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THE COSMOLOGICAL
FOUNDATIONS OF MECHANICS
AND THE FUNDAMENTAL
LAWS OF DYNAMICS

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PROLOGUE

This study was published for the first time in Vol. IX of this PHILOSOPHICAL YEARBOOK for 1976. After 17 years we thought it opportune to revise it, referring to the most up-to-date studies, which improve on certain points which were obscure at that time and others which were inadequately or even erroneously expounded, in the light of more recent theoretical and experimental discoveries. The philosophical aspects are practically unchanged, though not the physico-mathematical developments which have been substantially modified; this is because we had previously only surmised the formulation of the foundations of a New Dynamics (ND), of which the Classic or Newtonian (CD) is a particularly restricted case. We never even suspected its subsequent mathematical development. Interest and effort to maintain the general validity of the CD (apart from the problems concerning relativity and Quantum Dynamics) then led us to formulations which have now been omitted as we consider them unsatisfactory. We have replaced them with others which have been elaborated in far greater detail and which are, in our opinion, more accurate and coherent with the starting points. Nevertheless, the conclusions reached remain basically the same. The first result of this ND is the *dynamical irreversibility of a material point trajectory*. The ***CHAOS presence in the dynamical world*** is an immediate consequence.

The notes at the foot of the page refer to another fundamental study: *Dynamics of Irreversible Mechanical Systems* , (1985), in which the physico-mathematical aspects of this ND are expounded in their most complete and detailed form, (at present a second revised edition which explains it more extensively, is under way). In this study, which is basically philosophical in the first part, we thought it out of place to include all those mathematical formulations that are not strictly necessary in order to explain the fundamental ideas correctly.

Various reports of experimental work, which corroborate the assertions of this ND have also been recorded. Some of them, which had already been published, dealing with the subject of insect flight -which has still not been explained within the framework of the CD- are quoted in this study.

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THE COSMOLOGICAL FOUNDATIONS OF MECHANICS AND THE FUNDAMENTAL LAWS OF DYNAMICS

I. 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 lucubrations 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 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 JUVET¹ puts the indeterminist position in its exclusively experimental 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"².

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 *nexo* between them both. Nexa 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:

¹ G. JUVET, *La Structure des Nouvelles Théories Physiques*. p. 141. Ed. Alcan. Paris. 1933.

² P. F. SCHURMANN, *Luz y Calor*. p. 148. Ed. Espasa-Calpe. Madrid. 1948.

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"³.

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 experimentable: 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 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"⁴. 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*⁵, 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,

³ C. KITTEL, and others, *Mechanics Berkeley Physics Course*, vol. 1. p. 60.

⁴ P. F. SCHURMANN, *op.cit.* p. 208.

⁵ E. MACH, *Mechanics*, published in 1903.

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 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 mechanicians 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 WEIZSÄCKER⁶ 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 time, a starting point for further philosophical elaboration of modern physics". P. F. SCHURMANN⁷ 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 intellecto-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"⁸.

⁶ C.F. VON WEIZSÄCKER, *La Imagen Física del Mundo*. pp. 76 & c. Ed. B.A.C. Madrid. 1974.

⁷ P. F. SCHURMANN, *op. cit.* p. 205.

⁸ P. F. SCHURMANN, *op. cit.* p. 211.

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 OSWALD⁹ 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'être" 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 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"¹⁰ and because of the sophisms of his slanderers SOCRATES had to drink hemlock for his wisdom.

⁹ To his great regret, as he was the author of *The Defeat of Atomism*.

¹⁰ 2. *Tim.* 4, 3-4.

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* and *sophists* whose most outstanding intellectual characteristic was their zeal for novelty¹¹. 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 WEIZSÄCKER¹² 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

¹¹ 2. *Tim.* 4, 3.

¹² C.F. VON WEIZSÄCKER, *op. cit.* p. 165.

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 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 attempt¹³ 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 mechanists 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. DOU¹⁴ 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

¹³ A. DOU, *Fundamentos de la Matemática*. p. 105. Ed. Labor. Barcelona. 1970.

¹⁴ *Ibidem*, pp. 109 and 110.

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 mechanists, nor energeticists, nor this last attitude of Kantian following which has just been analysed can adequately explain the 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. BONDI¹⁵ has this to say on the subject:

"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 origins 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.

¹⁵ H. BONDI, *Cosmología*, p. 17. Ed. Labor. Barcelona. 1970.

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 WEIZSÄCKER¹⁶ 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 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 platonist, 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

¹⁶ C.F. VON WEIZSÄCKER, *La importancia de la Ciencia*. p. 140. Ed. Labor. Barcelona. 1968.

(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)¹⁷ 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*, 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 study¹⁸, 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.

¹⁷ Cf. H. BONDI, *op.cit.* p. 159.

¹⁸ J. RIUS-CAMPS, *La afirmación del Principio de Mach y sus consecuencias dinámicas*. pp. 10 & c. E.T.S.A. Pamplona. 1975.

