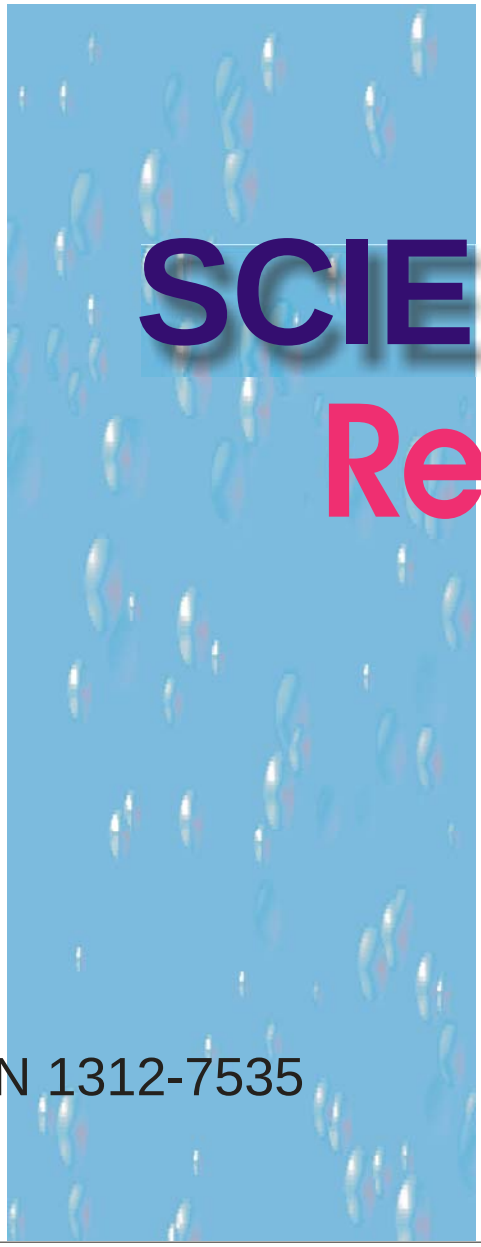
SOUTH-WEST UNIVERSITY
·NEOFIT RILSKY·
BLAGOEVGRAD, BULGARIA

VOLUME 5
2007



SCIENTIFIC Research

ISSN 1312-7535

ELECTRONIC ISSUE

NEWTON'S CONCEPT OF GRAVITY – A CATEGORIAL CHANGE IN PHYSICS AND PHILOSOPHY

RENATE WAHSNER
Max Planck Institute for the History of Science
Boltzmannstr. 22, D-14195 Berlin
wahsner@mpiwg-berlin.mpg.de

Abstract

It was shown that the great representative of the Enlightenment movement Voltaire popularized Newtonianism as a new worldview and, as a result, made philosophy and humanities acquaintanced with Newtonian science. This course was the reason why in the following time there were long discussions on Newtonian mechanics and its concept of gravity – discussions which continue till today among non-physicists.

According to his enlightening aim, Voltaire had interpreted mechanics as a science on the whole world and, as a result of this, he had misinterpreted or even had falsified it. Simultaneously popularization of Newtonian mechanics as a new worldview had prepared the intellectual ground, promoting the work of such physicists like D'Alembert, Laplace and Lagrange and providing them with a response; it prepared the ground which allowed to elaborate mechanics as a physical theory.

Distortions of mechanics made by the mechanistic worldview are perceptible till today. Thus there is the prejudice that mechanics is mechanistic,. But this was as inaccurate as the belief that mechanistic worldview could be eliminated simply by founding a new theory in the natural sciences. There are also mechanizations of modern science.

By elaborating his mechanics Newton founded physics in the Modern-Age understanding, and in so doing it triggered the need to investigate what, in the terms of this new science, *the physical* means; and this has to be done in contrast to *natural philosophy*, on the one hand, and to *mathematics*, on the other. By implication, Newton had created an entirely new meaning for the concept of *the physical*, *physical law* and the *relationship between bodies and motion*. He had provided these concepts with a new categorial constitution: the body–motion question was no longer framed by the categorial relationship *thing – property*, but by the new categorial relationship *object – behavior*.

