Historical Introduction of vis-viva or the 'living forces'

M.Sc Florian Millo[1]
Dr. Muhammad Akram[2]
Dr. Ejaz Rafique[3]

[1]Universite Paris-Saclay, Department of Physics, France
[2]Government College University Faisalabad, Department of Eastern Medicine, Pakistan
[3]University of Lahore, Department of Microbiology, Pakistan

$$\sum_i (F_i - \dot{p}).\, \delta r_i = 0$$

Abstract: The roots of the problem of vis-viva or the living forces are potentially from the ancient Greek philosophy, more specifically Aristotle. He wanted to know, **What is motion?, Why things move?**, **Is movement 'real' or 'not-real'?**. Answer to this question never came until 16th century. Philosophers and scientists such as Galileo, Descartes, Huygens, Leibniz, D'Alambert found an approach to this problem that seems rigorously to our observations. Even though, we do not know if that was the intention of Aristotle?

Key words: vis-viva, Living Forces, Aristotle.

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Corresponding Author: Dr. Muhammad Akram. Department of Eastern Medicine. Government College University Faisalabad.
Mail: makram_0451@hotmail.com

1 Early Concept

We will start by a definition of Aristotle's book **Physics**. What is Change? - Things exist either only actually, or both potentially and actually; and things are either 'such-and-such a particular object' or 'of such and such a quantity' or 'of such-and-such a quality', and so on for all the other categories of being. Things are described as 'relative' either because of excess and deficiency, or because of their ability to act and be acted on, or in general because of their ability to cause change and be changed. These are relative in the sense that anything which can cause change must cause something to change and it must be something that can be changed.

Similarly, what can be change must be changed by something and it must be something that has the ability to cause change.

Here is the starting point of the whole problem of the living forces, and we will explain shortly. On this definition there are still two other things that must be explained, actuality and potentially. Aristotle uses respectively this as **energeia** and as **entelechia**. Energeia for being at-work and entelechia for being-at-end, and for being-at-work represents actuality and being-at-end represents potentially. What we think of this, is, motion as change of places. Point of start and point of end, which is by kinematics correct, but is by dynamics correct?

This change happens on what space? On what time?

To define motion, one must know the mass of the 'being' or 'object'. At that time, it was a very difficult concept to implement mass, change and time together. We will leave the concept of time out of this presentation.

Aristotle was puzzled on this problem because of the metaphysics of motion itself. Place, existential being, do they exist?

What is behind these things? **How** many principles are in Nature?, Does change oppose rest, and does rest oppose change?, and so forth.

2 Mechanics

In the end of 16th and beginning of 17th century began a very profound method or science called Mechanics. Started by kinematics of Galileo, to go further to Newton's Laws and then by analytic mechanics of D'Alambert and Lagrange.

Therefore the 18th century noticed innovative laws, such as the projected and controversial theory of minimal action. This was also discussed in times of Pierre de Fermat and Maupertuis but in a different context.

The vis-viva controversy began as a conflict between the philosopher Gottfried Wilhelm Leibniz (1646-1616) and Descartes' followers (1596-1650). It persisted in the eighteenth century; turn out to be the focus of numerous contests. In 1788, Joseph Lagrange (1736-1813) opened a new chapter of his Mecanique Analytique by raising again the vis-viva question.

At that period, the debate was usually interpreted as a disagreement about Descartes presentation $\sum_i m_i \vec{v}_i$ (or momentum) versus $\sum_i m_i {v^2}_i$ (or kinetic energy) by Leibniz as the 'living forces' of the system.

Newtonian mass had not become a part of the argument. To neglect this is to lose sight of Newton's conception of dynamics. In first place, Newton pioneered mass (Latin massa) as short for "quantity of matter" within the Principia. Ab initio, he spoke of "heaviness"

(Latin pondus). He stressed in implementing mass that "very right pendulum studies" had shown it to be approximately equal to weight.

