Comparing historical conceptions of projectile motion: Impetus theory and Newtonian mechanics

Jafari Matehkolaee, Mehdi; **Khorasani, Shayan**
Sama technical and vocational training college, Islamic Azad University, Sari Branch, Sari, Iran.
Shahid Beheshti High school in Sari, Mazandaran, Iran.

E-mail: mehdijafarimatehkolaee@yahoo.com

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Abstract

This paper show that the comparison between impetus theory and Newton's view. At first we offer historical conceptions of projectile motion then we investigate one of the great philosophers, say that Mulla Sadra's view about motion. In fact we show that the impetus theory is a forgotten controversy in the classical mechanics and now it's rejected without any proper reasons. Our study indicates that in Ibn-Sina's view the range and the area of projectile obtained as complex statements.

Keywords: Impetus theory, projectile motion, Historical conception.

Resumen

Este artículo se muestra una comparación entre la teoría del ímpetu y la visión de Newton. Al principio ofrecemos concepciones históricas de movimiento de proyectiles y luego se investiga uno de los grandes filósofos, digamos que la visión de Mulla Sadra sobre el movimiento. De hecho, se muestra que la teoría del ímpetu es una controversia olvidada en la mecánica clásica y ahora se ha rechazado sin que existan causas justificativas. Nuestro estudio indica que en la concepción de Ibn-Sina el rango y el área del proyectil se obtienen como instrucciones complejas.

Palabras clave: Teoría del ímpetu, movimiento de proyectil, concepción histórica.

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I. INTRODUCTION

Although many years have passed since the presentation of formulation of projectile motion but, there are still a lot of challenging discussions in this area to be mentioned. Our aim of this paper is to indicate the notion of impetus is still alive and it can be well in the 21th century. In spite of, impetus theory is forgotten controversy in literatures of classical mechanics; however we believe that this theory was rejected without enough reasons. Also there are many clear indications that a thrown object is given an impetus which maintains its motion. In this paper at first we review historical views of projectile motion from Aristotelian through impetus theory to Newtonian mechanics. So after we review glance to Mulla Sadra's theory of motion and projectile motion. Especially we try to say substantial motion that it's one of the most important Mulla Sadra's theories. We have been followed Mulla Sadra's theory, because as will see in general motion was a subject in a natural science or physics but based on the Mulla Sadra's perspective motion was a metaphysical matter. For such reasons, in the investigation the historical evolution of motion and projectile motion, Mulla Sadra's view is important and impressive.

Today, we know that projectile motion in the absence of air resistance is a parabolic motion and there are many papers about it [1,2,3,4,5,6,7].

II. HISTORICAL VIEWS OF PROJECTILE MOTION

Aristotle (4th centry BC) believed that an external force is needed to maintain the motion of an object. To account for the movement of projectiles that are not in direct contact with any observable mover, Aristotle suggested that air rushes around the moving object and pushes it forward.

The Greek philosopher John Philoponus (6 th century AD) argued against the Aristotelian theory of motion and introduced the impetus theory [8]. The essence of his theory is that the act of setting and object in motion imparts to the object force, called an impetus, that maintains the motion. This force allows the object to move in the direction in which the mover starts it. Since a projectile has no obvious external force, the impetus is said to be internal to the object.

The 11 th century persian scientist Ibn-Sina held that the impetus is self-expending [9]. When the impetus is diminished or runs out, the natural heaviness of the object supplies a downward force and object falls straight down (in the point of A in figure (1)). Ibn-Sina's theory extends to a stone thrown at an angle. From his perspective, the stone would travel along an oblique line until the impetus is exhausted, when it would momentarily stop. Then its natural gravity would impart an impetus, causing it to fall straight down.

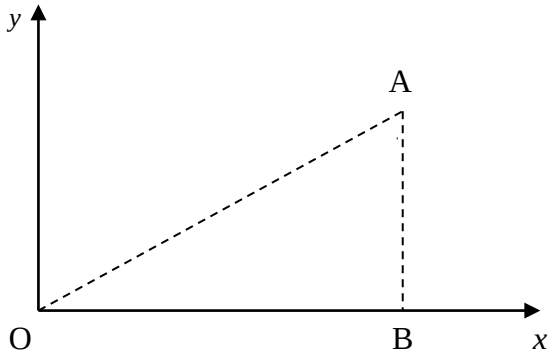

FIGURE1.The trajectory of projectile in Ibn-Sina's view.