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, it might not require a beginning and an end. Christians know from the Revelation of God¹⁹ 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*

¹⁹ *Genesis*, 1, 1. "In the beginning GOD created the heavens and the earth".

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 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 philosophers²⁰. Is inertia a quality which is inherent to 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 read²¹: "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

²⁰ Cf. J. MERLEAU-PONTY, *Cosmología del siglo XX* pp. 41 & c. Ed. Gredos. Madrid. 1971.

²¹ *Ibidem*, p. 53.

other hand, claimed the existence of an absolute space, or substratum²². 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 Universe²³: "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"²⁴.

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 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

²² Cf. *Principia Mathematica*, published for the first time in 1686.

²³ J. MERLEAU-PONTY, *op.cit.* pp. 44 & c.

²⁴ *Ibidem*, p. 53.

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 "an inertially isolated system *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. SCIAMA²⁵, who has a precedent in FELIX TISSERAND (1872) who tried, on the basis of his 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 does 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

²⁵ D.W. SCIAMA, "On the origin of inertia", *Monthly notices of the Royal Astr. soc.* (1953), n° 1. pp. 34 – 39.

processes. The forces that 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 that 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 that 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"²⁶ at the "end of time"). The only body that does not occupy a place is the Universe, the Cosmos

²⁶ *IV Liber Esdrae*, 6, 39 and 7, 30.

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 EPHEBUS), 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 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 expression²⁷.

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"²⁸, as misunderstood by DUHEM; instead it is an *active* property of *all* the medium, not of the particles in immediate contact: something along the lines of LORENTZ's ether?²⁹ 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

²⁷ 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.

²⁸ DUHEM, *Etudes sur Léonard de Vinci*, I. pp. 109 & c. *Le système du monde. Histoire des doctrines Cosmologiques de Platon a Copernic*. pp. 321 & c.

²⁹ Cf. P. HOENEN, *Filosofia della natura inorganica*. pp. 128 & c. Ed. La Scuola. Brescia. 1949.

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*³⁰: "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 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

³⁰ ARISTOTLE, *Fisica*, lib. VII, ch. 4.

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 AQUINAS³¹ 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 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".

³¹ T. of AQUINO, *Summa contra gentes*, Lib. 3, ch. 82.

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.

II. STUDY OF THE EXPRESSION OF FORCE IN THE ND.

(SUPPLEMENTARY NORMAL ACCELERATION a_n^* AND KINEMATIC AND DYNAMIC MEANING OF ANGULAR VELOCITY $\dot{\varphi}^*$)

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 referential frame is used. The acceleration components in this circle are

$$a_s = (dv/dt)s \quad \text{and} \quad a_{\varphi} = -(v^2/\rho)n \quad (1)$$

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: $b = s \wedge n$, respectively. The angular velocity is

$$\dot{\varphi} = (v/\rho)b$$

A definite trajectory has a well defined *evolute*, and in the calculation of the normal component in the expressions (1) the differentials dv and $d\rho$ are obviously not taken into account. But, as we will demonstrate, when $dv \neq 0$ and $d\rho \neq 0$, the *arc* of the *evolute*

does not correspond with the real one: it turns locally at an angular velocity

$$\dot{\varphi} = (dv/d\rho)\mathbf{b}$$

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 $\dot{\varphi}$, we shall study an element $d\mathbf{s}$ of trajectory which corresponds to the $d\rho$ of the *evolute*; they are both located on the plane of osculation (see Fig.1 when $dv/dt > 0$; and Fig. 2 when $dv/dt < 0$). Thus we can consider the trajectory as being locally plane and referred to an intrinsic frame with *versors* \mathbf{s} , \mathbf{n} , \mathbf{b} , formed by the *tangent*, *normal* and the *binormal*. The *arc* $d\mathbf{s}$ of the trajectory is determined by the points A, B , and the $d\rho$, of the *evolute*, on account of its equivalent points A, B . The speed of the particle in A is v and in B it is $v + dv$. The radii of curvature at these points are: $\rho + d\rho$ and ρ . The angle turned by the radius of curvature when it passes from A to B is

$$d\varphi = ds/\rho$$

and the corresponding angular speed will be as we have seen

$$\dot{\varphi} = d\varphi/dt \quad (\text{with } \dot{\varphi} = \dot{\varphi} \mathbf{b})$$

We can also write: $\dot{\varphi} = v/\rho$, which evidently does not depend on dv and $d\rho$. When we calculate the centripetal acceleration we get the expression (1) 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 $d\mathbf{s}$ 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 $d\varphi$ are omitted. In order to rectify this deficiency it is necessary to rotate AB' an angle

$$d\varphi^* = BB'/d\varphi$$

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

$$(BB'/d\varphi)/dt = (d^2s/d\varphi^2)/dt = dv/d\varphi = d\varphi^*/dt = \varphi^*$$

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 φ^* , 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 $d\varphi^*$, with respect to the initial AB (see Fig. 1 and Fig. 2). It will be necessary to turn AB' this angle, in the *same sense* (when $dv/dt > 0$) and in the *opposite sense* (when $dv/dt < 0$), so that it coincides with the *real* one. As a result, the *radius* φ has increased in a second order infinitesimal amount:

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

and

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

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

$\begin{aligned} \ddot{\varphi}^* &= B'B''/dt^2 = ds d\dot{\varphi}^*/dt^2 = v\dot{\varphi}^* \quad (\text{when } dv/dt > 0) \\ \ddot{\varphi}^* &= B'B''/dt^2 = -ds d\dot{\varphi}^*/dt^2 = -v\dot{\varphi}^* \quad (\text{when } dv/dt < 0) \end{aligned}$
--

superimposed to the *normal acceleration* a_{φ} (1). So the *total normal acceleration* is

$$\begin{aligned} a_{\varphi} + a_{\varphi}^* &= -(v\dot{\varphi} + v\dot{\varphi}^*) = -v(\dot{\varphi} - \dot{\varphi}^*) \\ a_{\varphi} + a_{\varphi}^* &= -(v\dot{\varphi} - v\dot{\varphi}^*) = -v(\dot{\varphi} + \dot{\varphi}^*) \end{aligned}$$

in the two possible cases.

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

$$\begin{aligned} a_s \mathbf{s} + a_{\varphi} \mathbf{n} + a_{\varphi}^* \mathbf{n} &= \mathbf{a} + v\dot{\varphi} \mathbf{n} = \mathbf{a} - v\dot{\varphi} \mathbf{n} \\ a_s \mathbf{s} + a_{\varphi} \mathbf{n} + a_{\varphi}^* \mathbf{n} &= \mathbf{a} - v\dot{\varphi} \mathbf{n} = \mathbf{a} + v\dot{\varphi} \mathbf{n} \end{aligned} \tag{2}$$

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

and

$$\begin{aligned} \mathbf{f}_n &= -mv (\dot{\varphi} - \dot{\varphi}^*) \mathbf{n} = mv \dot{\varphi} (\dot{\varphi} - \dot{\varphi}^*) \\ \mathbf{f}_n &= -mv (\dot{\varphi} + \dot{\varphi}^*) \mathbf{n} = mv \dot{\varphi} (\dot{\varphi} + \dot{\varphi}^*) \end{aligned} \tag{3}$$

in both possible cases.

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

$$\mathbf{f} = m(\mathbf{a} \pm \mathbf{v} \times \frac{d\mathbf{v}}{ds}) \quad (4)$$

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

The result (4) is surprising: even more so when we remember that "LORENTZ's force" is exclusively experimental. Moreover, in FRENET's trihedron the value v of speed is always *positive* in the sense in which the particle is moving. We know that while the moving point follows the trajectory, the *centre of curvature*, at the corresponding point, describes the *evolute*, and we can take the sign of $d\varphi$ as *positive* because the sense of its movement follows the *changing sense* of the velocity \mathbf{v} . This result is of the major importance (see the two possible cases in Figs. 1, 2', y 1', 2) because $\varphi = dv/d\varphi$ *changes sign*, when the movement is inverted (dv changes to $-dv$ whereas $d\varphi$, in the *evolute* does not change). When the *movement is inverted*, the versor $\mathbf{s} \times \mathbf{b} = -\mathbf{n}$ *manteins its sense*, but the *supplementary acceleration* $\mathbf{a}^* = \mathbf{v} \times \frac{d\mathbf{v}}{ds} = \mathbf{s} \times \mathbf{b} v \varphi$ *changes it* when φ^* *changes to* $-\varphi^*$. Consequently, the **reversibility** of the trajectory in CD **does not hold up** in the ND, (see Figs 1 and 2', pp. 31-34).

3. We shall now study the case in which $m = m(t)$, i.e., that in which (4) is proved:

$$U_c(P, t) + U_p(P, t) = (1/2)mv^2 + U_p(P, t) = C \quad (5)$$

We keep the same definition given for the force which acts on m . We will simply bear in mind that the kinetic energy will depend on the position and time, as shown in (5). We shall now work out the forces acting on m , following the preceding process. We shall have

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

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

and analogously the total force on m will now be

$$\begin{aligned} \mathbf{f} &= m\mathbf{a} + (1/2)(dm/dt)\mathbf{v}\mathbf{s} + \mathbf{f}_{\square} = \\ &= m\mathbf{a} + (1/2)(dm/dt)\mathbf{v}\mathbf{s} + (mvdv/d\square)\mathbf{n} + (1/2)(dm/d\square)v^2\mathbf{n} \end{aligned}$$

and we can write

$$\begin{aligned} \mathbf{f} &= m(\mathbf{a} + \mathbf{v} \square \square^*) + (1/2)(dm/dt)\mathbf{v}\mathbf{s} - (1/2)(dm/dr)v^2\mathbf{n} = \\ &\mathbf{f}_o + (1/2)(dm/dt)\mathbf{v}\mathbf{s} + (1/2)(dm/d\square)v^2\mathbf{n} = \\ &\mathbf{f}_o + (1/2)(dm/dt)\mathbf{v}\mathbf{s} - (1/2)(dm/d\square)v^2\mathbf{s} \square \mathbf{b} = \\ &\mathbf{f}_o + (1/2)(dm/dt)\mathbf{v}\mathbf{s} - \mathbf{v} \square (1/2)(dm/d\square)\mathbf{v}\mathbf{b} \end{aligned}$$

