dinámicos no lineales que no poseen la propiedad de predecibilidad conocida a partir de los sistemas deterministas lineales, las teorías deterministas tienen que ser diferenciadas de acuerdo con su posible resultado. Dichas teorías pueden comportarse de la forma descrita en el esquema popperiano y puesto que su funcionamiento no difiere esencialmente de los sistemas lineales, pueden denominarse sistemas dinámicos cuasi-lineales. Sin embargo, no debe olvidarse que existen teorías deterministas que se comportan de una forma aleatoria, apareciendo así los conocidos como sistemas no lineales caóticos.

La teoría del caos, cuya principal aportación es, como se ha visto, que proporciona un medio para producir un origen determinista para un proceso estocástico, añadiendo a las variables aleatorias otra posible fuente de azar, presenta dos aspectos que han recibido un interés creciente en las últimas décadas:

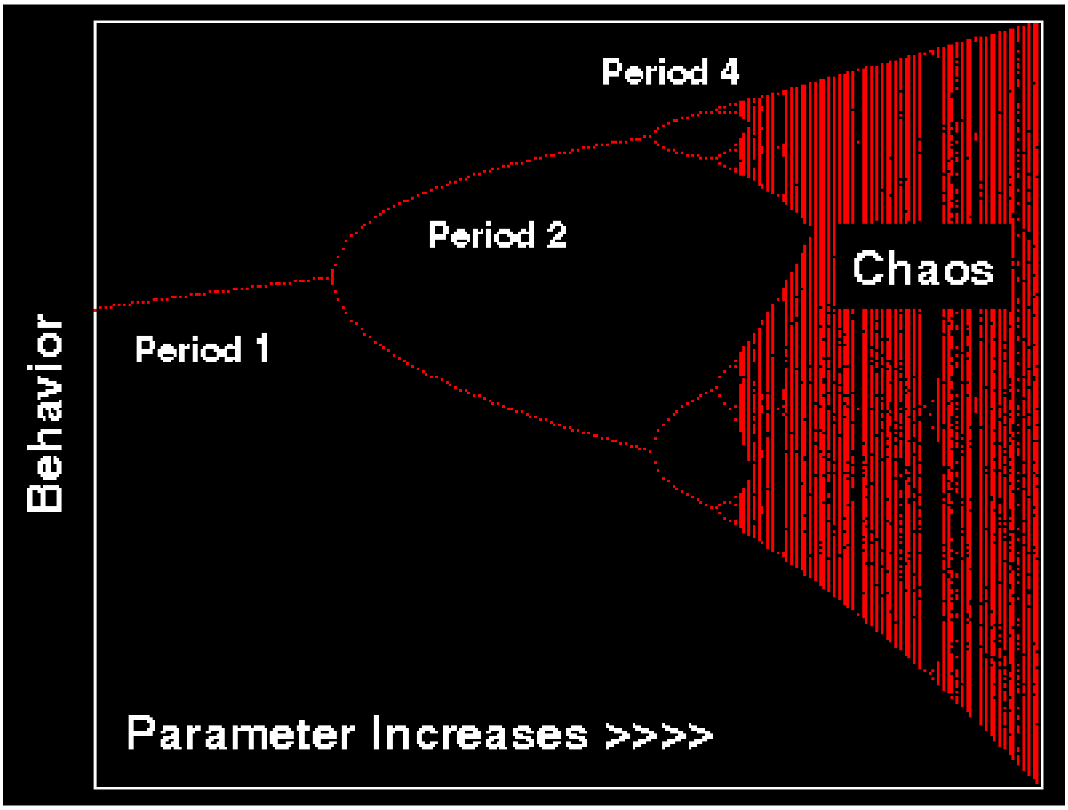
El comportamiento caótico puede ser extraño, pero no es raro, de ahí su aplicación a disciplinas tan diversas como la física, la química, la meteorología, la biología, la epidemiología y la medicina.

· El caos en una clase creciente de sistemas dinámicos puede ser descrito a través de un número relativamente pequeño de objetos matemáticos y se han descubierto ciertas propiedades universales que no parecen depender del sistema específico bajo estudio.

Por lo tanto, la teoría del caos, desde el comienzo tuvo un carácter interdisciplinario muy marcado, aunque su naturaleza universal se haya exagerado en ocasiones…"

[1] Prigogine, I. (1997): *El fin de las certidumbres*; Taurus, pag. 217.
[2] Poincaré, H. (1952): *Science and Method*; Dover Publications, pag. 76.
[3] Popper, K:R. (1994): *El universo abierto*; Tecnos, pag. 59.

c) " BIFURCATION" (1)[48]



"Roughly speaking, a bifurcation is a qualitative change in an attractor's structure as a control parameter is smoothly varied. For example, a simple equilibrium, or fixed point attractor, might give way to a periodic oscillation as the stress on a system increases.

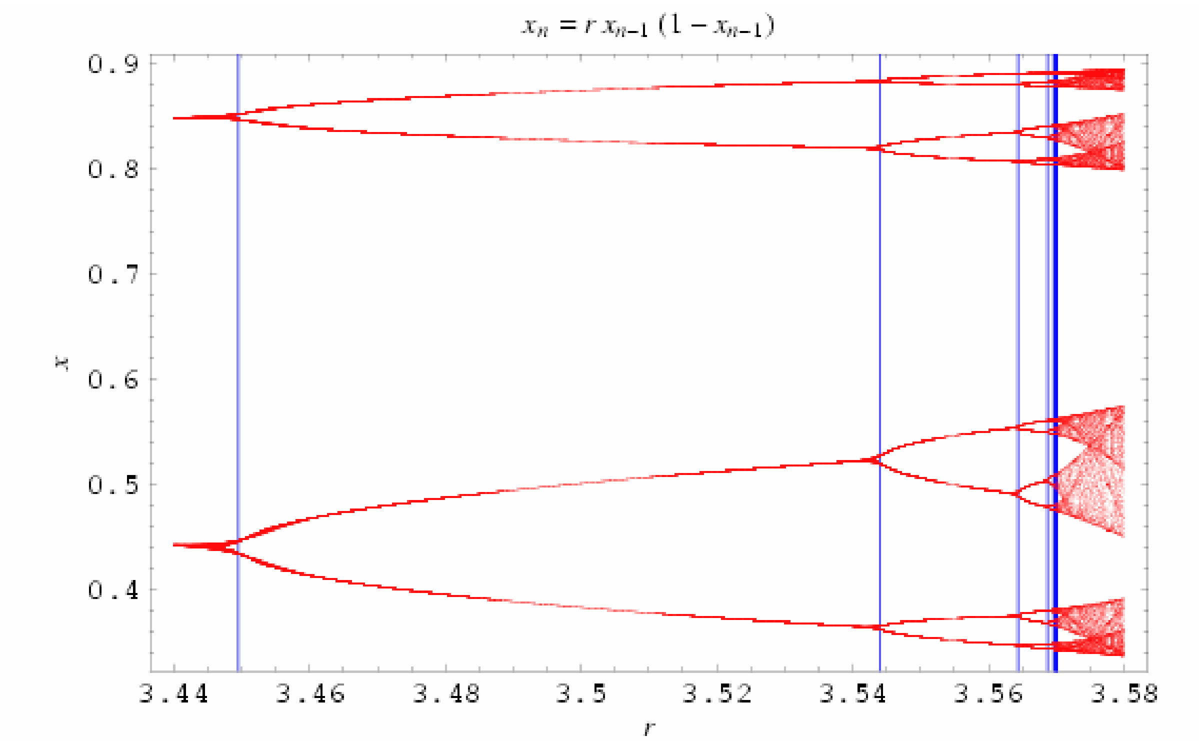
[48] Exhibits || CompLexicon || Timeline. © The Exploratorium, 1996

Similarly, a periodic attractor might become unstable and be replaced by a chaotic attractor.

In Benard convection, to take a real world example, heat from the surface of the earth simply conducts its way to the top of the atmosphere until the rate of heat generation at the surface of the earth gets too high. At this point heat conduction breaks down and bodily motion of the air (wind!) sets in. The atmosphere develops pairs of convection cells, one rotating left and the other rotating right.

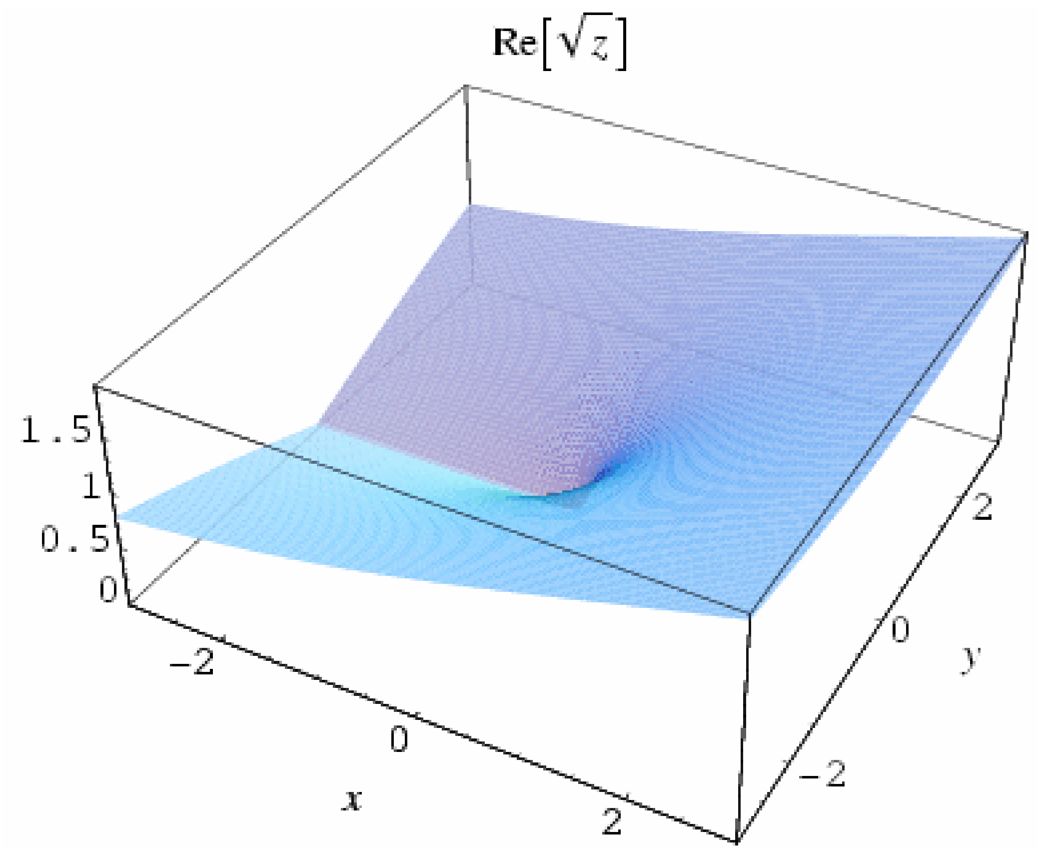
In a dripping faucet at low pressure, drops come off the faucet with equal timing between them. As the pressure is increased the drops begin to fall with two drops falling close together, then a longer wait, then two drops falling close together again. In this case, a simple periodic process has given way to a periodic process with twice the period, a process described as "period doubling". If the flow rate of water through the faucet is increased further, often an irregular dripping is found and the behaviour can become chaotic…"

d) " BIFURCATION" [49] (2)



[49] Weisstein, Eric W. "Bifurcation." From *MathWorld*--A Wolfram Web Resource. http://mathworld.wolfram.com/Bifurcation.html
© 1999 CRC Press LLC, © 1999-2006 Wolfram Research, Inc.

