

BORIS HESSEN AND NEWTON'S GOD

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Abstract. A significant thread in Boris Hessen's iconic essay, *The Social and Economic Roots of Newton's Principia* (1931), is his critique of Newton's involving God in his physics. *Contra* Newton, Hessen believes that nature does not need God in order to function properly. Hessen gives two, quite distinct, 'internal' explanations of Newton's failure to see this. The first explanation is that Newton's failure is caused by his believing that motion is a mode instead of an attribute or essence of matter. The second explanation is that Newton's failure is owed to his considering mechanical motion as the sole form of the motion of matter: Newton, in Hessen's view, did not realize that matter has many forms of motion which constantly transform into one another while conserving energy. In the present paper, I defend the thesis that none of these explanations can account for Newton's failure. Hessen's first explanation is problematic because even if Newton believed that motion is an attribute or essence of matter, he would still be obliged to involve God in physics. His second explanation fails too because he does not show exactly how the multiplicity and inter-transformation of forms of motion can account for nature's organizational structure.

Keywords: Hessen, Newton, God, motion, mechanics, Descartes, mode, attribute

[T]o treat God from phenomena is certainly a part of natural philosophy.

Isaac Newton

Introduction

At the outset of the last part of *The Social and Economic Roots of Newton's Principia*¹ (1931; hereafter *TSEERNP*) the Soviet physicist, historian and philosopher of science Boris Hessen, while acknowledging Newton's enormous contribution to solving "the complex of physical and technical problems" of his era,² insinuates that Newtonian physics was limited and even wrong insofar as it did not accommodate "the view that nature is in a process of unceasing development"³. He advises that "[Newton] came to a halt, helpless, before nature as a whole"⁴ and earlier spoke of a "weakness" in "Newton's general philosophical conception of the universe"⁵. Precisely because Newton did not realize that nature undergoes a process of unceasing development, he held two – in Hessen's view – mistaken beliefs about nature in general and the solar system in particular. First, Newton maintains that nature could not *originate* through natural causes alone. Second, he claims that it could not *preserve* its

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state through natural causes alone. These two beliefs enabled Newton to hold that nature or the solar system was created *by God* and that its state is preserved *by God*.

This view of nature, Hessen continues, became obsolete with Kant and Laplace, who ratified the notion of nature as undergoing a process of unceasing development:

After Newton, Kant and Laplace were the first to make a breach in the view of nature as eternal and unchanging throughout the ages. They showed, albeit in a far from complete form, that the solar system is the product of historical development. It was through their works that the notion of development, which was subsequently to become the basic and guiding principle of all teaching on nature, entered into natural science for the first time. The solar system was not created by God, the movement of the planets is not the result of divine impulse. It not only preserves its state solely as a consequence of natural causes, but also came into existence through their influence alone. Not only does God have no place in a system whose existence is based on the laws of mechanics, but he is unnecessary even as an explanation of its origin.⁶

In the present paper I focus on the following question: *Why, according to Hessen, did Newton fail to see that nature is in a process of unceasing development?* I understand this question as equivalent, *mutatis mutandis*, to the question: *Why, according to Hessen, did Newton fail to see that nature does not need God in order to function properly?* I consider these questions equivalent because I take it that *for Hessen* P1 and P2 are in a *biconditional* relation:⁷

(P1) Nature is in a process of unceasing development.

(P2) Nature does not need God in order to function properly.

Hessen gives two, quite distinct, 'internal' explanations of Newton's failure to see that nature does not need God in order to function properly. His first explanation is that Newton failed to see this because he took mechanical motion to be a mode instead of an attribute or essence of matter. His second explanation is that Newton's failure is owed to his considering mechanical motion to be the sole form of motion. *In the present paper I will defend the thesis that none of Hessen's explanations can account for Newton's failure.* I begin by making a case for Hessen's use of an internal explanation in *TSERNP*. Next, I describe his first explanation of Newton's failure, that is, Newton's belief (a) that mechanical motion is only a mode, not an attribute, of matter and (b) that, as a mode, mechanical motion cannot account for the movement in nature without the involvement of God. I proceed to argue that Hessen's first explanation of Newton's failure is unsuccessful because even if we assume that mechanical motion is an attribute of matter, Newtonian physics would still require God's presence in order to explain the organizational structure of nature. I then consider Hessen's objection that Cartesian physics, which is also purely mechanics, works unproblematically without involving God in its operations, even though it too takes motion to be a

mode of matter. If this were true, it would show that God's involvement is not a necessary consequence of mechanical physics. I argue that Cartesian physics does in fact need to involve God in its operations and therefore that Hessen's objection is false. Finally, I take issue with Hessen's second explanation of Newton's failure, to wit, that Newton's belief in mechanical motion's being the sole form of motion forced him to involve God in his physics. I argue that this second explanation is also unsuccessful because Hessen does not explain how the belief in a multiplicity of forms of motion can account for the organizational structure of nature without involving God in such an account.

Internal and External Explanation

Hessen is known as one of the pioneers of the 'externalist' approach in the historiography and philosophy of science. According to this approach the trajectory of science is interwoven with the trajectory of human society as a whole and the explanation of the former's content requires reference to events that took place in the latter. In *TSERNP* Hessen attempts to establish the thesis that there are external explanatory interconnections between three distinct histories: (a) the history of physics, especially the history of the conceptions of matter's motion, (b) the history of technology, and (c) the history of economic production. He is particularly interested in providing external explanations of the history of the conceptions of matter's motion, to wit, in explaining events in *this* history by referencing events in the other two.

In an accomplished study of Hessen's work,⁸ Dialetis argues convincingly that Hessen's external explanation of physics involves reference not only to the three aforementioned histories but also to the *ideology* of physicists (in *TSERNP*'s case, to Newton's ideology). A physicist's ideology includes her religious, legal and political views and, Hessen judges, is the product of her social class.

What has eluded Dialetis and, in fact, most readers of *TSERNP*, is that *Hessen himself* recognizes the involvement of 'internal' explanations in any complete account of a theory of physics. Internal explanations attempt to explain an event in a particular history without exceeding its limits. So, an event in the history of the conceptions of matter's motion is explained 'internally' if the *explanantia* belong neither to the history of technology nor to the history of economic production nor to the physicist's ideology but solely to the history of physics.

Conceptions of motion in physics are, *to a degree*, internal explanations (they are arguments that develop, *to a degree*, purely within physics) and these explanations are exactly what constitutes the history of physics (as a history *distinct* from the history of technology, the history of economic production, and ideology). If Hessen wishes to provide external explanations of those conceptions of motion's history, he must *first* be aware of their internal explanations, namely of this history *itself*. Moreover, if he wishes to provide *external* explanations of the history of physics, he must first be aware of the *distinct* history of technology, the *distinct* history of economic production, and the *distinct* history of a physicist (i.e. her biography). The following diagram illustrates this view:

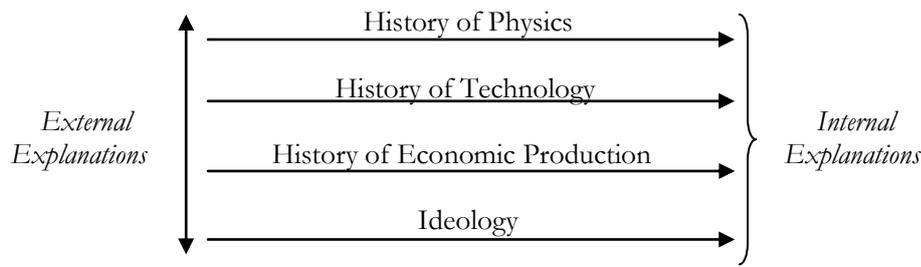


DIAGRAM 1: The structure of explanation

Hessen, I contend, subscribes to this view. First, he devotes large chunks of *TSERNP* to giving exclusively internal accounts of the three aforementioned histories and Newton's ideology. Second, he explicitly recognizes that there was a moment in history when physics conceived of itself independently of the resolution of "empirically particular problems" and attempted "to establish a synthetic summary and solid theoretical basis for solving, by general methods, all the [problems of physics] [...]"⁹ This purely "theoretical" attempt led to an "encyclopedic survey of the physical problems" which, in Newton's era, "amounted to creating a consistent structure of theoretical mechanics which would supply general methods for solving the problems of celestial and terrestrial mechanics."¹⁰ In fact, Newton's *Principia* was presented and conceived of as just such a purely theoretical "encyclopedic survey" or a "synthesis" of entirely theoretical problems and solutions.¹¹

There is no denial that physics can be explained externally (in fact, Hessen does this masterfully), yet *methodologically* this is only possible if physics, technology, economic production and ideology *already* have their 'own' histories – however limited they may explanatorily be. The vertical arrow(s) in the above diagram would have no object of application if the horizontal arrows were absent.

Merton implies that Hessen failed to understand the independent "logical concatenation of scientific problems," present in "the intrinsic developments of science," which plays a crucial role in the explanation of the content of science, even though "in point of fact [...] *some* role must be accorded [to] factors external to science."¹² Dialetis blames Merton for failing to comprehend that for Hessen there can be no "logical concatenation of scientific problems" that is not *already* determined by technology, economic production and ideology.¹³ In my view, there is a sense in which both Merton and Dialetis are amiss: Hessen does think that there is a "logical concatenation of scientific problems" which is, *to a degree*, independent of technology, economic production and ideology.¹⁴ This independence is determined *methodologically*: in order *to even begin* narrating a story about the external dependence of science upon technology, economic production and technology, the purely internal story of science (as well as those of technology, economic production and ideology) must *already* be known (with all their explanatory flaws).

The present paper explores *TSERNP* with the aim of discussing Hessen's account of the *internal* (and therefore, according to him, limited) explanation of the fact that Newton failed to see that nature is in a process of unceasing development or, what is the same, that nature does not need God in order to function properly.

First Response: Motion as a Mode of Matter

Hessen's first response to the question presented in the Introduction is that Newton failed to see that nature does not need God in order to function properly precisely because his view of matter's motion could not allow it. Newton had a solely or predominantly *mechanical* view of matter's motion¹⁵ and therefore his physics was solely or predominantly mechanical. Two basic features define the mechanical view (M). (M1) It presents motion in terms of *causation*: when a body moves, this is an effect of a cause.¹⁶ (M2) It sees motion solely as *displacement*: a body moves only if it changes place. Since Newton held these two beliefs, he had a mechanical view of motion.

The mechanical view is also often characterized by the following feature. (M3) It understands motion in terms of bodily contact: the cause of a body's motion is always another body.¹⁷ Since matter is exhausted by bodies, all elements involved in this understanding would be material. The presence of this feature in the mechanical view turns it into a *materialist* mechanical view.

Newtonian mechanics, however, is not materialist, as it denies M3. For Newton, matter's motion involves *forces* as causes, though forces are not bodies. Since he endorses the mechanical view but rejects M3, M3 does not belong to the definition of mechanics. Rather, M3 belongs to the definition of *materialist mechanics*. Given that Newtonian mechanics accommodates forces as causes of motion, it is a form of *immaterialist mechanics*. It is 'immaterialist' only in the sense that it holds that *besides other bodies*, a given body's motion involves elements which are not part of matter, to wit, forces.

There is yet another division of mechanics, which is grounded in the question of whether motion is to be considered (a) an attribute or essence of matter or (b) simply a mode of matter.¹⁸ Based on which of these two is accepted, mechanics is either essentialist or modal. For *essentialist mechanics* motion is a necessary feature of matter: matter is always in motion. By contrast, for *modal mechanics* motion is not a necessary feature of matter: it is possible that at some moment it is at rest. Rest is another mode of matter. Toland was a supporter of essentialist mechanics. Bacon, Descartes and Newton were all supporters of modal mechanics.

Newtonian mechanics' can therefore properly be characterized as *modal immaterialist mechanics* (hereafter 'MIM'). It accepts the following four claims:

(MIM 1) When a body moves, this is an effect of a cause. (*Causation*)

(MIM 2) A body moves only if it changes place. (*Displacement*)

(MIM 3) The cause of a body's motion involves not only another body but also forces, which are not material elements. (*Immaterialism*)

(MIM 4) Motion is only a mode and not an attribute or essence of matter. (*Modality*)

When Hessen writes that "the conception of divinity in Newton's system is by no means accidental but is organically connected with his views on matter and motion"¹⁹, he speaks as if the phrase "his views on matter and motion" stands specifically for MIM 4, as he explicitly writes that

by depriving motion of the character of being an attribute of matter, and recognizing it only as a mode, Newton deliberately deprives matter precisely of that inalienable property without which the structure and origin of the world cannot be explained by natural causes.²⁰

Let us assume that this reading is correct and that what Hessen is claiming here is that it is Newton's acceptance of MIM 4 that led him to introduce God in physics. It would then hold that MIM 4 prevented Newton from seeing that nature does not need God in order to function properly. But what is, according to Hessen, Newton's *argument* for MIM 4's necessarily leading to God's involvement in physics?

Hessen begins his account of Newton's argument by noting that

Newton's appeal to divine reason as the supreme cause, organizer and prime moving force of the universe is by no means incidental but is the inevitable consequence of his conception of the principles of mechanics.²¹

Significantly, Hessen regards Newton's involving God in physics here as a consequence of his principles of mechanics, *not as a consequence of his ideology*. He thus provides an internal, not an external, explanation of that involvement. The phrase "the principles of mechanics" refers to Newton's laws of motion. Hessen will then argue that Newton's involving God in physics is "the inevitable consequence" of his laws of motion. In fact, however, Hessen derives this only from the first law, the law of inertia, *and in connection with MIM 4*.

Newton's first law states that "every body perseveres in its state of being at rest or of moving uniformly straight forwards, except insofar as it is compelled to change its state by forces impressed."²² Hessen takes this to be a statement about the nature of matter, that is, that *matter* is characterized by inertia: "Newton's first law of motion attributed to matter the faculty of maintaining that state in which it exists."²³ But since the law speaks of two states of matter that cannot coexist in a body, rest or motion, Hessen interprets Newton as saying that "motion is not an immanently inherent *attribute* of a body, but is a *mode* which matter may or may not possess."²⁴ Matter can be in *one of two states*, either at rest or in motion.

If in the beginning matter was in motion, then moving bodies and forces could either "alter or stop this motion"²⁵. But if the universe started with matter being at rest, only a force that did not follow from a moving body could move it. This modal reading of Newton's first law of motion necessitates the involvement of God both in the creation and in the preservation of nature: "It is clear that such a conception of the modality of motion must inevitably lead to the introduction of an external motive force, and in Newton this role is performed by God."²⁶ The argument goes as follows.

