DESCARTES AND BOYLE'S THEORY OF MATTER: HISTORICAL AND PHILOSOPHICAL CONNECTIONS.

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Abstract

In the current thesis I investigate the historical and philosophical connections of Descartes and Boyle. The historical part of the thesis is devoted to an analysis of Boyle's direct and indirect acquaintance with Descartes' theory of matter: Boyle himself read Descartes and studied him with his assistant Robert Hooke. Also, Boyle was aware of the discussions of Descartes' laws of motion conducted in Oxford and was informed about the outcomes via his colleague John Wallis. In the philosophical part I discuss mainly Boyle's attitude towards Descartes' Vortex Theory, the method of mechanical explanation and the method of quantification of laws of motion. The analysis of Boyle's attitude towards Descartes' Vortex Theory shows that the acceptance of the theory in his early works was later on transformed into a critical approach, though not into a rejection. The cases with the mechanical and mathematical methods are different: despite Boyle's claims about his method to mechanically and mathematically treat natural phenomena, these claims were not fully realized. In the case of the mechanical treatment the full realization is absent because of the criticism of exclusive mechanical approach. In the case of mathematical treatment the realization is absent because Boyle's claims about the usefulness of mathematization were not applied to his law of fall.

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I dedicate my thesis to my family whose support was, as usual, invaluable, and to *The Seven*, especially to P.A. hoping that the thesis, besides being the reason, will also be an apology for forgetting her birthday.

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Introduction

The similarities to Descartes' theory of matter, i.e. explanations that could be interpreted as Cartesian in Boyle's early stage of career, lead to the following question: were Boyle's ideas concerning his theory of matter influenced by Descartes' theory of matter? Suppose the similarities to Descartes' theory of matter in Boyle's theory are an effect of an influence by Descartes. In that case what was the influence? The question of the influence can have two directions: the historical and the philosophical. The historical question leads to the research of how Cartesianism was spread in 17th century England, what was the level of its reception, whether there is a good reason to think that the general influence on 17th century England could have reached Boyle as well. Therefore, the focus of the question is the study of the connections that can be made between the scientific environment of the time, the role of Descartes in it and Boyle's scientific activity in that environment. More specifically, how could Descartes' general influence on 17th century England's scientific life and the discussions of his ideas influence Boyle's career.

The second direction of the research question is dedicated to the presentation of Descartes' and Boyle's theories of matter and to their comparative analysis, which leads to an assessment of the level of influence. In the thesis I will conduct an analysis of Descartes and Boyle's theories of matter, which would lead to the conclusion concerning the role of some aspects of Descartes' theory of matter in the development of respective parts of Boyle's theory of matter.

I discuss historical connection and philosophical influence in the first and second chapters respectively. The first chapter, *Boyle's Acquaintance with Descartes' Ideas: Historical Evidence*, includes short biographies of Descartes' and Boyle's. These are relevant for the latter discussion of the acquaintance of Boyle with Descartes' ideas, which is the third section of the first chapter. It is a discussion of the biographies of the thinkers and some additional historical facts. The latter will help to connect the facts from their biographies and have a conclusion about Descartes' influence on Boyle.

The second part of the paper consists of an analysis of some aspects of the theory of matter of both thinkers. The first and second sections of the second chapter, *Descartes and Boyle's Theories of Matter*, include the presentations of Descartes' and Boyle's theories of matter respectively. The second section also includes the discussion of Boyle's attitude towards Descartes' Vortex Theory, mechanical method and the method of quantification.

The main statement of the thesis is the following: Boyle's acquaintance with earlier mentioned parts of Descartes' theory resulted in acceptance of the Vortex Theory, in realization of the importance of the method of mathematization and in rejection of Descartes' exclusive mechanical approach in explanation of physical phenomena.

1. Boyle's Acquaintance with Descartes' Ideas: Historical Evidence.

The current chapter is dedicated to the study of Boyle's acquaintance with Descartes' theory of matter. In the first section I present relevant aspects of Descartes' influence on the Early Royal Society and Boyle's biography in the first and second sections respectively. These are important in providing context for the third section, where I will connect the evidence brought in the above mentioned sections to support the claim about Boyle's acquaintance with Descartes and mainly, to show how the acquaintance took place.

1.1. Descartes: the Development of the Theory of Matter and the Influence on the Early Royal Society

The part of Descartes' work I want to focus on, considering its importance for the current discussion, is his theory of matter: what does it include, how and in which works was it developed. As in the second part of the thesis separate sections will be devoted to the introduction of Descartes' theory of matter and, particularly, to the Vortex Theory and the laws of motion, I will here focus on the historical aspects of the development of the theory of matter and of the mentioned works. As the title indicates, in this section I will also discuss Descartes' general influence on 17th century England and, particularly, on the Royal Society, the connection with the fellows of the Society as well as the discussions held in the Royal Society concerning different aspects of Descartes' physics.

Descartes' theory of matter includes more generally the mechanical philosophy, as well as more specific aspects. The latter include, among other things, Descartes' theory of celestial

phenomena – the Vortex Theory, the theory about the structure and movement of particles. All the above mentioned theories or ideas were mainly discussed in Descartes' two works *The World* (published posthumously in 1664) and *The Principles of Philosophy* (1644). The mechanical philosophy – the view that natural phenomena should be treated in terms of shape, size and motion – was also discussed in the *Discourse on Method* and its accompanying essays (1637) and in *Meditations on First Philosophy* (1640).

A very important influence on Descartes' development of mechanical philosophy was Beeckman's, whom Descartes met at the end of 1618. The evidence on Descartes' excitement from Beeckman's method of doing natural philosophy and practical mathematics can be read in Beeckman's notes made in December 1618. Beeckman writes that Descartes says "he has never met anyone other than me who pursues studies in the way I do, combining physics and mathematics in an exact way. And for my part, I have never spoken with anyone apart from him who studies in this way."[1] The treatment of natural phenomena in mathematical terms was further developed by Descartes and made into the cornerstone of his natural philosophy.

This further development, as mentioned above, was made primarily in *The World* and in *The Principles of Philosophy* as well as in the *Optics* and *Meteorology*, published together with *Discourse on Method* in 1637. The first book was the result of four years of work, from 1629 to 1633. And the years spent resulted in a work that played an important role in the system of Descartes' natural philosophy and in the scientific revolution of 17th century generally, though it remained unpublished during his lifetime.[2] As Gaukroger suggests, the whole program of *The*

[1] Gaukroger, "Life and works", 4-5.
[2] Clarke, *Descartes*, 97-98.

World can be presented in Descartes' letter written to Villebressieu in the summer of 1631. In this letter Descartes congratulates the mentioned author on discovering that

> there is only one material substance which receives its action, or ability to move from one place to another, from an external agent, and that it acquires from this the different shapes or modes which make it into the kind of thing we see in the primary compounds we call elements. Moreover you have observed that the nature of these elements or primary compounds – called Earth, Water, Air, and Fire – consists simply in the difference between the fragments, or small and large particles of this matter; and that the matter changes daily from one element into another, when the finer particles change into larger ones as the action of heat and motion ceases. You have also seen that the primary mingling of these four compounds results in a mixture which can be called the fifth element. This is what you call the principle of the most noble preparation of the elements; because it is, you say, a productive seed or a material life which takes specific form in all the noble particular individuals which cannot fail to be an object of our wonder.[3]

The more mature and complete version of Descartes' theory of matter is presented mainly in the second work mentioned above, *The Principles of Philosophy*, particularly in the second part of the book. Descartes started working on the *Principles* in 1641 and after three years of work, in 1644, the work was ready. It is mainly a more systematic version of *The World*, as in its discussions of natural philosophy it does not contain much material that was not included in *The World*.

