THE IMPETUS THEORY OF THE VAIŚEṢIKAS*

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(*Received-December 13, 1965*)

In Europe, the Impetus Theory of Motion was developed in the fourteenth century, although ideas resembling such a theory appeared in the writings of John Philoponus (sixth century A.D.) and, further back, in those of Hipparchus. In India, the basic principles of the theory appeared during the formulation of the Vaiśeṣika aphorisms (third century B.C.), and a fully developed Impetus Theory is recognized in Praśastapāda's *Bhāṣya* (fifth century A.D.). The paper briefly discusses how the inadequacy of the Aristotelian dynamical principle led to the Impetus Theory in Europe. The Vaiśeṣika concept of motion, as developed by Praśastapāda, is then discussed with special reference to the various forces causing motion, e.g. *abhighāta, nodana, gurutva, dravatva* and *saṃskāra.* The term *saṃskāra* (impetus) of which the Vaiśeṣikas recognize three types, e.g. *vega, bhāvanā* and *sthiti-sthāpaka,* is the cause of uninterrupted continuity of motion in a fixed direction even when the initial force ceases to act, and thus holds the key to the Vaiśeṣika Impetus Theory. It is shown that this *saṃskāra* or *vega* is the nearest approach to our modern conception of momentum. The interplay of various kinds of forces and the part played by *saṃskāra* in maintaining the motion of bodies when all forces cease to act are explained by three illustrations, e.g. the motion of the pestle and the mortar, the motion of a javelin discharged by the hand and the motion of a body catapulted from a machine.

The Hindu ideas and theories on motion are of special significance because of the very difficulty of the subject of motion itself throughout antiquity and of the paucity of its treatment, in any great detail, except by only one philosophical school, namely, the Vaiśeṣikas. The importance the Vaiśeṣika realists attached to the subject is readily recognizable in their early appreciation of motion (*karma*) as one of the six categories, coming third in order. Even there, the very creditable efforts of the early Vaiśeṣikas in understanding and explaining the nature of motion were not followed up by the later exponents of the school. After the subject received its highest water-mark in the hands of Praśastapāda (+fifth century), the subject witnessed not only no further development but hardly found able commentators, with the exception of Śrīdhara, Vyomaśivācārya and a few others, to explain adequately what Praśastapāda had written on it.

The Impetus Theory of Motion of the Vaiśeṣikas, which is proposed to

*A brief summary of this paper dealing with the interpretation of *Saṃskāra* was presented at the 11th International Congress of the History of Science held in August 1965 at Warsaw and Cracow, Poland.

be dealt with in this paper, merits serious attention in view of the importance attached to it in the history of mechanics prior to Galileo's work. In Europe, the Impetus Theory was developed in the fourteenth century by William of Ockham, Jean Buridan, Albert of Saxony, Nicholus of Oresme, Nicholus of Cusa and others in the wake of a progressive reaction against Aristotelian scholasticism. Ideas resembling an impetus theory have, however, been noticed in the writings of John Philoponus (+sixth century) and further traced to Hipparchus on the basis of certain passages preserved in the writings of the Aristotelian commentator Simplicius (+sixth century).[1]

In the twelfth and the thirteenth century some Arab scholars and philosophers are also known to have attempted to explain acceleration due to gravity by arguments akin to an impetus theory.[2] Whatever the sources of inspiration, Greek or Arabic, the Impetus Theory in its fully recognized form and in its attempt to offer an explanation more satisfying than the Aristotelian of the motion of a projectile or of a falling body appeared in Europe in the fourteenth century. In India, the same theory in a different language is recognized in Praśastapāda's *Bhāṣya*, also known as *Padārthadharma-Saṃgraha* (+fifth century).[3] The basic principles of the theory, however, appear much earlier in the Vaiśeṣika aphorisms and, if we bear in mind the history of development of the Vaiśeṣika system, the origin of the Impetus Theory in India, according to a conservative estimate, may be traced to a period not later than the third century B.C.[4]