It is undeniable that space presently contains moving matter. Yet, if matter could be at rest, there is the possibility that in the *beginning* of creation *all* matter was distributed in space as motionless matter.²⁷ The problem is how this state of matter can acquire motion (which it must, given its presently moving state). The law of inertia

dictates that matter would have remained at rest unless a force affected it. Since *all* matter is at rest in the beginning, no force *deriving from a body* can generate motion. Only a *divine* immaterial force could do this. Moreover, if *all* matter could *become* motionless via forces deriving from bodies, such as, for example those deriving from the collision of bodies,²⁸ it would be possible that *at any moment* all matter could be at rest – and, therefore, as before, by the law of inertia, matter would never again be in motion if no divine being were involved. By involving God in both the creation and the preservation of matter, Newton excludes the possibility of absolute, universal, eternal rest.

One may object that *for Newton* a motionless body can start moving if it is affected by a force deriving from a body *which remains at rest during the affection*. There is no need for a body to move in order for another body to move: a motionless body can cause another body to move without any alteration to its own state of being at rest. In this way, one can explain the beginning of motion from a state of rest without invoking a deity.

If this objection held, Hessen's claim that MIM 4 leads to Newton's involving God in physics would be mistaken, because motion could be generated from a state of absolute rest by means of natural causes alone (i.e. by bodies and the forces deriving from them). Yet, in a letter to Bentley dated 25 February 1692/3 Newton scolds his friend for ascribing to him the view that a *distant* body can affect another body without having contact with it:

It is inconceivable that *inanimate brute matter* should, without the mediation of something else, *which is not material*, operate upon and affect other matter *without mutual contact*, as it must be, if gravitation in the sense of Epicurus, be essential and inherent in it. And this is one reason why I desired you would not ascribe innate gravity to me. That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial, I have left to the consideration of my readers.²⁹

It is clear from this passage why Hessen's objection cannot hold. Newton emphatically tells Bentley that motionless matter ("inanimate brute matter") cannot affect other motionless matter without the mediation of an immaterial being.³⁰ Epicurus, who ascribes innate (i.e. essential) gravity to matter, is obliged to argue that motionless matter "operates upon and affects" other motionless matter without contacting it ("without mutual contact"), that "one body may act upon another at a distance through a vacuum without the mediation of anything else." This, Newton exclaims, is "so great an absurdity" that no competent thinker can ever accept it.³¹ It is

evident that the dilemma Newton raises in the last sentence is only rhetorical. For if we assume that in the beginning or at a certain moment *all matter* was at rest, no *material* agent could have caused motion in other motionless matter without having the ability to affect it from a distance. But this is exactly what Newton denies. Therefore, only an *immaterial* agent could have caused the gravitation of one motionless body to another motionless body.

Assuming the success of this reply to Hessen's objector, our question has thus received a first response: Newton failed to see that nature does not need God in order to function properly because he believed that motion is only a mode, not an attribute, of matter. His physics was modal rather than essentialist mechanics. This forced him to find a way out of the possibility of absolute rest and no such way presented itself without involving God in physics.

The Collapse of Essentialist Mechanics

Hessen's first specification of the root of Newton's failure, i.e. modality, would hold only if *essentialist* mechanics does not result in the same failure. Newton, however, denies that essentialist mechanics could explain nature without God's involvement. If Newton could make a case for this denial, we would be compelled to search for a second specification of the ground of his failure to see that nature does not need God in order to function properly.

Immediately before he describes Newton's argument from modality, Hessen says that Newton aspires to prove "the necessity of a divine power as the organizing, moving and directing element of the universe."³² Yet, the argument from modality says nothing about God's being the universe's principle of *organization*, but only about God's being a principle of *movement*. Therefore, even if *modal* mechanics were successful, Newton would need another argument for the thesis that matter requires God for its organization. Moreover, Newton argues that essentialist mechanics cannot explain matter's organization: bodies affecting one another (causation), either directly or through forces deriving from bodies (materialism or immaterialism), and simply changing places in space (displacement), even being combined with the mechanical laws determining their behaviour, cannot account for the way a body is organized. So, even if one did accept *essentialist* mechanics as an explanation of matter's motion, one would need another explanation of matter's *organizational* structure. In Newton's view, such an explanation cannot but resort to the positing of a divine being, an immaterial³³ omnipotent being with intelligence and a will. As Hessen himself observes, Newton makes this point in a long letter to Richard Bentley dated 10 December 1692. The letter contains several arguments for the thesis that it is necessary to involve God in physics. Here I will present three of them. In all cases let us assume that motion is an attribute (or essence) of matter and hence that the whole discussion unfolds from the perspective of essentialist mechanics.

I. Newton's first argument focuses on "innate gravity", which is a force that is innate or essential to matter. As a force, it is not a body, yet it derives from bodies in the sense that its involvement in motion requires one body contacting another body. Newton characterizes this force as 'blind' because it is simply the consequence of sheer bodily (or, if you will, 'mechanical') contact and involves no intelligence or will.

He contemplates two possibilities: (a) innate gravity in finite space and (b) innate gravity in infinite space.

First, assume that the universe consists of bodies having essential motion and innate gravity and existing in *finite* space. Such a scenario results in *one* spherical mass, because “the matter on the outside of this space would by its gravity tend towards all the matter on the inside, and by consequence fall down into the middle of the whole space, and there compose one great spherical mass.”³⁴ More simply, if there were only moving bodies gravitating towards one another ‘blindly’ in finite space, all bodies would collapse into each other, thereby begetting one mass. Thus, in the first scenario, all differentiation and organization between bodies would vanish. As Newton puts in the General Scholium of the Third Book of the *Principia*, “no variation of things arises from blind metaphysical necessity, which must be the same always and everywhere.”³⁵ Clearly, this case of essentialist mechanics cannot explain nature’s differentiation and organization.

Second, assume that the universe consists of bodies that have essential motion and innate gravity and exist in *infinite* space. The result is the formation of an *infinite number* of distinct masses:

But if matter was evenly dispersed throughout an infinite space, it would never convene into one mass, but some of it would convene into one mass and some into another, so as to make an infinite number of great masses, scattered at great distances from one another throughout all that infinite space.³⁶

In this scenario *differentiation* of bodies can be accounted for, but can it explain the organization of the universe? In Newton’s view, the answer must be negative. It cannot explain why there is *one* luminous mass, the sun, and *many* opaque masses around it, the planets. For this organizational structure to have occurred, matter should have

divide[d] itself into two sorts, and that part of it, which is fit to compose a shining body, should fall down into *one* mass and make a sun, and the rest, which is fit to compose an opaque body, should coalesce, not into one great body, like the shining matter, but onto *many* little ones.³⁷

Newton’s complaint is that essential motion, innate gravity and infinite space cannot explain the *very specific* organization of matter: the fact that luminous matter coalesces into *one* mass and opaque matter coalesces into *several* masses remains unexplained. Why did luminous matter stay together in one body and opaque matter get distributed into a multiplicity of bodies? Newton believed that mechanics in general (hence essentialist mechanics as well) with all its laws could not give an answer to questions of this kind (i.e. questions about fundamental organizational structures). If one assumes that in the beginning matter was not a mixture of luminous matter and opaque matter but rather (a) only opaque matter or (b) only luminous matter,

organization becomes even more difficult to explain. If one assumes that in the beginning there were only opaque bodies, why and how *only one* body was transformed into the sun – by means of essential motion, innate gravity and infinite space *alone* – cannot be explained. Conversely, if we assume that in the beginning there were only luminous bodies, then essential motion, innate gravity and infinite space *alone* could not explain why and how all those bodies developed into opaque bodies *except one* of them.³⁸ So, nature's organization is not "explicable by mere natural causes,"³⁹ that is, by the content of mechanics. In order to explain organization, physics must involve an immaterial omnipotent being; a being that creates and preserves a certain organizational structure through its intelligence and volition.⁴⁰

II. Newton's second argument⁴¹ stresses the difference between planets and comets regarding motion. Whilst comets in our planetary system "move all manner of ways, going sometimes the same way with the planets, sometimes the contrary way, and sometimes in cross ways," all the planets "move the same way [...], without any considerable variation."⁴² "It is plain" that this difference "could not spring from any natural cause alone, but [was] impressed by an intelligent agent."⁴³ For given that *both* comets *and* planets (a) are masses of matter and (b) move in the same region of space, the fact that the two groups behave, with respect to motion, so *radically differently* cannot be explained by referring only to their mechanical motion and the laws determining it.⁴⁴ And if mechanical motion, which is the only form of material motion (including the motion affected by forces deriving from bodies), cannot explain an organizational structure of nature, some immaterial cause not deriving from bodies, an omnipotent being with intelligence and a will, must be involved in such an explanation.