This categorial change inherent in Newton's concept of *gravity* is the physical expression of *a new thought principle*, a principle which has been aptly described as *functional thought* (*Funktionsdenken*), by contradistinction to the *substantial thought* (*Substanzdenken*) of the Classical world and the Middle Ages. This principle is obliged to the device: *the acting determines the being*, a device that was not seen by the mechanistic worldview, although Modern-Age science could only be founded on this basis.[1]

1. Introduction

In his lecture on natural philosophy in 1819/20, the philosopher Hegel complains about the implicit faith in Newton that one can find since one and a half centuries. He explains: "Voltaire made known Newton in France and from there then Newton came to Germany" [10].

[1] The present essay is essentially a synthesis of Refs. [20, 21, 24-27, 43].

Why this is worthly of note? Of course, mathematicians and physicists did not became familiar with Newton's work in this way. However, Voltaire popularized Newtonianism as a new worldview and, as a result, made philosophy and humanities acquaintanced with Newtonian science. This course was the reason why in the following time there were long discussions on Newtonian mechanics and its concept of gravity – discussions which continue till today among non-physicists.

Voltaire, as a literary man, adopted Newtonian mechanics with fascination. But according to his enlightening aim, he had interpreted mechanics as a science on the whole world and, as a result of this, he had misinterpreted or even had falsified this and that.

Consequences of this continue till our days and show that evolution of physics does not happen in an isolated way but is embedded in the general mental development.

Voltaire, celebrated beacon of the French Enlightenment, claimed: "My fate has decreed that I should be the first of my countrymen to be permitted to explain the great Newton's discoveries. I have been the apostle and the martyr of the English" [40]. His aim, according to his own account, was "to comprehend Newton and to render him comprehensible" [38].

As was saying, it was Voltaire who unleashed the spread of Newtonianism in France. Certainly, the Paris Academy was aware of all Newton's writings from 1699, and in the period which followed there were other Frenchmen – Maupertuis, d'Alembert, Clairaut, Lagrange and Laplace among them – who developed classical mechanics further, but it was Voltaire who really popularized these works in France. In so doing, he prepared the ground which allowed to elaborate mechanics as a physical theory. However, his efforts did not only exert an influence on the scientific, but also on the philosophical and, indeed, cultural developments in general. By propagating Newton's findings as a worldview which ultimately challenged the altar and the crown in an absolutist state, he struck a decisive blow for justifying the claim of reason, helping to establish it as the sole criterion for all activity, thereby paving the way intellectually for the French revolution and the progress of Enlightenment in France.

To note this is important for Newtonianism would not have been accepted in France in its English form. Born essentially from an empirical attitude, English Newtonianism had to be dressed for the Cartesian rationalism which prevailed in France. Voltaire found the recipe, and in the process he opened up traditional philosophy, understood as rational metaphysics, to problems which hitherto had lain within the territory of empiricism. Inherent in Voltaire's success, however, there was a mechanistic interpretation of Newton's teaching, which after all had not been empiricism as such, but an empirical natural science expressed in a mathematical language.[2] When Voltaire adopted *Newtonian physics as a worldview*, he was ignoring its conditionality and limited nature. Voltaire initiated a philosophical reading of mechanics which subsequent generations of philosophers regarded as the only reading possible, rather, mistaking it for mechanics pure and simple. Specifically, *the concept of mechanics which came to underlie German Idealism reflects Voltaire's reading of Newton*. There is a twofold implication to this: classical mechanics is identified with the mechanistic worldview, and Newton's principles were schare to be of general *cultural* importance. The

[2] To recognize this one must, first, be able to conceptualize the difference between natural science and philosophy (cf. Refs. [22, 23, 49] and, second, grasp that an action is not the same as consciousness of this action. In his *Principia*, therefore, Newton founds not only a physical theory in the modern sense, but also discusses problems relating to its epistemological status. The principles substantiated by Newton were later developed in more depth and detail, and Newton's geometrical formulation was transposed into analytical form (cf., for example, Refs. [19], [42, pp. 194-210]. In the process, Newton's action made its mark on philosophical consciousness, which enabled the difference between mechanics and the mechanistic world view to be recognized. Although this did not happen until the late 18th century, this does not alter the fact that the conception used in the *Principia* cannot be equated either with the Ancient concept of tevcnh, or practical mechanics, or with the mechanistic world view (cf. Ref. [28].

impact of Voltaire's perspective remains with us today, even if the second side to this coin has been much neglected.