In Europe, the development of the Impetus Theory was necessitated by the failure of Aristotle's law of dynamics to account for the motion of a projectile. Aristotle granted a 'natural' motion to a heavy or a light body towards or away from the centre of the earth in a vertically downward or upward direction. Motion in any other direction was regarded 'non-natural' and required the application of a continuous force. Such motion or velocity was thought to be proportional to the force, leading to the conclusion that bodies not acted upon by forces are at rest and, therefore, can be maintained in a state of motion only as long as forces act upon them. The principle is summed up in one of his fundamental dynamical principles: *Omne quod movetur ab alio movetur* (Moving bodies are moved by something else). For a given force, velocity again depended upon the nature of, or the resistance offered by, the medium, a body moving faster in a less tenuous medium like air than in water. An important consequence of this view is that in vacuum a body acted upon by any force will move with infinite velocity, a conclusion which was negatived by the assumption in the Peripatetic school of the impossibility of vacuum.

The above-mentioned theory clearly breaks down in the case of a projectile where a body continues to move even after the moving force *motor conjunctus* has ceased to act. Aristotle was aware of the weakness of his theory and proposed an ingenious solution to save the entire fabric of his conception of motion, which may be summarized as follows. In the case of the projectile the medium plays a crucial role. The original projector still in contact with the projectile sets in motion the adjacent layer of the medium during the process of its pushing the projectile. Moreover, the projector transfers to the medium a *virtus movens,* that is, a power to act as a mover itself. The layer of the medium thus endowed with the power of a mover moves the projectile and as before transfers to the next layer of the medium a *virtus movens.* With each such transfer of power, the power of projecting is progressively weakened till the projectile is overcome by its natural and vertically downward motion towards the centre of the earth. The relevant passage from his *Physica* is as follows:

> 'We are forced, therefore, to suppose that the original mover conveys to air . . . the power of being a mover, but that the air does not cease simultaneously to be a mover and a moved ; it ceases to be moved at the moment when its mover ceases to impart motion to it, but it continues to be a mover and so moves whatever is adjacent to it, and of this again the same thing is true.'[5]

Aristotle further elaborated the matter by the motion of *antiperistatis,* by which air in front of the moving projectile may be thought of being continuously pushed to the rear and from there of exerting forward pressure to the projectile.

The supposition that an inanimate object, namely air, water, etc., is able under special circumstances to assume simultaneously the function of the mover and the moved contradicts the basic principle that in non-natural motion the mover and the moved are two different and distinct things. The hollowness of the whole explanation is shown by the simple question, as asked by Philoponus, whether a body can be set in motion by pushing the surrounding air, that is, the medium, instead of the body itself. Apart from exposing the inherent weakness of the theory, Philoponus' merit consisted in suggesting that the problem can be simplified by assuming that the *motor conjunctus* directly imparts to the projectile a moving or kinetic power in which the medium has no contribution to make.

> 'It must rather be that some incorporeal kinetic power is imparted by the thrower to the object thrown and that the pushed air contributes either nothing or very little to this motion.'[6]

The basic argument of Philoponus, in denying the surrounding medium any role in the motion of the projectile and in regarding the original mover to have imparted something to the projectile at the time of separation which enabled the latter to continue to move, was developed into an impetus theory in the works of Oresme, Buridan and others. The theory of impetus, called *vis impressa* by Galileo, was applied not only to explain the motion of a projectile, but also to account for the motions of a falling body, of planets in circular orbits, and undoubtedly stimulated Galileo's work which eventually proved so rewarding to the subsequent growth of mechanics. The exact nature of the impetus, it should, however, be borne in mind, that is, whether it meant quantity of motion or momentum or kinetic energy or something else, remains vague and disputable and is yet to be clarified.[7]

The Vaiśeṣika concept of motion, or, more correctly, the developed version due to Praśastapāda, does not suffer from any anthropomorphic or zoomorphic approach such as characterizes the Aristotelian. Within the limitations of its own epistomological framework the concept is clear, rational and direct. Praśastapāda defines motion by enumerating a number of its characteristic properties. These are:

(i) Peculiarity of a single motion affecting a single body (at a time)—एकद्रव्यवत्वम्

(ii) Instantaneity—क्षणिकत्वम्

(iii) Property of appertaining to corporeal bodies only—मूर्तद्रव्यवृत्तित्वम्

(iv) Lack of qualities—अगुणवत्वम्

(v) Ability to be generated by gravity, fluidity, volitional effort and conjunction—गुरुत्वद्रवत्वप्रयत्नसंयोगजत्वम्