"In a dynamical system, a bifurcation is a period doubling, quadrupling, etc., that accompanies the onset of chaos. It represents the sudden appearance of a qualitatively different solution for a nonlinear system as some parameter is varied. The illustration above shows bifurcations (occurring at the location of the blue lines) of the logistic map as the parameter is varied. Bifurcations come in four basic varieties: flip bifurcation, fold bifurcation, pitchfork bifurcation, and transcritical bifurcation (Rasband 1990).



More generally, a bifurcation is a separation of a structure into two branches or parts. For example, in the plot above, the function $\mathbb{R}\left[\sqrt{z^2}\right]$

where $\mathbb{R}[z]$ denotes the real part, exhibits a bifurcation along the

negative real axis $x = \mathbb{R}[z] < 0$ and $y = \mathbb{I}[z] = 0$

SEE ALSO: Branch, Codimension, Feigenbaum Constant, Feigenbaum Function, Flip Bifurcation, Hopf Bifurcation, Logistic Map, Period Doubling, Pitchfork Bifurcation, Tangent Bifurcation, Transcritical Bifurcation. [Pages Linking Here] "·

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e) "SCIENCE OF CHAOS OR CHAOS IN SCIENCE"

Physicali agazine, 17, (1995) 3-4, pp.159-208*a M*[50]

(For our pourpose we quote here only part of this important study of Jean Bricmont).

"Chaos and determinism: Defending Laplace."

The concept of dog does not bark.
B. Spinoza

…

"Determinism and predictability."

"A major scientific development in recent decades has been popularized under the name of “chaos”. It is widely believed that this implies a fundamental philosophical or conceptual revolution. In

[50] Jean Bricmont Physique Théorique, UCL, B-1348 Louvain-la-Neuve, Belgium

particular, it is thought that the classical world-view brilliantly expressed by Laplace in his “Philosophical Essay on Probabilities” has to be rejected <4>. Determinism is no longer defensible. I think this is based on a serious confusion between *determinism* and *predictability*. I will start by underlining the difference between the two concepts. Then, it will be clear that what goes under the name of “chaos” is a major scientific progress but does not have the radical philosophical implications that are sometimes attributed to it.

In a nutshell, determinism has to do with how Nature behaves, and predictability is related to what we, human beings, are able to observe, analyse and compute. It is easy to illustrate the necessity for such a distinction. Suppose we consider a perfectly regular, deterministic *and* predictable mechanism, like a clock, but put it on the top of a mountain, or in a locked drawer, so that its state (its initial conditions) become inaccessible to us. This renders the system trivially unpredictable, yet it seems difficult to claim that it becomes non-deterministic <5>. Or consider a pendulum: when there is no external force, it is deterministic and predictable. If one applies to it a periodic forcing, it may become unpredictable. Does it cease to be deterministic?

In other words, anybody who admits that *some* physical phenomena obey deterministic laws must also admit that some physical phenomena, although deterministic, are not predictable, possibly for “accidental” reasons. So, a distinction must be made <6>. But, once this is admitted, how does one show that *any* unpredictable system is *truly* non-deterministic, and that the lack of predictability is not merely due to some limitation of our abilities? We can never infer indeterminism from our ignorance alone.

Now, what does one mean exactly by determinism? Maybe the best way to explain it is to go back to Laplace : “ Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it- an intelligence sufficiently vast to submit these data to analysis- it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present before its eyes.” The idea expressed by Laplace is that determinism depends on what the laws of nature are. G ven the state of the system at some time, we have a formula (a differential equation, or a map) that gives in principle the state of the system at a later time. To obtain predictability, one has to be able to measure the present state of the system with enough precision, and to compute with the given formula (to solve the equations of motion). Note that there exist alternatives to determinism: there could be no law at all; or the laws could be stochastic: the state at a given time (even if it is known in every conceivable detail) would determine only a probability distribution for the state at a later time.

How do we know whether determinism is true, i.e. whether nature obeys deterministic laws? This is a very complicated issue. Any serious discussion of it must be based on an analysis of the fundamental laws, hence of quantum mechanics, and I do not want to enter this debate here <7>. Let me just say that it is conceivable that we shall obtain, some day, a complete set of fundamental physical laws (like the law of universal gravitation in the time of Laplace), and then, we shall see whether these laws are deterministic or not <8>. Any discussion of determinism outside of the framework of the fundamental laws is useless <9>. All I want to stress here is that the existence of chaotic dynamical systems does not affect *in any way* this discussion. What are chaotic systems? The simplest way to define them is through sensitivity to initial conditions. This means that, for any initial condition of the system, there is some other initial condition, arbitrarily close to the first one so that, if we wait long enough, the two systems will be markedly different <10>. In other words, an arbitrarily small error on the initial conditions makes itself felt after a long enough time. Chaotic dynamical systems are of course unpredictable in practice, at least for long enough times <11>, since there will always be some error in our measurement of the initial conditions. But this does not have any impact on our discussion of determinism, since we are assuming from the beginning that the system obeys some deterministic law. It is only by analysing this deterministic system that one shows that a small error in the initial conditions may lead to a large error after some time. If the system did not obey any law, or if it followed a stochastic law, then the situation would be very different. For a stochastic law, two systems with the *same* initial condition could be in two very different states after a short time <12>.

It is interesting to note that the notion that small causes can have big effects (in a perfectly deterministic universe) is not new at all. Maxwell wrote: “There is a maxim which is often quoted, that ‘The same causes will always produce the same effects’ ”. After discussing the meaning of this principle, he adds: “There is another maxim which must not be confounded with that quoted at the beginning of this article, which asserts ‘That like cause produce like effects.’ This is only true when small variations in the initial circumstances produce only small variations in the final state of the system” <13>. One should not conclude from these quotations <14> that there is nothing new under the sun. A lot more is known about dynamical systems than in the time of Poincaré. But, the general idea that not everything is predictable, even in a deterministic universe, has been known for centuries. Even Laplace emphasized this point: after formulating universal determinism, he stresses that we shall always remain “infinitely distant” from the intelligence that he just introduced. After all, why is this determinism stated in a book on *probabilities*? The reason is obvious: for Laplace, probabilities lead to rational inferences in situations of incomplete knowledge (I'll come back below to this view of probabilities). So he is assuming from the beginning that our knowledge is incomplete, and that we shall never be able to *predict* everything. It is a complete mistake to attribute to some “Laplacian dream” the idea of perfect predictability <15>. But Laplace does not commit what E. T. Jaynes calls the “Mind Projection Fallacy”: “We are all under an ego-driven temptation to project our private thoughts out onto the real world, by supposing that the creations of one's own imagination are real properties of Nature, or that one's own ignorance signifies some kind of indecision on the part of Nature” <16>. As we shall see, this is a most common error. But, whether we like it or not, the concept of dog does not bark, and we have to carefully distinguish between our representation of the world and the world itself.

Let us now see why the existence of chaotic dynamical systems in fact supports universal determinism rather than contradicts it <17>. Suppose for a moment that no classical mechanical system can behave chaotically. That is, suppose we have a theorem saying that any such system must eventually behave in a periodic fashion <18>. It is not completely obvious what the conclusion would be, but certainly *that* would be an embarassment for the classical world-view. Indeed, so many physical systems seem to behave in a non-periodic fashion that one would be tempted to conclude that classical mechanics cannot adequately describe those systems. One might suggest that there must be an inherent indeterminism in the basic laws of nature. Of course, other replies would be possible: for example, the period of those classical motions might be enormously long. But it is useless to speculate on this fiction since we know that chaotic behaviour is compatible with a deterministic dynamics. The only point of this story is to stress that deterministic chaos increases the explanatory power of deterministic assumptions, and therefore, according to normal scientific practice, *strengthens* those assumptions. And, if we did not know about quantum mechanics, the recent discoveries about chaos would not force us to change a single word of what Laplace wrote <19>."

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f) "Chaos Theory : On a disorderly note[51]

"A glimpse into the orderly world of disorder - a study of the **chaos theory.** *The flapping of a single butterfly's wing today produces a tiny change in the state of the atmosphere. Over a period of time, what the atmosphere actually does diverges from what it*

[51] By Anirban Ray Choudhury. Published: 5/24/2004:
"BUZZLE.COM" Intelligent Life on the web".
" Home World News Article Directory Escape Hatch Message Boards Free eCards Lo"

would have done. So, in a month's time, a tornado that would have devastated the Indonesian coast doesn't happen...

Ian Stewart

Sounds too much like the insane ramblings of a lunatic, does it not? Well, my friend, welcome to the world of Chaos, a world where order is a tailor-made creation of disorder.

The Chaotic Universe

To understand Chaos, let us first begin with Linear and non-linear systems. Linear systems, simply defined, are a set of repetitive events where the principal event is the sum of the secondary events, all the secondary events following a linear relationship. Periodicity is the most important factor in establishing a linear system. Take, for example, the motion of a bicycle. The forward motion of the vehicle is determined by the circular movement of its wheels, which is periodic in nature (i.e., any given point on the wheel would rest on the surface of the road at periodic intervals).