2. Voltaire's little catechism on gravity

Voltaire's writings on English philosophy and Newtonian physics [specifically his *Philosophical Letters* (1733), the *Eléments de la philosophie de Newton* (1738/41) and *Défense du Newtonianism* (1739)] attracted considerable attention. His accomplishment was acknowledged even by some not especially well disposed towards him.[3] At the same time, a whole range of pamphlets and open letters expressed vehement criticism, not only from the Church, but also from most professional scientists.[4] The impact of Voltaire's *Elements* [5] can only be compared, some would maintain, with that of Darwin's *Origin of Species* [1]. To assess that claim, we must consider the situation in that period. Condorcet, an informed witness, reports: "When M. de Voltaire published this book, Europe's greatest mathematician Johann Bernoulli was still opposed to Newton's teaching; over half the *Académie des sciences* supported Cartesian thinking; even Fontenelle, so far removed from any sectarian or national prejudice and not yet thirty when Newton's system was published, and one of the few people capable of comprehending it, clung obstinately to his original views. If, in addition to all this, one considers that the first textbook for French schools to address Newton's theory did not appear until ten years after M. de Voltaire's work, one can only conclude that the publication of 1738, which our famous master so modestly called his little catechism on gravitation, deserves great credit" [6].

3. Philosophy's new role

Voltaire's great impact was due essentially to the new role of philosophy: *To enter people's minds, science must become literature* (called philosophy), conceding a role for charm, frivolity and worldliness. Fontenelle had shown the way, but he had been too cautious and too harmless to threaten power with anything more than a mild disturbance. In 1727, for example, he as an acknowledged and respected personage had delivered a speech on Newton's death in homage to the author of the *Principia*, seeking to defend the Cartesian worldview without discarding Newton's discoveries [8].

Philosophy, the exploratory quest for truth, after this modification, was primarily a movement to combat the influence of prejudices which barred access to knowledge and obstructed its efficacy. Philosophy as Voltaire and his contemporaries understood it was only conceivable as a rival to religious propaganda. It could only hope to win people over by occupying terrain where the church had been entrenched for centuries. Philosophy had to fight above all on the territory occupied by religion: knowledge, education, emotions, morality, politics.

[3] A Jesuit remarked: The great Newton seemed forgotten. At last M. de Voltaire appears, and at once Newton is understood, or at least people make an effort to understand him; all Paris resounds with Newton, all Paris stutters Newton, all Paris is studying and learning its Newton [2, 14].

[4] Some of the latter because they still adhered to pre-Newtonian opinions, and others because they found Voltaire's account betrayed the amateur.

[5] First published in English in 1738 as: The Elements of Sir Isaac Newton's Philosophy. By Mr. Voltaire. Translated from the French. Revised and Corrected by John Hanna, M. A. London. As this edition does not contain the "metaphysical" chapter, Voltaire published the separate edition The Metaphysics of Sir Isaac Newton: or, A Comparison between the Opinions of Sir Isaac Newton and Mr. Leibnitz. By M. de Voltaire. Translated from the French. By David Erskine Baker, London 1747.

4. Mechanics as world law

The second reason of Voltaire's success was his fascination with Newton. He mused: "A new universe was discovered by the philosophers of the last century one that was all the more difficult to understand as people did not even suspect that it existed. The wisest felt that there was some temerity in so much as dreaming that one could divine the laws by which the heavenly bodies move and by which light manifests itself" [29, p. 75]. Newton had formulated answers to many questions which absorbed thinking minds at the time: Why do planets and comets follow a particular path and what holds them there? Why do bodies fall to the earth? What causes the tides? Newton answered these questions, and what is more – according to Voltaire – by applying a single principle: "*attraction,* the great means by which all nature is moved" [29, p. 72], he explains in his *Philosophical Letters*, while in his *Philosophical Dictionary* he says of Newton: "He has discovered and demonstrated a new principle which causes all movement in nature" [34].