Leaving the further discussion of the content of Descartes' theory of matter to the second part of the paper, I now turn to the discussion of the role that Descartes and his theory of matter played in the scientific discussions in 17th century England and in the Early Royal Society.

[3] Gaukroger, *Descartes: An Intellectual Biography*, 226.

The introduction of Descartes to England was probably in 1637. In October 4, 1637 in Kenelm Digby's letter to Hobbes, Descartes is mentioned as a man who "had carryed the palme from all men living"[4]. Another significant date is 1649, when the translations of Descartes' books started to appear. From that time on Descartes' works and ideas became widely discussed. The following facts are important to mention for the current discussion: firstly, Descartes' correspondence (from 1667) with the fellow of the Royal society (founded on November 1660) and a friend of Robert Boyle, Henry More. Another important fact is the notes of Boyle's assistant, Robert Hook, who mentioned Descartes and the wide discussions of his ideas in his diary (on 19 December 1672 and on 6 July 1674).[5] Thirdly, John Wallis, a fellow of the Royal Society, was very impressed by Descartes' analytical geometry and together with Christopher Wren and Christian Huygens conducted research on Descartes' explanation of planetary motions.[6]

The influence of Descartes' physics and its role as initiator of discussions in the Royal Society can be concluded from the following example: Wren had conducted experimental study of laws of impact in 1661. This fact, according to Bennet, shows that Wren must have been acquainted with Descartes' *Principles of Philosophy*, especially with part two. The fact that Wren's study was directed towards constrained circular motion also serves as supporting evidence for claiming that Wren must have been familiar with Descartes' *Principles*.[7]

[4] Nicolson, "The Early Stage of Cartesianism in England", 358.
[5] Armitage, "Rene Descartes and the Early Royal society," 15.
[6] Ibid.
[7] Bennet, "Hooke and Wren and the System of the World: Some points Towards an Historical Account," 99. Also, Wren was in closely associated with Boyle in the early 1660s and correspondenced with him concerning the Cartesian explanation of tides (Ibid, 47).

Wren, with other fellows of The Royal Society (Wallis, Willkins, Hooke), was engaged in the explanation of planetary motions and its laws. And Descartes' influence on these discussions is seen, as Bennet writes, from the "concentrate attention on the centrifugal tendency of a body constrained to move in a circle."[8]

The correspondence with Henry More and the wide discussions of his works and theories in the mid 17th century, particularly in the Royal Society, demonstrate the significant role Descartes' ideas played in the scientific life of England in the second half of the 17th century.

1.2. Boyle: Relevant Biographical Facts

This chapter relates to some relevant facts and events in Boyle's life, and also discusses the possible connections that Boyle could have had on Boyle. Robert Boyle was born on 25 January 1627 in Lismore Castle, Ireland.[9] He received his initial education at Eton College. During the time at Eton (1635-1639) his interest in study was already revealed, as is evident from a letter sent to his father from the College. In that letter it is stated that Robert "prefers learning afore all other ventures or pleasures".[10]

After finishing his studies Boyle settled in Stalbridge and remained there for almost a decade with only occasional trips. During the first three years after his return (1645-1649) Boyle was interested in ethics and theology. A letter to his sister Katherine, in which he writes that his Ethics "goes very slowly on",[11] shows his interest in and occupation by moral philosophy at the

[8] Ibid, 60.
[9] MacIntosh and Anstey, "Robert Boyle", section one.
[10] Hunter, *Boyle: Between God and Science*, 30.
[11] MacIntosh and Anstey, "Robert Boyle", section one.

period. The turning point from a moralist to an experimenter and a natural philosopher happened in 1649, when not after the first but the most successful trial to install equipment for carrying chemical operations, Boyle's excitement changed his scientific taste. The interest in natural philosophy could also have developed from the earlier experiments and the contacts that Boyle had with such famous thinkers of the time as Mersenne, Spinoza, Pascal and others.[12] However, the successful installment made a very deep impression on him, as he writes to Lady Ranelagh that "Vulcan has so transported and bewitch'd mee" that the delights he tasted in his laboratory made him see it as "a kind of Elizium".[13]

Another important stage in Boyle's life can be considered his years in Ireland and Oxford (1652-1658). In 1654 Boyle settled in Oxford and together with such thinkers as John Wallis, John Wilkins, Jonathan Goddard and others made plans for a scientific academy "for promotion of philosophical knowledge by experiments".[14] In these Oxford years his acquaintance and friendship with Robert Hooke started.

The acquaintance with Robert Hooke was important for the Descartes-Boyle connection. Hooke was not only Boyle's assistance during the four years of work from 1658, but also continued significantly to Boyle's acquaintance with Descartes' works. Boyle confesses that Descartes' *Passions* is "the only book of his which I remember my selfe to have read over"[15] and further acquaintance with Descartes' works was through Hooke's teaching.[16]

[12] Fulton, "The Honorable Robert Boyle," 121.
[13] Hunter, *Boyle: Between God and Science,* 70.
[14] Fulton, "The Honorable Robert Boyle," 123.
[15] Boyle writes this in an unpublished work on generation, dating from early or mid 1650s. See Davis, "'Parcere Nominibus': Boyle, Hooke and the Rhetorical Interpretation of Descartes", 160-161.
[16] Ibid.

On 28 November 1660 Boyle inaugurated the Royal Society of London, where he had an important role as the list of inaugurated people indicates (the second name in the name-list of the 12 inaugurated people of the year).[17] Since he was a member in the Royal society, he had worked in the field of science extensively. The years from 1660 to 1691, the year of his death, were the years of fulfillment in science. The works that he wrote during these years which are important for his theory of matter are: *New Experiments Physico-Mechanical: Touching the Spring of the Air and their Effects* (1660); *The Sceptical Chymist* (1661); *Considerations touching the Usefulness of Experimental Natural Philosophy* (1663); *Origin of Forms and Qualities according to the Corpuscular Philosophy* (1666); *A Free Enquiry into the Vulgarly Received Notion of Nature* (1686). Apart from that he had established contacts with such famous thinkers of the time as Henry More, Christiaan Huygens (who had visited him during his visit to London in 1661[18]), and others.

I will focus on the studies of matter conducted by Boyle in the works mentioned above. I will try to focus on the development of the theory of matter as well as the possible changes made in the later works in comparison with the earlier ones where the theory of matter was also introduced.

1.3. Boyle's Acquaintance with Descartes' Theory of Matter

Apart from the biographical events and facts mentioned above, there is some other relevant evidence that can help to connect the information brought in the above sections. In the current section I will discuss Boyle's acquaintance with Descartes, which, in its turn, resulted in some

[17] Hunter, "Robert Boyle and the Early Royal Society: A Reciprocal Exchange in the Making of Baconian Science", 1.
[18] Maddison, "Studies in the Life of Robert Boyle", 4.

developments in Boyle's theory of matter and in accepting specific aspects of Descartes' theory of matter. The developments of Boyle's theory of matter will be discussed in the following chapter, in the philosophical analysis. In this section only historical aspects of Descartes' influence will be addressed.