A non-linear or chaotic system, on the other hand, is a set of non-linear, non repetitive events resulting in the principal event which is not predictable as the sum of the individual events. In other words, chaos is the randomness originating from sensitivity to initial conditions. For example, let us consider a long queue of bicycles parked next to each other, the last bicycle being parked against a, say, explosive detonator. Now, if there is a piece of brick lying say a foot away from the first bicycle upon which John happens to stumble, the result would follow a sequence of events as shown below: The first◊ falls on the first bicycle ◊ John Stumbles on the brick the last bicycle lands on ◊ ◊ ◊ ◊ bicycle topples over onto the second bicycle there is an explosion five hundred metres away.◊the detonator Now, we can see from the above example that while there is seemingly no relationship between a brickbat and an explosion a few hundred metres away from it, if we rollback for n number of iterations, we find that a chain of events interlinks the two. With a little imagination, the example can be stretched to the theory of chaos which states that any uncertainty in the initial state of a given system would give rise to rapidly growing errors in the effort to predict the future behaviour - (Gollub and Solomon). And when we speak of the butterfly calming flapping its wings, we are actually speaking of tiny errors being inserted into the wind flow at the point of origin, which would gradually avalanche into a much larger error, causing a tornado somewhere that was not supposed to happen at all had the weather stuck to its initial state of motion.

The Initial Steps

The first signs of thinking in "chaotic" terms were observed way back in 1900, when **Henri Poincaré** came up with the idea that in case of three bodies in mutual gravitational attraction, there can be orbits which are not periodic, though not perpetually expanding or contracting. In 1961, a meteorologist by the name of **Edward Lorenz** came to realize that seemingly minuscule events may have a large bearing on subsequent events, i.e., there need not be a linear relationship between two events affecting one another. While experimenting with a twelve equation model of the weather, Lorenz observed that the same set of data yielded surprisingly dissimilar results depending upon the number of digits in use after a decimal point. After further observations, Lorenz concluded that it was impossible to predict the weather with accuracy even though the seasons followed an order. Encouraged by the uniqueness of the results, Lorenz then proceeded to analyze the behaviour of convection currents, and after making several observations with varied data sets, he developed a three equation model for the water wheel. On proceeding to graph the observations, Lorenz observed that the curve maintained the shape of a double spiral. This was a surprising discovery indeed, inasmuch that the curve deviated from the principles of the two known order states – the steady state and the state of periodic behaviour (where the system indefinitely repeats itself). While his curve was ordered, it was neither in a steady state nor repetitive (and therefore not in periodic motion).

Thus began the Theory of Chaos. Lorenz proceeded to write a paper on his discovery, but failed to cause much stir in the scientific community – the class bias that persisted in those days did not encourage the idea of treating a meteorologist as a mathematician!

The Mathematician & His Fractals

Benoit Mandelbrot, a mathematician working with IBM, was studying the fluctuations in cotton prices, when he observed that whatever be the mode of analyzing the data on the prices, the results invariably refused to fit into a normal distribution, even though they fit perfectly into trend models. Thus, although each price change was random and unpredictable, a scaled up graph of the price changes showed that there were surprising similarities between the daily and monthly price variation trends, regardless of the fact that the period over which the data had been accumulated had seen two world wars and a depression. His observations led to the conclusion that there was a scaled down self duplication as the reference frame grew smaller; i.e.; there is order hidden within chaos and vice-versa. It was the study of this non-periodic self similarity that gave rise to the idea of fractal dimensions.

Fractal Dimensions

A fractal is simply any image that has the attribute of self similarity. Though nearly impossible to conceive, a fractal dimension is easy to understand. Take for example **Koch**'s Curve which is nothing but equilateral triangles being added on to each side of another equilateral triangle, the process being repeated an infinite number of times. The result is a star like formation with infinite number of star like arms which in turn nest an infinite number of star formations and so on. Owing to this crinkly, star like formation, a Koch curve takes up a lot more space than a one dimensional line. At the same time, since it does not have an area (area being a two-dimensional concept), it is not as effective in filling up space as a rectangle or a square. Therefore, the dimension of a Koch curve fractal lies somewhere between one and two.

But why does a fractal have to exist? What is it that creates a fractal? Well, at the core of all chaotic motion there are strange attractors - attractors that form the "nucleus" of the motion curve. When a complex dynamical chaotic system because unstable, these attractors draw the stress and the system splits. This is called bifurcation. In Lorenz's tri-equation formula for the curve of a water wheel's motion, the spiral distribution of the motion has a narrow base which fans out towards the exterior and then again contracts back towards the centre. The attractors, known as Lorenz attractors, split the stress of the motion in two directions. Actually, it is these attractors that cause order to be maintained in chaotic motion – without them there would be an unbounded state, that is, the motion curve would be forever expanding.

The Chaotic Contributions

Okay, so we now have a reasonable picture of the properties of a chaotic system; it is bounded, sensitive to initial conditions, transitive, and is aperiodic. But how does it aid the advancement of science, or for that matter, mankind?

Before the advent of the theory of chaos, the consensus of the scientific community was that if the uncertainty in initial conditions could be marginalized, the uncertainty in the final conditions would shrink proportionately. Chaos theory has shaken the fundamentals of this belief to the core, meaning that probably nothing is sacrosanct anymore. This has also opened up a whole new way of looking at systems – a degree of dynamism has been introduced to what was earlier considered static.

There are several ways in which science can benefit with a proper understanding of chaos. For example, in any living being, the genetic code defines the species, the structure and the identity of an individual. However, while the function of the gene code is understood, it is not known as to how the basic building blocks, i.e, DNA, distribute the information required to create a complex organism. The chaos theory could perhaps hold the key to this query. Again, while earlier all systems were considered as non-chaotic, thereby leading to the possibility of fatal errors of judgement, now we can distinguish between chaotic and non-chaotic systems. The theory can also explain the turbulence in fluid motion and non-periodic oscillations in radio circuits. The fractal nature of blood vessels can also be studied, thanks to chaos.

While a lot of work has already been done in this field, there remains many a dark corner which is yet to be explored – theories such as the one of Chaos lead the way towards the ultimate aim of mankind – the understanding of everything."

5. We finished here our exposition in which a series of investigations, made during an ample time interval, has lead us to the present etiogénesis of the ***CHAOS,*** subject that has occupied eminent scientists in very diverse areas of the knowledge. Already it has been alluded to the "arrow of the time" of EDDINGTON, in which the attempts of explanation go back mainly to the remote antiquity of ARISTOTLE and TOMÁS OFAQUINO in the Middle Age: "Time is the measurement of the movement *("numerus motus") "according to before and later".* For the existence of this *"accident of the substance"* it is necessary that t*he matter should be in motion and in addition that this movement should be irreversible,* otherwise it does not have sense the connotation *"according to before and later".* The ND, whose departure point is the discovery that the trajectories –departing from the described by a material point– are generally ***IRREVERSIBLE,*** has allowed us to give a more unitary vision of the ***COSMOS.***

CHAPTER V

EXPERIMENTAL TESTS

Inseparable to the creation of the theoretical framework that has been put forward here, a series of experimental tests have been carried out that confirm it and have served also to overcome many important stumbling-blocks which would otherwise have been very difficult and even impossible to deal with. The most significant of these tests are summarized ihere. Further explantations and details will be given in this chapter corresponding to the experimental research.

1. ***Non-aerodynamic lift in flying insects.*** This test was carried out for the first time in 1977 in the laboratory of the Pharmacy Faculty at the University of Navarra, Pamplona. Experiments were made using hymenoptera: *bombus terrestris* and with diptera: *calliphora vomitoria,* at a pressure of *13 mb* corresponding to the partial pressure of water vapour at $15^o\ C$. The water vapour cannot be eliminated without using a vacuum pump of the type known as a "water trunk", otherwise the insect becomes greatly deformed and cannot fly. In this rarefied fluid (*98.5%* of normal atmospheric pressure: *1013 mb*) they fly perfectly for over *1–2 minutes* , even *hovering*, without any noticeable difference in their lift and manoeuvrability.

This study was registered in 1977. Since then it has been repeated several times by different people; always with the same results. At the end of this chapter our article in "Scientific American" appears in complete form, describing how this experimental test is performed.

2. ***Rotative mechanical system which destroys angular momentum*** related to a fixed vertical axis with negligible friction, violating the law of conservation. Registered in 1984. This extremely simple mechanism is comprised of a disc, of mass M , that rotates around vertical axis, to which an elastic vertical rod is fixed; at one end of this rod is attached another mass $m < M$ oscillating with it and rotating with the disc. The system comes to stop after a few rotations leaving only the oscillation of mass m on a vertical plane. The inital angular momentum in relation to the axis has disappeared. The initial kinetic energy has been transferred to the oscillating mass m. (See development and squemes in pp. 120-123)

3. ***Rotative mechanical system which creates or destroys angular momentum*** starting out from initial rest, or modifying that it had until a steady rotation is obtained with the initial angular momentum increasing or decreasing with respect to the vertical axis of rotation. This device consists of a disc of mass M which can rotate in relation to its vertical axis with negligible friction; an electric motor is attached in it (whose mass is included in M) with vertical axis parallel to the other one. This motor moves, eccentrically, a mass $m < M$ by means of a horizontal arm. The battery *(4.5 V)* is also fixed to the disk (and its mass is also included in M). This experiment was carried out for the first time and registered in 1984. (see a more detailed description in pp. 124-125)

4. ***Rotative motor without a crankshaft nor connecting rods,*** based on the transformation of energy from a piston into its corresponding cylinder, without having recourse to a connecting rod-crank mechanism or similar. Two different models have been built. Barcelona, 1989.