In other words, Voltaire saw Newton's law of gravity (a specific law of a specific theory pertaining to a particular science) as a principle which explained the whole world. The kind of world law which he believed to have been demonstrated implies, first, that everything which happens does so of absolute necessity and, second, that there must be a lawgiver and a motor. According to Voltaire, everything is subject to one law. Countering the objection that nothing therefore exists but machines, he argued: "Well, would you have everything rendered subject to a million of blind caprices? Either all is the consequence of the nature of things, or all is the effect of the eternal order of an absolute master; in both cases we are only wheels to the machine of the world" [36]. Voltaire relates this omni-explanatory principle not only to nature, but also to human beings. Taking this natural law to be universal, he uses it to substantiate the absence of free will, and thus the impossibility of arbitrary human action. His axiom: We may do what we want, but we cannot want what we want [36, pp. 128-132; 30, pp. 38-51]. He writes: "Every being, every kind of existence is dependent of necessity on the world law. […]. How can we be free […] if the universe is a slave? […] All our losings, all our emotions, all our thoughts are absolutely necessary things" [39]. When Voltaire states that everything – from a blade of grass to an oak tree, from a flea to a man, from the grain of sand up to our clouds – is a spring, lever and roller", a hydraulic machine or a chemical laboratory [33, p. 55], he is expressing his view that the law of the world is a universal mechanism to which everything which happens is slavishly subsumed. He sees the world as a machine which functions according to a pre-ordained law with no exceptions. There is no such thing as accident. In this manner, a world law amounts to exactly the same as divine providence [32]. To this end, however, Voltaire needs a god as lawgiver and as the workman who builds the world according to plan, a god as learned as the Royal Society in London [33, p. 130]. But for Voltaire's world machine to work, it also needs a motor. Voltaire's god must perform this function, too. Without this motor, matter cannot be either ordered or brought to life. For, "how can matter have motion by itself, as it has, according to all the ancients, extent and divisibility?" [37]

Voltaire believed that all this was implicit in Newton's mechanics. He fell prey to this misunderstanding because he was unaware of the reason why Newton spent his life wrestling with the phenomenon of gravity and the character of physical laws. Although he knew Newton's *Principia* and the Questions on the *Opticks*, he evidently did precisely what Newton feared readers would do if they "lacked sufficient insights into the principles".

5. Newton's mechanics as a measuring and calculating science

What worried Newton about readers of this kind? In the Introduction to Book Three of his *Principia*, his book on the *System of the World*, he writes: "In the preceding Books I have laid down the principles of philosophy [physics]; principles not philosophical but mathematical: such, namely, as we may build our reasonings upon in philosophical [physical] inquiries. These principles are the laws and conditions of certain motions, and powers or forces, which chiefly have respect to natural philosophy [science]" [15, p. 397].[6] Now that Newton has formulated the laws of motion, he demonstrates mathematical propositions in Book One which he then uses in Books One and Two to derive mathematical conclusions about centrosymmetric forces and other situations (including motion subjected to various retarding forces), and he expresses these in the form of theorems. By and large these are calculations which he carries out as generally as possible, without reference as yet to any specific physical instances. It is only in Book Three that he then applies many of the theorems he has derived to the specific instance of gravitational motion by the moon, the planets, the comets and the sea.

Anybody unaware of the role played by mathematics and experimentation, and unable to follow the ideas in the first two books due to a lack of knowledge and practical experience in the fields of mathematics and physics, would not really be in a position to grasp the *Principia* as a whole. This reader would only understand a few of the more general passages in the first two books and a number of pages in Book Three. Evidently, the scope for misinterpretation was, therefore, considerable. Newton, at least, had suspected that this might be a danger, and it had prompted him to drop his original plan of publishing a popular version of Book Three, hoping that anyone incapable of comprehending the earlier parts would be deprived of the opportunity to read the third. "I had, indeed," he relates, "composed the third Book in a popular method, that it might be read by many; but afterwards, considering that such as had not sufficiently entered into the principles could not easily discern the strength of the consequences, nor lay aside the prejudices to which they had been many years accustomed, therefore, to prevent the disputes which might be raised upon such accounts, I chose to reduce the substance of this Book into the form of Propositions (in the mathematical way), which should be read by those only who had first made themselves masters of the principles established in the preceding Books" [15, p. 397].

Newton, then, explicitly maintained that anyone seeking to prise a handful of verbal sentences from the overall fabric of the work would fail to understand his physics, or his *Mathematical Principles of Natural Philosophy*, for, his mechanics expressed natural laws in the form of mathematical equations connecting physical quantities and was not viable without this mathematical language or without empirical foundations. Naturally, his unambivalent declaration did not prevent some people who had not mastered the preceding principles from reading the book, and thus the matter was sucked after all into dispute, a dispute which has essentially persisted until today. One of the core issues is the debate about the mechanical concept of force and Newton's law of gravity.