An important development for the Descartes-Boyle connection where the discussions concerning scholasticism vs. ancient philosophy debate that were taking place in Cambridge in 1646-1649. The initiator of these discussions was Henry More (1614-1687). More read Descartes' *Principles* in 1646, and the book made a deep influence on him. He writes to Hartlib in 1648, December 11: "All that have attempted anything in natural Philosophy hitherto are mere shrimps and fumblers in comparison of him"; the deep impression Descartes' thought made on him brought him teach Cartesianism in Cambridge.[19] His teaching Descartes' natural philosophy to interested students in Cambridge resulted in one of his students (John Hall) writing essays that contained criticisms of the method of teaching in Cambridge. Hall writes:

> Raw striplings come out of some miserable country school with a few shreds of Latin, that is as unmusicall to a polite ear, as the gruntling of a sow, or the noise of a saw can be to one that is acquainted with the laws of harmony. And then possibly before they have surveyed the Greek alphabet to be racked and tortured with a sort of harsh abstract logicall notions, which their witts are no more able to endure, than their bodies the strapado; and to be delivered over to a jejune Peripatetic philosophy; suited only (as Monsieur Descartes sayes) to witts that are seated below mediocrity.[20]

That More was the sponsor of the discussions of Descartes' works is clear also from the fact that he wrote a complementary verses for Hall's book.

[19] Henry, "Henry More", section 2.
[20] Nicolson, "The Early Stage of Cartesianism in England", 361.

Turning to the Descartes-Boyle connections, as was already mentioned, the turning point in Boyle's life concerning his interest in natural philosophy was in 1649 (though early experiments and studies in natural philosophy were also done). In 1649 Boyle was already in England, where the scientific circles were widely discussing Descartes. Moreover, Boyle's friend, Henry More, was the initiator of these discussions and deeply engaged in them. Accordingly, it is unlikely that Boyle was unaware of the discussions, and, therefore, of Descartes' role in contemporary developments in natural philosophy.

Boyle's joining the Royal Society in 1660 created new routes for Descartes' influence to reach him. Though he was not very enthusiastic in attending the meetings of the royal Society,[21] his connection with the society and its fellows is important in finding links between him and Descartes.

John Wallis, a fellow of the Royal society, used Descartes' analytical geometry as a tool in doing natural science. Wallis, with Wren and Huygens, conducted a research on the theory of impact. And during this visit to Gresham College, Huygens visited Boyle as well. Huygens has several letters and notes about this trip to Gresham College in 1661 in which he mentions Boyle as well. From one of his letters one can judge that they discussed some of Boyle's experiments and work:

> Mr. Boyle is he who has done a great number of experiments on void which you can see in his book, the Latin version of which will be published, and among the experiments there are several very strong and considerable ones, as the experiment on the hot water, when it is in the vessel without being boiled

[21] Hunter, "Robert Boyle and the Early Royal Society", 3.

but creates big bubbles every time the pump takes some air.[22]

The interest of the fellows of the Royal Society in the Cartesian theories, and Huygens' visit and the discussions of natural philosophy indicate the scientific environment Boyle was in. And as these scientific circles were interested in inquiries into Descartes' theories, they could draw also Boyle's attention to the latter.

To sum up, Boyle's acquaintance with Descartes' theory of matter was via the scientific environment of the time and his connections with the thinkers of the same scientific circles.

[22] The translation is mine, it can contain some inaccuracies. The original is quoted in Maddison, "Studies in the Life of Robert Boyle", 5: "[…]Monsieur Boile est celuy qui a fait quantity d'experiences du vuide que vous pourrez veoir bientost dans son livre, dont la version Latine estoit sous la presse, et il y en a parmi quelques nouuelles et fort considerables, comme celle de l'eau chaude estant mise sans bouillir dans le vase, s'esmeust a gros bouillions a chasque coup que la pompe attire de l'air".

2. Descartes' and Boyles' Theories of Matter

2.1. Descartes: Vortex Theory and the Quantification of Motion

In the following sections I present two important parts of Descartes' physics – his Vortex Theory and the quantification of motion. The aim of this introduction is to serve as context for the comparison with Boyle's respective physical theories.

2.1.1. The Vortex Theory of Planetary Motions

Descartes' Vortex Theory is responsible for the explanation of celestial phenomena – orbits of planets and comets, gravitation. It is based on a three part division of matter and a theory of motion. Therefore, in order to be able to understand the Vortex Theory, I will start with a discussion of these mentioned ideas. This will make it possible for us to see how the vortices explain gravitation in Descartes' physics.

Descartes describes the three parts or elements in the fifth chapter of *The World.* The first element in his system is the element of fire. This is the most subtle element, which moves with great speed and has no determinate shape. The element of air – the second element – is less subtle and moves with less velocity. Another difference is that the second element has fixed shape and size. The third element is the element of earth. This element is described as moving very slowly and as having much bigger size in comparison with the first and second elements. In Descartes words:

> Now I cannot find any such forms in the world except the three I have described. For the form I have attributed to the first element consists in its parts moving so extremely rapidly and being so minute that there are no other bodies capable of stopping them; and in addition they need not have any determinate size, shape, or position. The form of the second element consists in its parts being so moderate in their motion and size that if there are any causes in the world which may increase their motion and decrease their size, there are just as many others which can do exactly the opposite; and so they always remain balanced as it were in the same moderate condition. And the form of the third element consists in its parts being so large or so closely joined together that they always have the force to resist the motions of the other bodies. [23]

Further discussion will show the importance of Descartes' theory of matter to his Vortex Theory. For that purpose Descartes' ascription of elements to different bodies is needed. The sun and stars, according to Descartes, are composed of the first element; the second element composes the heavens; the earth, planets and comets are composed of the third element.[24] Therefore the movement of the heavens and the movement of the planets and comets are according to the characteristics of the elements they are composed of.

We turn to Descartes' theory of motion. What is important for this paper is (i) God as the first cause of motion, (ii) the idea of circular motion and (iii) the three laws of motion. According to Descartes, God created nature and is the cause of motion.[25] This motion is circular and the explanation of the latter is based on the impossibility of the existence of void. The argument is as follows: everything in the material world is extended. There cannot be a place in the universe that cannot be described by having an extension. Therefore, void, or empty space does not

[23] Descartes, *The World*, Chapter V, Cottingham, Stoothoff, Murdoch (CSM) trans., 1992.

[24] Ibid.

[25] Ibid.

exist.[26] If there is no void, motion has to be circular, otherwise, when a body moved from where it started a void will be formed at that place: "…when a body leaves its place it always enters into the place of some other body, and so on to the last body, which at the same instance occupies the place vacated by the first".[27]

Another part of Descartes' Theory of Matter that is of great importance for the Vortex Theory is the explanation of the laws of motion. These laws are responsible for the development of motion from its initial state that was the effect of God's interference as well as its continuation (as God never changes, the laws that He created, the actions that take place due to that laws, never change[28]).

The first law of motion, as Descartes states it in *The World*,[29] is as follows:

> The first is that each individual part of matter continues always to be in the same state so long as collision with others does not force it to change that state. That is to say, if the part has some size, it will never become smaller unless others divide it; if it is round or square, it will never change that shape unless others force it to; if it is brought to rest in some place, it will never leave that place unless others drive it out; and if it had once begun to move, it will always continue with an equal force until others stop or retard it.[30]

[26] Descartes, *The Principles of Philosophy*, Part II, Section IV.

[27] Descartes, *The World*, Chapter IV, CSM trans., 1992.

[28] Ibid, Chapter VII and *The Principles of Philosophy*, Part II, Section XXXVI.

[29] The succession of the laws in The *World* and in *The Principles* is not the same. In *The Principles* the second law of nature as stated in *The World* is the third one. Compare: *The World* , Chapter VII and *The Principles*, Part II, Sections XXXIX and XL.

[30] Descartes, *The World*, Chapter VII, CSM trans., 1992.

The second law is a collision rule. According to it "… when one body pushes another, it cannot give the other any motion unless it loses as much of its own motion at the same time; nor can it take away any of the other's motion unless its own is increased by as much"[31].