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

$$\mathbf{E} = (1/m)[\mathbf{f}_o + (1/2)(dm/dt)\mathbf{v}\mathbf{s}]$$

$$\mathbf{B} = -(1/m)(1/2)(dm/d\square)\mathbf{v}\mathbf{b}$$

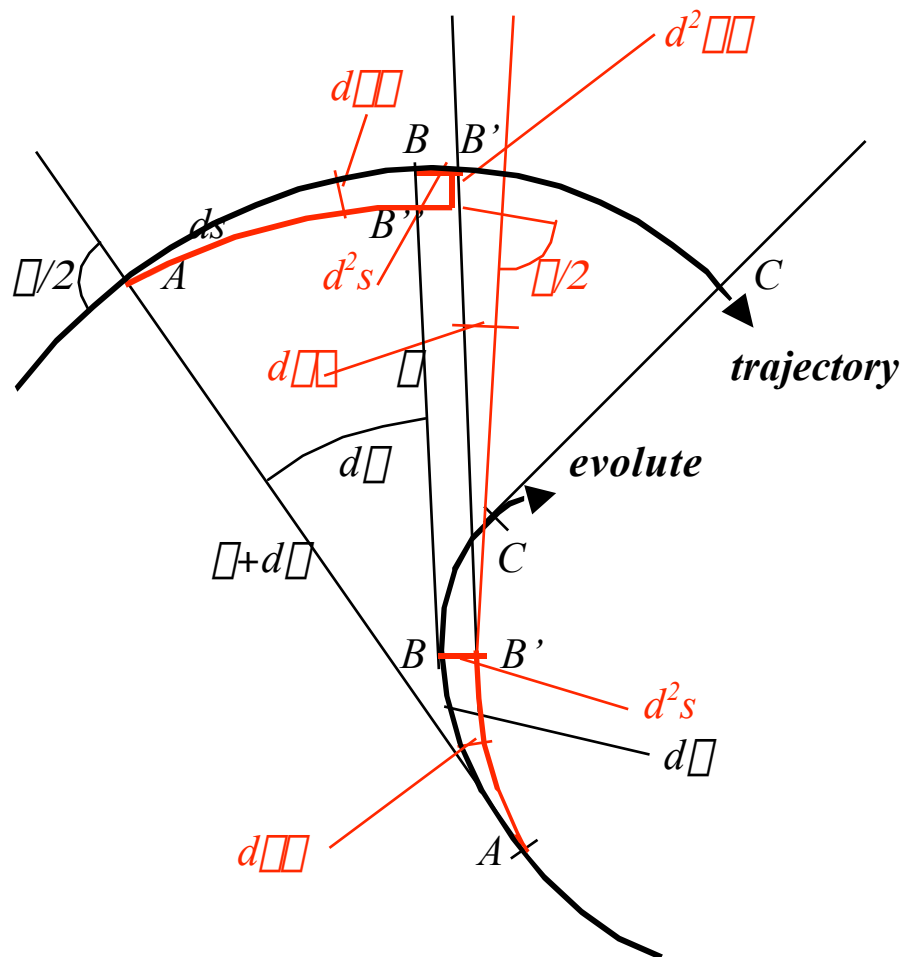
with the result

$$\boxed{\mathbf{f} = m(\mathbf{E} + \mathbf{v} \square \mathbf{B})} \quad (6)$$

Starting from this basis, and with certain complementary hypotheses, it is possible to deduce isomorphic equations for this ND together with those of MAXWELL, which govern all electromagnetism,

and which we shall not expound here³². In this ND forces (6) are no longer *invariant* with regard to "GALILEO's transformations", analogous to what occurs with electromagnetic forces. In the next chapter we will explain a completely different method for studying the *irreversibility* of mechanical systems in general which, as has been 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* of the mechanical system, which we shall call *mechanical entropy* of the same, which enables us to study the possible states of *stable equilibrium* which may be obtained.