Prior to Newton the consistency word was "bulk" (Latin moles). During his first written response to the movement of colliding spheres, in his Arithmetic Universalis, published in 1707 in Latin, he used the older word. "Bulk" re-acted the widely reading, which is verified by scholars at that time and also by the Cartesians, that weight and gravity involve etheric matter putting pressure on dense objects, only in such a manner that weight is approximately equal to dense material. In $\sum_i m_i\vec{v}_i$ and $\sum_i m_i{v^2}_i$ the opposite anachronism is that symbols are used in the slightest way. Until, calculus took throughout the 18th century, quantities were not really represented by algorithmic signs but by geometric constructions such as shapes and lines, and relations between quantities also were not demonstrated as calculations but as quantities. These two quantities initially transformed into the vis-viva argument, were "motion" and energy, the implementation of mass and velocity or rate, momenta, and the implementation of mass and velocity square, after philosopher, vis-viva. Leibniz, Newton and D'Alambert kept this problem only in physics and on observation rather than passing on metaphysics as Aristotle.

3 Galileo's Discorsi

The idea that perhaps the **square of velocity** is significant, gleans from three observations that are essential to Galileo Galilei's writings (1564-1642) in his Dialogue on Two New Sciences, published in 1638, on "nearby movements".

1 Without opposing media, upright fall is a constant fasten motion, and subsequently the square of the velocity gained through drop is relative to the stature of drop.

2 Without opposing media, the velocity gained through fall from starting point is exactly adequate to increase an object back to its unique point, however no advanced.

3 The velocity obtained in a drop in inclined plane from a given point is similar as paying little heed to the tendency of the plane.

These three observations, which we will call Galileo's rule of free fall, contributes vitally to the idea of vis-viva by giving the square of the velocity a simplification that it would somehow

be needed. After death, the release of the Discorsi offered a strong base, dependent on the size of the vertically suspended weight needed to hold an object in balance on an inclined plane. Galileo's protege Evangelista Torricelli (1608-47) offered a reduction promotion absurdum deduction of it in 1644 from a rule that came to manage his name: Two objects combined cannot start to move without anyone else except if their basic focal point of gravity descends.

Thirty years after the fact, Christian Huygens (1629-95) focused on the significance of path, the privilege it has, in his Horologium oscillatorium, offering a reduction derivation for curved paths.

4 Descartes' Argument

From the beginning, the Cartesian rule against which Leibniz sought to maintain vis-viva seems insane to us. It states that the complete amount of movement-that is, the absolute amount of mass occasions velocity-consistently continues as before. Velocity at that time was said to be independent of path, still not the idea of vector. The appropriate response lies in Descartes' from the earlier demand that a vacuum is inconceivable. All space is along these lines filled up with objects, and the movement of any piece of object requires that the object in front of it be pushed forward. In this way, Descartes asserts, "A complete chain of bodies' moves at the same time in every creation. The situation emerged along with Descartes' awareness of the element which changes the movement of ratios during the nearby-body. Together his first two laws of nature stated that movement, if not hindered, proceeds in an orderly path. He was indeed the first to suggest that the curvilinear movement of planets, expect from straight paths something to occupy them. In all things considered, he has more grounded claims than any other person to whatever exactly happened to be recognized as the rule of absence. Descartes' third principle of nature apprehensions nearby changes of movement: When a body comes up against another, in the event that it has less power to keep on moving in an orderly fashion than different needs to oppose it, it is turned aside toward another path, holding its amount of movement and altering just the direction of that movement. Assuming, be that as it may, it has more power, it transfers to the other body power, and misplaces as a lot of its movement as it provides for the other.

The idea of power in this way enters through changes of path directed by a sum of powers: the power to oppose transformation of movement and the power to deliver it.

The last mentioned, Descartes' attested, relies upon the dimension of the area and its velocity. In the 1644 Latin release of Descartes' law, he finished his conversation of exchange of movement by commenting that what occurs in singular circumstances can be controlled by figuring "how much power to transfer or to oppose process, there is in all body, and to acknowledge as a conviction that the one which is more grounded will consistently deliver its impact."

5 Huygens Perception

Huygens established precise instructions for the direct effect of heavinly spheres during the 1650s, though in his twenties. He appointed no longer to finalize them on time, but throughout an official visit to London in 1661, he mentioned them to many who had then taken steps towards the establishment of the Royal Society. At the end of 1668, Wallis presented the issue of an inelastic collision, and Wren took flawless of elastic collision into consideration.