(vi) Ability to be opposed by conjunctions caused by themselves—स्वकार्यसंयोगविरोधित्वम्

(vii) Ability to act as independent cause of conjunctions and disjunctions—संयोगविभागनिरपेक्षकारणम्

(viii) Ability to act as non-inherent cause—असमवायिकारणत्वम्

(ix) Ability to initiate effects (by conjunctions and disjunctions) in their own as well as in other substrates—स्वपराश्रयसमवेतकार्यारम्भकत्वम्

(x) Inability to initiate its own kind—समानजातीयानारम्भकत्वम्

(xi) Inability to generate substances—द्रव्यानारम्भकत्वम्

(xii) Classifiability into distinct types characterized by the directions of initial motions—प्रतिनियतजातियोगित्वम् दिग्विशिष्टकार्यारम्भकत्वम्

A simple definition of motion is given in (*vii*). As an independent cause of conjunction and disjunction in the spatial environment, motion means change of position. This is taken care of in the *Vaiśeṣika Sūtra* 1, 1, 17—संयोगविभागेष्वनपेक्षकारणम्. That motion is not a mere displacement (संयोगविभाग) but is endowed with specific directional properties (दिग्विशिष्टकार्यारम्भकत्वम्), or, in other words, a vector quantity, is indicated in (*xii*). (*i*) states the well-known principle, elaborately commented upon, that a single motion can exist at a time in one substance. This has been more forcefully expressed by Śrīdhara as एकदा एकस्मिन द्रव्ये एकमेव कर्म वर्तते.[8] The principle of the impossibility of perpetual motion is contained in (*x*) which is borrowed from the

Vaiśeṣika Sūtra कर्म कर्मसाध्यं न विद्यते (1, 1, 11). 'That motion is produced by (another) motion is not known.'

As causes of motion, gravity, fluidity, volitional effort and conjunction are here mentioned (*v*). But these by no means exhaust the list. The impact (अभिघात) and impelling push (नोदन), as special forms of conjunction, are of course included in conjunction. Two other important causes of motion not included in the opening definition, but discussed and mentioned several times elsewhere, are *Saṃskāra* and *adṛṣṭa* (unforeseen causes). A fuller enumeration of the various causes of motion is given as follows—गुरुत्वद्रवत्ववेगधर्माधर्मसंयोगविशेषाः क्रियाहेतवः।[9] Vega, as we shall see, is a form of *Saṃskāra* and *dharmādharma* is the other name for *adṛṣṭa*. It is this term *Saṃskāra* or *vega* which holds the key to the Vaiśeṣika Impetus Theory of motion. The term *Saṃskāra* has been variously rendered into English as 'Faculty', 'Resultant Energy', 'Persistent tendency', etc., and the term *Vega* as 'speed' and 'momentum'.

Gravity is the cause of the falling motion of bodies and rests with water and earth—गुरुत्वं जलभूम्योः पतनकर्मकारणम्. It is imperceptible by the senses and can be inferred only from the act of falling. Gravity is countered by conjunction, volitional effort and impetus—संयोगप्रयत्नसंस्कारविरोधि. Thus a body can be prevented from falling in three circumstances, e.g. (i) when it is in contact with something else and is unable to separate from it; (ii) when it is held by volition and (iii) when it possesses impetus. As illustration of impetus counteracting gravity, Śrīdhara[10] cites the example of a flying arrow and Vyomaśivācārya the case of a flying vulture in the sky—आकाशावस्थितेषु शकुनिषु गुरुत्वं न पतनं करोति संस्कारप्रतिबन्धात्.[11] It is to be noted that unlike Aristotle, the Vaiśeṣikas did not have to resort to an anthropomorphic approach, endow heavy bodies with a natural inclination to proceed to the earth as an act of home-coming, and classify motion into two artificial categories 'natural' and 'non-natural'. In the Vaiśeṣika view, motion is caused by various forces and gravity is the cause of falling motion.

Fluidity (द्रवत्व) is the cause of flowing motion exhibited by all liquid substances, and animate bodies only are capable of calling to play volitional effort (प्रयत्न).