III. The third argument for the necessity of involving God in physics is based on the harmonious complexity of our solar system.⁴⁵ Newton's point is that mechanical motion plus the laws of motion simply cannot generate *such* a complexity, so a being with intelligence and a will must have intervened. He first describes this complexity. In order for the (primary and secondary) planets to move in the exact way in which they do around the sun and other central bodies, their velocity must be proportional to their distance from the central bodies. Were they as swift as the comets, they would not move in concentric orbits, as they actually do, but in eccentric orbits, as comets do. If all planets had exactly the same swiftness, or if the velocity of each had been greater or lesser than it really is, or if the distances from the centres around which they move had been greater or lesser than they actually are, or if the quantity of matter in them had been greater or lesser than it really is, then the planetary system would not be what it is but something entirely different. Newton insists that all these specific numbers and degrees and quantities and their specific connection that makes a harmonious complexity possible cannot derive from mechanical motion (i.e. motion caused by bodies affecting one another in space and the forces accompanying this affection) and its laws. Since, however, our planetary system does exhibit a harmonious complexity, its cause is not mechanical motion or matter and the forces deriving from it, which are "blind and fortuitous," but rather an immaterial omnipotent being with intelligence and a will.⁴⁶ Such a cause would be an agent that has the capacity to understand and combine a colossal variety of variables

in that singular perfect way that produces a harmoniously complex planetary system.⁴⁷ Mechanical motion, even with the assistance of its laws, cannot “compare and adjust” all the elements present in a region of space.⁴⁸ A being with intelligence and a will must be posited for this to be accounted for.

With these three arguments Newton claims to have established the necessity of God's involvement in physics even if motion is taken to be an attribute of matter (essentialist mechanics). For even in this scenario nature's *organizational structure* would still require an immaterial omnipotent cause that has intelligence and a will. The three arguments have illustrated what is meant here by nature's 'organization', that is to say, that bodies acquire a specific position in the system of nature and exhibit a specific behaviour and relationality therein. Based on the three arguments we have examined as well as some others, Newton claims that essentialist mechanics cannot explain nature's organization because the specific position, behaviour and systematic interrelations of bodies cannot be accounted for by employing solely the conceptual tools of mechanics (causation, bodily forces, displacement, mechanical laws). Hessen is aware of this Newtonian notion of 'organization' because he paraphrases Newton as saying that “in no case can it be explained by natural causes how the luminous mass – the sun – is in the centre of the system and precisely in the position in which it is placed.”⁴⁹ But if the acceptance of essentialist mechanics does not remove God from physics, we cannot accept Hessen's first response to our question, namely that the acceptance of the modality of motion (MIM 4) – modal mechanics – was the reason why Newton failed to see that nature does not need God in order to function properly. This obliges us to search for a second response from Hessen, for another ground of Newton's failure.

God and Cartesian Physics

It has been shown above that both modal and essentialist mechanics necessitate God's involvement in their respective domains. Since these two kinds of mechanics exhaust the determination of mechanical motion, the very nature of mechanics requires God's presence. Yet, as Hessen notes, for Newton *physics* (the explanation of nature) is solely or predominantly mechanics,⁵⁰ so for Newton *physics* requires God's presence. Our discussion has shown that in Newton's case God's involvement in physics-as-mechanics is not due to his ideology, but rather to physics-as-mechanics' own limitations. Freudenthal and McLaughlin write that for Hessen “Newton drew back from fully endorsing the mechanization of the world picture and adapted his concept of matter so as to be able to introduce God into the material world.”⁵¹ This insinuates that Newton *could* develop physics-as-mechanics in such a way that God would play no role in it but he did not do it for *ideological* reasons, “so as to be able to introduce God into the material world.” The previous analysis has shown that this is incorrect: Newton did not develop physics-as-mechanics *with the aim of* giving God a role therein, but rather he gave God a role in physics-as-mechanics *because* it could not work without God's presence.

One may object that this conclusion is mistaken, for, as Hessen remarks, *Cartesian physics, which is also pure mechanics*, works fine without involving a divine

force.⁵² Hessen suggests that Descartes's physics was superior to Newton's. In his words,

the latent materialistic germs of the *Principia* did not grow to become a consistent system of mechanical materialism, *like the physics of Descartes*, but were interwoven with his idealistic and theological views, to which, on philosophical questions, even the materialistic elements of Newton's physics were subordinated.⁵³

The "idealistic and theological views" to which Newtonian physics was subordinated are the two beliefs we have already mentioned: the belief in the creation of nature by God and the belief in divine intervention to the running of nature. Thus, Hessen seems to be saying that in contradistinction to Newtonian physics Cartesian physics was free of these beliefs and that this is the reason why the latter is a "consistent system of mechanical materialism." This is confirmed by his statement that "in his physics, Descartes does not recognize any supernatural causes."⁵⁴

Yet, as Hessen's text continues, it becomes increasingly difficult to abide by this statement. He writes:

It is true that Descartes also considers motion only as a mode of matter, but, in contrast to Newton, for him the supreme law is the law of conservation of the quantity of motion.⁵⁵

Since Descartes, like Newton, considers motion only as a *mode*, not an attribute, of matter, he espouses modal mechanics. If he is indeed a follower of modal mechanics, Cartesian physics is open to the problematic possibilities we have specified with regards to Newtonian mechanics, namely (a) that the beginning of matter could be made with universal rest and (b) that there could be a moment when all motion stops (and hence when matter exists in a state of universal rest). Hessen emphasizes that Descartes reacts differently to this problem than Newton. Instead of involving God in physics, like Newton did, he involved *the law of conservation of the quantity of motion*. The law says that "individual material bodies can acquire and lose motion, but the general quantity of motion in the universe is constant."⁵⁶ Thus, the solution to the problem is that the universe as a whole maintains a particular quantity of matter in motion. So even if a particular quantity of matter comes to rest, matter as a whole will never completely be at rest; some other quantity of matter will be in motion. Moreover, the universe does not require a divine force in order to *start* moving, since a particular quantity of matter would have *always already* been in motion: this is a consequence of there being a *law* of conservation of the quantity of motion. Consequently, as Hessen observes, Descartes's law of conservation of the quantity of motion makes motion "indestructible."⁵⁷