At that point, **R.S.S H**enry Oldenburg asked from Huygens a document on the subject, which appeared in early 1669. It was given the same importance as Wrens'. The Wren and Wallis documents were already placed within side of 11 January 1669 journal of Royal Society of Philosophical Transactions, and not including Huygens. **O**ldenburg was obliged to ask **H**uygens' paper to go beyond their claims.

In the 1650s, he formed advanced telescopes, allowing him to find out Titan, the most important satellite of Saturn. **H**uygens also set up the cycloidal pendulum isochronism, constructed cycloidal pendulum clocks with significant advantage for telescopes, and utilized pendulums.

When **H**uygens' manuscript in Philosophical Transactions became no longer studied, he posted a model within Journal des Scavans' of 8 March 1669. Recognizing the idea, Oldenburg quickly posted a **L**atin translation in Philosophical Transactions 11, collaboratively with a proof of what had happened. This document pointed out the problems of heavinly spheres effects. It ends with this solution having four results:

1 The amount of movement that hardens our bodies can be elevated or dwindled through their collide, however while the amount of movement within side the opposite path has been deducted, there stays constantly the equal amount of movement within side of right path.
2 The sum of the goods acquired through multiplying the value of every frame through the rectangular of its pace is constantly equal, before and after collision.
3 A frame at rest will acquire greater movement from some other, higher or lesser frame, if the third intermediate object is interposed as if it were directly struck, and the sum of both if the mathematical mean is three.
4 In the center of gravity of three objects, moving through a straight line, we find constant action, before collision, and after, there will be chaos.

6 The trouble

Leibniz and Newton triggered a vis-viva debate, starting in 1686. Newton started using the force which pushes object and to find out how it relates to motion. Is force a cause or effect?. He published in the new journal Acta **E**ruditorum, in 1684, his pioneering paper on calculus; Leibniz printed a brief letter in the journal titled "A brief demonstration of a notable error of **D**escartes and Others concerning a Natural Law, according to which God is said always to conserve the same quantity of motion; a law which they also misune in Mechanics".
The writings was to refuse the Cartesian view among the living forces, that Leibniz allowed, is preserved in nature and the amount of motion that he disagreed is not.
His disagreement was based on two hypothesis:

1 An object dropping from a specific height receives the similar force essential to push it into its current height;

2 It takes the same power to raise four pounds one foot as it does to raise one pound four feet.

Leibniz inferred from that remark, "energy is quite to be calculated from the number of impact it can create". **L**eibniz's note from 1686 did not reveal vis-viva, nor did it cite the observations of **H**uygens' effect.

7 The solution

These all are shown to the subject as a background because of importance to vis-viva. D'Alambert in 18th century thus presents his principles, by stating that, the total virtual work of the impressed forces plus the inertial forces vanishes for reversible displacements.
In special case, with constant mass, we will get the Newton's 2nd Law. Here work is introduced for simplifying the problem, with time, because power is work over time. This is not only a problem of mechanics, but also in thermodynamics and caloric theory, for which Antoine **L**avoisier and **L**aplace tried to implement the vis-viva and caloric theory. This mechanical motion turned into heat was used by **T**homas **Y**oung. Now vis-viva or the 'living forces' is the kinetic energy: $E = \frac{1}{2}\sum_i m_i v^2{}_i$. It was also a large work of **C**oriolis and Poncelet to prove this energy theoretically.

8 Conclusions

We tried to focus more on the description of vis-viva and its history, in classical branches of physics rather to the solution provided. These developments are due to a large number of scientists and we tried to cover mostly the important ones. The vis-viva debate is still going on, for metaphysicists, philosophers of science, historians, etc. The kinetic energy, 'living forces' or vis-viva, now represents a part of the mechanical energy conservation, and as Aristotle thought of *energeia* being-at-work was a right assumption for actuallity. *Entelechia*, being-at-end will represent to us a metaphysic problem of place and space, since the end that can exist or say infinity may only be potentially. In physics, we always try to remove the problem of infinity with our boundaries, and trying to keep in an ideal form of the situation. Vis-viva can be found also in new physics of 20th century, it is implemented in action, thus having **P**lanc's constant in **Q**uantum Mechanics and further, and thus having action of **E**instein - **H**ilbert of a point particle due to relativity implications. These two physics do not converge to one.

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