Impact or striking (अभिघात) responsible for motion is a special kind of conjunction (संयोगविशेष) which is brought about by a body possessing speed (वेगापेक्ष). Such impact results in motion by instantaneous disjunction (विभागहेतोरेकस्य कर्मणः कारणम्). When a falling stone strikes a hard surface, the resulting conjunction is a case of impact. In impelling push (नोदन), the conjunction brought about by gravity, fluidity, speed, volitional effort between the impeller and the impelled continues and is not followed by disjunction

(नोदनमविभागहेतोरेकस्य कर्मण: कारणम्). The gradual sinking of a piece of stone in mire and the pushing of the javelin with the hand in the initial stages of throwing are given as examples of *nodana*.

Saṃskāra as a cause of motion deserves a closer and a more careful consideration. The Vaiśeṣikas recognize three forms of *Saṃskāra*, e.g. *vega*, *bhāvanā* (mental impression) and *sthitisthāpaka* (elasticity)—संस्कारस्त्रिविधो वेगो भावना स्थितिस्थापकश्च.[12] *Vega* has been rendered as 'speed' by G. N. Jha[13] and as 'momentum' by Seal.[14] As 'speed' and 'momentum' have different meanings in modern connotations, it is necessary to understand the sense in which this word is used by the Vaiśeṣikas. We have already seen that *vega* is given as one of the causes of motion. In the same *Guṇagrantha*, *vega* is again stated to be producible by motion in the same manner as conjunctions and disjunctions are produced by motion—संयोगविभागवेगा: कर्मजा:. Thus *vega* is not only caused by motion, but is a cause of motion itself. It is clearly not motion, as motion cannot generate its own kind. Another important point is that any motion is not endowed with *vega*. Normally motions are instantaneous and short-lived, क्षणिक, and are destroyed as soon as they are produced, क्षणिकत्वमाशुतरविनाशित्वम् (Śrīdhara). A motion is persistent only when it possesses a sufficient *vega*. So *vega* which arises out of, and is associated with, motion must have causes other than the motion itself. These special or efficient causes, निमित्तविशेषा:, are forces such as impelling push (नोदन), impact (अभिघात) and those which bring about conjunction with the conjoined (संयुक्तसंयोग). Praśastapāda has been content by saying that *vega* is generated in five corporeal substances (earth, water, fire, air and wind) by efficient causes without going into the details of the causes which his commentators Vyomaśivācārya and Śrīdhara have supplied. Vyomaśivācārya says, 'These special efficient causes are impelling push, impact and (forces brought about by) conjunction with the conjoined; *vega* is caused by them'—निमित्तविशेषोनोदनाभिघातसंयुक्तसंयोगास्तदपेक्षादिति.[15] According to Śrīdhara, it is only when motion is assisted by such efficient causes as impelling push, impact and the like that *vega* is produced.

It is, therefore, clear that in a moving body a force produces *vega* or a kind of *saṃskāra*. Will it be logical to assume at this stage a direct proportionality between force and *vega*? It is true we do not find in the various statements a time-displacement relationship, nor is there any direct indication of a relationship between the force and the weight or gravity of the body, except what may be inferred from the assertion that *saṃskāra* or *vega* counteracts gravity. This inference is that the heavier the body, that is, greater the force of gravity to be counteracted, the greater should be the amount of *saṃskāra* or *vega*. In the case of the motion of a javelin discharged from the hand, there is, however, a suggestion that the distance over which a javelin can travel under the influence of *saṃskāra* before falling to the ground depends upon the intensity of the effort of the thrower—संस्कारादूर्ध्वं तिर्यग्दूरमासन्नं वा प्रयत्नानुरूपाणि कर्माणि भवन्त्यापतनादिति.[16] From such statements it may be inferred that the Vaiśeṣikas, at least from Praśastapāda onwards, considered a direct proportionality between *nodana*, *abhighāta* and such other forces on the one hand and *vega* on the other obvious and also probably appreciated, if vaguely, the relationship of mass or weight of the body with the *vega*.