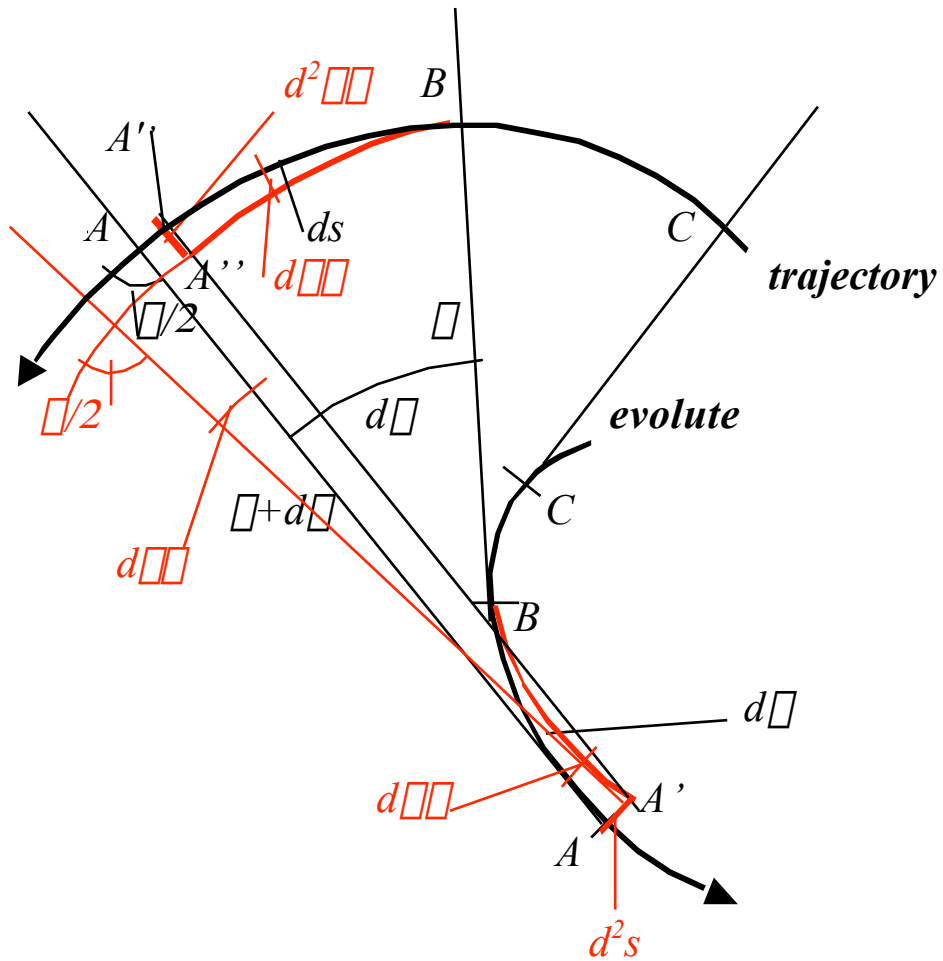
³² For the explanation of this, see our study: *Dinámica de Sistemas Mecánicos Irreversibles*, registered and published for the first time in 1985. A second revised edition is under way.



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

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

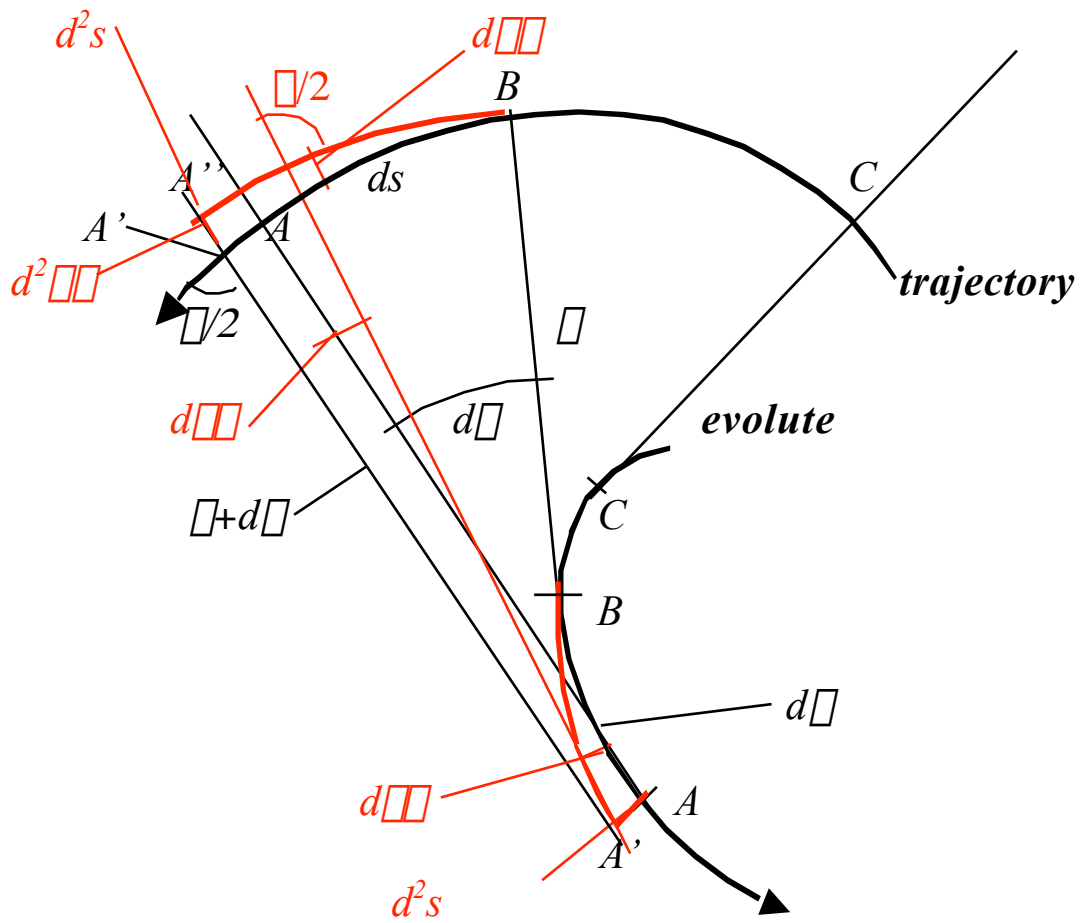
FIG. 2



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

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

FIG. 1'



