Newton (1686) is the EDITOR and PROPGATOR of the First Law of Motion. Aristotle (350 BC) and Galileo (1613) are the innovators. The original innovators should also be given credit.

The contents of Newton's First Law of Motion (1686) existed earlier in scientific literature. The first part of the First Law of Motion was given by Aristotle (350 BC) and the second part by Galileo (1613). Newton gave a precise statement of the First Law of Motion combining two. But Newton never mentioned the names and contributions of Aristotle and Galileo. So Newton is simply the Editor and propagator of the ideas of Aristotle and Galileo in his First Law of Motion:

Basis of discussion. The paper has been presented and published at International conferences. Paper in press in Scopus Indexed journal.
The discussion is also on www.Newton99.com and the book Newton's Laws of Motion in 21st Century.

Q.1 First of all let us know if you have any different ideas than the prevalent theories, about the study of the motion of bodies.

Ajay Sharma: Yes, in the 21st century the motion of bodies needs to be studied in slightly different ways than the existing methodology. I mean to say that the motion of bodies be studied separately for terrestrial systems or realistic systems and ideal systems specifically. The mathematical equations must be purposely used. Further scientific meaning between motion and velocity needs to be clearly distinguished.

(i) **Terrestrial or realistic or practical systems:** In such systems the resistive forces (frictional, gravitational, atmospheric forces, etc.) are present. These are the systems we encounter in daily life. Aristotle's assertion is meant for such systems.

(ii) **Ideal Systems:** In these systems in which the resistive forces as mentioned above are completely absent. In actual practice, these are imaginary systems as these are non-existent on the earth.

Galileo described the motion of bodies mainly in the ideal systems in 1613. Newton's First Law of Motion is another form of Galileo's perceptions in a definite and precise form, so it is also primarily meant for the ideal systems.

Q2 What is the theme of this discussion? Do you mean Newton's First Law of Motion is not his original work?

Ajay Sharma: Yes, Newton is not an innovator of the First Law of Motion. The contents of the First Law of Motion existed in literature before Newton. Newton is the editor or propagator of the First Law of Motion, as concepts were earlier given by Aristotle (350BC) and Galileo (1613). Newton precisely and elegantly edited the above existing contributions without acknowledging Aristotle and Galileo in *the Principia.*

(i) The first part of Newton's First Law of Motion is about the state of rest, it was given by Aristotle (350 BC) i.e. 2036 years before Newton's Principia. Galileo after careful observations and deep ponderings also arrived at the same conclusions in 1613, hence vindicated the same.

(ii) The second part of Newton's First Law of Motion is about the state of uniform motion which was originated by Galileo in 1612 i.e. 74 years before Newton's Principia.

Newton picked up the existing works from literature but did not mention that these works had been earlier published by Aristotle and Galileo.

Q3. What is Aristotle's assertion about the motion of bodies given in 350 BC?

Ajay Sharma. Aristotle (350BC) stated that - *"A continual external force is required to set and keep a body in motion".*

So, Aristotle's assertion (AA) has two parts.

(i) The first part is that the state of rest is the natural state of the body.

(ii) The second part is that the body only moves due to the application of external force.

This perception is supported by some physical examples e.g. a gunny bag remains lying on the ground or road or at any other place from morning to evening. It does not move by itself. It only moves if somebody pushes or pulls it. It was taught for about 2000 years as supported by some physical examples. But it is now abandoned as it is not found correct in some observations.

Q.4 Is Aristotle's assertion meant for realistic systems or ideal systems? Can it be understood with a mathematical equation?

Ajay Sharma: It is useful for terrestrial or realistic systems when resistive forces or dissipative forces (frictional force, atmospheric force, gravitational force, etc.) are present. The reason is that the body remains in its natural state (the state of rest), and moves when an external force is applied to overcome resistive forces.

The externally applied force overcomes the resistive forces. Thus body moves due to the effect of the resultant force or impressed force; which is the difference between externally applied forces, and resistive forces.

Resultant Force or Impressed force (net force)

= External force – Resistive force (1)

Both Galileo and Newton realized the importance of resistive forces but did not explain the same in the form of an equation due to conceptual limitations in the very early or early days of Physics.

(i) If an external force is applied in an adequate amount, then the resultant force (which causes motion) is more than resistive forces. In this case, the body moves.

(ii) If the external force is applied on the body and the body moves in the realistic system, but after it force is discontinued e.g. a stone is thrown in the air. Then, the magnitude of resistive forces continuously increases with time; thus the resultant force becomes zero, and hence body stops.