5. ***Non-reactive lineal propulsor.*** It is based on the fact that $m = m(t)$ in this ND and on the "uncoupling" of forces by means of kinetic energy dissipation, by friction, between two masses of the system (it must be formed by a minimum of *three*). A number of models were constructed, based on possibilities opened up by ND, but always with negative results. In May 1988 we discovered by experimentation that part of the system kinetic energy in must be *dissipated* in order to undo the *"coupling"* of forces described by ND. In this way we managed to obtain a *not null resultant of force;* this possibility is corroborated by theory since these forces depend on the velocity of each mass of the system. Supposing that the non-reactive lineal propellent (LPWR) is made up of *three masses* m_1, m_2, m_3, which interact on the same straight trajectory by means of potential and kinetic energy. Additiona to the forces of acceleration, anticipated by CD and whose resultant is null, there should also appear, in this particular case, the forces anticipated by ND:

$$(1/2)\sum(dm_i/dt)v_i\mathbf{s} \qquad (42)$$

where $\boldsymbol{s}$ is a *versor* according to the common straight line of action. Due to "coupling" fenomenon this resultant is also null because no propulsion is observed at all; nonetheless, by dissipating kinetic energy through reciprocal friction between *two* of the *masses,* their respective velocities will vary but this will not necessarily affect the velocity of the *third mass* (or it will do so in a very different proportion); thus the *resultant* (42) will no longer be null: the forces of ND have been "uncoupled" and this LPWR is possible. This fundamental discovery enabled the difficulties to be overcome. Since then, increasingly efficient machines have been built; the latest are very recent (1993) and run with batteries *(3 V)* and small electric motors; they reach speeds of between *15* and *40 m/min*. over *one* of the *two reciprocal dissipation masses* which completes the system. It can be clearly observed –by means of a suitable device that isolates the *total system*– that there is no reaction; in other words: t*lineal momentum is created*. Flying insects' propulsion and lift are derived from what is anticipated in this ND. In the next section we shall talk about the state of investigation on insect flight, reported in an article of ours whose final conclusions will be included here.

6. *Conclusions and physical applications* of ND:

a) The logical process of explanation leads us to conclusions and to ways in which the principles and theoretical laws which have been established can be applied. Nevertheless, creativity, research and synthesis sometimes follow a different path. This is what has happened in this study, so that this chapter corresponds, at least in part, to a series of experimental facts that led to the theoretical analysis of the principles and laws which govern them.

The *laws of conservation* in CD account for the majority of common processes, at least with sufficient approximation (for example: the movement of planets and their satellites) and other factors such as friction, viscosity, turbulence, etc., disguise the problem when the effects deduced from the preceding theoretical speculations should be taken into account. In our opinion this is the reason why the *Three Fundamental Laws* of Dynamics that we have expounded here were not formulated much earlier.

Aristotelian and Thomist Metaphysics called for a greater consideration and appreciation of the qualitative aspects of the Cosmos – and in particular of Dynamics– which could only be supplied by asserting that the *essence* of things in themselves were accessible and objective.

"Transcendental metaphysics"– which I would rather call pseudo-metaphysics– takes us away from the World and, as a result, only helps us to penetrate more deeply into the knowledge derived from laws and qualities which we already know, yet –strictly speaking– "solutions can be lost" if we do not take into account some qualities of the thing in itself, which do not necessarily have to provide us with models of reality based on immanent apriorities.

b) In one of our first recorded studies, we came to the conclusion –in a completely heuristic way and not without error, since we knew nothing at that time of ND– that it was possible to cheat the laws of conservation of *angular momentum* and *lineal momentum* in a closed, unbound system. In ND, as we mentioned earlier, it is easy to construct systems which do not conserve angular momentum; so as not to conserve the lineal momentum, as has already been pointed out, there must be *dissipation* of kinetic energy by *radiation* in order to *uncouple* the forces acting on the system; otherwise its resultant is null and this "propulsion without reaction" is impossible.

This made us think that there might be living beings in Nature whose movement would be based on the *Three Fundamental Laws* of ND. The most obvious answer is, we believe, in the flight of the majority of insects, whose wingbeats reach very high frequencies, with an extremely low number of REYNOLDS, which excludes lift based on aerodynamics as we know it. In the next section we shall cite some examples and assertions on this matter, taken from the most recently published studies.

c) In the diminutive insect *Haplothrips verbasci*, it can be observed that its two pairs of "wings" are nothing more than beating bars, approximately elliptic, with extremely fine and very flexible cilia, which cannot act as a surface for lift but must rather serve –in our opinion– to avoid air resistance by making the laminae more effective; the extremely rapid oscillation of the wing-bars would be less efficient if turbulence were produced. In the section on "discussion and suggestions" of one of these studies it is asserted: "Ignorance of the details about the mechanism of flight, at such a low number of REYNOLDS, points out the need for extensive observation, during flight, in order to determine the movement of the wing-bars and the cilia, and also the need for further study of these details with the electronic microscope, and also for measurements designed to determine the physical properties of the group of cilia..." Another study ends with the following words: "therefore, it must be concluded that there is little reliable information about the aerodynamic forces generated by wingbeating and that the problem must be studied further". And in the publication "Scientific American", an article about unusual lift in certain insects, asserts: "The most important aspect, (the lift of) those insects and other flying creatures which I have discussed, depends largely on aerodynamic effects which are not stationary, and hitherto unknown, which for them are useful and not a hindrance, as they would be for man-made aeroplanes".

Clearly there is still a great deal of ignorance about insect flight and lift. If what has been expounded here and the experimental tests which were carried out are not mistaken, the explanation is clear and simple in the framework of ND put forward here: they would fly even in the absence of atmosphere or, at least, a good part of their lift and manoeuvrability is derived from forces, which do not exist in CD, but are dealt with in ND; air acts fundamentally to make respiration possible.

Nota bene:

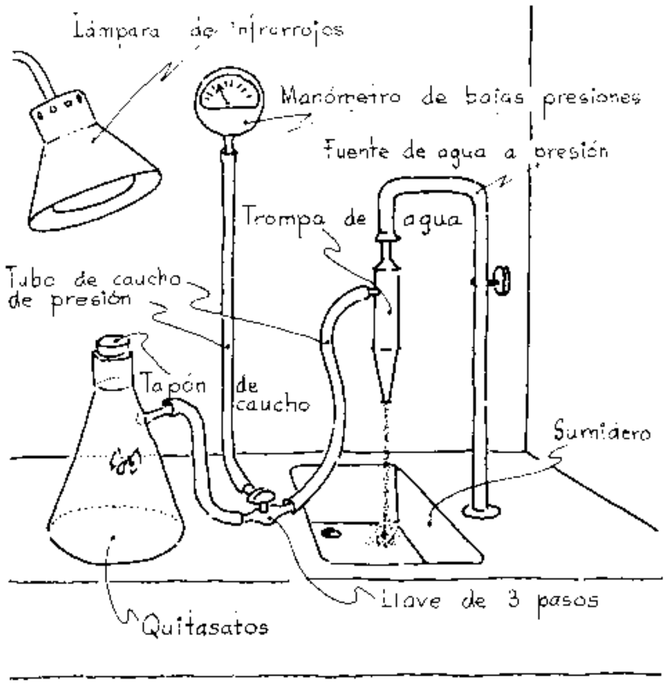
This study is, as pointed out in the Introduction, a second, revised edition of the 1976 publication. The most recent investigation on the subject of insect flight has progressed very little since 1975. We may point out here that in May 1977, after this article was published, tests were carried out on insects (Hymenoptera: *Bombus terrestris* and Diptera: *Calliphora vomitoria*) which were made to fly in a rarefied atmosphere (*13 mb*, equivalent to *98.7%* of normal atmospheric pressure: *1013 mb*). This experiment has been repeated several times since then. See our small article: *The flight of the bumblebee*, in "Investigación y Ciencia", February 1986, page 41.

An interesting article appears in the magazine "Nature", Vol. 344, 5 April 1990: *Unconventional aerodynamics* by ROLAND ENNOS, who gives a clear explanation of the problems of the most recent investigation. By way of illustration we have selected some extracts: "More evidence has appeared showing that insects fly by mechanisms quite unlike those used by aeroplanes and helicopters. ZANKER and GOTZ have measured the instantaneous forces produced by tethered *Drosophila melanogaster* flies and find that they cannot be explained by conventional aerodynamic theory. The forces are also evidence that these flies have unusual methods for producing lift... Studies over the past twenty years of the aerodynamics of insects in free flight have usually concluded that the forces resulting from a conventional lift mechanism would not be adequate to support or propel the insect, and this has been verified by the results of ZANKER and GOTZ..." and he finishes the article by saying: "Their results have two important implications. Firstly, it is clear that to solve the problem of how insects control their flight will be extremely difficult; even if we discover exactly how the large numbers of direct flight muscles control the fine details of wing movement, we will not be able to solve this problem until we have a better understanding of unsteady aerodynamics. Secondly, studies of the aerodynamics of aerofoils in unsteady motion are urgently needed. Such investigation might not only clarify how animals fly, but would help us to improve our own aerodynamic designs; insects and birds are, after all, far more manoeuvrable than helicopters and aeroplanes."

7. ***The flight of the bumblebee.*** An article published in "Investigación y Ciencia", February 1986. This study is transcribed in full here below, together with the corresponding illustration (see Fig. 3):
SIKORSKY, the famous aeronautic designer, ordered this notice to be hung up in the lobby of his technical office: "the bumblebee, according to our engineers' calculations, cannot fly at all, but the bumblebee does not know this and flies". There are quite a number of studies about insect flight and all of them come up against enormous difficulties when they try to explain the mechanisms of lift through the dynamics of stationary fluids. Let us take a look at some examples.

TORKEL WEISS-FOGH wrote eleven years ago (in 1975) in *Scientific American* that: "the most important aspect (lift) of these insects and other flying creatures depends largely on aerodynamic effects which are not stationary, and hitherto unknown, which for them are useful and not a hindrance as they would be for man-made aeroplanes". In another study, on the subject of *Haplothrips verbasci,* ARNOLD M. KUETHE said something similar: "Ignorance of the details about the mechanism of flight, at such a low number of REYNOLDS, shows the need for extensive observations during flight in order to determine the movement of the wing-bars and of the cilia and, likewise, the need to penetrate more deeply in the study of these details using the electronic microscope, and also measurements designed to determine the properties of the group of cilia..."
We could add a great deal more evidence. The reader will find the problem dealt with clearly in the article by JOEL G. KINGSOLVER published in these same pages about the engineering of butterflies (October 1985). Amongst other things he described the difficulties found in complex insect flight, many of them insuperable, having recourse once more to TORKEL WEIS-FOGH's hypotheses.

For some years I have been investigating, empirically and theoretically, a new approach to dynamics of which Classical Dynamics would be a restricted part. Amongst other things it opens up the possibility that propulsion and lift exist even in the absence of atmosphere. How can insect flight be explained, from the dynamic point of view? Evidently it is not reasonable in the framework of Newtonian dynamics in which the conservation of lineal momentum, in an isolated system, excludes this type of lift and propulsion.



Vuelo del insecto en el vacío. Montaje del experimento.