About the directional property of the *vega*, there is no such uncertainty, as Praśastapāda unambiguously states that *vega* is the cause of uninterrupted continuity of motion in a fixed direction—नियतदिक्क्रियाप्रबन्धहेतुः.[17] In other words, motion takes place in the direction in which the *vega* is impressed (by the force). In the course of his explanation of the vectorial property of *vega*, Vyomaśivācārya raises the question of rotatory motion in which direction does not remain fixed but changes continuously. If *vega* is the cause of continued motion in a fixed direction, how can one justify the motion of rotation in which direction changes continuously ? He justifies both as correct although he is far from hinting at the real cause of circular or rotatory motion.

Since *vega* is the cause of uninterrupted motion in a fixed direction there must be a way to its ultimate exhaustion or destruction if only to prevent perpetual motion. Praśastapāda, therefore, lays down that *vega* is counteracted by contact with special tangible substances—स्पर्शवद्द्रव्यसंयोगविरोधी.[18] By special tangible substances are meant solid substances capable of offering effective resistance—कठिनावयवसंयोगेनादावपि तद्विनाशोपलब्धेः (Vyomaśivācārya). When *vega* is not strong enough the motion of an arrow can be exhausted in contact with, and by the resistance offered by, air—वायुसंयोगेन विरोधादिषोर्गमनं न स्यात्.[19] What will happen in the case of an arrow shot into the ether where there is no such thick and tangible substance to offer resistance and destroy the *vega* ?—asks Vyomaśivācārya. Will it always move and never fall ? Although he says that such a situation is not possible and the arrow must fall, it is due to the arrow's doing several works and to the operation of the laws of rules and their exceptions. It is curious that in cases of motion, due to *vega* or *saṃskāra*, gravity is not brought into the picture until the *vega* or *saṃskāra* is completely exhausted. In the treatment of motion of bodies with *vega*, other than that of a freely falling body, the Vaiśeṣika conception is that gravity somehow remains suspended throughout the impressed motion and takes over only after its *vega* ceases to exist and then brings it down to the ground. The notable exception to this is when a body falls vertically downwards. In this case the initial falling is started by gravity and as it gets going its motion is characterized by the combined action of gravity and *saṃskāra* or *vega*—गुरुत्वाद्यदधोगमनं तत्पतनम् ।. . . तत्राद्यं गुरुत्वाद्द्वितीयादीनि तु गुरुत्वसंस्काराभ्याम्.[20] The Vaiśeṣikas stopped here and did not ask the next question whether as a result of such combined action of *vega* and gravity the *vega* of the falling body should not go on increasing. If they had done they would have in all probability discovered the force-acceleration relationship.

The foregoing discussions clearly show that *vega* is the nearest approach to our modern conception of momentum.

The second type of *saṃskāra*, e.g. *bhāvanā*, belongs to psychology and need not be considered here. But the third type, *sthitisthāpaka*, is very relevant to our discussion. This property resides in tangible and at the same time densely packed substances in particular—स्थितिस्थापकस्तु स्पर्शवद्द्रव्येषु वर्तमानो घनावयवसन्निवेशविशिष्टेषु.[21] According to Śrīdhara, densely packed tangible substances mean those in which the constituent molecules are solidly packed together. When such substances are deformed through displacement (of their constituent parts), this property helps them in reverting to their original positions, स्वाश्रयमन्यथाकृतं यथावत् स्थापयतीत्यत: स्थितिस्थापक:.[22] '*Sthitisthāpaka* is that which brings to its original form its own substrate which has been deformed.' This property may be observed in a bow, a twig, a horn, teeth, bones and such other inanimate and animate objects which when deformed by bending and then let go will be found to revert to their original forms. There is, therefore, no difficulty in calling this property 'elasticity'. Elasticity has been called a form of '*saṃskāra*', because it is not only a restorative tendency but also a cause of motion. Thus in the act of bending a bow, for example, by the application of an impelling pull, a tendency to oppose the pull is generated and stored in the body, which becomes active as soon as the pull is withdrawn. It not only restores the bow bent into the arc of a circle to its former shape but also initiates a motion in much the same way as *vega* causes motion. In both the cases, *saṃskāra* may be regarded as a *tendency* or an *impetus*, originally caused by a force, *abhighāta* or *nodana*, by virtue of which a body in motion will continue to move or an elastic substance deformed by stress will revert to its original form. It may also be regarded as a capacity for action or work—in the former, due to the motion of the body (*kinetic energy*) and in the latter, due to the configuration of the body (*potential energy*).