[6] In this connection, Newton does not differentiate between natural philosophy and physics. Therefore, in present-day language instead of the term "philosophy" one must read "physics", instead of the term "philosophical" "physical".

6. A new concept of force

In Newtonian mechanics the concept of force is essentially determined by means of the three laws of motion, and in particular the second, which states that *mass* × *acceleration* = *force*, or $m\ddot{\vec{x}} = \vec{F}$.

Voltaire, by not appreciating the significance for mechanical statements of Newton's three laws or, indeed, of any mathematical-physical principles developed in the first two books, also failed to realize that no statements can be made about the mechanical concept of force in isolation from these principles. To him, the concept of force was mainly sensuous. Force was anything which induced movement [30, pp. 75-78].

In mechanics, however, *force* is determined (in the second law) as something which can cause a deviation from the state of rest *or* rectilinear uniform motion which is posed as etalon of motion; in other words: which can caused an acceleration. Newton did not see force – as most of his contemporaries did – as impulse or impact. By equating force with impulse or impact, they not only overlooked the physical conceptualization by which forces are always equivalent to accelerated motions, that is, alterations to rectilinear and uniform motions; they also passed over an opportunity to give conceptual form to the ability of matter to act, in spite of the fact that they were at such great pains to grasp force as the potential of matter to act.[7] Therefore, the role played by the *second derivatives*, and thus by the second law of motion, in founding of mechanics as physical dynamics, as physics, is not recognized [21, pp. 13-72; 42, pp. 29-40, 50-56, 109-114; 45, pp. 14-19, 54-60, 115-130; 47]. (Not even Kant and Hegel understood this point and, until now, all those who do not differentiate mechanics and mechanistic worldview.)

6.1 GRAVITY – A PROPERTY ESSENTIAL TO MATTER?

Together with these different understandings concerning the concept of force there are different answers to the question whether gravity is or is not an essential property. If Newton insists at various points in his work that gravity is not a property essential to matter [15, pp. 400, 547; 17], this must be seen in the light of the contemporary concept of matter. In Newton's day, the only features that were regarded as essential to matter and thus as *physically real* were those which could be attributed to the atom as such. Gravity, however, decreases as the distance between masses increases, and in this sense it cannot be attributed to the smallest parts of bodies as such in the same way as hardness, extension, indivisibility, mobility or inertia. Nevertheless, Newton wished to show that gravity was something physical and not simply a mathematical figment, and he sought long and hard for a way to derive it from the primary properties of atoms, at least as a secondary effect. Finally, in the 31st Question appended to his *Opticks*, he introduced the idea that not only the hitherto recognized primary qualities as passive principles can be attributed to atoms, but that they are also moved by *active principles*, which are realized by dynamic interaction, and that first these principles form the things as such [16]. *These principles express something which is constituted by the mutual relationship of bodies, by their behavior towards each other.* As bodies are only heavy towards each other, gravity (like any other physical force) is dependent on the existence of more than one body or point of mass, and *its existence cannot be seen in isolation from its action.* Therefore, gravity, and force in general, cannot be conceived as the property

[7] On the relationship between Newton's three laws see: the editors' annotations and epilogue to Ref. [41, pp. 534-536, 600-604]; see also Ref. [25, pp. 33-38].

of a natural object in itself, but nor can it be conceived as existing separately from bodies, that is, merely as a relationship. It simply cannot be reduced to an *impact* or *contact*.

If one does not share Newton's concept of matter as an incarnation of individual atoms with their passive properties, but integrates this mutual relationship between bodies into the very concept of matter (thereby redefining the concept *matter*), one would have to conceive gravity as inherent to matter. In actual fact, Newton did this in his physics, but instead of calling the thing "matter", he called it "nature".

If, on the other hand, one adopts a different concept of matter from the one explicitly offered by Newton, and takes matter to mean what Newton called "nature", and if one accepts his formulation that gravity is not inherent to matter or an essential property of it, then one would be obliged to isolate the active principles from matter, and thereby divide matter from motion. *Vice versa*, if one claims that gravity is inherent to matter without understanding that this means altering the concept of matter, one is subjecting mechanics to a mechanistic misreading by attributing properties to isolated, individual atoms or bodies which they can only have in relationship to one another. – This complex state of affairs prompted many a misinterpretation of Newton's position.