Finally, the third law of motion claims that bodies always tend to move in straight line. In Descartes word:

> […]when a body is moving, even if its motion for the most part takes place along a curved line and, as we said above, it can make any movement which is not in some way circular, yet each of its parts individually tends always to continue moving along a straight line. And so the action of these parts – i.e. the tendency they have to move – is different from their motion.[32]

We now turn to Descartes' argument. God creates matter and causes it to move. As there is no void, matter moves circularly. As a result of the circular motion three elements of matter are formed. All bodies, according to the third law, tend to move in a straight line. Therefore, the bodies that move faster and are so subtle that they can move easily 'realize' their tendency to move in a straight line more than the bodies that move slower and are bigger in size. So, the element of air – the subtle matter – moves higher in the heavens than the Earth, other planets and comets – the bodies comprised of the element of earth. In this way – by the rotation of subtle matter in the high circles of the heavens – the vortices are created. And the latter are responsible for the orbits of the planets and comets, i.e. for the gravitational phenomenon.[33]

[31] Ibid.

[32] Ibid.

[33] The movement of subtle matter explains not only the celestial but also the terrestrial gravitation (e.g. the wine vat example in *The Dioptrics*, Discourse I).

The explanation of gravity due to the vortices is as follows. The planets are in a state of rest relative to the vortex, and are carried by the Vortex. Due to the movement of the Vortex, planets move around the axis of the Vortex. A question can now arise, that has in fact been raised by Descartes himself: why don't planets move to the center of the heaven (to the Sun) and finally rest there?[34] The answer is based on the third law of nature. The subtle matter that arises from the Sun pushes back the planets that move towards the Sun. That is to say, the two direction force (from the vortex and from the subtle matter that moves from the Sun) is responsible for the permanent movement of planets around the Sun.

2.1.2. The Quantification of Motion

Descartes' theory of motion (from which the three laws were introduced above) includes many aspects and can be discussed form different perspectives. The current discussion will be devoted to the analysis of Descartes' method of presenting the laws of motion (the quantification of the laws of motion) as well as to a brief discussion about the origin of the view and what 'quantification' means for Descartes.

The rejection of the necessity to define the concept of motion in Descartes' early works – in the *Rules for the Direction of Mind* and in *The World* – was not consistently followed later on. In *The World* Descartes had stated that

> Again, when people say that motion, something perfectly familiar to everyone, is 'the actuality of a potential being, in so far as it is potential', do they not give

[34] Descartes, *The World*, Chapter X, CSM trans., 1992.

> the impression of uttering magic words which have a hidden meaning beyond the grasp of the human mind? For who can understand these expressions? Who does not know what motion is? Who would deny that these people are finding a difficulty where none exists? It must be said, then, that we should never explain things of this sort by definitions, in case we take hold of composite things instead of simple ones. Rather, each of us, according to the light of his own mind, must attentively intuit only those things which are distinguished from all others.[35]

The same attitude is presented in *The World.*[36] However, definitions are presented both in *The World* and in the *Principles* with a huge difference from the scholastic understanding of motion, as Descartes thinks, as his definition "is easier to conceive than the lines of the geometers…".[37] There are also differences between the definition presented in *The World* and the one stated in the *Principles.*[38] I will not discuss these definitions, or the reasons of Descartes' change of definition. Instead, I directly move to the discussion of Descartes' views on the quantification of motion.

Descartes' interest in mathematics, which played an important role in his introduction of quantifiable motion, started already from his school years, as he states in the *Discourse on Method:* "Above all I delighted in Mathematics, because of the certainty and self-evidence of its reasoning".[39]

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[35] Descartes, *Rules for the Direction of the Mind*, Rule XII, CSM trans., 1992.

[36] Descartes, *The world*, Chapter VII, CSM trans., 1992.

[37] Ibid.

[38] In *The World*: motion is "that by virtue of which bodies pass from one place to another and successively occupy all of the spaces in between" (Chapter VII). In the Principles: "Motion…as commonly understood is nothing but the action by which some body passes [migrat] from one place to another" (Pr II 24).

[39]Descartes, *Discourse on Method*, Part II, CSM trans., 1992.

The interest in mathematical studies was newly provoked by Beeckman whom Descartes first met on November 10, 1618 during his visit to Holland.[40] As Gaukroger states, at that time Beeckman had "applied corpuscularian natural philosophy in a number of areas, including hydrostatics, optics, gravitation, and acoustics. In each case the aim was to effect a reduction of the phenomena to a micro-corpuscular model in which impact was the sole form of action, and in which transfer of motion was the sole outcome of this action"[41] The fact that Descartes' laws of impact as presented in the *Principles* and those of Beeckman's *Journal* are very similar also speaks about the great influence Beeckman had on Descartes in developing his project.[42] Although Descartes' interest in pure mathematical started to decrease from 1637 on,[43] the impact on the development of the theory of motion remained.

Descartes' mathematical studies with Beeckman inspired him to connect mathematics with physics; and that, in its turn, led to quantification of the laws of motion. Descartes had found a universal method, a tool with the help of which it would be possible to reach true knowledge – *Scientia*. And as treatment of natural phenomena, including the laws of motion, must have the same method and the same criterion, the laws of motion must be quantifiable. What is important is that actual quantification is not a must. The only criterion for the laws of motion to be accepted by Descartes as treated by the correct method, is to be quantifiable. As it can be read in Descartes' works and in the definition of, for instance, the law of impact, there are

[40] Gaukroger, *Descartes: An Intellectual Biography*, 68.

[41] Ibid, 72-73.

[42] Garber, *Descartes' Metaphysical Physics*, 231.

[43] Mancosu, "Descartes and Mathematics," 103.

no actual geometrical measurements, arithmetical calculation or algebraic formulae. However, this is not to say that mathematical calculations play no role in Descartes' theory of motion.

In Part II of the *Principles*, Descartes introduces seven laws of impact "for determining the speed and direction of bodies after impact" and they all "depend on an implicit mathematical formula for the conservation of the quantity of motion measured as the product of size and speed".[44]

2.2. The Development of Boyle's Theory of Matter

2.2.1. Boyle's attitude Towards Descartes' Vortex Theory

Although Boyle had not developed a theory concerning explanations of celestial phenomena, he was acquainted with and showed interest in the theories developed in the previous centuries. As Hunter and Davis write:

> Already during his moralistic phase – and even during his European tour – Boyle had taken some interest in the marked changes in understanding of the workings of the Universe that had occurred during the previous century, notably the astronomical revolution associated with Nicolaus Copernicus (1473-1543), Johannes Kepler (1571-1603) and Galileo Galilei (1564-1642)….[45]

As was already mentioned in earlier sections, Boyle was studying Descartes with Hooke's help during the years 1658-1662, studies that also included the reading of the *Principles.* It means that Boyle was familiar with Descartes' physics as well and with the Vortex Theory particularly. The level of influence can be discussed by the analysis of the discussion of Descartes' mentioned

[44] Cottingham, *Descartes*, 89.