Praśastapāda gives three examples of motion to illustrate the interplay of various kinds of forces, including the *saṃskāra*: (*a*) motion involved in the operation of a pestle and a mortar, (*b*) motion of a javelin discharged by hand and (*c*) motion of a body catapulted from a machine.

(*a*) *Motion in the operation of a pestle and a mortar.*—Praśastapāda's description is as follows: In this case a pestle is clasped in the hand and a desire to lift it is generated. By cause and effect relationship a volitional effort (प्रयत्न) is called into play. This effort, by virtue of conjunction of the hand with the soul and again of the pestle with the hand, produces an upward motion first in the hand and then in the pestle. When the pestle is thus lifted, the previous desire to lift it further ceases and a desire for downward motion develops. This leads to a volitional effort which produces a downward motion in the hand and the pestle due to cause and effect relationship as explained above. At the end of the last stage of motion of the pestle is produced a conjunction, called impact, of the pestle with the mortar. This conjunction due to the momentum inhering in the pestle produces in it an involuntary bouncing motion—स संयोगो मुसलगतवेगमपेक्षमाणोऽप्रत्ययं मुसले उत्पननकर्म करोति.[23] This (bouncing) motion due to impact initiates an impetus (संस्कार) in the pestle which in its turn, because of the conjunction of the hand with the pestle, produces an involuntary motion in the hand as well—तत्कर्माभिघातापेक्षं मुसले संस्कारमारभते तमपेक्ष मुसलहस्तसंयोगोऽप्रत्ययं हस्तेऽप्युत्पतनकर्म करोति.[24] Although the former impetus (which the pestle had in the course of its downward motion) is destroyed (by the conjunction with the mortar), the special character of the conjunction of the pestle with the mortar (that is, the impact) is an efficient cause of motion and assists the pestle to be endowed from the very beginning with a (new) impetus—यद्यपि प्राक्तन: संस्कारो विनष्ट: तथापि मुसलोलुखलयो: संयोग: पटुकर्मोत्पादक: संयोगविशेषभावात् तस्य संस्कारारम्भे साचिव्यसमर्थो भवति.[25] In this case, the motion is divided into two parts—(i) the descent of the pestle before impact with the mortar and (ii) ascent of the pestle after the impact. In (i), the motion is caused by volitional effort which acts upon the body till the moment of impact and is endowed with a *saṁskāra* or *vega*. This *vega* is responsible for the special type of conjunction called impact which the pestle experiences with the mortar. At the impact the aforesaid *saṃskāra* or *vega* or impetus is destroyed, the volitional effort ceases and the pestle, following the impact, receives an upward thrust. In (ii), the upward motion is involuntary and is caused by impact. At the same time, a new *saṃskāra* or impetus is generated, which continues the upward motion for some time even when the impact ceases to operate and there is no volitional effort. At the impact, the operations of action and reaction in opposite directions (Newton's 3rd law) are noticeable, although this point has not been specially dealt with.

(*b*) *Motion of a javelin discharged by hand.*—When a javelin is taken in the hand and desired to be thrown, volitional effort is caused, which, by virtue of the conjunction of the two (that is, of the hand with the soul and of the javelin with the hand), as previously explained, leads to drawing motions simultaneously in the hand and in the javelin. When the javelin is (fully) extended, volitional effort for the purpose of attracting (the javelin) ceases and a desire to throw the javelin obliquely or upwards, far away or near, develops. Thereupon volitional effort caused by, and dependent (for its intensity) upon, the desire (to throw it obliquely, upwards, far or near) brings into play (a type of) conjunction of the hand with the javelin, called *nodana* or impelling push; this impelling push gives rise to motion in the javelin and at the same time causes a *saṃskāra* or impetus to develop,—तदनन्तरं तदनुरूपः प्रयत्नस्तमपेक्षमानस्तोमरहस्तसंयोगो नोदनाख्यः तस्मात् तोमरे कर्मोत्पन्नं नोदनापेक्षं तस्मिन् संस्कारमारभते.[26] Thereafter, the impelling push and the impetus jointly continue to be responsible for the motions until the disjunction of the javelin from the hand,—ततः संस्कारनोदनाभ्यां तावद् कर्माणि भवन्ति यावद्धस्ततोमरविभाग इति.[27] With the disjunction *nodana* ceases to act and the impetus continues to be the (sole) cause of motions (in the javelin) upwards or obliquely, to a far or a near point, depending on (the intensity of) the (initial) effort, until it falls (to the ground),—ततो विभागान्नोदने निवृत्ते संस्कारादूर्ध्वं तिर्यग्दूरमासन्नं वा प्रयत्नानुरूपाणि कर्माणि भवन्त्यापतनादिति.[28]