6.2 GRAVITY – DESCRIBED MATHEMATICALLY ONLY?

These misinterpretations concern also the following point. In his *Principia* Newton claims that he has described gravity mathematically, but not yet explained it physically. In the definitions given in this work he writes that he uses "the words attraction, impulse, or propensity of any sort towards a centre, promiscuously, and indifferently, one for another; considering those forces not physically, but mathematically" [15, p. 5]. Although he was fully aware that the insights gain in physics could not be prised out of the mathematical structure in which they were expressed, he was nevertheless dissatisfied with this state of affairs and sought an additional – so he believed – *physical explanation*. His dissatisfaction was rooted in the fact that Newton, as the founder of theoretical physics, had created something new, but that naturally the full consequences could not be perceived at the moment of birth, not even the consequences for the relationship between physics and mathematics and for the concept of physical explanation. But because he introduced the concept of the active principle, a "physical explanation" was implicitly no longer the same thing as deriving an explanation from the primary properties of atoms. Instead, it meant reducing the phenomena to laws of nature grasping physical interactions. This had made it necessary to come up with a mathematical expression, but it had also established the ability of natural bodies to act. All in all, this was to create a new conception of physical reality [25, 42, 49], but to begin with – one might say – it simply created an objectively new concept.

If the new conceptuality is not recognized then all misunderstandigs of mechanicism follow.

By interpreting gravity as a central force which is *in* each separate body, Voltaire ignores the ability of bodies to interact. It is of no matter to him that bodies are only heavy *towards each other*. He thinks of the dynamic interaction known in a physical theory as "force" as an impact. Having assumed that force is inherent in separate pieces of matter, Voltaire imagines that to each gravitating body belongs a central point to which it must be striving towards. However, as geometric points cannot exert a physical force, Voltaire must have recourse to god as the cause of motion. "If matter strives towards a points, as has been proven, it nevertheless does not appear to gravitate of its own accord, as it acquires its extent from nature. It has acquired its gravity, therefore, from god" [30, p. 26]. "He has decreed a law for

all bodies by which they must all strive in the same way towards their central point" [30, p. 76]. Thus Voltaire separates matter from motion; matter acquires its motion from outside.

As a result of this conception, god or some other principle, external to physics, essentially had to keep pumping motion into the world, accomplishing a function that Newtonian physics demonstrates to be a characteristic of nature itself.

7. Physical and metaphysical explanation of nature

Admittedly, there is something which Newtonian mechanics cannot achieve, and which explains why Newton needs god to exert an influence on the world [30, p. 26]. Newton's reasons for bringing god into discussion is caused by the boundaries of his own physical theory and of physics in general. These boundaries exist since physics is a special science and not a principle explaining world as a whole. (Here the point is *only* about physics or about that Newton called "natural philosophy").

If the basic principle of mechanics is equated with the law of gravity and this with the term for the gravitational force, or rather a diffuse notion of force, and all of this at once with the law of the whole world, as Voltaire is doing, then to some extent the reason – or rather the trigger – for this conflation is rooted in mechanics itself.

Although the dynamics of gravity is merely a specific instance of Newton's universal dynamics, it also plays an outstanding role in history in that their development was a synthesis between experimental research into earthly mass (above all by Galileo) and theoretical astronomy (primarily formulated by Kepler). The law of gravity was the answer to a question much discussed at the time about whether bodies fell to the ground for the same reason that planets remained within their orbit. Following the Copernican principle, Newton's gravitational dynamics assumed the unity of natural law, so that the same natural laws were at play on earth as anywhere else in the universe, and proved it. Nature now embraced heaven and earth, things and phenomena were universally comparable – an idea pursued since the dawn of the Modern Age, but now realized for the first time in a scientific theory [44]. Gravity made this possible because it takes effect universally, over distances of both terrestrial and cosmic magnitude. That is why it was easy to regard the law of gravity as the law of the world. In this context, unlike Newton, one often understood "world" not as the solar system or as the system of fixed stars but in a philosophical sense.