(iii) If in a special or imaginative case, Resistive force = 0 but the body is pushed externally, then Eq.(1) becomes

Resultant Force (impressed force) = External force (2)

So the external force is not dissipated, hence the resultant force (cause of motion) remains the same as the externally applied force. In the absence of resistive forces body moves with uniform velocity in a straight line. This situation was first imagined by Galileo in 1613, and then Newton repeated or applied the same in the second part of Newton's First Law of Motion. The further body also remains at rest in an ideal system, but it can be pushed with an exceptionally small force.

Part II. Galileo's general contemplations about the motion of bodies.

Q.5. Name the documents where Galileo elaborated on both the state of rest and the state of motion of bodies.

Ajay Sharma: Galileo wrote *Letters On Sunspots* (LOS) written to Illustrious Mark Welser, the Duumvir of Augsburg in 1612, published in Italian by the Accademia dei Lincei in 1613. It contains exceptionally useful statements and explanations about the state of rest and state of motion of bodies. These are based on Galileo's decades-long contemplations or ponderings and observations.

Galileo's monograph was translated into English by Stillman Drake in the book *Discoveries and Opinions of Galileo* published in 1957. Galileo's two prominent statements

from the **Letters On Sunspots** may be re-quoted as

Statement 1:

"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,"

Simple meaning: If the body is placed at rest, it remains at rest**.** If the body is pushed, then it moves in a straight line with the same velocity or uniform velocity. The second part is only true for the ideal system.

Statement 2:

"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."

Simple meaning: The body has an inherent tendency to some motion (uniform velocity), even if it is not pushed by an external force, and no resistive forces obstruct the body. This is true in an ideal system.

Newton picked up these inferences (or maybe extrapolations) from the existing literature to form the second part of the First Law of Motion in very precise and elegant language or wordings.

In the book **Dialogue Concerning Two New Sciences (1638)** at page p.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 that is uniform and perpetual, provided the plane has no limits.

Simple meaning: If the body is set in motion in an ideal system (free from resistive force), then the body moves forever in a straight line.

Q.6 How terminology in Galileo's time (1564-1642) was different from that in the current or present time?

Ajay Sharma. Galileo described his perceptions when physics was not a subject but a part of Natural Philosophy.

(i) In Galileo's time, there were no separate subjects such as mathematics, physics, astronomy, chemistry, philosophy, etc. All subjects were taught under a single heading called Natural Philosophy. Newton originated Physics separating it from Natural Philosophy when he

wrote the Principia in 1686 i.e. 44 years after Galileo's death. In *the Principia,* Newton defined 8 terms and gave three laws of motion, the law of gravitation, etc.

(ii) The velocity was mathematically defined by J Jennings in 1721 in the book Miscellanea as

Velocity = Distance traveled / time taken (5)

(iii) In Galileo's time friction was a general term, the laws of friction were defined 57 years after the death of Galileo by Amontons in 1699. Thus, in Galileo's time scientific terminology and phraseology were bare minimum.

Part III. About the State of Rest

Q.7 How did Galileo vindicate or arrive at conclusions about Aristotle's assertion after 1963 years?

Ajay Sharma: As Aristotle's assertion has two parts and Galileo vindicated both parts.

(i) In the *Letters on Sunspots* on page 113 in Statement I Galileo stated that the body conserves a state of rest i.e. body remains in the natural state of rest. It is the first part of Aristotle's assertion.

(ii) Further in Statement I, Galileo stated that the body has to be pushed with force to set it in some motion (if placed in some movement). Thus the body changes its state when an external force is applied, it is nothing but the second part of Aristotle's assertion. So both parts of Aristotle's assertion are authenticated by Galileo in 1613 i.e. about 1963 years after given by Aristotle.

Q8. How did Newton repeat Aristotle's assertion in the first part of the First Law of Motion?

Ajay Sharma: The first part of First Law of Motion (1686) states-

"*Everybody perseveres in its state of rest unless it is compelled to change that state by forces impressed thereon"***.**

In simple words this part means body remains in state of rest, the body moves when external force acts on it. It may be understood in two parts.

(i) The body remains in the state of rest, it implies that the state of rest is the natural state of the body. It is the first part of Aristotle's assertion.

(ii) The body moves from the state of rest when impressed forces (resultant force, the bet effect of external force, and resistive force) act on the body.

So this part of the first law of motion is nothing Aristotle's assertion given about 350 BC. Then Newton in 1686 picked it up from existing literature and re-quoted the same (as the first part of Newton's First Law of Motion).

Newton used Aristotle's assertion in more precise and compact scientific phraseology. But

Newton never mentioned that the basis of the first part of Principia's First Law of Motion existed earlier and was given by Aristotle (350 BC) i.e. 2063 years ago.

Part IV. About the State of Motion.

Q.9 Now explain what are Galileo's doctrines on the state of uniform motion of bodies. How did Galileo envision the state of uniform motion of the body?