Yet, what is the ground of this law? How is it established? Descartes could respond dogmatically by saying that the law is an *axiom*, a self-evident or rational *fact* about matter. But, *Hessen himself tells us* that Descartes does not respond in this way; instead Descartes refers to God in order "to *prove* that the quantity of motion in the

universe remains constant.”⁵⁸ So, while Descartes “refused to admit the conception of an external impetus imparted by God to matter,” he *justified* the existence of constant motion in matter by reference to God. His argument, *according to Hessen*, was that “constancy is one of the principal properties of the deity,” so “we cannot assume any inconstancy in his [i.e. the deity’s] creations, since by assuming inconstancy in his creations we also assume inconstancy in him [i.e. the deity].”⁵⁹ This tells us that a particular amount of motion is sustained in the whole of matter *because*, ultimately, (a) a change in that amount would mean that God has created an inconstant universe and (b) we ‘cannot’ assume any inconstancy in God’s creations because constancy is a property of God. This means that for Descartes (according to Hessen) the constancy of motion in matter as a whole is *sustained* ultimately by God because *at any time* for there to be constancy of motion there has to be *at any time* reference to the law of conservation of the quantity of motion, which is grounded in God. It also means, though, that for Descartes (according to Hessen) matter is *created* by God as having a particular amount of motion and rest. This holds because if matter had not been created in this way, the law of conservation of the quantity of motion would not have been grounded by Descartes in the way that it is, namely in God. *It is only the assumption that matter has been created by God that obliges God to sustain the constancy of motion (and rest) within it* (in the manner explained above). In this way, God reenters Cartesian *physics* from the backdoor. This is why Hessen, who previously declared that Cartesian physics is “a consistent system of mechanical materialism,” now retracts this declaration:

[...] Descartes’s reason for introducing a deity is different from Newton’s, but his conception also requires a deity, since Descartes, too, does not maintain an entirely consistent view of the self-movement of matter.⁶⁰

Furthermore, if we assume (wrongly) that Descartes was a supporter of *essentialist* instead of modal mechanics, it is evident why Cartesian physics could not be “a consistent system of mechanical materialism.” Being a general approach that thematizes only *mechanical* motion, essentialist mechanics’ horizon of explanation cannot overcome the problem of explaining nature’s fundamental organization. A different account of the laws of motion and of the space in which mechanical motion occurs (for example, as a plenum instead of as a vacuum) can be provided, but whatever the account may be, *as long as it only pertains to mechanical motion*, it will fail to give a fully mechanical explanation of nature precisely because nature’s organization will always be left unexplained. The problem here is not with Newton or Descartes, but with the character of the approach, namely that of *mechanics*.⁶¹

This is the reason why Descartes, *pave* Grossmann⁶² and Freudenthal and McLaughlin⁶³, does *not* really espouse a *fully* materialistic conception of the *physical* world. He is not an idealist only with respect to thought and its laws. He is also an idealist with respect to extension and its laws, in the precise sense that an immaterial being must ultimately be involved in extension if the latter is to take the shape of moving, organized nature. Grossmann is right that Descartes saw the physical world as

a clock whose structure is purely mechanical,⁶⁴ but he failed to comprehend that Descartes also saw the physical world as being in need of a clockmaker, just like *and in the exact manner* that Newton did. For while the clock works without the clockmaker's help if all its parts are in good condition and have been put together in the right order, someone still had to put them together correctly in the first place and must continue to keep them in good condition.⁶⁵

This understanding of Descartes, that is, as someone who involves God in his *physics* (and not just in his metaphysics), is confirmed by the findings of a scrupulously researched article by Daniel Garber.⁶⁶ Garber concludes that "Descartes is quite explicit that it is God who grounds the laws of motion in the world"⁶⁷ and that "Descartes, along with the tradition in Christian thought, holds that God must not only create the world, but he must also sustain the world he creates from moment to moment."⁶⁸ Descartes explicitly *justifies* the law of conservation of the quantity of motion, which is the ground of his laws of motion, by reference to God in the *Principles*, Part II, article 36:

[...] it is most in harmony with reason for us to think that merely from the fact that God moved the parts of matter in different ways when he first created them, and now conserves the totality of that matter in the same way and with the same laws with which he created them earlier, he always conserves the same amount of motion in it.⁶⁹

Bodies, then, do not move by themselves: if God were removed from Descartes' *physics*, bodies would stop moving altogether; nay, they would completely disappear. "God causes bodies to move in the physical world"⁷⁰ both by being "the primary cause of motion"⁷¹ and by "preserv[ing] the same amount of motion or transfer in it as he placed in it at the beginning."⁷²

Second Response: Multiplicity and Inter-Transformation of Forms of Motion

Since *all* possible mechanics necessitates God's involvement in physics, Newton's endorsement of modal instead of essentialist mechanics (MIM 4) *could not* have been the reason why he failed to see that nature does not need God in order to function properly. Between his discussion of Newton's and Descartes's modal mechanics and the last theme of *TSERNP*, namely, the correlation between unemployment and the increased use of machines, Hessen discusses only one other topic: *the multiplicity of forms of the motion of matter and their transformation into one another*. He argues, following Engels,⁷³ that by regarding motion as solely mechanical, that is, solely as *displacement*, Newton fails to comprehend the truth of matter's motion, which is that it is not only mechanical (displacement), but also thermo-dynamic and electro-magnetic (at least). Hessen's point of attack, therefore, is now *MIM 2* rather than *MIM 4*. The affirmation of *MIM 2* is now taken to be the reason why Newton failed to see that nature does not need God in order to function properly.

Yet for this to be the explanation of Newton's failure, Hessen's own belief in the multiplicity and inter-transformation of forms of motion should explain nature's *organizational* structure. According to Hessen, Newton's inability to consider the latter

view is ultimately the reason why he involved God in physics. If it holds (a) that the motion of matter has a multiplicity of inter-transformational forms, (b) that this multiplicity/transformation accounts for nature's organization without God's involvement, and (c) that Newton involves God in physics because he takes motion to have only been mechanical, it certainly follows that the reason why he fails to see nature as not needing God in order to function properly is because he thought that motion is only mechanical.

This would accord nicely with the biographical fact that, as Sean Winkler acutely observes, Hessen

belonged to the Deborinite (so called after A. M. Deborin) School; a Hegelian wing of revisionist, as opposed to orthodox, Marxists that was founded upon Lenin's initiative to encourage the study of the philosophy of G. W. F. Hegel for the sake of developing ever-improved accounts of materialist dialectics.⁷⁴

In the 1920s mechanism, according to which motion was only conceived in mechanical terms, was a powerful intellectual movement in the Soviet Union. All endeavours to present motion as having multiple forms were deemed "idealist" and "bourgeois" by the Marxist mechanists. Contrastingly, Hegel saw the logical categories involved in mechanics (which occupy the field of the logic of being, found in the first part of his *Science of Logic*) as being "sublated" (i.e., incorporated and thereby overcome)⁷⁵ by the logical categories involved in accounts of self-organization (which belong to the logic of the concept, found in the third part of the *Logic*). More concretely, in his *Naturphilosophie*, the second part of the system, Hegel argues that "mechanics," due to its own limitations, is "sublated" by "organics," the part accounting for nature's self-organization.⁷⁶

Dialectis provides more details of this historical connection. After Lenin's death in 1924 Marxism was dominated by "mechanism," which was characterized by anti-Hegelianism and the ambition to reduce all qualities to quantities.⁷⁷ A. K. Timiryazev and L. I. Axelrod were well-known mechanists. The rise of mechanism caused a widespread, long-term and sometimes bloody dispute in the Soviet Union between the Marxist mechanists and the Marxist "dialecticians." The latter were mainly students of Deborin, who maintained that mechanics could not account for nature's unity and organization and hence needed to be supplemented with Hegelian philosophy, which would unite the "data" offered by mechanics and other sciences into an organized whole.⁷⁸

Hessen was Deborin's most promising student. He tried to show that contemporary non-mechanical physical theories, such as thermo-dynamics, electromagnetics and the general theory of relativity, confirm the presence of Hegelian "dialectics" in nature.⁷⁹ I understand this to mean that Hessen had the view that these theories explain what mechanics cannot: nature's (self-)organization.