By elaborating his mechanics Newton founded physics in the Modern-Age understanding, and in so doing it triggered the need to investigate what, in the terms of this new science, *the physical* means; and this has to be done in contrast, on the one hand, to *natural philosophy* and, on the other, to *mathematics*. By implication, Newton had created an entirely new meaning for the concept of *the physical*, *physical law* and the *relationship between bodies and motion*. He had provided these concepts with a new categorial constitution: the body–motion question was no longer framed by the categorial relationship *thing – property*, but by the new categorial relationship *object – behavior*.[8]

Of course, some time was required to become aware of this new situation. This consciousness-raising process carried out by furious considerations, in Germany, e.g., by sharp controversies between Wolffians and Newtonians, i.e., between the followers of the Leibnizian metaphysicist Christian Wolff and those of Isaac Newton.

The controversy between the Wolffians and the Newtonians was also the latters' battle to free natural science of philosophical patronage (of whatever complexion). To this end, even

[8] The term "object" translates here the German word "Gegenstand" determined within the framework of the philosophical conception "Gegenständlichkeit". In more detail see Refs. [25, 28, 45, 46, 48], and also the literature quoted there.

Leibniz supporters such as Lambert stood up for Newtonian mechanics, attempting to place it on a Leibnizian foundation or else blending the two bodies of thought, while Newtonians such as Euler offered alternative philosophical interpretations for what they saw as defects in Newton's mechanics (action at a distance, empty space), and physicists such as Maupertuis and, again, Euler, who accepted Newtonian mechanics, devised a new physical framework for it.

The new natural science was not a branch of metaphysics, and this was by no means to its detriment. However, it implied a completely new cognitive approach which needed to be understood philosophically [3, 4, 5, 13, 28]. Insofar as it ever has been, this did not happen until German classical philosophy, notably Kant, recognized that there was an essential difference between natural science and philosophy in terms of epistemological status and point of departure [22, 23, 25, 42, 49, 50].

But before this point was clarified both sides reproached one another for that their teachings were not metaphysics and physics, respectively. The Wolffians, meanwhile, wanted a metaphysical cognition of nature, ascribing secondary scientific significance to empirical, mathematical research, however much they extolled the virtues of experimentation and mathematics. In their opinion, physics which did not culminate in metaphysics did not even deserve the name "physics".

Wolff's cardinal objection to Newtonian mechanics was that it was not philosophy, and that it was therefore, or perhaps in addition, open to exploitation by deists and sceptics.
He wrote: "The foreigners […] are fascinated by Locke's principles and Newton's attractions, in a word no true philosophers" [51]. Of Musschenbroek, Wolff comments that "his head is full of nought but attractionibus Newtonianis". "Those who hold truck with Newtonian philosophy, which in my opinion is a non ens, are so lofty because Newton's great name swells them up, and the freethinkers also believed they have surmounted the highest peaks of reason, since they cannot distinguish reason from an excrescence of their imaginations" [51]. As to the "Newtonian" Maupertuis: "He would probably be of one mind with Algarotti, both in his view of religion, and in what is known by the simple-minded as Newtonian philosophy, which does not warrant the name of physics, let alone of all philosophy. Much as I esteem Newton for his advanced geometry, I cannot regard him as so much as a novice in philosophy, let alone a philosopher. […] Mr. Maupertuis is one of those who admire the so-called Newtonian philosophy, confusing philosophy with the cognitione Naturae mathematica, and not distinguishing this adequately from mere geometry […] But the so-called Newtonians despise the Cartesians, and in Paris they currently believe that there is no other philosophy but the Newtonian and Cartesian varieties. Geometry and astronomy constitute the core of this activity. In Paris philosophy is in a gloomy condition. Maupertuis assumes that Newton understood all there is to philosophy better than any other can" [51]. Wolff firmly believed that: "The Newtonians are haughty creatures and despise all who do not blow their trumpet, and yet nobody with any inkling of it can recognize the so-called Newtonian philosophy as a philosophy at all. I surely struck the calf between the eyes when I demonstrated as much in the fifth part of my Elementorum Mathesos" [51].

