In press

Aristotle, Galileo, Newton and Newton's First Law of Motion

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Abstract: Aristotle's assertion (350 BC) states that rest is the natural state of the body and force is needed to set the body in motion and maintain the same. It is justified in some experiments in terrestrial or resistive systems and taught for about two millennia, but now abandoned. Galileo published Statements (G1 & G2) in *Letters On Sunspots* in 1613. Contrary to Aristotle, Galileo in Statements puts forth that the body moves with uniform velocity in a straight line without any external force which is only true in an ideal system. However, the first part of Statement G2 (body conserves state of rest) also validates Aristotle's Assertion. Newton took Aristotle's and Galileo's existing doctrines as the basis for both parts of the First Law of Motion i.e. body perseveres state of rest or moves with uniform velocity in a straight line if not compelled by impressed force. Thus the first part of Newton's First Law of Motion (FPNFL) is first part of Aristotle's Assertion. So, Aristotle's assertion is as useful as the first part of Newton's first law. Newton combined Aristotle's assertion and Galileo's statements into a single law known as the First law of motion. Thus, both Galileo and Newton have recognized Aristotle's assertion. Descartes in 1644 re-wrote Aristotle's and Galileo's doctrines as the First Law of Nature. Newton, edited existing perceptions of Aristotle and Galileo in the *Principia* (1686) and stated the First Law of Motion without acknowledging the original pioneers.

Key words: First law , Newton, Galileo, Avicena, Descartes

INTRODUCTION

Greek philosopher Aristotle (384BC-322BC) and his ancient law of motion

A continual external force is required to set and keep or sustain a body in motion [1,2,3,4].

So, Aristotle's assertion (AA) has two parts i.e. rest is the natural state of the body (first part) and the body moves due to an external force (second part). The table, chair, boulder, iron girder, etc., naturally, remains at rest on the ground at rest, these bodies only move as long as an external force act on them. Thus, a sufficient external force is needed to set the body in motion to overcome existing resistive forces in terrestrial or realistic systems,

Resistive forces ($Resistive_{force}$) or dissipative forces =

Gravitational force + Frictional force + Atmospheric force +F_{other} (1)

F_{other} may be the force due to other effects which may be significant in one case but not in another.

The externally applied force on the body and resistive forces act in opposite directions; hence body moves due to the resultant or net or impressed force. Resnick **[5]** mentioned that the movement of the body is due to the vector sum of all interacting forces on the system, Newton also meant the resultant force.

Resultant Force or Impressed force (net force)

= External force ($External_{force}$) - Resistive force (2)

In realistic systems ($Resistive_{force} > 0$), when resistive forces are present AA appear to be logical, as force is required to overcomes these forces, hence to move body. Consequently, Aristotle's proposition was taught for about two millennia.

Criticism of Aristotle's Assertion (AA)

Aristotle's argument was strongly opposed in some cases by different philosophers and scientists at different times; Philoponus (490-570), and Buridan (1295-1360) supported, *Theory of Impetus* **[6-7]** to explain the motion of bodies. Buridan named the motion-maintaining property "impetus."

The peripatetic followers argued that a projectile (an arrow, say) moving through the air would owe its continuing motion to *eddies* or *vibrations* in the surrounding medium **[3],** a phenomenon known as *antiperistasis*. However, an arrow also moves in a vacuum, when it is not pushed by air. So Aristotle's assertion (force is required for continuous movement of the body) has been abandoned in view of such cases [3-4,6] and it is also supported by Galileo's more fundamental insight or intuition.

Speculation of the ideal or hypothetical system (when Resistive $_{force}$ = 0)

According to Galileo (1564-1642), no force is needed to maintain the motion of the body (the body moves on its own); the force is needed to produce a change in motion (in uniform velocity and direction). Thus Galileo has given more fundamental insight **[3],** that bodies have an inherent tendency to move with uniform velocity, which is practically true for ideal systems (Resistive$_{force}$ = 0). If the dissipative or resistive forces are zero,

Resistive $_{force}$ = 0 (3)

Resultant Force or Impressed force =

External force (External$_{force}$) (4)

In this ideal system for moving the body needs to be initially pushed with a subtle or trivial force so that the body may move with velocity u_0 or U_0; then the body would sustain uniform velocity perpetually (without any further external force). The magnitude of velocity u_0 or U_0 depends upon the magnitude of the initially applied force. Hence subsequently body would move with uniform velocity (u = constant or u =v) in a straight line without any force, as dissipative (resistive) forces are zero. The momentum (mv) and Kinetic energy (½ mv^2) will be conserved, in the system. But these are thought experiments or Gedankenexperiments; such experimental setup has not been practically created by scientists and technocrats to date.

LITERATURE REVIEW

Avicenna's qualitative and kinematical views in 10th or 11th century.