Ajay Sharma: Galileo pondered over the observations for decades to arrive the conclusions about the motion of bodies.

(i) Perception of intrinsic horizontal motion: Practically Galileo drew an analogy between naturally falling bodies, revolving planets, and the horizontal motion of bodies, in the very early days of physics. Galileo concluded that bodies naturally fall without any apparent external force. The planets also revolve around the Sun without any apparent external force.

It must be noted that in Galileo's time, the law of gravitation was not discovered. The law of gravitation was discovered by Newton *in the Principia* in 1686 i.e. 44 years after the death of Galileo. So Galileo inferred the same i.e. state of similar motion is true for horizontal motion as well. Thus he concluded that bodies too have an intrinsic tendency of body to move in a horizontal motion without any external force, like the vertical motion of bodies and the motion of planets. But also added that bodies stop due to 'some obstacle' or resistive forces in the horizontal motion.

(ii) Galileo's perception is meant for an ideal system. If the body is placed at rest in an ideal system, it remains at rest (natural state). But the body may move with an exceptionally small force in ideal system. When the body is set in motion in an ideal system then (Resistive force = 0), then Eq.(1) becomes

Resultant force = External Force (2)

If it is just pushed with exceptionally small or suitable external force then the body maintains uniform velocity u or U (i.e. 1m/s or 10m/s or different). In an ideal system, as the external force is not dissipated, and the body moves with uniform velocity in a straight line, as it is unable to change the magnitude and direction of movement (due to the absence of resistive forces). Thus body moves with uniform velocity in an ideal system only.

Q.10. Now, let us come to the real point. What is the second part of Newton's First Law of Motion? How did Newton repeat or re-quote it from the existing literature i.e. work of Galileo (1613)?

Ajay Sharma: The second part of Newton's First Law of Motion is

Everybody perseveres in its state of uniform motion in a right line, unless it is compelled to

change that state by forces impressed thereon.

In simple words this part means everybody continues in a state of uniform motion, this state is only changed when external forces act on the body.

The second part of Newton's law may be understood in two parts.

(i) Everybody remains in a *state of uniform motion* in a straight line i.e. everybody keeps on moving in a straight line with constant velocity if once pushed. It is evident from Q5 i.e. Galileo's from Statement 1, Statement 2, etc.

(ii) The state of uniform motion is changed by *impressed forces thereon*.

The impressed forces mean resultant forces i.e. net effect of external force and resistive forces or Galileo has used the word 'Some Obstacle'. Galileo has stated that uniform motion is changed when the body is impeded by 'Some Obstacle'.

So the second part of Newton's first law of motion was visualized by Galileo as early as 73 years before. But Newton did not mention the name of Galileo at all, who elaborated the second part of the law earlier.

Q.11 Thus, you mean to say that Newton has re-quoted, re-stated, or edited the First Law of Motion from the existing works of Aristotle and Galileo. Did Newton acknowledge the names of Aristotle and Galileo in the Principia?

Ajay Sharma: Yes. Newton is the editor and preacher of Aristotle's and Galileo's observations and perceptions. Newton elaborated textual versions of Galileo's perceptions in 1686, in a precise and graceful statement about the First Law of Motion. In brief, Newton is the Editor and propagator of the doctrines of Aristotle and Galileo. Newton combined the laws of Aristotle (350 BC) and Galileo (1612) in a single precise statement known as the First Law of Motion in the Principia (1686).

Newton did not acknowledge the works of Aristotle and Galileo, however, Newton acknowledged the works of many other scientists including even names of books (e.g. Huygens's book *Horologium Oscillatorium*).

Interestingly in the first edition of *the Principia* Newton gave some references mentioning Robert Hooke regarding the inverse square law of gravitation. Robert Hooke died in 1703, and in the second edition of the Principia was published in 1713, Newton removed all references to Robert Hooke; as Hooke was claiming that he had also contributed to the discovery of the law of gravitation published in the Principia by Newton. Newton may have not mentioned the names of Aristotle and Galileo regarding the First Law of Motion in the past for any reason, but errors may be corrected at any time by giving due credit to genuine innovators

Aristotle and Galileo, as it would be both moral and scientific.

Q12 How did Descartes' book Principles of Philosophy (1644) influence Newton's Laws of Motion in the Principia (1686) ?

Ajay Sharma: Descartes wrote the book Principles of Philosophy in 1644. In the book, Descartes has given **'Three Laws of Nature'** which are different from Newton's Law of Motion. Scientists widely believe that Newton might have given **Three Laws of Motion** in 1686 as Descartes has given **Three Laws of Nature** in 1644.

The comments are requested from readers, so that this discussion and research papers may be further improved.

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Forthcoming book : Newton's Laws of Motion in the 21st Century