[45] Boyle, *A Free Enquiry into the Vulgarly received Notion of Nature*, XI (ed. Hunter and Davis).

theory in Boyle's following works: *Certain Physiological Essays (from 1655 to 1659), Origin of Forms and Qualities (1666)* and *Spring of the Air: first Continuation (1669).*

As I mentioned, there is no close consideration of celestial phenomena or a developed theory of these phenomena in these works. However, there is a certain attitude towards Descartes' Vortex Theory. Mary Boas argues that Boyle accepted the Vortex Theory in his early works, however did not proceed to accept it in the later ones; and the later development of Boyle's theory resulted in the rejection of the Vortex Theory. I will argue that though in Boyle's later work his attitude towards Descartes' Vortex Theory changes, and he has some objections to the Cartesian vortices, it does not mean doubt in the *existence* of the theory. I will argue that the skepticism refers to some aspects of the Vortex Theory only: the claim that it does not need God's interference to explain the planetary motions and that it is difficult to prove its existence experimentally. Yet, and this is what I conclude, this objections did not lead to a rejection. It is not the case, as Mary Boas thinks, that Boyle "never proceeds to accept it and elsewhere expressed his disbelief in its existence".[46]

In the winter months of 1655-1666 Boyle moved to Oxford.[47] His activity there resulted in several books on natural philosophy, such as *The Usefulness of Natural Philosophy, Certain Physiological Essays,* and *Skeptical Chymist.* Boyle's first statements about the structure and properties of matter appeared in these works. According to Boyle the component particles must be small and have "a store of vacant spaces intercepted betwixt the component particles of the

[46] Boas, "The Establishment of Mechanical Philosophy," 465.
[47] Hunter, *Boyle: Between God and Science*, 92.

fluid body"[48], as he writes in the *Certain Physiological Essays*. In the *Skeptical Chymist* Boyle describes the particles in the following way:

> […] the first production of mixed bodies, the universal matter, whereof they consist, was actually divided into little particles of several sizes and shapes, variously mov'd.
>
> Besides what happens in the generation, corruption, nutrition, and decrease of bodies; microscopes, by discovering the extreme minuteness of the sensible parts of concretes; chemical resolutions of mixed bodies, and many other operations of fire upon them, seem sufficiently to manifest, that they consist of parts very minute, and of different figures.[49]

As one can see, according to Boyle, the observations have shown that the consisting parts of matter are "very minute", and that particles have size, shape, and motion. Following the mechanical hypothesis, Boyle considers the above mentioned qualities of matter as primary. The other qualities are reducible to the primary ones and are, therefore, claimed to be secondary. What is more important for the current discussion is that the particles must be "Agitated Variously and Apart, whether by their own innate and inherent motion, or by some thinner substance that tumbles them about in its passage through them".[50] The innate substance Boyle speaks about is identical to the explanation of the planetary motion provided by Descartes: the explanation of the movements of the planets due to the subtle matter. This description of the "thinner substance" and the acceptance of its existence, as Boas claims, is the acceptance of Descartes' Vortex Theory.[51]

[48] Boas, "The Establishment of the Mechanical Philosophy," 465.
[49] Boyle, *Skeptical Chymist*, 263.
[50] Boyle, *Certain Physiological Essays*, 130.
[51] Boyle does not make a direct reference to Descartes' vortices in the passage where discusses the "Chief Condition of fluid Body" (Ibid). The claim that the description of the fluid body amounts in acceptance of Descartes' vortices is based on Boas' interpretation only. I have searched for evidence in some secondary sources I had access to, and

I will now turn to the discussion in his *Origin of Forms and Qualities* and in the *Final Causes (1688),* based on which one can understand the reasons why Boyle had changed the initial attitude towards the Vortex Theory.

As in the early works, Boyle's conception of body remained loyal to the mechanistic natural philosophy. The basis of Boyle's corpuscular philosophy is universal matter which is extended, divisible, and impenetrable: "I agree that with generality of Philosophers so far, as to allow, that there is one Catholick or Universal Matter common to all Bodies, by which I mean Substance extended, divisible, and impenetrable".[52] Boyle continues that motion was endowed by God, which divides matter into particles. The argument for the mentioned claim is that the universal matter is one in itself and there could not be the diversity one can observe if it was at rest:

> But because this Matter being in its own Nature but one, the diversity we see in Bodies must necessarily arise from somewhat else, then the Matter they consist of. And since we see not, how there could be any change in Matter, if all its (actual or designable) parts were perpetually at rest among themselves, it will follow, that to discriminate the Catholick Matter into variety of Natural Bodies, it must have Motion in some or all its designable Parts: and that Motion must have various tendencies, that which is in this part of the Matter tending one way, and that which is in that part tending another; as we plainly see in the Universe or general Mass of Matter, and that variously determin'd, and that yet diverse portions of Matter are at rest.[53]

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could not find discussion about Boyle's mentioned claim in the *Certain Physiological Essays*. The sources I have searched in that contained discussion on several aspects of Boyle's Theory of Matter are Anstey's *The Philosophy of Robert Boyle* and papers by Harwood, Sargent, Henry, Davis and Shanahan in *Robert Boyle Reconsidered*, edited by Hunter.

[52] Boyle, *Origin of Forms and Qualities*, 2.

[53] Ibid, 2-3.

We turn to the reasons why Boyle had critical approach towards Descartes' vortices. Starting his discussion "touching the Origine of Forms" Boyle states his similarities and differences from Descartes and Epicureans:

> But in this last Summary Account of the Origine of Forms, I think my self oblig'd to declare to you a little more distinctly, what I just said now intimated to be my own opinion. And this I shall do by advertising you, that though I agree with our Epicureans, in thinking it probable, that the world is made up of an innumerable multitude of singly insensible Corpuscules, endow'd with their own Sizes, Shapes, and Motions, and though I agree with the Cartesians, in believing (as I find that[54] Anaxagoras did of old) that Matter hath not its motion from its self, but originally from God; yet in this I differ both from Epicurus and Des Cartes, that whereas the former of them plainly denies that the world was made by any Deity, (for Deities he own'd,) and the latter of them, for ought I can find in his writings…that God having once put Matter into Motion, needed not more particularly interpose for the production of things corporeal, nor even of Plants or Animals, which according to him are but Engines…[55]

The similarities Boyle enumerates are, firstly, the acceptance of atoms. As it is not mentioned that the particles can be infinitely divisible, or at least that they are divisible but due to their small size do not practically divide[56], and as Boyle mentions that he agrees with Epicureans (not, for instance, mechanical philosophers), one can conclude that by 'Corpuscules' here Boyle means atoms. Boyle also shares one of Descartes' ideas – the idea that God is the first cause of motion. But the criticism of both thinkers is done on the ground that they do not accept God's power to intervene (though Descartes accepts that God has that power) in the further development of matter. Boyle opposes Descartes' idea that the further development could be solely due to the laws of motion that God had imprinted in Nature. He criticizes the elimination

[54] Here Boyle has a footnote saying that Aristotle speaks of Anaxagoras in the first chapter of the last book of his physics.
[55] Ibid, 101-102.
[56] Boyle has such a claim in the *Origin of Forms.* See Boyle, *Origin of Forms and Qualities*, 47.

of God's activity from the further explanation of the development of matter after being the initial cause of the movement. Boyle assures, though without giving any further explanations, that God established the laws of motion and his further interaction is needed for conservation of matter. He writes:

> I do not at all believe, that either these Cartesian Laws of Motion, or the Epicurean casual concourse of Atoms could bring meer Matter into so orderly and well contriv'd a Fabrick as this World; and therefore I think that the wise Author of Nature did not only put matter into motion, but when he resolv'd to make the World, did so regulate and guide the motion of the small parts of the Universal Matter, as to reduce the greater Systems of them into the order they were to continue in; and did more particularly contrive from portions of that Matter into seminal Rudiments or Principles, lodg'd in convenient receptacles, (and as it were Wombs,) and others into the bodies of Plants and animals.[57]

As can be seen from the above brought passages Boyle does not doubt the existence of the Vortex Theory. He has objections to it because of Descartes' ideas concerning the development of the initial matter. Though Boyle does not believe that "Cartesian Laws of Motion… could bring meer Matter into so orderly and well contriv'd Fabrick as this World" it does not yet mean that he rejects the Vortex Theory. The world "meer" can be a key word here. In the objections to Descartes' above mentioned theory, there is still a possibility that the planetary motions take place in the way described in the Vortex Theory, only with the guidance and regulation of the "wise Author of Nature". From the fact that Boyle criticizes the approach to eliminate God's participation in the development of the universal matter it does not necessarily follow that Boyle should have for that reason doubted the existence of Descartes' theory. This can be seen in the following passage of the *Final Causes* as well. He writes:

[57] Ibid, 102-103.