The Muslim scholar Abu Ali ibn Sena (980-1037) also known as Avicenna **[4]** stated that

'Nobody begins to move or comes to rest of itself.'

Hetch stated about Avicena's above shortest and qualitative statement in *The Physics Teacher* [4] that this is probably the earliest precursor of the first law and that revelation would re-emerge centuries later.

Galileo's statements in 1612 in Letters On Sunspots

Galileo discussed the motion of bodies in the widest way i.e. for both ideal and realistic systems, whereas Aristotle discussed the realistic systems only. Galileo [8] quoted thoughtful arguments about the motion of bodies in *Letters On Sunspots* (LOS) written to Illustrious Mark Welser, the Duumvir of Augsburg in 1612 and published in Italian by the Accademia dei Lincei in 1613. LOS was translated into English in 1957 in the book *Discoveries and Opinions* (p.113) by an extraordinary scholar of Galileo's work, Stillman Drake **[8].** The meanings of Galileo's these lesser conversed acumens (Statement G1, Statement G2, and related Explanations) in LOS need to be discussed.

Galileo's Statement and Explanations

Galileo's explanatory statements and applications [8] as given in 1612 are interrelated or supplementary to each other as given in continuous discussion. It may be the scientific trend in those days of natural philosophy as Galileo published famous books in the form of conversations or dialogues **[9,10]** in the last decade of life. These statements and explanations (1612) have exceptional importance; as these authenticate the theme of about 1960 years old, Aristotle's assertion and foundations of Newton's first law of motion and the law of inertia are based on these in the Principia (1686).

(a) **Statement G1** *"For I seem to have observed that physical bodies have a physical inclination to some motion (as heavy bodies downward), which motion is* *exercised by them through an intrinsic property and without the need of a particular external mover, whenever they are not impeded by some obstacle."*

Thus, in Statement G1, Galileo considered a system devoid of 'some obstacle' or resistive forces ($Resistive_{force} = 0$), and no external force ($External_{force} = 0$) acts on the body (then resultant force is also zero); then body possesses an intrinsic inclination to some motion. So under these conditions i.e. in an ideal system body cannot change its inherent physical inclination to some motion (its velocity and direction) by itself. Obviously by the phrase 'some motion' Galileo meant uniform motion of the body in a straight line. Thus

Some motion ≡ Body moving with uniform velocity in a straight line.

Some Obstacle ≡ Resistive force ($Resistive_{force}$)

In Galileo's days (1564-1642) scientific concepts and vocabulary were limited, Newton initiated in the Principia (1686), physics as a subject (established basic concepts and definitions) separating it from natural philosophy.

(b) **Statement G2:** *"And it (physical body) will maintain itself in that state in which it has once been placed; that is, if placed in a state of rest, it will conserve that; and if placed in the movement toward the west (for example), it will maintain itself in that movement."*

Explanations of the Statements (G1 and G2) in the physical examples by Galileo.

Explanation G1 (1612):

"*Thus a ship, for instance, having once* ***received some impetus*** *through the tranquil sea, would move continually around our globe without ever stopping; and placed at rest it would perpetually remain at rest, in the first case all extrinsic impediments could be removed, and in second case no external cause of motion were added."*

Here Galileo illustrated the statement for water as a medium, but it is true for all other instances (solid bodies and surfaces) as illustrated in Explanation 2.

Explanation G2 (1638):

This application was quoted by Galileo in 1638 in *Dialogue Concerning Two New Sciences* [9] 1638 at page 195.

Imagine any particle projected along a horizontal plane without friction; then we know, from what has been more fully explained in the preceding pages, that this particle will move along this same plane with a motion which is uniform and perpetual, provided the plane has no limits.

In Galileo's time, friction was a general term (used in philosophical and qualitative ways) the laws of the force of friction were discovered afterward by Guillaume Amontons in 1699. The gravitation was introduced in 1686 by Newton. Thus friction in 1638 may be understood as resistive forces (or resembling these) or some obstacle.

NOVELTY OF PROPOSED WORK

Galileo vindicated both parts of Aristotle's assertion (AA). The first part of Statement G2 is the first part of Aristotle's assertion.

The first part of Galileo's Statement G2 (1612) implies that the body is placed in a state of rest, it will conserve that state. In Explanation G1 the ship (body) perpetually remains at rest. Thus Galileo has simply re-quoted the first part of AA (the rest is the natural state) given about 1960 years ago, in different wordings. The body remains at rest or natural state in both cases i.e. in a realistic system ($Resistive_{force} > 0$) or ideal system ($Resistive_{force} = 0$). So the first part of AA is justified.

The second part of Galileo's StatementG2 is the second part of Aristotle's assertion.