(Fig.3)

In the field of cosmology the insufficiencies of Newtonian mechanical theories in their fundamental axioms were detected many years ago. Thus, the "first principle" asserts that an isolated material point (or system) follows a straight trajectory with a constant velocity; but the movement must be related to some inertial coordinated axes, external to the particle (or system) in question, which means that the isolation which is postulated is questionable, since it leads us to the contradiction that an isolated system has the property of not being isolated. This is the "weakest point of the magnificent edifice of Newtonian mechanics" (P. HOENEN, 1948). This *First Principle* must be rectified asserting that *there are not inertially isolated systems*.

With this new starting point, together with the axiom of energy conservation, this new dynamics began to take form beginning with the simplest case in which the potential energy is conservative, to generalize it, in a second step, to the non-conservative case. It leads us to the surprising result that in addition to the Newtonian forces of inertia, which only consist of the accelerations of particles and their respective masses, there are in fact other forces of inertia –hitherto unknown– which also include the velocity of particles, whose mass may behave as non-constant in the non-conservative case. These forces are isomorphic with "LORENTZ's forces" of electromagnetism, whose origin is purely empirical.

In the conservative case, the particle is affected by only one other force in addition to the classical ones: we have called it the *force of drag,* which is superimposed on the Newtonian one and is normal to the trajectory; it has the quality of changing sign when the physical point reverses the sense in which it is moving on the trajectory. We have an example in HALLEY's comet, which could be asymmetric when it passes through the perihelion, that is to say, the ingoing arc might not be identical to the outgoing one.

Passing on to empirical observation, we can use the bumblebee, *Bombus terrestris*, as an experimental source. The equipment I used to observe the "abnormal" lift of the insect in a vacuum consisted of a vacuum pump, a glass container, a triple stopcock and a pressure gauge (see the adjoining illustration). The vacuum pump must be one of the kind known as "water trunk", used as a filter in chemistry laboratories. No other kind of pump must be used for a very simple reason: it is vital to maintain the partial pressure of the water vapour at room temperature, so that the insect does not swell up or become otherwise deformed, as would happen if we used a different type of pump, even if the vacuum obtained were greater. Moreover, it is so quick and effective that the insect remains active in the vacuum for a maximum of one or two minutes. At a room temperature of *15 degrees* CELSIUS, a vacuum of *10 tor (13 mb)* is obtained, which compared with the normal value of atmospheric pressure *(1013 mb)* implies a vacuum of *98.7%*.

A transparent glass container of *1000 cubic centimetres* is used to hold the insect, closed hermetically with a rubber stopper and an outlet in the side to which the pressure tube, also rubber, is attached in order to cause the vacuum at the right moment. Larger containers should not be used in order for the emptying time to be minimal –about ten seconds– thereby allowing a maximum period of observation. The insect is introduced through the opening in the top which is then hermetically sealed.

Valves, or triple stopcocks, of this kind are very simple and cheap, made of glass; it is inserted into the pressure tube, to connect the vacuum pump to the glass container. This valve enables us to re-establish atmospheric pressure in the container, after having produced the vacuum, without it being necessary to disconnect the pump, and to maintain the vacuum indefinitely once it has been obtained. It also serves to check the level of vacuum that has been produced, by means of a pressure gauge. On the question of low pressure gauges, the mercury ones are very reliable and also digital precision pressure gauges.

It is well known that insects activate their flight capacity if they reach a suitable temperature. (It would be a good idea to place a "flexi" lamp near the container for illumination and also to provide sufficient heat for radiation.)

The observational results are surprising: for one or two minutes the insect continues flying, or takes off in flight, without any perceptible difference from flight at normal atmospheric pressure, even when hovering. The insect's legs are in the habitual position for flight, that is, gathered up and folded backwards.

The wingbeat frequency is a characteristic of each insect which varies betwen very narrow limits in each species: around *300 hertz* for the bumblebee and *150 hertz* for the fly. Lift has an approximately lineal variation with the fluid density, so that flight in these conditions if we wish to explain it in terms of aerodynamics– would mean that the insect is capable of lifting a weight which is more than a hundred times greater than its own in normal atmospheric pressure; which does not seem scientifically acceptable.

In the case of insect flight the problem is generally not conservative and in this New Dynamics –which we have presented generically at the beginning of this article– there appear forces, which were hitherto unknown and responsible for lift and propulsion (without air being needed) which allow the empirical fact which we are putting forward to be explained. This is because in this new dynamic approach the laws of conservation of lineal momentum and angular momentum do not generally apply.

Classical dynamics is still perfectly applicable to those cases in which the system behaves *as if it were* inertially isolated, because of symmetries, zero tangential acceleration, circular orbit, etc., or else the new forces are negligible with regard to those which result exclusively from the masses and accelerations of the particles.

Thermodynamic *irreversibility*, the "strange and troublesome second principle" (J. MERLEAU-PONTY) which is incompatible with classical dynamics (MISRA-POINCARE theorem), is clearly shown to be corollary to the new dynamic approach, as is the particle-wave dualism. MAXWELL's equations of electromagnetics are deduced as a particular limit case of this ND. It must be noted that D. W. SCIAMA in 1953, FELIX TISSERAND eighty years earlier and, more recently, BRANS and DICKE all attempted an inverse process: to construct a theory of gravitation which was isomorphic with MAXWELL's electromagnetism.

d) DESTRUCTION AND CREATION OF ANGULAR MOMENTUM with respect to a VERTICAL AXIS OF ROTATION:

MACHINE A. *" destroys" angular momentum.*

This machine is compound of a steering wheel of mass M that turns around a vertical axis, with minimum friction. I n the same axis direction is mounted an elastic iron strap of *200 mm* length, *2 mm* width and *0,5 mm* of thickness that can oscillate in the vertical plane and rotates with the steering wheel. To its end a small mass $m<<M$ is fixed that oscillates with the iron strap, and remains in the rotation axis when it does not oscillate and the steering wheel is at rest. (See the machine scheme and the corresponding photos in following pages)

In CD it is necessary the conservation of *angular momentum*, referred to the vertical spin axis, when m is in this axis with initial angular speed ω_o. If m separates of the axis a distance r, the speed of rotation will be reduced so that the following relation is satisfied:

$$I_r\omega_r = I_0\omega_0 \qquad (43)$$

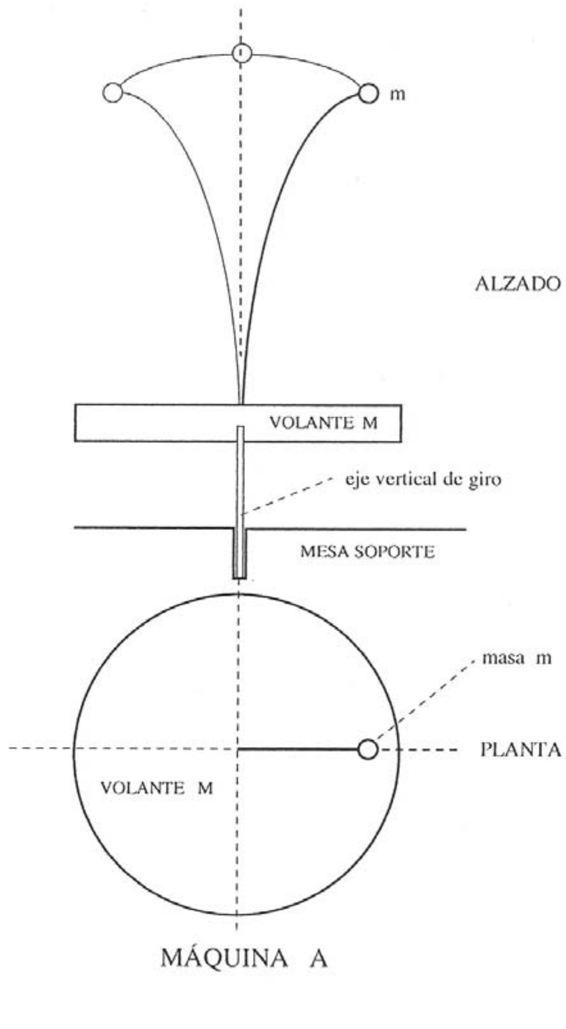
Being I_o the *inertia momentum* of the steering wheel M and ω_o the initial angular speed (m is assimilated to a material point); I_r is the *total inertia momentum* when, during the oscillation, mass m is detached a distance r from the axis. Its value is expressed by:

$$I_r = I_0 + mr^2$$

t is therefore $I_0 < I_r$ and by (43) it must be:

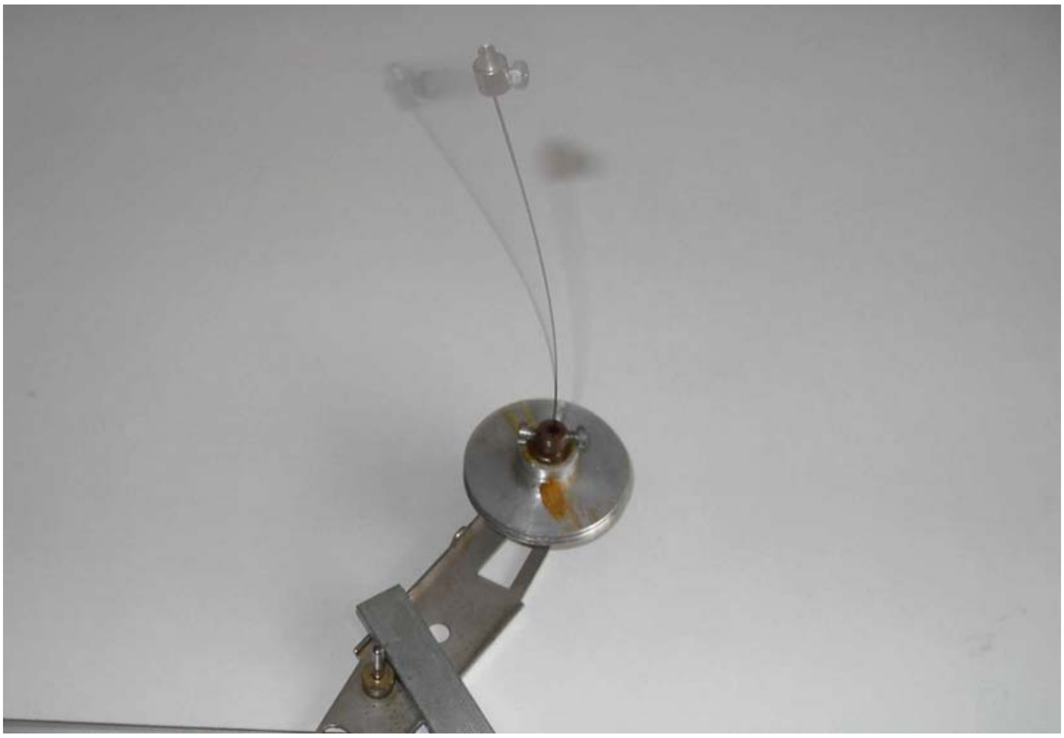
$$\omega_0 > \omega_r$$

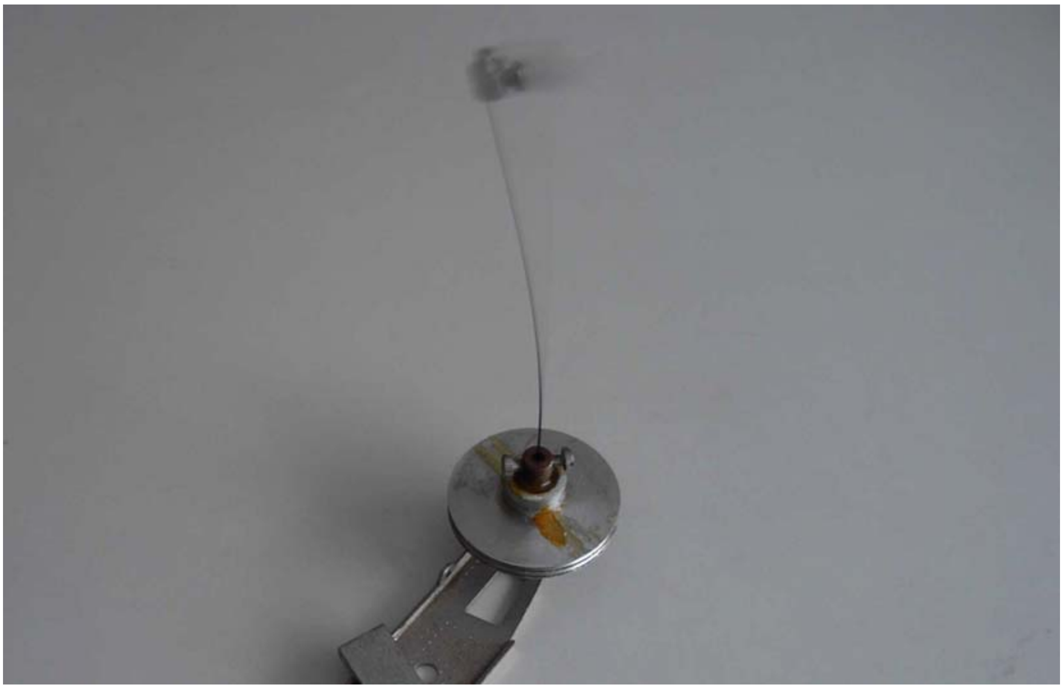
When, due to the elasticity of iron strap, it happens that m pass again through its position in the spin axis, the angular velocity will be ω_o , by the conservation of the *initial angular momentum,* and so on in each oscillation. *But this is not what is observed,* because when m leaves their unstable starting point, in the spin axis, the oscillations become important by the action of the centrifugal force on m , and the steering wheel stops quickly –in three or four turns– and the total initial kinetic energy of the steering wheel has been transformed into oscillating energy of the iron strap and mass m . The *initial angular momentum,* with respect to the spin axis, that must be conserved, has disappeared; this machine ***"destroys" angular momentum,*** against the exigencies of the CD , nevertheless this fact is perfectly coherent within the framework of the ND..



SCHEME OF MACHINE A

PICTURES OF MACHINE A.

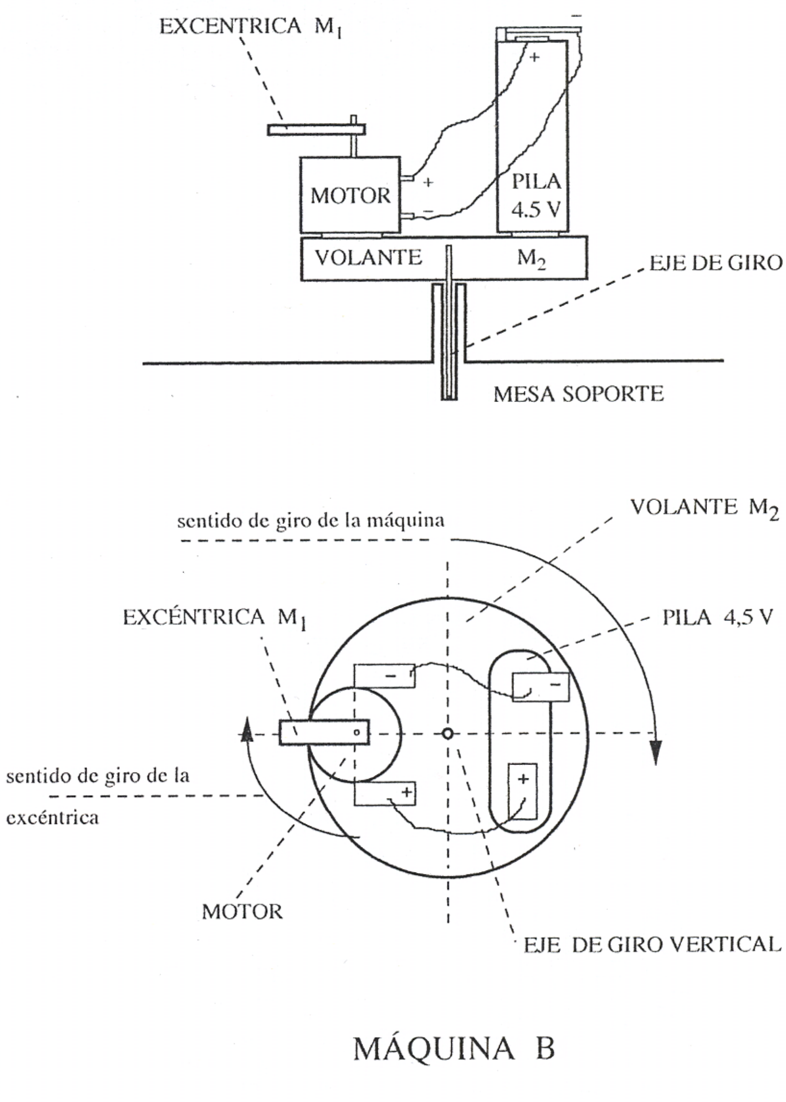




PICTURES OF MACHINE A.

MACHINE B. ***"Destroyes"* and *"creates" angular momentum .***

This machine is formed by a steering wheel of mass M that turns around a vertical axis fixed in support-basis (see the scheme and photos of this device).



SCHEME OF MACHINE B

PICTURES OF MACHINE **B**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e) LINEAL PROPULOR WITHOUT REACTION *(LPWR).*

1 In the environment of the New Dynamics (ND) that have presented here, and that it comes to enlarge the frame of the Newtonian or Classic (CD), it is possible that the *laws of conservation of the lineal momentum* and of *the angular momentum* do not fulfil in an isolated system, as demands the CD. In this ND the force that acts on a material particle, of mass m, is no longer only due to the acceleration that suffers in an inertial frame, but other forces intervene up to now not taken in consideration. Without going down to details, neither theoretical considerations that it is not here our purpose, the *total force* $\boldsymbol{F}$ that acts on a particle or material point that describes a generic trajectory, with *velocity* $\boldsymbol{v}$*, acceleration* $\boldsymbol{a}$, (and taking in account the corresponding *evolute* linked with the trajectory through the curvature radius R) it is given by:

$$\boldsymbol{F} = [m\boldsymbol{a} + (1/2)(dm/dt)v\boldsymbol{s} - mv(dv/dt)/(dR/dt)\boldsymbol{n} - (1/2)(mv^2/R)\boldsymbol{n}] \qquad (44)$$

in which the trajectory is referred to a FRENET trihedron, whose *versors* are $\boldsymbol{s}$, $\boldsymbol{n}$, $\boldsymbol{b}$, being $\boldsymbol{b} = \boldsymbol{s} \times \boldsymbol{n}$. As it can be observed in (44) the mass m no longer behaves as a *constant,* it varies with the *time* in general:

$$m = m(t) \qquad (45)$$

2. In view of the expression (44), even in the case that the trajectories are right, it is possible the non conservation of the *lineal momentum:*

$$\boldsymbol{p} = \sum m_i \boldsymbol{v}_i$$

in an *isolated system;* because, besides the forces of acceleration over each m_i, there exists the force:

$$(1/2)(dm_i/dt)\boldsymbol{v}_i = (1/2)(dm_i/dt)v_i\boldsymbol{s}_i \qquad (\boldsymbol{s}_i \text{ versor}) \qquad (46)$$

and doing things in an appropriate way, it can allow the *non conservation* of ***p*** demanded by CD. For simplicity we will center ourselves in this simple case in order to explain the working of ***Lineal Propulsion Without Reaction*** **(LPWR)** that will be presented later.

In the precedent detailed theoretical works it is exposed how to reach the conclusion of being $m = m(t)$ and how to attain the general expression (44), etc.

3. In an *isolated system* formed for only *two bodies* in rectilinear interaction, although the forces (46) can exist, their *resultant is null* and it is impossible the *"uncoupling"*. For this aim it is necessary the interaction of *three or more bodies*.