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

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

FIG. 2'

III. MECHANICAL ENTROPY. THE SECOND FUNDAMENTAL LAW.

1. We are going to study *closed* mechanical systems, that is, those which comply with the *First Fundamental Law*; we are going to establish in them a *function of state*, the *mechanical entropy* of the system, which we will call S , parallel to the entropy studied in Thermodynamics. It will express a *qualitative* characteristic of the system, different from its energetic situation which is regulated, from the *quantitative* point of view, by the *First Fundamental Law*: the conservation of energy. The *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 would have a valuable instrument which could no doubt be called the *Second Fundamental Law* of Mechanics. This *Law*, together with the *First*, defines for us the *evolution* of mechanical processes in "isolated systems" energetically speaking which we call *closed*. A system which is closed and unbound by the rest of the Universe cannot properly be called "isolated" either; as has already been seen, the omnipresent quality of *inertia* exists, binding together all the systems in the Cosmos: so that we can say: "inertially isolated systems do not exist". This proposition coincides basically with "MACH's Principle" which we quoted earlier on, (it was already known by NEWTON though less clearly), which we can formulate as: "the only accelerations which make sense are those which concern movement in relation to the distant stars"; that is why it is necessary to use "frameworks of inertia" in order to construct the Mechanics. As has already been explained, this affirmation 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*. However, the other aspect of the "third Principle" which requires that the *lineal momentum* be conserved in an

isolated system³³, 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 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 movement may be not conserved, against the requirements of CD . 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 from the path travelled in the evolution of the same, from one equilibrium state to another equilibrium state. In order to arrive at a formulation for it, we shall start out from the customary requirements, adapted to our case, and laid out axiomatically:

- 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 by: $U_c = (1/2)mv^2$, when m is the total mass and v the average quadratic speed. The simplest function for S that complies with the preceding conditions is

$$S = \text{constant}(m_i v_i) \geq 0$$

³³ *isolated system* = energetically *closed* plus *unbound* (without any kind of link).

with v_i being the speed of particle m_i taken in its absolute value. If we bring in the average speed v^* of the system, we can then write

$$S = mv^* \geq 0 \quad (7)$$

and with CAUCHY–SCHWARZ's inequality, it is

$$S \leq S_{max} = mv \quad (8)$$

In the states of equilibrium which are possible for the system it must be constant the cinetic energy, that is:

$$\boxed{dU_c = 0} \quad (9)$$

Thus U_c must be constant (or: *max.*, *min.*, *horitz. inflex.*). but this condition is not generally sufficient. As well there may exist systems whose kinetic energy is constant and yet which are not in steady equilibrium, but rather oscillate; for example: four masses bound together by four rigid bars, in the shape of a rhombus and lain out symmetrically on the same plane; the opposite sides will be equal³⁴. The rhombus is articulated, so that the masses can oscillate, without bumping into each other, and rotate around an axis that is perpendicular to the plane and passes through the centre of mass and symmetry. It is clear that with an initial impulse they will maintain their kinetic energy constant, but the latter will not be so for each one of the masses. The CD resolves the problem of their movement by maintaining the angular momentum in relation to the rotational axis, but in the ND this requirement does not exist. What will the possible states of steady equilibrium be, that is if they exist? We can see that condition (9) is *necessary* but *insufficient* when the equilibrium is steady. Since the entropy, defined by (7) will be variable

³⁴ This mechanism, which is only given in schematic form here, can be constructed so that the four masses can slide through their respective guides without bumping into each other. The real mechanism is somewhat more complicated but it is perfectly feasible. As usual, all the elements in the system except the four masses: $2m$, $2M$, are considered as valueless mass.

during the evolution of the system, even if the energy is constant; we are going to insist on a second condition for the steadiness of the equilibrium:

$$\boxed{dS = 0} \quad (10)$$

We must remember that now, in this ND, it will generally be $m=m(t)$. Thus the two conditions for the equilibrium to be steady are (9) and (10), which when expanded give us

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

$$mdv^* + dmv^* = 0$$

and simplifying the first:

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

$$mdv^* + dmv^* = 0 \quad (11)$$

homogeneous equations –considering the independent variables m , dm – which require for compatibility