Where OAB is projectile path and AB is maximum height and OB is maximum horizontal distance. From Ibn-Sina's view natural gravity of object is along AB.

Albert Saxony (14 th century) amended Ibn-Sina's theory by introducing transition phase. In the firing of cannon, he believed, there is a first phase when the impetus provided by the canon is greater than the weight of the canon ball, so the ball moves in a strairht line. During the second phase, as the initial impetus reduces the downward force has an increasing influence on the object , causing the object to fall below its original path. In the third phase the impetus is spent and the cannon ball falls straight down.

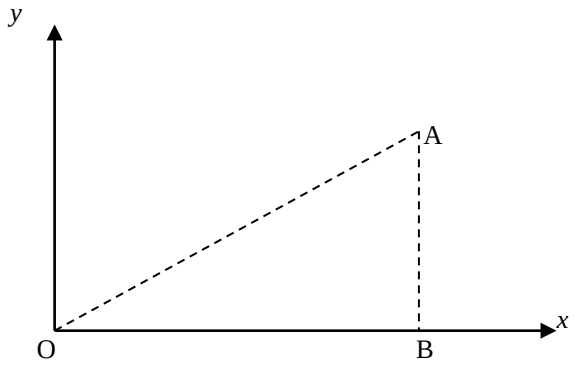

FIGURE2. The path of projectile in Saxony's perspective is same to Ibn-Sina but he consider three phase transition for path.

According to the above figure OA is the first phase and point of A is the second phase and finally AB is the third phase. Note that if we remove the second phase then the object have to move along to straight line OA.

French philosopher Jean Buridan (14 th century) believed that the impetus is sapped by external influences such as air resistance or friction. Buridan also believed that an object dropped from a moving carrier does not acquire impetus.

Mulla Sadra (early 17 th century,1571 or 1572), the great persian philosopher has considerably discussion about motion. One of the most important philosophical theories of Mulla Sadra is the theory of substantial motion in which he peresents a new interpretation of motion in general, which differs considerably from former philosophers[3]. Indeed the theory of substantial motion has greatly influenced other philosophical discussions. As we said other philosophers were consider the discussion of motion so that, the discussion of motion must be dealt with in physics or the traditional philosophy of nature. Conversly, Mulla Sadra considers this discussion to be a metaphysical one, and deals with it under the title, *Division of Existence in to the Unchanging and the Flowing* [10]. The reson of changing this position is that from meditating on substantial motion. Mulla Sadra has concluded that motion is basically an analytical accident of the renewing existence rather than its external accident, i.e., motion is not added to the renewing existence from the exterior. In substantial motion the moved and motion are not separate from one another. Rather, a changing thing in every instant is other than itself in former and preceding instants, so motion and the moved are one thing: the renewing existence. From Mulla Sadra's viewpoint, all bings are divided into two kinds. 1) Stable benigs that have no dimension of time and cannot be measured by the criterion of time, and so they are not changed and transformed. 2) Renewing beings that are in a state of flux forever and have the dimension of time. Accordingly, in a fundamental division, existence is either fixed or flowing, which is like the other divisions of existence into cuase and effect, one and many, potential and actual, temporal and eternal, and other divisions. These divisions are considered to be the essential accidents of existence a qua existence, therefore they should be discussed in first philosophy. On this basis, Mulla Sadra has moved the position of motion from physics to metaphysics.

Mulla Sadra confirmed impetus theory. He believed impetus is internal to the object and when that projectile is projected it decrease gradually. Mulla Sadra tried to combine physics and metaphysics and no use from mathematical methods. But temporal scientist with Mulla Sadra say Galileo Galilei (1564) no consider impetus theory and he refers to physics and mathematics straightforwardly.

Of course he puts forward the impetus idea through his caracter Sagredo who says:

So therefore the impressed force may exceed the resistence of gravity so slightly as to raise it only a finger-breadth; and finally the force of the projector may be just large enogh to exactly balance the resistence of gravity so that the body is not lifted at all but merely sustained [11].

Later Galileo theorized that the trajectory of a projectile could be thought of as two independent motions: one component consisting of uniform motion in a horizontal a direction and other component consisting of vertical motion under acceleration due to gravity. By combining these two motions, he was the first to deduce that the trajectory of an ideal projectile is a parabola.

Later in the 17th century, Isaac Newton devised an universal theory of mechanics that validated Galileo's treatment. Newtonian mechanics, including the famous three laws of motion, is now the accepted way of modeling projectile motion.