In this passage the manner in which *saṃskāra* or impetus is generated as the javelin is set in motion by the impelling push and then continues to maintain the motion when the push ceases is clearly stated. As already explained, the amount or intensity of the impetus is directly proportional to the applied push or volitional effort, and likewise the distance of travel of the javelin depends on the intensity of the impetus.

(*c*) *Motion of a body catapulted from a machine.*—In this category the case of an arrow shot from a bow is considered. As in the previous cases, the first act of drawing the bow-string and the arrow with the finger is caused by volitional effort. After the bow-string is pulled up to the ear and no farther pulling thought possible, volitional effort ceases and a desire to release the bow-string and the arrow develops. This desire gives rise to another effort responsible for the motion of the finger and consequent disjunction of the bow-string from the finger. With the loss of conjunction (of bow-string with the finger) and in the absence of obstruction, the impetus of elasticity present in the bow restores the bow bent into a circle to its original shape; at the same time this impetus, by virtue of the conjunction of the bow-string with the bow, causes motion in the string and in the arrow (in contact with the string)—ततो विभागात् संयोगविनाशः तस्मिन् विनष्टे प्रतिबन्धकाभावात्यदा धनुषि वर्तमानः स्थितिस्थापकः संस्कारो मण्डलीभूत धनुर्यथावस्थितं स्थापयति तदा तमेव संस्कारमपेक्षमाणाद्धनुर्ज्या-संयोगाज्जायां शरे च कर्मोत्पद्यते.[29] This motion, by its own cause, begets an impetus (*saṃskāra*) in the bow-string. The conjunction of the (moving) bow-string with the arrow gives rise to the impelling push (*nodana*) which initiates the first motion of the arrow and at the same time develops in it an impetus—तत्स्वकारणापेक्षं ज्यायां संस्कारं करोति तमपेक्षमाण इषुज्यासंयोगो नोदनं तस्मादिषावाद्यं कर्म नोदना-पेक्षमिषौ संस्कारमारभते. The subsequent motions in the arrow are due to the combined action of the impetus and the impelling push till the arrow disjoins from the bow-string when the impelling push ceases and the successive series of motions take place on account of the impetus (only) until the arrow falls (to the ground)—तस्मात् संस्कारान्नोदनसहायात् तावत् कर्माणि भवन्ति यावदिषुज्याविभागो विभागान्निवृत्ते नोदने कर्माण्युत्तरोत्तराणीषुसंस्कारादेवापतनादिति.[30]

Apart from the brevity and clarity characteristic of the Sanskrit language in which such physical phenomena have been described, the entire approach is rational and logical. Starting with a general definition of motion and discussion of its various properties, and developing further the concept of *saṃskāra*, Praśastapāda explained the phenomena of motion from the principle of causality. Philoponus, his Byzantine contemporary, does no more than hint at an impetus theory. Hipparchus, who of course flourished several centuries before Praśastapāda, has been credited with the fertile idea of impetus, but nothing more than the idea is known and even that from the secondary source due to Simplicius. Actual development in any detail is really witnessed in Europe in the thirteenth and the fourteenth century. But here in Praśastapāda's *Padārthadharma Saṃgraha*, we have more or less a complete and full-fledged impetus theory in the fifth century A.D. of which the germ can be traced without any ambiguity to the third century B.C. when the Vaiśeṣika viewpoints were formulated.