The second part of AA states that when external force is applied the body moves. The second part of Statement G2 (1612) is that if the body is placed in movement (or external force is applied to set it in motion) then the body moves. In Explanation G1 the ship (body) receives some impetus or an external force is applied to it, then it moves. In Explanation G2 the body is projected (which means the external force is applied to the body) on the horizontal floor, then it moves. Thus, Galileo vindicated or authenticated Aristotle's assertion (rest is the natural tendency of the body, and force is required to move it) in 1612. In an ideal system ($Resistive_{force} = 0$), subtle or trivial force is needed to set the body in motion (then the body moves on its own) whereas, in a realistic system, a considerable amount of force is needed depending upon the resistive forces. So body moves due to external force from the rest, thus second part AA is justified.

Newton repeated themes of Aristotle's assertion (350 BC) and Galileo's doctrines (1612) in the First Law in the Principia (1686)

Newton's first law (NFL) captivates all previous doctrines, in a precise and poetic form in the Principia (1686) but without any acknowledgment of previous originators i.e. Aristotle and Galileo. The laws or propositions are assessed from the inherent themes; a different way of expression and phraseology of existing themes does not conjecture a new law.

Newton stated the First Law of Motion in Latin as

Corpus omne perseverare in statu suo quiescendi vel movendi uniformiter in directum, nisi quatenus a ***viribus impressis*** *cogitur statum illum mutare* **[11].**

For the first time above definition is translated into English by Andrew Motte from Latin in 1729.

Everybody perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon **[12].**

Newton illustrated after the definition of the first law in the Principia that the motions of projectiles are retarded due to the resistance of air and gravity. The heavenly bodies (planets and comets) persevere their motions for a long time due to the absence of air. Thus Newton perceived that bodies move due to the resultant force (*forces impressed or viribus impressis);* in a general way, the resultant force is given by Eq.(2). Newton did not write any mathematical equation, as analytical methods were initiated by Euler in early 1730s. In the definition, Newton did not directly mention resistive forces, but he mentioned these in his explanation.

(a) The State of Rest in NFL (Validity of Abandoned Aristotle's Assertion)

The first part of Newton's first law of motion (FPNFL), states that the body perseveres state of rest, and further it only moves due to impressed forces. Practically, it is nothing but Aristotle's assertion (rest is the natural state of the body and moves when an external force is applied)

So the theme of both FPNFL and AA is the same. Hence abandoned Aristotle's assertion is as useful as the first part of Newton's First Law of Motion as Newton himself re-quoted it (given about 2030 years ago) and he was aware of the limitations of AA and existing literature regarding it.

(b) The State of Uniform Motion in NFL (re-quotation of Statements G2 & G1)

The second part of Newton's first law of motion (SPNFL) implies body perseveres state of uniform motion in a straight line and this state is only changed when impressed force acts.

Galileo's Statement G1 implies that if $External_{force} = 0$, $Resistive_{force} = 0$ (resultant force is zero), then the body moves with uniform velocity (some motion). It further infers that the uniform motion is changed when an external force is applied to the body ($External_{force} > 0$), which is the same is SPNFL. So Newton re-quoted the theme of Galileo's doctrine after 74 years. In Explanation 2, the uniform velocity of the body varies if the friction (resistive forces, in general) varies. According to Eq.(2), the resultant force varies if $External_{force}$ or $Resistive_{force}$ varies, hence uniform velocity also varies in SPNFL.

The equation F =ma = m(v-u)/t implies that when no external force acts on the body (F=0) then the body remains either at rest, u=0 (first part of Aristotle's assertion, first part of Galileo's Statement G2, first part of Newton's first law of motion) or moves with uniform velocity, v = u (second part of Statement G2, second part of Newton's first law, Statement G1). So AA is consistent with equation F =ma. Thus, Galileo's Statement G2 embodies the inertial frame of reference (not undergoing any acceleration). Thus Aristotle and Galileo gave basic perceptions about the state of rest or motion of bodies. Stillman Drake [9] stated that Galileo perceived the law of inertia in 1612, which was re-quoted by Newton in *the Principia* in 1686.

Descartes' first law and Huygens Hypothesisl; re-quotations of Galileo's and Aristotle's work.

Descartes (1596-1650) had given his three Laws of Nature in 1644 these are published in a book, *Principles of Philosophy* **[13-14]** in 1644. Descartes stated the First Law of Nature as

"*Each thing in so far as it lies always perseveres in the same state, and when once moved, always continues to move"*.

If the 'same state' is considered as a state of rest, then it is the same as the first part of Aristotle's assertion. However, Aristotle added force to his assertion in the second part as early as 350 BC. Descartes further stated when the body once moved (the body is externally set in motion), then it continues to move. Then it is a re-quotation of the second part of Galileo's Statement G2. Galileo published Descartes's law in 1612 i.e. 32 years before Descartes. Thus Descartes repeated as the first part of Aristotle's assertion and the second part of Galileo's Statement G2 in combined form.