TSERNP disappoints us at this juncture. Its discussion of the multiplicity and inter-transformation of forms of motion does *not* contain an argument concerning how these forms account for nature's organizational structure. Instead of pursuing *that*

argument, Hessen, like Engels before him,⁸⁰ seems content with establishing that mechanics (a) fails to grasp the richness of the motion of matter, because while it is a phenomenon with many dimensions, mechanics presents it one-dimensionally, thus remaining “within the bounds of one form of motion, that is, mechanical displacement;”⁸¹ and (b) fails to appreciate the “development and transition from one form of motion to another.”⁸²

Looking at nature, Hessen holds, “we observe an endless variety of forms of motion of matter.”⁸³ Contemporary physics has succeeded in explicating “a number of different forms of motion (mechanical, thermal, electromagnetic).”⁸⁴ Thus, for physics itself

in addition to [the mechanical] form of motion there are a number of other forms of motion of matter, in which mechanical displacement recedes to the background by comparison with new specific forms of motion.⁸⁵

Motion is no longer understood as “the simple displacement of bodies in space”⁸⁶ and mechanical motion is no longer considered “the sole and universal aspect of motion.”⁸⁷

Mechanics not only fails to capture motion’s richness; it also fails to recognize the relations between its forms. Such recognition is attained by “dialectical materialism” which “regards the principal task of natural science as the study of the forms of motion of matter in their interconnections, interactions and development.”⁸⁸ More concretely, Hessen advises that the forms of motion are transformed into one another:

In nature, in real matter, absolutely isolated, pure forms of motion do not exist. Every real form of motion, including, of course, mechanical displacement, is always bound up with the transformation of one form of motion into another.⁸⁹

Contemporary physics, Hessen continues, should “[study] the development of inorganic matter in the microcosm and the macrocosm” in order to “[understand] the connection between the various forms of motion of inorganic matter and reciprocal conversions of one to another” and to “lay a sound basis for a natural classification of forms of motion of matter.”⁹⁰ Based on *this* classification, natural sciences should be classified hierarchically:

Every science analyses a single form of motion or series of forms of motion that are interconnected and transformed into one another. The classification of sciences is none other than a hierarchy of the forms of motion of matter in accordance with their essential order, in other words, in accordance with their natural development and the passing of one form of motion into another, as they occur in nature.⁹¹

The consideration of the inter-transformation of the forms of motion forced contemporary physicists (Mayer and Helmholtz, most prominently) to “[pose] the problem of the conservation and conversion of energy.”⁹² Naturally, then,

the category of energy as one of the basic categories of physics appeared at the time when the problem of the correlations between various forms of motion emerged. And as the forms of motion investigated by physics became more varied, so the category of energy acquired ever more significance.⁹³

Hessen stresses that it was “the discovery of the transformation of forms of motion along with the conservation of energy in these conversions” that generated the result that

the different isolated forces of physics (heat, electricity, mechanical energy), which until then had been seen as comparable to the invariable species of biology, were transformed into interconnected forms of motion that convert into one another according to definite laws.⁹⁴

Since all forms of motion are transformed into one another while conserving energy, “physics came to the inevitable conclusion that the end result was the eternal circulation of moving matter.”⁹⁵ Matter’s eternal circulation, its motion’s indestructibility,

consists not only in the fact that matter moves within the limits of one form of motion, but also in the fact that matter *itself* is capable of producing *from itself* all the endless variety of forms of motion in their *spontaneous* transformations into one another, in their *self*-movement and development.⁹⁶

This is all that Hessen asserts in *TSERNP* about the multiplicity and inter-transformation of forms of motion. We notice that he does *not* address the question of how this multiplicity/transformation accounts for nature’s organization. Although Hessen, following dialectical materialism, portrays motion as being richer than Newton’s concept of motion and as developing its forms spontaneously, this does *not* entail God’s absence in physics. Hessen makes a convincing case against MIM 2 but he does not concatenate it to the explanation of nature’s organization. As long as Hessen does not demonstrate how dialectical materialism or non-mechanical physics explains nature’s fundamental organization, Newton will be *justified* in including God in physics.

Conclusion

This paper aimed to explain why, according to Hessen, Newton failed to see that nature does not need God in order to function properly. Hessen’s first explanation was that Newton failed to see this because he took mechanical motion to

be a mode instead of an attribute of matter. This explanation was rejected because even if Newton took mechanical motion to be an attribute, he would still have to involve God in physics, as mechanical motion's being an attribute of matter does not account for nature's organizational structure either. The second explanation was that Newton's failure is due to his considering mechanical motion as the sole form of motion, to wit, his recognizing neither the multiplicity nor the inter-transformation of forms of motion. This explanation was also rejected because Hessen does not tell us how multiplicity and inter-transformation account for nature's fundamental organization. Yet, the second explanation need not be rejected altogether; its acceptance is conditional upon the provision of a successful description of how dialectical materialism or non-mechanical physics explains nature's organization. *TSERNP*, for one, provides no such description and hence fails to explain Newton's failure.

Assume (wrongly) that Hessen has provided a successful explanation of how dialectical materialism or non-mechanical physics accounts for nature's organization. In this event one could maintain that Newton failed to see that nature does not need God in order to function properly because he perceived mechanical motion as motion's only form. *As soon as one makes this claim*, the horizon for asking a new question is opened: *why did Newton regard mechanical motion as motion's only form?* Hessen offers an external response: the historical conditions of economic production and technological advancement did not provide Newton with the idea of the multiplicity of forms of motion and of their inter-transformation. Nevertheless, we should not disregard the fact that there is a gap between this external response and Newton's failure to see that nature does not need God in order to function properly. The response does not explain *this* failure.

Since no successful internal explanation of Newton's failure is given, Hessen sometimes resorts to *ideology* as its external cause. He writes that

the *ideological* cast of mind of Newton, who was a child of his class, *explains* why the latent materialistic germs of the *Principia* did not grow to become a consistent system of mechanical materialism [...], but were interwoven with his *idealistic* and *theological* views, to which [...] [they] were subordinated.⁹⁷

It has been shown above that Newton involved God in physics because of the limitations in mechanics' explanation of nature; *ideology had nothing to do with it*. Even Hessen himself sometimes agrees with this:

[...] Newton's appeal to divine reason as the supreme cause, organizer and prime moving force of the universe is by no means incidental but is *the inevitable consequence* of his conception of the principles of mechanics.⁹⁸

All Hessen had to do in order to explain Newton's failure was to describe how exactly dialectical materialism or non-mechanical physics accounts for nature's *organizational* structure, but he did not do this.

My criticism of Hessen is hardly intended to be a sweeping censure of his iconic paper. *TSERNP* retains its legendary status as a monument of externalist history and philosophy of science even withstanding my critique. I did, though, aspire to analyze a rather overlooked facet of *TSERNP* in Hessen scholarship, that is, his critique of Newton's involving God in physics, and to do this in an internalist manner, hoping thereby to enrich our appreciation of *TSERNP*, in particular, and of Hessen's complex enquiry into the history of physics, in general.⁹⁹

References

¹ Hessen, B., "The Social and Economic Roots of Newton's *Principia*" in *The Social and Economic Roots of the Scientific Revolution*, ed. G. Freudenthal and P. McLaughlin (Dordrecht: Springer, 2009), 41-101.

² Hessen, B., (2009), 82.

³ Hessen, B., (2009), 83.

⁴ Hessen, B., (2009), 82.

⁵ Hessen, B., (2009), 68.

⁶ Hessen, B., (2009), 83.