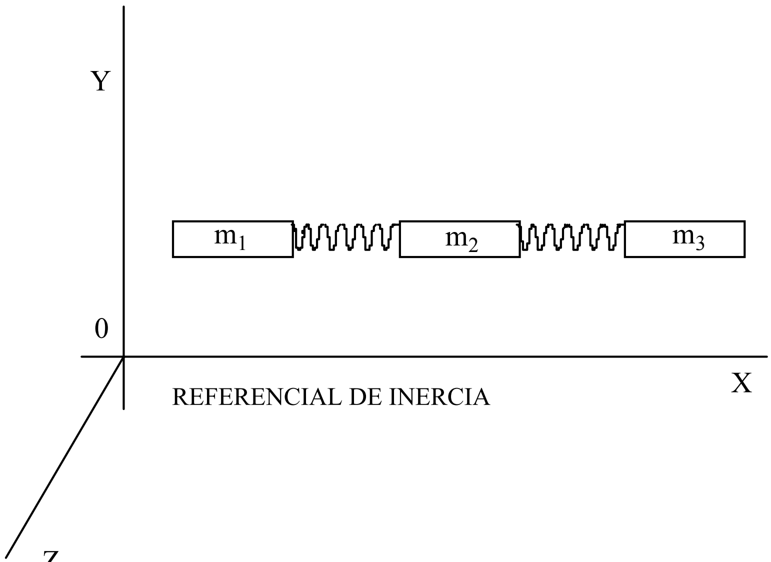


FIG. 1

Let us suppose, for bigger simplicity that is three bodies (material points) linked by means of interactions *(potentials)* that all act on the same straight line (see outline in the fig. 1); in which the "springs" that unite the masses m_i express the potential energy U_{12} , U_{23} that depend on the distances x_{12} , x_{23}, among the masses of the system (in a frame of inertia OXYZ). Under these conditions the *subsystem* formed by each mass m_i has a potential energy U_i that depends on its *position* x_i and of the *time* t, because the other two masses evolve simultaneously and they cause this temporary variation of their potential. In these circumstances can be write:

$$U = U_{12}(x_1,x_2) + U_{23}(x_2,x_3) = U_1(x_1,t) + U_2(x_2,t) + U_3(x_3,t) \qquad (47)$$

It interests to us this last individualized form [right-hand term of (47)] of expressing the potential energy, while in AD the first one is used [first member of (47)].

In our ND these individualized variations, are the cause that m_i can be time dependent:

$$m_i = m_i(t)$$

therefore on each mass m_i my act the additional force:

$$(1/2)(dm_i/dt)v_i\mathbf{s}_i \qquad (48)$$

described in (46) (being $\mathbf{s}_i$ the *versor* according to OX_i).

According to this, if the forces (48) are reached, it seems that the problem of the PLSR would be solved; however it is not so, because the experimental tests carried out (more than twenty) they teach us the *"coupling"* of forces (48) . Consequently we have

$$\sum(1/2)(dm_i/dt)v_i\mathbf{s}_i = 0 \qquad (49)$$

Consequently lineal propulsion is not observed in an *isolated system* without *energy dissipation*. However this becomes patent when *energy dissipation* exists between *two* of the masses of the system, for example between m_2 and m_3 , and there it is not between m_1 , m_3 , neither between m_1 , m_2 . It is enough observeing (49) to notice that these forces depend on the *velocity* $\mathbf{v}_i$ of each particle. The *dissipation by friction* (or similar phenomenon) makes vary the velocities of the two masses over that it acts directly; for example: the *friction* between m_1 and m_2 , but it doesn't vary the velocity of third mass m_3 (or it occurs in a completely different way) and then the *"coupling"* desappears. It is possible to write

$$\sum(1/2)(dm_i/dt)v_i\boldsymbol{s}_i \neq 0 \qquad (50)$$

Evidently, the action of these forces (50), additional to the classics, it is the cause that the *lineal momentum* $\boldsymbol{p} = \sum m_i v_i \boldsymbol{s}_i$, is not conserved, in spite of being an *isolated system.*

4. In the Nature they exist "machines" propelled without reaction, by the forces (44), up to now not taken in consideration because they were ignored. We refer primarily to the flight of the insects, up to now practically inexplicable. –in most of the cases at least– based on the well known dynamics of fluids. We have made fly insects *("Bombus terrestris", "Calliphora vomitoria", etc.)* in the vacuum *(13 mb)* (1.976-77). Their flight is perfectly regular and without differences regarding to that observed at normal atmospheric pressure *(1.013 mb)*. For to do this experience with the insect in flying conditions it is necessary to conserve the partial *water vapor pressure* at room temperature (15º C approx.), otherwise the insect is deformed because it "boils" (at this temperature) and it cannot fly. It supposes a vacuum of the order of 98,7% that doesn't allow the sustentation based on aerodynamic forces (see **chapter III**).

We make reference to these tests because they had been the incentive in the work of to invent and construct machines doing the same thing. Otherwise we would probably have abandoned the task. In order of doing it has been necessary, in the first place, to elaborate the theoretical frame that allowed us to arrive to the expression (44); in second place to realize the existence of the *"coupling"* and find the way to undo it, by means of partial *dissipation* of the available energy. This work has lasted twelve years. The most effective lineal propulsors are the recent ones.

This succinct description is very related with the *Thermodynamical Second Principle:* "it is impossible to get work without "losing" in the "radiator" part of the available energy ".

5. Up to 1990 the built machines were based on the interaction of *three masses (PLWR –3)* or f*our masses (PLWR. – 4)*, moved by coils, fed by *ac 40 V.* The device described here works by means of vibration (see fig. 2 of the present study) that is produced by the action of a small mass, m_1 which rotates in eccentric way and moved by a motor of *3.– 8 V* , fed by a battery of *3 V* (alkaline or rechargeable) mounted on a small platform whose total mass is m_2 *(motor + battery + platform).* The mass m_2 slips, with energy dissipation by friction, over a third mass m_3 (formed by an horizontal board) by means of two supports (see fig. 2), made of steel wire of *0.5 mm ,* in form of "U" subject to platform m_2 . The "U" horizontal part slips on m_3 , while its subjection parts form with vertical an approximate angle of 15^o *grad*. (see fig. 2). The experience has shown us that this angle is the good one.

The *PLWR* by vibration that we present here *(PLWR–vib.)* is formed by a group of *three masses* and it is propelled in the sense indicated by the inclination *(*15^o *grad.)* of the two supports (see fig. 2). To check that appreciable reaction doesn't exist, m_3 has been hung at the roof by means of *4* nylon threads (of *1.5 m* of longitude) forming with the suspended board a deformable parallelogram that conserves the horizontal position. The vibrant system $m_1 + m_2$, moves on m_3 with a speed that reached *40 m/minute,* while the last one remains immobile. In this sense the effectiveness of this machine is very superior to that of the precedent models: *PLWR.–3 , PLSR.–4 ,* being its construction much more simpler.

The two "U" steel supports can be substituted by other equivalent in form of "toothbrush" whose fibre have an inclination of 15^o *grad*. with vertical.

Some years ago appeared in the Spanish market toys that were propelled this way (by means of "brushes") without suspecting the propulsion without reaction described here. Actually they are not for sale.

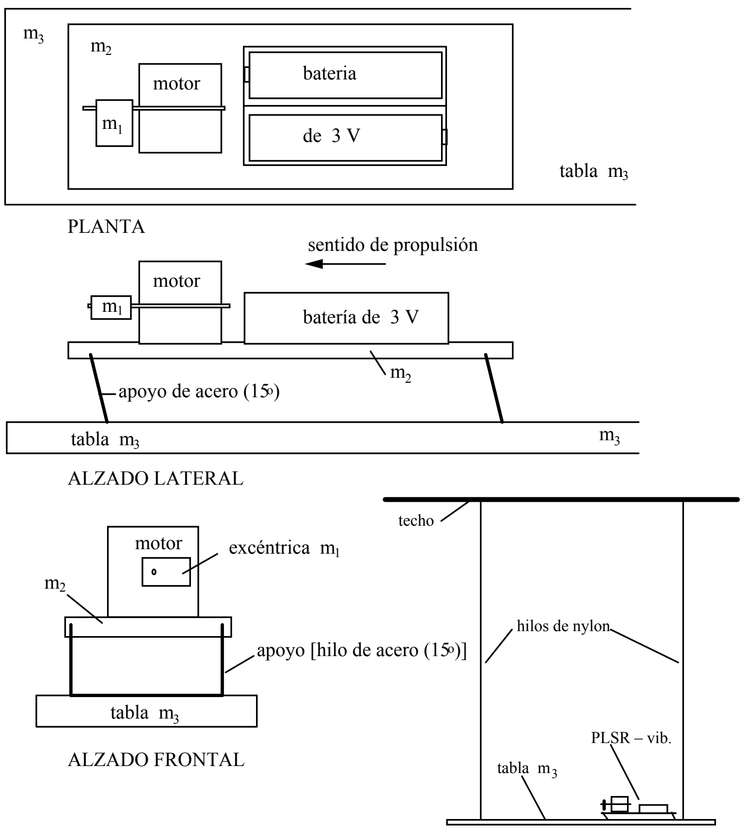
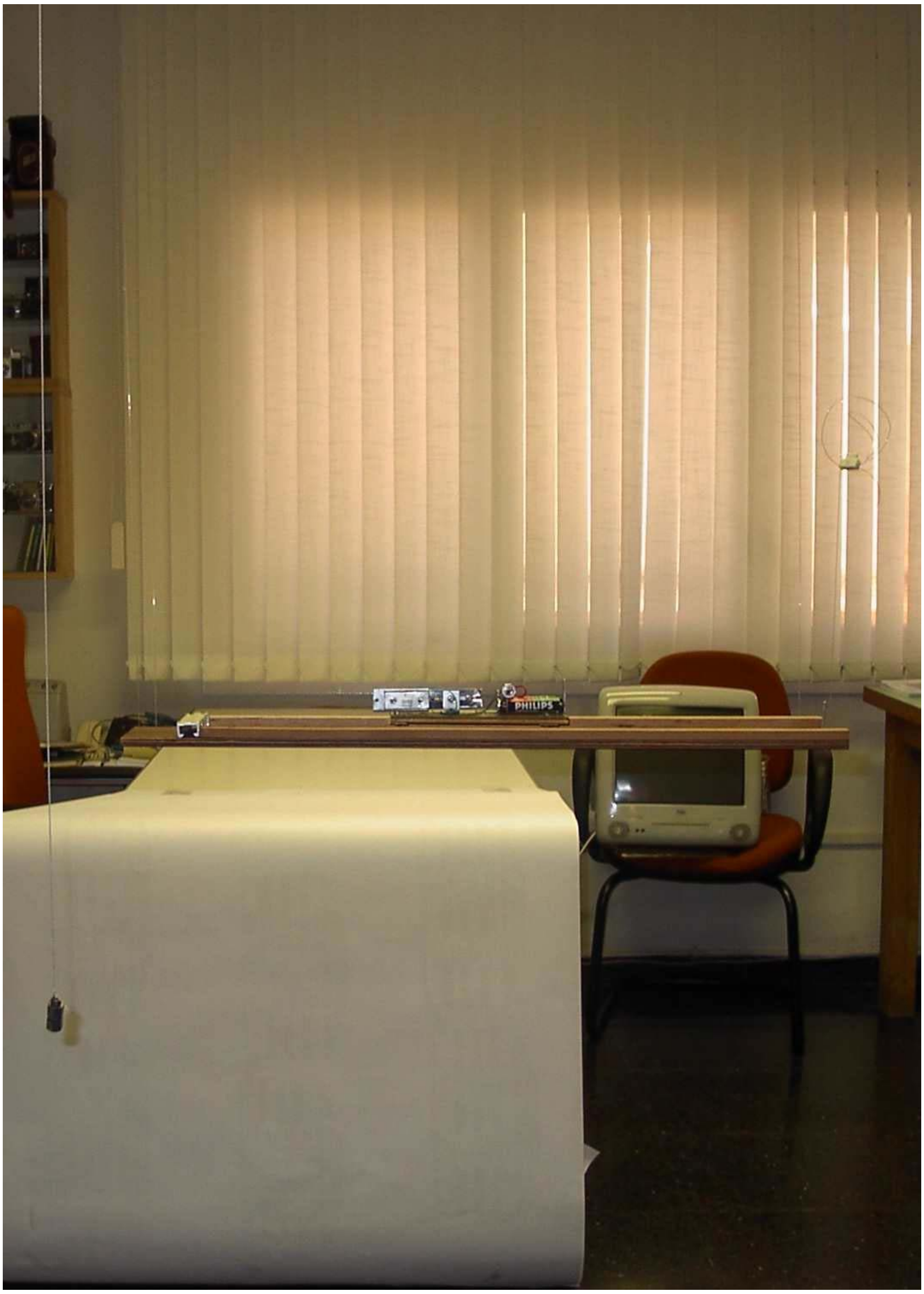