> […] On the other hand, it may be said, that in bodies inanimate, whether the portions of matter they consist of, be greater or less; the contrivance is very rarely so exquisite , but that the various motions and occursions of their parts may, without much improbability, be suspected capable, after many essays, to cast one another into several of those circumvolutions call'd …by Descartes', Vortices; which being once made, may continue a long time, after the manner explain'd by the latter.[58]

We now turn to the discussion of Boyle's experiment described in *Spring of the Air: first Continuation.* The experiment contains important material concerning Boyle's attitude towards Descartes' Vortex Theory. That is the work Boas refers to and on which she grounds her argument about Boyle's rejection of the Vortex Theory. She particularly mentions the experiment xxxviii. This experiment is "About an Attempt to examine the Motions and Sensibility of the Cartesian "Materia subtilis", or the Ether, with a pair of bellows (made of Bladder) in the exhausted Receiver".[59] I will argue that the discussion presented in the mentioned experiment does not lead to judge about the rejection of the Vortex Theory, as Boas claims. Although in his experiment Boyle shows that the existence of the "Materia subtilis" is not confirmed by the conducted experiment, he does not explicitly make any claims about rejecting it. Boyle does not clearly state that the outcomes of the experiments result in his rejection of the Vortex Theory. Instead, he claims that his intention was not to

> […] discuss the Controversie betwixt some Modern Atomists, and the Cartesians; the former of whom think, that betwixt the Earth and the Stars, and betwixt these themselves there are vast tracts of Space that are empty, where the beams of Light do pass through them; and the later of whom tell us, that the Intervals betwixt the Stars and Planets (among which the Earth may perhaps be reckon'd) are perfectly fill'd, but by a Matter far subtiler than our Air, whic some call Celestial, and others Ether.[60]

[58] Boyle, *Final Causes*, 159.
[59] Boyle, *Spring of the Air: 1st Continuation*, 128.
[60] Ibid.

After stating that he will not "engage in this controversie"[61], Boyle continues writing that Cartesian hypothesis is very important and is worth examining. As the “Materia subtilis” is such matter that can “make up far the Greatest part of the Universe known to us"[62], he “thought it might very well deserve a heedful Enquiry, whether we can by sensible Experiments (for I hear what has been attempted by Speculative Arguments) discover any thing about the existence, or the Qualifications of this so vast Ether".[63]

Boyle does not go farther than claiming that he wants to see whether it is possible to justify the Vortex Theory experimentally. Though his experiment shows that it is not the case, he, as stated in the beginning, does not engage in the controversy and does not proceed to reject the Vortex Theory on the basis of the experiment.

It may seem strange that Boyle conducts an experiment to “discover any thing about” the existence of the “Materia subtilis” but does not make any conclusions after the results of the experiment are known. However, the hypothesis is defined in such a way that allows Boyle not to reject the existence of the “Materia subtilis”.

The “Engine” described by Boyle consists of a pair of bellows the lower and upper bases of which are fastened with a “convenient weight…great enough to keep it Horizontal and immovable”. Later the upper basis is raised to its full height, thus the receiver is freed from Air. After that the upper basis is let go which makes it fall down to the lower one. There is also a thin tube fastened to the bottom of the bellows, or in the upper basis. Near a hole of the tube a feather

[61] Ibid.
[62] Ibid, 129.
[63] Ibid.

(the feather is chosen as it is light enough to be moved by the matter that is forced out of the tube) is place "at a convenient distance".[64]

According to Boyle's hypothesis, if the feather is moved, it will mean that despite the atomists' claims "there may be a much subtiller Body than common Air…and that it is not safe to conclude form the absence of the Air in our receivers, that there is no other body left but an absolute Vacuity or (as Atomists call it) a vacuum coacervatum". The continuation of the hypothesis is that the absence of the movement, on the other hand will mean either that vacuum exists or that the matter contained in the receiver was so subtle that does not "either easily impel such light bodies as even Feathers, or sensibly resist as does the Air".[65]

The way Boyle states the hypothesis creates the following situation: even if the feather does not move, it does not rejects the existence of the "Materia subtilis". That kind of result will only mean that either the vacuum exists or the matter in the receiver is too subtle to be able to prove its existence by an experiment. And the experiment shows that

> […] the feather that lay just over and near the orifice of the little Glass Pipe, had some motion, yet this seem'd to be plainly but a shaking and almost vibrating motion, yet (to the right and left hand,) which it was put into by the upper basis, which the string kept from a smooth and uniform descent; but not to proceed from any blast issuing out of the cavity of the Bladder.[66]

Boyle's experiment nether confirmed, nor rejected the existence of matter. And as Boyle himself does not give any priority to any of the possibilities (the existence of vacuum or the impossibility to show the existence of the "Materia subtilis"), one cannot conclude that this experiment can speak about Boyle's rejection of the Vortex Theory.

[64] Boyle does not give the precise distance. For a more detailed description of the experiment see Boyle, *Spring of the Air: 1st Continuation*, 128-131.
[65] Ibid, 130.
[66] Ibid, 131.

Two years after the publication of the *Spring of the Air: first continuation* – in 1671 Boyle publishes his *Cosmical Qualities.* In this work as well Boyle mentions the Cartesian "Materia Celestis" and, though claiming that he will not discuss "whether there be or be not in the world any Matter, that exactly answers to the Description" of the "Materia Celestis", Boyle suggests "That there are certain subtle bodies in the World, that are ready either to insinuate themselves into the Pores of any body, disposed to admit their Action; or by some other way to affect it; especially if they have the Concurrence of other unobserved Causes, and the establisht Lawes of Universe".[67]

It is evident here as well that even in later work there is no rejection of Descartes' "Materia Celestis", as Boyle names it in his *Cosmical Qualities.* Here, as in the *Spring of the Air: first continuation*, Boyle does not want to engage in the discussion of the existence of Cartesian vortices, but that does not lead to or does not mean the rejection of its existence.

In conclusion, the reasons of Boyle's objections towards Descartes' Vortex Theory were Descartes' idea concerning the interference of God in the development of initial matter and the fact that Boyle's respective experiment did not confirm the existence of the "Materia subtilis", though did not reject its existence either. The objections made by Boyle did not lead to and did not mean a rejection of the Vortex Theory.

[67] Boyle, *Cosmical Qualities*, 290.

2.2.2. Boyle on Descartes' Mechanical Philosophy and Method of Quantification

On Descartes' Mechanical Philosophy

Both Gassendi and Descartes accepted that natural phenomena must be explained in terms of shape, size and motion. Thus Boyle could be influenced in limiting his explanations in physics to the explanations in terms of shape, size and motion both by Descartes[68] and Gassendi. Therefore, one cannot argue that the acceptance of mechanical explanation or other general similarities can be taken as patterns of influence from Descartes. However, if evidence is found to support the claim that Boyle rejected 'dogmatically' mechanical way of treating physical phenomena, that evidence can be considered as a ground to argue about the criticism of Descartes' mechanical method as well. In the following discussion I develop Boyle's criticism of the mentioned method generally. I also discuss his criticism specifically on Descartes.