III. THE COMPARISON BETWEEN TWO THEORIES

The crucial difference between Newtonian mechanics and impetus theory is that, whereas impetus is the cause of the motion and is internal to the object, in Newtonian mechanics an external force is required to change motion – not to sustain constant motion.

When projectile motion is studied in classical mechanics books or in multiple papers often starts with basic parameters of projectile. Now we here start by introduction these parameters.

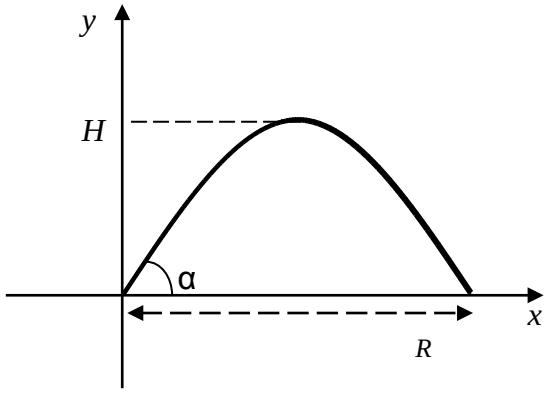

FIGURE3. The trajectory of projectile motion in Newtonian mechanics.

R is the range of projectile and

$$R = \frac{{V_0}^2 \sin 2\alpha}{g}. \qquad (1)$$

In above relation V_0 is initial speed of projectile motion. And *H* is the maximum height

$$H = \frac{{V_0}^2 \sin \alpha^2}{2g}. \qquad (2)$$

Finally we introduce the equation of path

$$y = -\frac{gx^2}{2{V_0}^2 \cos \alpha^2} + x \tan \alpha\,. \qquad (3)$$

Based on this introduction we want to make consistency between two theories. Note that we have to suppose that standard mathematical treatment is possible within the impetus framework. So we consider AB as maximum height, *H*, and OA that is tangent on the curve of projectile in figure (3), (see to figure (4)). Then we want to find range of projectile in figure (1), OA = *r*.

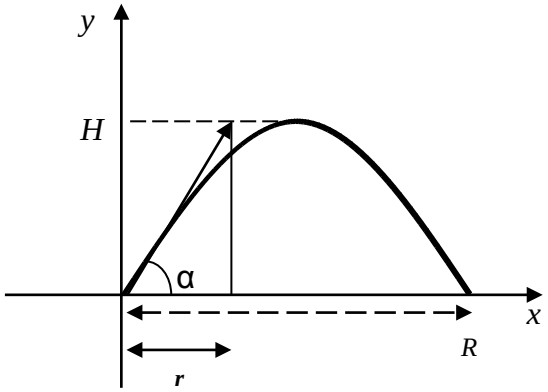

FIGURE4. In this figure show that accordance between impetus theory and Newtonian mechanics. Also in this figure we have *H* = AB and *r* = OB.

If we suppose point of A is in coordinate (*r, H*) then by derivative equation of (3) in this point we get

$$\frac{H}{r} = \frac{dy}{dr} = \frac{-gr}{{V_0}^2 \cos \alpha^2} + \tan \alpha\,. \qquad (4)$$

By the solution above equation we have

$$r = \frac{R}{4}(1 + i)\,. \qquad (5)$$

From relation (5) we see that the range of projectile in Ibn-Sina's theory led to complex statement because point of (r, H) is not root of equation (3). So this version in imaginary space may be a true conception. We think that according to such reason, this version of physics is frequently shown in cartoons such as Road Runner.

Now we calculate the area under projectile motion

$$S = \frac{2}{3}RH. \qquad (6)$$

And the area under projectile motion in Ibn-Sina's view is equal to the area of triangle OAB then we get

$$S = \frac{1}{2}rH = \frac{1}{8}RH(1 + i). \qquad (7)$$

So the area under projectile motion in Ibn-Sina's theory led to complex statement too.

IV. CONCLUSIONS

We conclude impetus theory can be used again and it can remove many misconceptions of projectile motion. Also if we try to compatibility impetus theory with Newtonian mechanics then we obtain a complex statement for some parameters of this motion. Projectile motion is not a mere physical concept but its philosophical discussions are very important. Therefore investigations of Avicenna's theory for remove misconceptions being in projectile motion are very impressive. Especially analysis results in complex space can make new insights in this field.

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