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

that is

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

which when integrated gives us

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

that is

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

In the general case which we are dealing with here, this last equation requires that :

$$v = \text{constant}$$

$$v^* = \text{constant}$$

and being now m necessarily constant, also will be $U_c = \text{constant}$; we have steady equilibrium. In short, conditions (10) and (11) are *necessary* and *sufficient* for steadiness of equilibrium in the general case which we are looking at here. If only the first of these two conditions is satisfied (*max.*, *min.* or *horizontal inflexion*), the equilibrium will be *unsteady*. If identical unsteady states of equilibrium occur the system will be *oscillating*; but it may also *evolve, irreversibly*, towards steady equilibrium passing through a finite, or infinite, number of unsteady situations, all different but tending towards steadiness in a finite, or infinite, time; in the latter case the system's evolution will be *asymptotic*³⁵. In this ND, although we do not feel that this is the right moment to expound it in detail³⁶, we know that when the different trajectories of the physical points m_i , which make up the closed system, are not circumferences, (since they cannot possibly be rectilinear and travelled with constant speed except in the case of a single physical point) and it is generally proved true that

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

³⁵ As a particular case it may occur that, although $U_c = \text{constant}$, S nonetheless is not, but at certain points and during a dt , it may be true that $dS = 0$ (*max.*, *min.* or *horizontal inflex.*). We would then have *unsteady* equilibrium.

³⁶ See our study *Dinámica de Sistemas Mecánicos Irreversibles*, published in Barcelona in 1985 and at present undergoing revision and amplification. It will include a detailed explanation of this assertion.

However, there may exist states of steady equilibrium, with trajectories which are not circular for the $m_i(t)$, in which $m = \text{constant}$ and likewise $v = \text{constant}$; for example: a symmetrical spinning top of mass m_1 , with a point of the rotatory axis fixed on another mass $m_2 \gg m_1$, with a *steady* precession as a result of reciprocal gravitational attraction which we assume is constant. It must be observed that in this case the system remains identical to itself.

In the example of the symmetric system given before, made up of four equal two by two masses in the form of a rhombus; there are two possibilities for the foreseeable evolution in this ND: it will either be a system with identical oscillations and equal periods, or else it will evolve in such a way that the trajectories of the four masses come closer, asymptotically, to the circular shape (in an extreme case: two immobile masses on the rotatory axis and the other two—those with greater mass—on the circular orbit itself). Thus it is clearly shown that the process is *irreversible*.

In the preceding case of the symmetrical spinning top, if the precession is *not steady*, that is, if *nutation* occurs, the ND allows the possibility that this may practically disappear after a certain delay; this is what happens in actual fact. The CD cannot account for this phenomenon unless it is responding to loss of rotatory energy due to friction at the point of support; in our opinion this explanation is not very convincing, since for the same reason that it disappears 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 the movement of *two* interacting bodies is resolved, and yet no general solution is found for the "simple problem of *three* bodies". It has only been possible to establish approximate solutions, by the "perturbations" method, when one of the particles has a greater mass than the other two (e.g. the Sun in the solar system). In 1912, SUNDMAN, having overcome serious difficulties, managed to solve this problem using the above method; but there is no simultaneous solution for the whole system and it is impossible for the general case of three physical points whose mass is identical³⁷.

³⁷ B. FINZI, *Meccanica Razionale*, vol. II. p. 89.

Circular trajectories are the limit to which the closed system tends when it evolves irreversibly towards stable equilibrium; whether they are each one of the m_i or those of the centres of mass of various groups of them (as in the case of the symmetrical spinning top cited earlier). As we have already stated, it may be that steady equilibrium is unattainable. Obviously we are studying the system in relation to a base of inertia at rest with regard to the centre of mass.

The CD's incapacity to solve the problem of systems made up of three or more interacting bodies is quite surprising. And yet Thermodynamics solves the problem of an infinite number of analogous particles (atoms and molecules). The *irreversibility* generally found in systems according to the ND, is closely connected to the "second Principle" of Thermodynamics, which many scientists consider "extremely troublesome and strange"³⁸. 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.

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

The isomorphism between the ND and electromagnetism, which we have put forward, likewise resolves the fundamental incompatibilities existent between the CD and electrodynamics.

IV CONCLUSIONS AND PHYSICAL APPLICATIONS.

1. The logical explanatory process leads us to conclusions and applications based on the theoretical principles and laws which have been established; however, it is not unusual for creation, investigation and synthesis to go in the opposite direction. This is what has happened in this study, so that this chapter corresponds, at least in part, to a group of

³⁸ J. MERLEAU-PONTY, *Cosmología del siglo XX*. p. 84. Ed.Gredos. Madrid. 1971.

experimental facts which led to the theoretical analysis of the principles and laws which govern them.

The *conservation laws* in the CD account for the majority of standard processes, approximately enough at least (e.g.: the movement of planets and their satellites) and other factors such as friction, viscosity, turbulence, etc., mask the problem when the effects of the preceding theoretical speculations should be taken into account. We believe that this is why the *Three Fundamental Laws* of Dynamics which we have expounded here were not formulated much earlier.