⁷ My assumption is that P1 and P2 are, for Hessen, equivalent only in the sense that they are *biconditionals*. That is to say it seems to be true, for Hessen, (a) that if nature is in a process of unceasing development, then nature does not need God in order to function properly, *and* (b) that if nature does not need God in order to function properly, then nature is in a process of unceasing development. I ground this assumption mainly in what Hessen says at the beginning of the last part of *TSERNP*; see Hessen, B., (2009), 82-83. He says that "Newton [...] rejected the view that nature is in a process of unceasing development" and a few lines below he asserts, contra Newton, that "the solar system was not created by God, the movement of the planets is not the result of divine impulse." The feeling I get is that there is a connection between these two statements: it seems that Hessen wants to claim that Newton's rejection of the view that nature is in a process of unceasing development leads logically to the positing of a powerful being that moves nature at those moments when its development ceases. Yet, the reverse seems to hold as well; if, in Hessen's view, nature does not need God in order to function properly ("not only does God have no place in a system whose existence is based on the laws of mechanics, but he is unnecessary even as an explanation of its origin"), it seems that cessation is non-existent in nature, that nature's development is unceasing. Hessen understands Newton's arguments for God as deriving from the necessary cessation of nature's development in mechanical physics, and he understands the removal of God from the physics of Kant and Laplace as the logical result of their espousal of the view that nature is in a process of unceasing development.

⁸ Dialectis, D., "Elements of the Life and Work of Boris Hessen" in *Marxism and the Sciences: Historiographical and Philosophical Approaches*, ed. D. Dialectis (Athens: Nefeli, 2010), 313-377 [in Greek].

⁹ Hessen, B., (2009), 56.

¹⁰ Hessen, B., (2009), 56.

¹¹ Hessen, B., (2009), 56, 61.

¹² Merton, R. K., "Science, Technology and Society in Seventeenth Century England," *Osiris* 4/2 (1938): 557. Although Merton does not refer to Hessen by name in this specific passage

(i.e. the last paragraph of chapter IX), he has already told us that the whole discussion “is heavily indebted to Hessen” (544, n. 10).

¹³ Dialetis, D., (2010), 368.

¹⁴ This is why Hessen writes that “it would, however, be a gross oversimplification to derive every problem studied by various physicists, and *every task* they solved, directly from economics and technology” (Hessen, B., 2009, 61).

¹⁵ Hessen, B., (2009), 61, 65.

¹⁶ Hessen, B., (2009), 67.

¹⁷ Janiak, A., “Introduction,” in I. Newton, *Philosophical Writings*, ed. A. Janiak (Cambridge: Cambridge University Press, 2014), xxvii.

¹⁸ Freudenthal and McLaughlin correctly observe that Hessen here uses the Spinozist terminology of “attributes” and “modes” (Freudenthal, G. and McLaughlin, P., “Classical Marxist Historiography of Science: The Hessen-Grossmann-Thesis,” in *The Social and Economic Roots of the Scientific Revolution*, ed. G. Freudenthal and P. McLaughlin (Dordrecht: Springer, 2009), 25, n. 38. For Spinoza, attributes are the essence of the one and only substance (God or nature) and modes are modifications of that substance. Their main difference is that while attributes are self-caused, modes are caused both by substance and other modes. For a detailed discussion of these terms see Melamed, Y., *Spinoza’s Metaphysics: Substance and Thought* (Oxford: Oxford University Press, 2013) and Trisokkas, I., “The Two-Sense Reading of Spinoza’s Definition of Attribute,” *British Journal for the History of Philosophy* 25/6 (2017): 1093-1115.

¹⁹ Hessen, B., (2009), 67-68.

²⁰ Hessen, B., (2009), 69.

²¹ Hessen, B., (2009), 69.

²² Newton, I., *Philosophical Writings*, ed. A. Janiak (Cambridge: Cambridge University Press, 2014), 90; hereafter “PW.”

²³ Hessen, B., (2009), 69.

²⁴ Hessen, B., (2009), 69, my emphasis.

²⁵ Hessen, B., (2009), 69.

²⁶ Hessen, B., (2009), 69.

²⁷ Hessen, B., (2009), 69.

²⁸ Newton, in fact, believed that the quantity of motion in the actual world is more likely to be decreasing than to be increasing in time. As Freudenthal observes, this is based on his belief that “material bodies, like the particles that compose them, are not perfectly elastic.” See PW 183 (*Opticks*, query 31) and Freudenthal, G., *Atom and Individual in the Age of Newton: On the Genesis of the Mechanistic World View* (Dordrecht: D. Reidel), 45.

²⁹ PW 136, my emphasis.

³⁰ Cf. Freudenthal, G., (1986), 49: “Newton maintains steadfastly that ‘plump inanimate matter’ cannot bring forth action and that its laws are passive;” 54: “[For Newton] even the laws of motion depend on God’s will to move the bodies according to those laws.”

³¹ Newton reacted this way to Bentley’s ascribing to him the view that there is *innate* gravity because he thought that a body affecting another body at a distance brings *occult qualities* into nature. He thought that God’s involvement was a way to avoid reference to occult qualities. Leibniz accused Newton that, contrary to what he thinks, in this way gravity is reduced to an occult quality (Leibniz, G. W., *Die philosophischen Schriften*, vols. I-VII, ed. C. I. Gerhardt (Berlin: Weidmann, 1875-1890), vol. III, 519 (hereafter ‘GP’); Janiak, A., (2014), xxvii).

³² Hessen, B., (2009), 68.

³³ PW 112: “[God] totally lacks any body and corporeal shape, and so he cannot be seen or heard or touched, nor ought to be worshipped in the form of something corporeal.”

³⁴ PW 120.

³⁵ PW 113.

³⁶ PW 120.

³⁷ PW 120-121, my emphasis.

³⁸ PW 121.

³⁹ PW 121.

⁴⁰ PW 121. Cf. PW 113: “All the diversity of created things, each in its place and time, could only have arisen from the ideas and the will of a necessarily existing being.”

⁴¹ A similar argument can be found in the General Scholium of the Third Book of the *Principia*; see PW 110.

⁴² PW 121.

⁴³ PW 121.

⁴⁴ Cf. PW 110: “[Planets and comets] will indeed persevere in their orbits by the laws of gravity, but they certainly could not have originally have acquired the regular position of the orbits by these laws.”

⁴⁵ PW 122.

⁴⁶ Cf. PW 111: “This most elegant system of the sun, planets, and comets could not have arisen without the design and dominion of an intelligent and powerful being.” See also PW 186: “[The harmony of the cosmos] can be the effect of nothing else than the wisdom and skill of a powerful ever-living agent [...]”

⁴⁷ PW 122.

⁴⁸ PW 122.

⁴⁹ Hessen, B., (2009), 68.

⁵⁰ Hessen, B., (2009), 69, 73.

⁵¹ Freudenthal, G. and McLaughlin, P., (2009), 3.

⁵² Cf. Freudenthal, G. and McLaughlin, P., (2009), 24: “Hessen maintained that Descartes’ mechanistic world picture was an adequate generalization of mechanics.” Back in 1986 Freudenthal argued that Leibniz’s physics “is not merely of equal value [to Newtonian physics] but also has some advantages;” see Freudenthal, G., (1986), 4. One of these “advantages” is that it does not involve God. Yet, Freudenthal’s interpretation of Leibniz is not convincing, as Leibniz seems to be critiquing mechanics for the same reason that Newton did, namely for not being able to explain the fundamental organizational facts of nature, and be involving God as the *explanans* of this phenomenon. See, for example, Leibniz’s letter to Nicolas Remond dated 10 January 1714 (GP III, 605-607) and Part I of *The Confession of Nature against Atheists* (GP IV, 105-110).