One behaved as if one was confronted with the alternative : Newton *or* Leibniz? Especially Voltaire's *Newton's Metaphysics or A Comparison of the Opinions of Mssrs. Leibniz and Newton* triggered a lively debate.[9] The bone of contention was Voltaire's critique of Leibniz [9, 11, 18]. Leibniz, it was felt, was to be dislodged in favor of a man who was respected by European scholarship as an extraordinary mathematician and physicist, but not as a great

[9] This paper was basically the metaphysical chapter from his *Eléments* which Voltaire fearing the censorship had originally left out an was published separately in 1740.

philosopher. At once a counterpaper with the polemic title *Comparison of the Leibnizian and Newtonian Metaphysics and of Several Other Doctrines of these two worldly wise men Objected to Mr. Voltaire* was published. It was seen as a necessary riposte to Voltaire's insolence. Its author, a less-known theologian, found Newton's metaphysical ideas wanting and stood up for Leibniz [12]. He criticized Voltaire for calling Newton a metaphysicist, for the Englishman had merely formulated a few disparate metaphysical propositions. Voltaire could only rank him higher than Leibniz by passing over the German's great service to this branch of worldly wisdom (Weltweisheit) in silence [12, p. 115]. His main purpose must surely have been "to find favor with the English" [12, p. 29]. He had read the German philosopher's work but fleetingly, or else forgotten the crux of it. There then followed nine chapters, reflecting the structure of Voltaire's book, in which Kahle scrutinized Voltaire's key postulations one by one and countered them in a most learned manner with all the tools of academic philosophy, examining Voltaire's statements individually from a primary perspective of metaphysical definition and formal logic founded on his own philosophical tenets, and seeking to construct evidence that his adversary has been guilty of errors of metaphysical deduction.

Nothing in the entire polemics (apart from the suggestion of a discussion about the true measure of force) related to Newton's physics, nor to the best method for measuring and calculating the motion of natural bodies; its purpose was the unconditional defence of Leibniz' philosophy, but in the wake of a previous Leibniz-Newton debate which is above all reflected in the correspondence between Leibniz and Clarke. There are no traces of any scientific progress having taken place in the thirty intervening years. Rather, this is a theologized, popularized reading of the debate, and the philosophy of Leibniz has been stripped of its flesh and blood in much the same way as the physics of Newton.

Notwithstanding of these defects Newtonianism in this way came to Germany.

8. Summary

The popularization of the new worldview was a necessary condition as well as for the development of mechanics as physical science and for the development of philosophy. The latter occur insofar as philosophy felt forced to comprehend the new natural science.

Popularization of the new worldview had prepared the intellectual ground, promoting the work of D'Alembert, Laplace and Lagrange and providing them with a response. For – as Emil du Bois-Reymond wrote – "Given the omnipotence of the court and the aristocracy, the influence of the women and the abbés, it was by no means a matter of indifference which theory they chose to embrace, and once Voltaire's *Eléments* had nudged Fontenelle's *Mondes* from the ladies' dressing-tables, Newton's victory over Descartes was as good as complete" [7].

Distortions of mechanics made by the mechanistic worldview are perceptible till today. Thus the prejudice was born that mechanics is mechanistic, and with it the assumption that it provided a foundation in natural science for so-called "mechanical materialism". But this was as inaccurate as the belief that mechanistic worldview could be eliminated simply by founding a new theory in the natural sciences. Even today, there are mechanizations of modern science.

However, the mechanistic worldview was also constructively effective as it used mechanics as a means to protect science from theology, as a line of defense for maintaining that the world could be grasped in terms of laws, as it found a path to connect English empirism with French rationalism or Locke with Descartes, as it initiated a debate on the role of mathematics for cognition of nature. Although its solutions were not durable they provoked following philosophy, especially German classical philosophy, to make this questions to

subject and to become aware of the categorial change which only Modern-Age (*neuzeitliche*) natural science makes possible and which came clearly into sight in Newton's concept of *gravity*.

The fact that Hegel damned the implicit faith in Newton is based on the named identification of Newtonian mechanics with the mechanistic worldview. All in all, Hegel's philosophy was a far-reaching disproof of this worldview. Kant's famous epistemological turn, which characterizes the beginning of German classical philosophy, ensues from the *philosophical* transformation of Newtonian method. And such philosophers as Hermann Cohen, Kurd Lasswitz and Ernst Cassirer most explicitly had worked towards awakening the fact that categorial change inherent in Newton's concept of *gravity* is the *physical expression* of *a new thought principle*. This new principle has been aptly described as *functional thought* (*Funktionsdenken*), by contradistinction to the *substantial thought* (*Substanzdenken*) of the Classical world and the Middle Ages. (This term "functional thought" does not signify mathematical thought; rather, "function" is used here as a general term for *order, relationship, collective unity*.) This principle is obliged to the device: *the acting determines the being*, a device that was not seen by the mechanistic worldview, although Modern-Age science could only be founded on this basis.

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