References

1 A good account of the theory and its developments in Europe is given in (i) Dijksterhuis, E. J., 'The Origins of Classical Mechanics from Aristotle to Newton', *Critical Problems in the History of Science*, edited by Marshall Clagett, University of Wisconsin Press, 1959; (ii) Dugas, R., *Histoire de la Méchanique*, Griffon (La Baconnière), Neufchâtel, 1950; *La Méchanique au XVII ème sciècle; des antécédents scholastiques à la pensée classique*, Griffon, Neufchâtel, 1954; (iii) Maier, A., *Die Impetustheorie der scholastik*, Vienna, 1940; (iv) Sambursky, S., *The Physical World of Late Antiquity*, Routledge and Kegan Paul, 1962.

2 Mieli, Aldo, *La Science Arabe et son rôle dans l'evolution scientifique mondiale*, Brill, Leiden, 1938; Pines, S., 'Les Précurseurs Mussulmans de la Théorie de I'Impétus', *Archeion*, 1938.

3 *The Praśastapādabhāṣyam* with *commentaries Sūktī* by *Jagadīśa Tarkālaṅkāra*, *Setu* by *Padmanābha Miśra* and *Vyomavatī* by *Vyomaśivācārya*, edited by Gopinath Kaviraj and Dhundhiraj Shastri, the Chowkhamba Sanskrit Series, 1930. All references to passages from the *Bhāṣya* are from this edition.

4 For a general discussion of the period of systematization of the Vaiśeṣika system *see* (i) Ui, H., *The Vaiśeshika Philosophy* according to the Daśapadārtha-Śāstra, Cambridge, 1917. Reprinted by the Chowkhamba Sanskrit Series Office, Vārāṇasī, 1962; (ii) Athalye, Y. V., and Bodas, M. R. (ed.), *Tarkasaṃgraha of Annambhaṭṭa*, Bombay Sanskrit Series, 2nd edition, 1930. *See* Introduction; (iii) Das Gupta, S. N., *History of Indian Philosophy*, Vol. 1, Cambridge University Press, 1951. Ui held that the origin of the Vaiśeṣika ideas was in the time of Mahāvīra and Buddha (sixth-fifth century B.C.), but its systematization was not earlier than 300 B.C. (pp. 33-34). Bodas traced the development of the literature of the Nyāya and Vaiśeṣika system from about the fourth century B.C. Das Gupta considered the Nyāya and the Vaiśeṣika Sūtras to be in all probability pre-Buddhistic.

5 Sambursky [1] (iv), p. 70.

6 ———, [1] (iv), p. 75.

7 Dijksterhuis [1] (i), p. 174.

8 Dr. Seal refers this as a quotation from Praśastapāda; this is actually from Śrīdhara's *Nyāyakandalī* (*see* ref. 14).

9 *Bhāṣya, Guṇagrantha, Sādharmanirūpaṇam*, p. 437.

10 *Bhāṣya of Praśastapāda together with Nyāyakandalī of Śrīdhara*, edited by Vindhyeśwarī Prasād Dvivedin, the Vizianagram Sanskrit Series, Benares.

11 *Bhāṣya, Guṇagrantha, Gurutvanirūpaṇam*, p. 630.

12 *Bhāṣya, Guṇagrantha, Saṃskāranirūpaṇam*, p. 633.

13 Jhā, Gangānātha, *Padārthadharmasangraha of Praśastapāda with the Nyāyakandalī of Śrīdhara*. Translated into English, E. J. Lazarus & Co., Benares, 1916.

14 Seal, Brajendra Nath, *The Positive Sciences of Ancient Hindus*, Longmans, 1915.

15 *Saṃskāranirūpaṇam*, p. 634.

16 *Karmagrantha, Satpratyayakarmanirūpaṇam*, p. 663.

17 *Bhāṣya, Guṇagrantha, Saṃskāranirūpaṇam*, p. 633.

18 ———, p. 663.

19 ———, p. 634.

20 *Bhāṣya, Karmagrantha*, p. 669.

21 *Saṃskāranirūpaṇam*, p. 633.

22 ———, p. 636.

23 *Karmagrantha, Satpratyayakarmanirūpaṇam*, p. 662.

24 ———, p. 662.

25 ———, p. 662.

26 ———, p. 663.

27 ———, p. 663.

28 ———, p. 663.

29 ———, pp. 663-64.

30 ———, pp. 663-64.