Aristotelian-thomistic Metaphysics demanded greater consideration and appreciation of the qualitative aspects of the Cosmos –and of Dynamics in particular– which could only be gained by the affirmation of the accessibility and objectivability of the *essence* of things, within themselves. "Transcendental metaphysics" –which I would rather call pseudo-metaphysics– draws us away from the World and, consequently, only helps us to penetrate more deeply into knowledge derived from laws and qualities which we already know, but -strictly speaking- it is possible to "lose solutions" if we do not take into account some qualities of the *thing in itself*, which do not necessarily have to give us the models of reality based on inherent apriorities.

2. In one of the first registered studies, which contained an intuition of the New Dynamics which we are propounding here³⁹, we came to the conclusion –in a completely heuristic way which was nor without its errors, due to complete ignorance at that time of the ND– that it was possible to frustrate the laws of conservation of the *angular momentum* and of the *linear momentum* in an unbound system. In the ND, as we have already said, it is easy to construct systems which do not conserve the angular momentum; for the non-conservation of the linear momentum there must exist, as has already been seen, *dissipation* of kinetic energy by *radiation* in order to "uncouple" the forces acting on the system, otherwise the result is null and this "propulsion without reaction" is not possible.

This made us think of the possibility that there might exist living beings in Nature whose mobility was based on the *Three Fundamental*

³⁹ J. RIUS-CAMPS, *La afirmación del Principio de MACH y sus consecuencias dinámicas*. Pamplona. 1975.

Laws of the ND. The clearest response, in our opinion, is in insect flight, in the majority of insects, whose wingbeats reach very high frequencies, with an extremely low number of REYNOLDS which excludes lift based on known aerodynamics. In the next section some examples and affirmations concerning this are cited, taken from the most up-to-date publications.

3. In the diminutive insect *Haplothrips verbasci*⁴⁰ it can be observed that two pairs of "wings" are nothing more than beating bars of approximately elliptic section, equipped with extremely fine and very flexible cilia, which cannot act as a surface for lift but must serve—in our opinion—rather to avoid the air's resistance by facilitating the laminar function; the extremely rapid oscillation of the bar-wings would lose efficiency through producing turbulence. In the section dealing with "discussion and suggestions" of one of these studies, it is affirmed⁴¹ : "Ignorance of the details about the mechanism of flight, at such a low number of REYNOLDS, points out the need for extensive observations, during flight, in order to determine the movement of the bar-wings and the cilia and likewise the need to study the details in greater depth by means of the electronic microscope, and also of measurements designed to specify the physical properties of the group of cilia...". Another study⁴² ends with the following words: "it must therefore be concluded that we have little reliable information about the aerodynamic forces generated by wing beating and that the problem must be studied anew". And in the publication *Scientific American*, in an article dedicated to unusual forms of lift in certain insects, it is stated⁴³: "The most important aspect, (lift in) of these insects and other flying creatures which I have discussed, depends largely on the non-stationary aerodynamic effects, unknown until now, which are beneficial and not a hindrance for them, as they would be in man-made aeroplanes".

Thus the ignorance that exists on the subject of insect flight and lift is evident. If we are not mistaken in all that has been expounded

⁴⁰ Cf. *Swimming and flying in Nature*, Ed. Plenum Press – N.Y.. London, vol. 2. pp. 803, & c. 1975, corresponding to: *On the mechanics of flight of small insects*, by A. M. KUHETE, university of Michigan, Ann Arbor, Michigan.

⁴¹ *Ibidem*, by the same author, p. 812.

⁴² *Ibidem*, p. 810. From the study: *Aerodynamic forces and their calculation in insect flight*, by W. ZARNACK. Universitat des Saalandes. Germany.

⁴³ T. WEIS-FOGH, Unusual mechanisms for the generation of lift in flying animals, "Scientific American", Nov.1975.

here and in the experimental tests which were carried out, the explanation is clear and simple in the framework of the ND presented here: they would be able to fly even in the absence of atmosphere or, at least, a good deal of their lift and manoevrability is derived from the forces, additional to those of the CD, which are dealt with in the ND; the basic function of air is to make respiration possible.

Nota bene:

As pointed out in the Introduction, this study is the revised and updated edition of the edition published in 1976. The most recent studies of insect flight have progressed little since 1975. We may point out here that in May 1977, after the publication of this article, experiments were carried out on insects (Hymenoptera: *Bombus terrestris* and Diptera: *Calliphora vomitoria*) by making them fly in a very scarce atmosphere (13 mb, the equivalent of 1,3% of normal atmospheric pressure: 1013 mb). This experiment has been repeated several times since then. For further information on this, see our small article: *El vuelo del abejorro* (Flight of the bumblebee), in "Investigación y Ciencia", February 1986. p. 41.

An interesting article appears in the magazine "Nature", vol.344, 5 April 1990: *Unconventional aerodynamics*, by ROLAND ENNOS, which expresses clearly the problems of recent research in this area. By way of illustration we cite some pieces: "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 dynamic 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 the article concludes by saying: "Their results have two important implications. First, 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. Second, 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".

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