In the *Origin of Forms and Qualities* Boyle claims to explain physical phenomena mechanically, and sees "no necessity of admitting in natural things any such Substantial Forms".[69] In this subsection I argue that despite Boyle's claims concerning his approach to the mechanical treatment of the physical phenomena in the *Origin of Forms and Qualities,* the development of his opinion had a different development in the *Cosmical Qualities* (1671). If in the *Origin of Forms* the approach to the explanation of the physical phenomena was exclusive – either mechanical explanations or explanations via substantial forms[70] – in the *Cosmical*

[68] Later in the text I refer to Descartes' mechanical method, by which I mean his idea of limiting explanations of physical phenomena to explanations via shape, size, and motion. On Descartes' mechanical philosophy see Garber, *Descartes Metaphysical Physics,* 63-116. I also use the expression *'dogmatically' mechanical method,* by which I mean Descartes' exclusive approach in explanation of natural phenomena.
[69] Boyle, *Origin of Forms and Qualities,* 73.
[70] And, of course, Boyle prefers is the mechanical explanations.

Qualities among mechanical explanations[71] the explanations via "unheeded Agents" were allowed.

In the *Cosmical Qualities* Boyle states that wants to develop a discussion on some matters that he had already done in the *Origin of Forms,* but in another way. The evidence about his changes in the approach can be read in the following passage:

> I have in the *Origin of Forms* touched upon this subject already, but otherwise than I am now about to do: for whereas that which I principally (and yet but transiently) take notice of is, that one body being surrounded with other bodies, is manifestly wrought on by means of those among whom it is placed; that which I chiefly in this discourse consider, is the impressions that a body may receive, or the power it may acquire from those vulgarly unknown or at least unheeded Agents by which it is affected, not only upon the account of its own peculiar texture or disposition, by virtue of the general fabrick of the world.[72]

From the discussion of the above brought passage one can assume that "general fabrick of the world" does not consist of solely mechanical properties described in the *Origin of Forms.* Firstly, if there was no difference in explanation, Boyle would not write that he had discussed the topic in the *Origin of Forms* "but otherwise". Secondly, the properties or "unheeded Agents" Boyle names do not depend on "peculiar texture or disposition". Therefore the powers Boyle describes can be understood "not barely upon the score of these qualities that are presumed to be evidently inherent in it, nor of the respects it has to those other particular bodies to which it seems to be manifestly related, but upon the account of a system so constituted as our World is".[73]

[71] Boyle writes that "Size, Shape, Motion, and Rest…may more conveniently be esteemed the Primary Modes of the parts of Matter." See Ibid, 267.
[72] Boyle, *Cosmical Qualities*, 288.
[73] Ibid, 287.

So, what that powers could mean. As Boyle argues, the "unheeded agents" that "may have great operations upon body", make that "operations" take place by "unheeded means", and as the "unheeded Agents" are not the properties "with which the body propos'd is taken notice of", they are not mechanical.[74]

The evidence that in the *Cosmical Qualities* Boyle argues for the existence of mechanically not expressible properties can be seen in the following passage as well:

> It may now therefore be not unseasonable to confesse to you, that I have had some faint Suspition, that besides those more numerous and uniform Sorts of minute Particles that are by some of the new philosophers thought to compose the Ether I lately discours'd of; there may possibly be some other kind of Corpuscles fited to have considerable operations when they find congruous Bodys to be wrought on by them. But though 'tis possible, and perhaps probable, that the Effects we are considering, may be plausibly explicated by the Ether, as 'tis already understood; yet I somewhat suspect that those Effects may not be due solely to the Causes they are ascribed to; but that there may be, as I was beginning to say, peculiar sorts of Corpuscles that have yet no distinct name, which may discover peculiar Faculties, and Ways of working, when they meet with Bodies of such a Texture as disposes them to admit, or to concur with the Efficacy of these unknown Agents.[75]

The causes of the effects described in the above passage are due to "Corpuscles" that do not have a distinct name. This leads to a conclusion that those "unknown Agents" are non mechanical qualities.

Boyle also thinks there are "greater number" of laws of motion that are not able to explain the world. He writes:

[74] Ibid.
[75] Ibid, 303.

> For as I am by some Notions and Obsevations inclined to think, that there may be greater number even of the more generall Lawes, then have been yet distinctly enumerated; so I think that when we speake of the establisht Lawes of nature in the popular phrase of that Phrase, they may be justly and commodiously enough distinguish: some of them being general Rules that have a very great reach, and are of greater affinity to Lawes, more properly so called, and others seeming not so much to be general Rules or Lawes, as the Customs of the nature in this or that particular part of the World: of which there may be a greater number, and those may have a greater Influence on many Phenomena of nature then we are wont to imagine.[76]

The thinker whose laws Boyle refers to is suggested by Henry to be Descartes.[77] Boyle writes that though he admires "the Industry of Astronomers and Geographers, especially of some later ones"[78], he anyway confesses that he

> […] had sometime suspected that there may be in the Terrestrial Globe it selfe, and the Ambient Atmosphere, divers whether Laws or Customs of nature that belong to this Orbe, and may be denominated from it, and seemed to have been either unknown to, or overseen by both Scholasticall and Matematicall Writers.[79]

As the critical approach to existing laws is presented with the criticism of the exclusive mechanical approach, one can conclude that the reason of the criticism to the laws is because the earlier criticized mechanical approach was applied to them. And as the "Mathematical Writer" is suggested to be Descartes, one can judge that the criticism was directed towards Descartes as well.

In conclusion, if in the *Origins of Forms and Qualities* Boyle supports mechanical explanations, in the *Cosmical Qualities,* he has a tendency to appeal to non mechanical

[76] Boyle, *Cosmical Qualities,*305.
[77] Henry, "Boyle and Cosmical Qualities," 124.
[78] Boyle, *Cosmical Qualities,*305.
[79] Ibid, 306.

properties. In the latter work Boyle accepts the possibility to explain physical phenomena with "unheeded Agents", "peculiar sorts of particles" with "peculiar faculties and ways of working". In this work, unlike in the *Origin of Forms and Qualities*, Boyle, though apologetically[80], accepts the possibility of explanation of phenomena by qualities that are not reducible to mechanical explanations. And as Descartes as well restricts the explanation of physical phenomena to mechanical explanations only, one can conclude that Boyle did not accept Descartes' approach either.

On Descartes' Method of Quantification.

In *Languid Motion* Boyle argues that explanation of motion is a philosophical problem that is still in process, and the best way is to leave the consideration of the problem to the mathematicians and specialists in mechanics.[81] However, motion is one of the most important principles in Boyle's Natural Philosophy. As he writes in the *Origin of Forms* "Local motion seems indeed the principal amongst second causes, and the agent of all that happens in nature" and that he is attempting "to resolve the phenomena of nature into matter and local motion".[82] In the *Cosmical Qualities* Boyle writes that "Size, Shape, Motion, and Rest…may more conveniently be esteemed the Primary modes of the parts of Matter"[83] and that "the other Catholick Affections of Matter are manifestly deducible from local motion".[84]

[80] Henry, "Boyle and Cosmical Qualities," 122. The part where Boyle fears that the new development in his discussion "may very much prejudice the receprtion of a good part of what I am to deliver about particular Qualities" can be read in the first Tract of the *Cosmical Qualities*, 268-269.
[81] Anstey, *The Philosophy of Robert Boyle*, 116.
[82] Ibid, 117.
[83] Boyle, *Cosmical Qualities*, 267.
[84] *Bid, 274.*

However, Boyle's attitude towards the importance of the local motion did not result in the development of a system of laws of motion. Despite the absence of the system of laws of motion he had a law of fall. Peter Anstey claims that Boyle did not have an interest in the quantitative aspect of mechanics[85] and that "in spite of all his talk about laws of motion, Boyle never presents us with one determinable law of his mechanical philosophy. The only laws he mentions when elaborating his argument from transduction are those of fall and of sciences such as dioptrics and hydrostatics, which refer to non fundamental qualities such as weight".[86] I argue that though approach of the application of mathematics in Physical explanations was not applied in Boyle's laws of fall, nevertheless he accepted and encouraged the above mentioned method. For substantiating the claim made above I will discuss the law of fall and the second essay of *The Usefulness of Natural Philosophy – Of the Usefulness of Mathematics to Natural Philosophy*. The mentioned essay contains Boyle's position concerning the application of Mathematics in Physics, his arguments why it is useful and illustrations how can the mentioned method work.