⁵³ Hessen, B., (2009), 67, my emphasis.

⁵⁴ Hessen, B., (2009), 70.

⁵⁵ Hessen, B., (2009), 70.

⁵⁶ Hessen, B., (2009), 70.

⁵⁷ Hessen, B., (2009), 70.

⁵⁸ Hessen, B., (2009), 70, my emphasis.

⁵⁹ Hessen, B., (2009), 70.

⁶⁰ Hessen, B., (2009), 71.

⁶¹ This is why Freudenthal’s and McLaughlin’s statement that “Hessen believed that Newton’s dualistic world picture was not necessitated by limitations inherent to the science of the day since Descartes had already gone farther” (Freudenthal, G. and McLaughlin, P., (2009), 24) states a belief Hessen was wrong about. The mistake is twofold: (a) Newton’s dualistic world picture *was* necessitated by limitations inherent to the science of the day (mechanics) and (b)

Descartes had *not* gone substantially farther than Newton (for he does eventually involve God in his *physics*).

⁶² Grossmann, H., “Descartes and the Social Origins of the Mechanistic Concept of the World,” in: Freudenthal, G. and McLaughlin, P., (2009), 218-220.

⁶³ Freudenthal, G. and McLaughlin, P., (2009), 24-25.

⁶⁴ Grossmann, H., “Die gesellschaftlichen Grundlagen der mechanistischen Philosophie und die Manufaktur,” *Zeitschrift für Sozialforschung* 4 (1935): 208.

⁶⁵ Cf. Freudenthal, G., (1986), 59-66.

⁶⁶ Garber, D., (1992) “Descartes’ Physics,” in *The Cambridge Companion to Descartes*, ed. J. Cottingham (Cambridge: Cambridge University Press, 1992), 286-334.

⁶⁷ Garber, D., (1992), 320.

⁶⁸ Garber, D., (1992), 320. Garber refers here to AT.VII.49/CSM.II.33 and AT.VII.369/CSM.II.254. (AT: Adam, C. and Tannery, P. (eds.), *Oeuvres de Descartes*, vols. I-XI (Paris: Vrin/C.N.R.S., 1964-1974); CSM: Cottingham, J., Stoothof, R., and Murdoch, D. (eds.), *The Philosophical Writings of Descartes*, Vols. I-II (Cambridge: Cambridge University Press, 1984-1985)).

⁶⁹ Cited in Garber, D., (1992), 320.

⁷⁰ Garber, D., (1992), 321.

⁷¹ Garber, D., (1992), 320.

⁷² AT.V.404/CSMK 381. (CSMK: Cottingham, J., Stoothof, R., Murdoch, D., and Kenny, A. (eds.), *The Philosophical Writings of Descartes*, Vol. III (Cambridge: Cambridge University Press, 1994). See also Garber, D., (1992), 321: “[...] Descartes’ whole strategy for deriving the laws of motion from the immutability of God presupposes that God is the real cause of motion and change of motion in the inanimate world of bodies knocking up against one another.”

⁷³ Engels, F., “Dialectics of Nature,” trans. C. Dutt, in K. Marx and F. Engels, *Collected Works*, vol. XXV (Chadwell Heath: Lawrence & Wishart, 1989), 356-377.

⁷⁴ Winkler, S., “Practice and ideology in Boris Hessen’s *The Social and Economic Roots of Newton’s Principia*,” *Telos* (2019, forthcoming).

⁷⁵ On Hegel’s notion of “sublation” see Trisokkas, I., “Hegelian identity,” *Journal of the British Society for Phenomenology* 47/2 (2016): 102-104.

⁷⁶ For a lucid overview of Hegel’s system of philosophy see Sebastian, S., (forthcoming) “Hegel,” in *Blackwell Companion to 19th Century Philosophy*, ed. J. A. Shand (Oxford: Wiley-Blackwell).

⁷⁷ Dialetis, D., (2010), 342. Cf. Hessen, B., (2009), 74: “[T]he mechanical worldview [...] regards the main task of natural science as the reduction of all forms of motion [...] to the one form of mechanical displacement [...]”

⁷⁸ Dialetis, D., (2010), 343.

⁷⁹ Dialetis, D., (2010), 337, 350. In the late 1920s Hessen wrote a large number of articles and at least two books defending the general theory of relativity against the critique of the mechanists. The largest portion of *TSERNP* was compiled from parts of those writings (Dialetis, D., (2010), 358). Although by the end of the 1920s the dialecticians came out winners of the dispute, the political emphasis on the practical dimensions of science (its employment in economic production) strengthened anew the movement of mechanism, which was incorporated in the dialectical theory of a fraction of the dialecticians in the early 1930s. This group of dialecticians that incorporated mechanism in their dialectics was led by Kolman, Mitin and Maximov and became dominant in the intellectual landscape of the Soviet Union from 1930 onwards. See Dialetis, D., (2010), 345-347. Kolman publicly accused Hessen of espousing the wrong kind of dialectics (i.e. non-mechanical dialectics) three months before Hessen’s presentation of *TSERNP* in London in 1931; see Graham, L. R., “The Socio-Political

Roots of Boris Hessen: Soviet Marxism and the History of Science,” *Social Studies of Science* 15/4 (1985): 715. Hessen was arrested on 21 August 1936 on a charge of “terrorism” against the Soviet government and shot to death on 20 December 1936 (Gorelik, G. E., “Moskva, fizika, 1937 god,” *VIET* 1 (1992): 15-32).

⁸⁰ Engels, F., (1989), 362-377.

⁸¹ Hessen, B., (2009), 73.

⁸² Hessen, B., (2009), 73.

⁸³ Hessen, B., (2009), 73.

⁸⁴ Hessen, B., (2009), 73.

⁸⁵ Hessen, B., (2009), 73.

⁸⁶ Hessen, B., (2009), 73.

⁸⁷ Hessen, B., (2009), 74.

⁸⁸ Hessen, B., (2009), 74. Cf. Engels, F., (1989), 356: “The general nature of dialectics [is] to be developed as the science of interconnections [...]”

⁸⁹ Hessen, B., (2009), 74.

⁹⁰ Hessen, B., (2009), 81.

⁹¹ Hessen, B., (2009), 81. Cf. Engels, F., (1927), 358.

⁹² Hessen, B., (2009), 80.

⁹³ Hessen, B., (2009), 80.

⁹⁴ Hessen, B., (2009), 81.

⁹⁵ Hessen, B., (2009), 81.

⁹⁶ Hessen, B., (2009), 82, my emphasis.

⁹⁷ Hessen, B., (2009), 67, my emphasis.

⁹⁸ Hessen, B., (2009), 69, my emphasis. God’s involvement in physics is *not*, for Newton, a *hypothesis*. In the *Principia* he defines “hypothesis” as “whatever is not deduced from the phenomena” and declares that “hypotheses [...] have no place in experimental philosophy” (PW 113). Yet, God’s involvement in physics *is* deduced from the phenomena and therefore is *not* a hypothesis. It is so deduced by means of showing that the present state of the cosmos cannot be explained fully mechanically and therefore it is necessary to refer to God in this explanation. Freudenthal (1986, 50) correctly notes that “in the text of the *Scholium Generale* Newton begins with a phenomenon, namely the wonderful order of the cosmos, and ‘deduces’ that it could only have been brought forth by God.” Newton concludes the *Scholium* by emphatically claiming that “to treat God *from phenomena* is certainly a part of natural philosophy” (PW 113). See Janiak, A., (2014), xv.

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