Christiaan Huygens [15] stated in 1673 in his book *Horologium oscillatorium sive de motu pendularium* at Part II page 1 as Hypothesis I.

If there is no gravity, and the air offers no resistance to the motion of bodies, then any one of these bodies admits of a single motion to be continued with an equal velocity along a straight line.

So, conceptually Huygens re-quoted Galileo's Statements G1, the second part of Explanation G2, etc. given about 61 years before. Huygens has considered a system that is devoid of gravity and air resistance. Galileo has included all types of resistive forces in his statements using phrases like 'some obstacle', extrinsic impediments, etc.

CONCLUSIONS

Newton edited existing Aristotle's assertion (2030 years old) and Galileo's doctrines (74 years old) into a single, precise, and all-inclusive statement, known as the first law of motion. Newton re-quoted Aristotle's assertion as the first part of the first law of motion (FPNFL); so abandoned Aristotle's assertion is as useful as FPNFL. Earlier Galileo vindicated or authenticated Aristotle's assertion. Scientifically and morally, the original innovators i.e. Aristotle and Galileo should have been acknowledged in *the Principia* by Newton. Thus the efficacy of Aristotle's assertion has been commended by both Newton and Galileo.

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Not In Press

Brief History of Newton's First Law of Motion.

1.0 The contents of Newton's First Law of Motion existed earlier.

(i) Newton wrote the First Law of Motion in *the Principia* in 1686. The study of the motion of bodies existed even before Aristotle's days (350 BC, say).

(ii) Many scientists or philosophers contributed to the motion of bodies right from Aristotle to Galileo (1613, 1638). The scientists successively used and improved existing views to give better doctrines.

(iii) The doctrines about the state of rest and the state of motion; were published, discussed, and taught well before when Newton wrote the Principia (1686).

(iv) Newton combined the previous laws about the state of rest and state of uniform motion in a single law (First Law of Motion).

It is scientific that Newton combined existing doctrines in a single law (better way than Galileo did),

but Newton did not acknowledge the names of Aristotle and Galileo in the Principia while quoting the First Law of Motion in *the Principia.* These acknowledgments should have been made by

Newton; as Newton has acknowledged the names of other scientists in the Principia.

Newton also has priority disputes with his contemporaries Robert Hook and Leibniz. Aristotle lived about 2000 years before Newton. Newton was born in the same year i.e. 1642 Galileo died.

2.0 Who gave the first part of Newton's First Law of Motion?

Aristotle (350 BC) i.e. 2036 years before published the first part of Newton's First Law of Motion.

The First part of Newton's first law (in simple words) is that the body remains in a state of rest, and moves when impressed forces act on the body.

(i) Aristotle stated that the body remains at rest i.e. rest is the natural state of the body. The body only moves when external force acts on the body.

(ii) The first part of Newton's law (in simple words) is that the body remains in a state of rest. The body moves when impressed forces act on the body.

(iii) Thus, Newton re-quoted Aristotle's published work (taught for about 2000 years), as the first part of the First Law of Motion. So, Newton repeated what Aristotle published in about 350 BC. So, Aristotle is the originator of the First part of the law; Newton is its prospective PROPGATOR.

3.0 Who gave the second part of Newton's First Law of Motion?

The second part of Newton's law (in simple words) is that the body continues to move with uniform motion (velocity), and this state of uniform velocity is only changed when external force acts on the body and changes its state.

Galileo (1613) i.e. 73 years before published the second part of Newton's First Law of Motion.

(i) In 1613, Galileo published in **Letters On Sunspots** that the body has an inherent tendency to move with uniform velocity without external force, in the absence of resistive force.

(ii) In the second part of Newton's Second Law of Motion; the body continues to move with uniform velocity. It same as Galileo started about 73 years ago.

(iii) Further, Galileo published (quoting the example of the ship) in 1613 that uniform motion is only hindered when external forces (external impediments) do not act on it).

(iv) The second part of Newton's First Law of motion, was the same as stated by Galileo earlier.

4.0 Do you mean to say Newton is not the originator of the First Law of Motion?

(i) Yes, there is no doubt about it. If a scientist copies or re-quotes the work of others in his book but does not acknowledge the names of originators; then he cannot be called an originator.
The first and second parts of Newton's First Law of Motion existed in the literature, for about 2000 years and 73 years before Newton's Principia.
So, Aristotle and Galileo are the originators of Newton's first law of motion; Newton is the only EDITOR and PROPAGATOR of the doctrines of Aristotle and Galileo. Newton should have acknowledged Aristotle and Galileo.

So, the names of Aristotle and Galileo should be associated as predecessors of Newton's First Law of Motion. It would be both moral and scientific to associate originators with the law.

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