Boyle describes the law of fall in his *Christian Virtuoso* (1690). It is presented to illustrate how experience is important in doing natural philosophy and how experience can show completely different picture than was thought of in theory. Giving a central place to the experience Boyle writes that

> If experience did not inform and certify us, who would believe, that a little heap of light, black grains of matter, should be able to over-turn stone-walls, blow up whole castles and rocks themselves, and to those other stupendous things, that we see actually perform'd by gun-powder, made use of in

[85] Anstey, *The Philosophy of Robert Boyle*, 116.
[86] Anstey, "Robert Boyle and the Heuristic Value of Mechanism," 163.

ordinance, and in mines?[87]

His understanding of the law of fall is presented to oppose the opinion of "the generality of philosophers" who state that

> […] in proportion as one body is more heavy than another, so it shall fall to the ground faster than another. Whence it has been inferr'd that of two homogeneous bodies, whereof one for example, weights ten pounds, and the other but one pound; the former being let fall from the same height, and at the same time with the latter, will reach the ground ten times sooner.[88]

And though Boyle claims that the hypothesis is plausible, it cannot be accepted as the experience shows something different, particularly, "That bodies of very unequal weight, let fall together, will reach the ground at the same time; or so near it, that 'tis not easy to perceive any difference in the velocity of their descent, from a moderate height".[89] As can be seen from the presentation of the law of fall, it is not quantified.

Now we turn to the discussion of Boyle's opinions on how mathematics can be used in Physics. Starting the essay on the usefulness of Mathematics in Physical explanations, Boyle refers to Kepler and some "Modern Astronomers" as people who applied mathematical knowledge in Natural Philosophy. After confessing that he would wish to have employed "Practick parts of Mathematicks" in his experiments and especially in the mechanical ones,[90] Boyle states that he wants to discourse "the utility of Mathematicks in reference to Modern Physicks, and therein not onley to the Notions of the Corpuscular Philosophie, but even to the

[87] Boyle, *Christian Virtuoso*, 251.
[88] Ibid.
[89] Ibid.
[90] Boyle, *The Usefulness of Natural Philosophy*, 440.

Practical and Experimental Knowledge".[91] Before turning to the illustration of how Mathematics can be useful to physics and in which fields it can be applied, Boyle brings his argument and the reasons why he considers Mathematics to be of great importance in Physics. The argument is presented in the following passage:

> And indeed the Operations of Symbolical Arithmetick (or the modern Algebra) seem to me to afford men one of the clearest Exercises of reason that I ever yet met with, nothing being there to be perform'd without strict and watchful Ratiocination, and the whole method and progress of that appearing at once upon the Paper when the operation is finish'd, and affording the Analyst a lasting, and as it were, visible Ratiocination.[92]

Boyle's argument is based on the idea that the Mathematical operations, firstly, provide the tools for clear reasoning, and, secondly, one is able to have the precise picture of the operations after they are finished, i.e. Mathematical way of expressing them and putting on the paper guarantees "lasting, and…visible Ratiocination".

One of the fields Boyle mentions considering that it is possible to apply mathematics in it, is explanation of motion. He writes:

> […]the knowledge of what figures are, (for instance) more or less capacious, and advantag'd or disadvantag'd, for Motion or for Rest, or for penetrating or resisting Penetration, or for being fasten'd to another &c. must be of considerable Use in explaining many of the Phenomena of Nature; and tis sufficiently known, how much of the Doctrine of Figures may be learn'd from Geometricians…[93]

[91] Ibid.
[92] Ibid.
[93] Ibid, 441.

Boyle continues: "There are divers Properties as well of Planets and Solid figures, and their Habitudes to each other; as of such lines describ'd by Motions, or wherein Motions may be made: the knowledge whereof may be of good use not onley to the Speculative Naturalist, but the practical".[94]

From the above cited passages it is yet not clear whether by the use of mathematical knowledge Boyle also means the application of the method of quantification. For the use of mathematical knowledge could mean using only the general mathematical knowledge in the investigation. However, as Boyle continues stating the uses of mathematics in Physics, it becomes clear that by encouraging to use mathematical knowledge Boyle also means the application of the method of quantification. He writes:

> […] of the use of Experimenter may make of pure Mthematicks, I might, if I could be sufficiently deliver'd in few words, adde the method of computing the Combinations, that may be made of any number of things propos'd, which some Mathematicians call Regula Combinatoria…it will, if I mistake not, want nothing, but the being skillfully applied by the Naturalist, to be on certain occasions very serviceable to him.[95]

As it can be seen the method of mathematization was considered by Boyle to be "very serviceable". Boyle thinks that the "method of computing the combinations" is a help for the Natural Philosopher.

On the basis of the above developed discussion it is possible to conclude that Boyle accepted the method of matematization in the explanation of the physical phenomena. And as Anstey claims that, "without a doubt", Boyle's "conception of motion owed most to

[94] Ibid, 442.
[95] Ibid, 444.

Descartes",[96] and considering the fact that he refers to "Contemporary Astronomers" whose method of applying mathematical knowledge he accepts, one can judge that the acceptance of the method could owe to Descartes as well.

[96] Anstey, *The Philosophy of Robert Boyle*, 116. Anstey refers to Boyle's criticism to Hobbes where he criticizes him for omitting "great personages", among the names of which Boyle mentions Descartes as well (Ibid). Also Anstey quotes Boyle saying that he approves "Descartes' definition of local motion, (which indeed is far more intelligible than Aristotle's)" (Ibid, 119).

Conclusion

The historical facts brought in the first part of the thesis speak about the historical environment developed in the 1660s in the scientific circles in England, especially at Oxford where a scientific society and, on the basis of it, the Royal Society of London were formed. The discussions that concerned Descartes and his theory of matter and Boyle's involvement and familiarity with them showed that Boyle was familiar with Descartes' theory of matter. We then turned to examine the influence on Boyle's thought of Descartes' Vortex Theory, the method of mechanical explanation and the method of quantification.

The analysis of the development of Boyle's attitude towards Descartes' Vortex Theory shows that the acceptance in the early works did not remain constant. In the later, more developed presentation of Boyle's theory of matter there are several objections to the Vortex Theory. However, the objections that Boyle expresses are not connected with the content of the theory itself (though Boyle does not state that explicitly, anyway, there is no evidence to claim the opposite either). The reasons of the objections are the elimination of God from the explanation of the development of the initial matter, as vortices do not need God's interference, also the fact that Boyle's experiment did not confirm the existence of the vortices. However, the failure of the confirmation did not mean the rejection of the theory either. The possibility was left that the matter the vortices comprise of is not experimentally observable.

The investigation of Boyle's attitude towards Descartes' mechanical explanation and the method of quantification presents a different picture. Boyle criticizes the exclusive mechanical approach Descartes' supports on the basis of accepting non-mechanical explanations in Physics.

And the approach of mathematical treatment of physical Phenomena is accepted, though not applied to his law of fall.

On the basis of the above described investigation the conclusion of the thesis is the following: Descartes' influence in the development of Boyle's attitude towards the Vortex Theory, mechanical approach in the explanation of physical phenomena and the method of mathematization can be seen. However, the development of the influence is not the same in all the mentioned fields because of the above described differences in Boyle's attitude towards each investigated field.

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