FIG. 2 ESQUEMA DEL PLSR – vib.

OUTLINE OF THE ***LPWR*** *(vibration)*

PICTURES OF THE ***LPWR*** *(Vibration)*



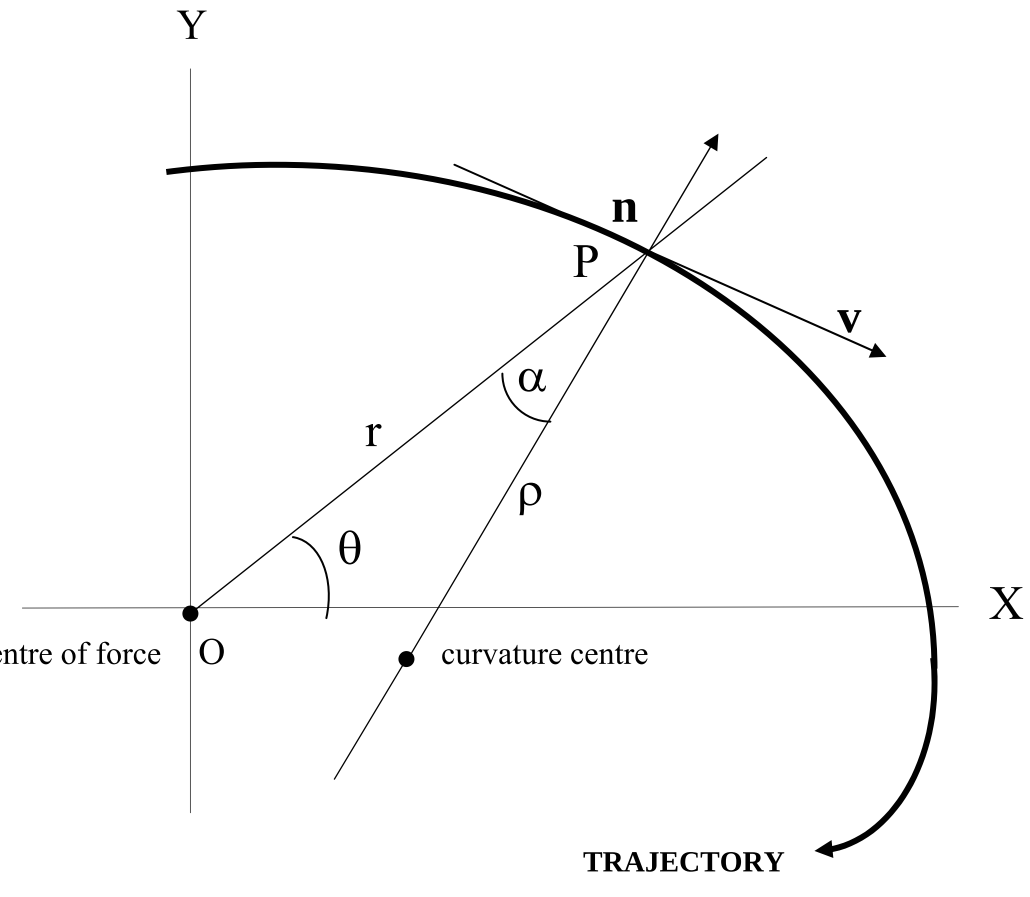
The initial rest position of the ***LPWR*** system with respect to the plumb–bob at links.

Oscilatory position of the sistem towards the link side. Distance of the system extreme border and the plumb–bob aprox 5 cm.

Oscilatory position of the sistem towards the right side. Distance of the system extreme border and the plumb–bob aprox 15 cm. Oscilation amplitude 15 – 5 = 10 cm.

f) THE PROBLEM OF *"two bodies"* IN THE ND

We study here the peculiar case of *two bodies* in interaction in the frame of the ND. We simplify the problem reducing it to the action of a *central force* on a material point of mass *m.* It is the case of the gravitation forces, of Coulomb forces, etc. We outline the problem with the hypothesis that the mass $m = Constant$ and we will expose that this is impossible, because even in this case of only *two bodies*, it should be $m = m(t)$. It is evident that the same thing will happen when three or more bodies are interacting. It is a plane trajectory travelled by a material point *m* with speed $\boldsymbol{v}$, acceleration $\boldsymbol{a}$, in *intrinsic coordinates*, being ρ the curvature radius. and $d\theta/dt$ the angular speed, while in *polar coordinates* *r* is the radius to the centre of force *0* , and $d\Theta/dt$ the angular speed (see figure).



In the ND the expression of the central force in polar coordinates (see **Chapter**. **IV, E** (41) p. 77) is given for:

$$\boldsymbol{F} = m(r\dot{\theta}^2 + r^2\dot{\theta}\frac{\ddot{\theta}}{\dot{r}} + \ddot{r})\hat{r} + \tfrac{1}{2}\frac{\dot{m}}{\dot{r}}(r^2\dot{\theta}^2 + \dot{r}^2)\hat{r} \qquad (51)$$

And in the intrinsic inertial trihedron their expression is:

$$\boldsymbol{F} = m\boldsymbol{a} - mv\frac{\dot{v}}{\dot{\rho}}\hat{n} + \tfrac{1}{2}\dot{m}v\hat{s} - \tfrac{1}{2}\dot{m}\frac{v^2}{\dot{\rho}}\hat{n} \qquad (52)$$

We make the hypothesis of $m = constant$, in which case (in the precedent expressions) are annulled the terms in which dm/dt appears.. In ND being central the force, the acceleration won't be it. The module of $\boldsymbol{F}$ should be:

$$F = projection\ \ of\ \ \boldsymbol{a}\ over\ \ \boldsymbol{r} + projection\ of\ -mv\frac{\dot{v}}{\dot{\rho}}\hat{n}\ \ over\ \boldsymbol{r}$$

and in view of the figure we can write this expression:

$$F = -mr\dot{\theta}^2 + m\ddot{r} + (-mv\frac{\dot{v}}{\dot{\rho}}cos\alpha)$$

that should be identical to the module of (51). And simplifying terms in this identification we have:

$$\boxed{2mr\dot{\theta}^2 + mr^2\dot{\theta}\frac{\ddot{\theta}}{\dot{r}} = -mv\frac{\dot{v}}{\dot{\rho}}cos\alpha} \qquad (53)$$

In the last one (53) we can observe that all the tangent trajectories in the point considered P had locally the same values for *m, r, dr/dt. dθ/dt,* $d^2\theta/dt^2$ *;* and consequently the same values for *v, dv/dt , α* and *curvature radius ρ* (notice that $v^2=\rho^2(d\Theta/dt)^2 = r^2(d\theta/dt)^2+(dr/dt)^2$ they don't have the same *dρ/dt*) . This way the things, the equality (53) won't be verified in general for the same central force ***F*** . We reach the conclusion that the simplifiying hypothesis of considering *m = constant* is generally insufficient; it will be necessary to admit that even in this simple case of interaction between *two bodies,* and c*entral force,* the mass will vary with the *time:*

$$\boxed{m = m(t)}$$

This function *m(t)* it will depend on the type of trajectory: hyperbola, logarithmic spiral, exponential, etc. that will also be different when changing the motion sense in each case. The equality (53) will come to be:

$$\boxed{\begin{aligned} &2mr\dot{\theta}^2 + mr^2\dot{\theta}\frac{\ddot{\theta}}{\dot{r}} + \tfrac{1}{2}\dot{m}\Big(\frac{r^2\dot{\theta}^2}{\dot{r}} + \dot{r}\Big) = \\ &= -mv\frac{\dot{v}}{\dot{\rho}}\cos\alpha - \tfrac{1}{2}\dot{m}\frac{v^2}{\dot{\rho}}\cos\alpha + \tfrac{1}{2}\dot{m}v\,sen\,\alpha \end{aligned}} \qquad (54)$$

And no longer inconvenience exists that equality (54) is verified, in each trajectory, by the action of a central force. In a point P each different trajectory will have different *dm/dt* and also different *dρ/dt* . changing its sing when the particle motion in the trajectory is *reversed*, causing the *trajectory* ***irreversibility*** (see **chapter II,** pp. 41 and ss.)

When *m = m(t)* it is immediate that the kinetic energy, that depends only from the position if *m = constant* , now will be also *time dependent*. The same thing will happen with those energy potentials in whose expression the mass intervenes. For instance: the gravity potential in an isolated system without disipation. The energy conservation will demand

$$T(P, t) + U(P, t) = constant \qquad (55)$$

In which also $U = U(P, t)$ if we suppose that t is *independent of the position* and not a *simple parameter*. It can happen that the *constant value* that appears in the expression of some potential energy, in fact it is not so, but from expression (55) it is *time dependent.* For example, in the elastic potential: $-Kx^2$, it will be $K = K(t)$.

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