Particle Physics and the *Vaisheshika* System: A Comparative Analysis

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ABSTRACT

We examine some aspects of *Vaisheshika darshana* (The philosophy of particularities) as developed by *Kanada* and make a comparative analysis with modern particle physics. The areas of agreement and departure are brought out and it is shown that the *Vaisheshika* system was surprisingly close to and probably even surpassed, modern particle physics in many important respects and provides us new insights for future scientific research. Some of the long-standing confusions regarding the interpretation of the words like *dik* and *akasha* occurring in the list of substances are clarified in light of modern physics. A logical and systematic argument based on number abundance of various fundamental particles in the substances is followed to pin-point Kanada's atoms in modern particle physics and it is found at long last that the electron, the photon, the up quark and the down quark may be taken as the respective atoms for air, fire, water and earth. A plausibility argument is given in favor of the neutrino being the candidate for the atomic mind.

Keywords: Vaisheshika darshana, Indian Philosophy, Particle Physics, Modern Physics, History of physics in India, History of Science

1. Introduction

A well-known fact, brought to the fore by Kak [i, ii, iii, iv] in recent years is that science had made great progress in ancient India in all its wide ramifications into a variety of branches, all deriving their existence from their common source, the Vedas, hailed as the most ancient treatises on wisdom. Compared to modern western sciences, what was missing in the ancient Indian sciences developed by the sages and seers was the characteristic mathematical sophistication that we have today, although many numerical estimations and formulae were there in the form of verses. But there was no dearth of conceptual understanding in all matters relating to the universe, man and beyond.

In this work, we give a brief description of the contents and the purport of the Vedas in section-2 and of the six systems of Indian Philosophy in section-3. We discuss certain salient features of *Vaisheshika* system in section-4 and give its classification of substances, interactions etc. among other things. The modern particle Physics classification of basic constituents of substances and of the interaction forces is given in section-5 and the comparative analysis between the two is made in section-6. We conclude with a discussion of the important unsolved issues and directions for future research in section-7.

2. The Vedas and Indian Philosophy

It is a fact that all science had its roots in philosophy both in the east and the west. The seeming alienation of philosophy and other branches of human knowledge from what we call science is a relatively recent phenomenon and is the result of the compartmentalization of knowledge by the western minds. After about a century of such compartmentalized approach they have now come to the realization that inter-disciplinary studies are a *sine qua non* if we are to have a complete understanding of Reality.

In the Indian context it was never so, although there were experts in all fields of human endeavor and aspiration to comprehend Reality. Philosophy in the western sense is love of knowledge and is more of an intellectual affair but in India, it is the practical experience and the living of that knowledge that is inextricably coupled with the love for it. Thus there arose SIX orthodox systems of philosophy (*Sad-darshanas*) in the pre-buddhist era (i.e. prior to 6^{th} century BC) all of which were derived from the Vedas and are called *Astika darshanas* since they admit the Vedas as eternal and infallible. These are *Nyaya*, *Vaisheshika*, *Samkhya*, *Yoga*, *Mimansa* and *Vedanta*. The Buddhist, Jain and the *Charvaka darshanas* are called *Nastika Darshanas*, since they don't admit of (or don't need to or care to admit of) the Vedas as eternal and infallible and are classified as heterodox systems [v].

The Vedas are the earliest known treatises of experiential knowledge or wisdom and have been verified to be valid and true repeatedly in subsequent experience by great sages and

saints of India through the millenia and hence are taken to be the ultimate authority in ALL matters. Though the VEDA is ONE, it was divided into four by Sri Vyasa, namely, *Rik*, *Yajuh*, *Sama* and *Atharva*, and each of these has four sections namely, *Samhita*, *Brahmana*, *Aranyaka* and *Upanishad*. The last of these i.e. the Upanishads are called *Vedanta* since they present before us the very culmination or the very end of all knowledge or the ultimate knowledge that can ever be gained. To understand the Vedas one needs to undergo training in the six *Vedangas* (limbs of the Veda), namely, *Siksha* (pronunciation), *Chhanda* (metre and rhyme), *Nirukta* (meaning of words), *Vyakarana* (grammar), *Kalpa* (practical aspects of rituals), and *Jyotisha* (astronomy).

It is to be noted that each mantra of the Vedas is considered to be a revelation having universal applicability that admits of all possible interpretations from all possible angles and perspectives and therefore extreme care is to be taken while drawing a conclusion from a statement in the Vedas. They can be likened to single mathematical formulae or formulations of physics like that for the Lagrangian or Hamiltonian or to the equations like the Schrodinger equation which have universal applicability in Physics. The only difference is that the versatile Veda mantras are simultaneously applicable to Physics, Biology, Philosophy, Mathematics, Economics, Music, Literature, Engineering, Medicine, Political science, Management and what have we. They can also be interpreted at various levels of sophistication within one particular perspective. In this regard, we may add that even the most basic principles, laws and equations of physics have been applied in other areas leading to the development of interdisciplinary studies like psychophysics, sociophysics and econophysics.

For this reason, though they may seem ambiguous or self-contradictory sometimes, they are not to be treated as such. Rather, they are to be given due reverence for being pregnant with all interpretational possibilities, just as we hold the equations or laws of Physics as inviolable and sacred within their specific ambit of application. The Vedas have an unlimited range of application covering the entire range of human aspirations, experience and appreciation of phenomena that can ever be conceived of or dreamt of- such is the astounding all-encompassing inclusiveness of the Vedas.

In the Indian Philosophical tradition, the whole purpose of philosophy is to attempt to give a comprehensive understanding based on direct experience of the nature of *Iswara* (GOD), *Jagat* (phenomenal universe) and *Jiva* (Individual) and of their functional interrelationship. The six systems of philosophy give us an empirico-rational route of ascendance to the final Truth in a bottom-up manner while the Vedas, being revelations place before us the self-same final Truth in its myriad facets in a top-down manner.

3. The Six Systems of Indian Philosophy

The *Nyaya* system of sage *Goutama* gives us the research methodology, so to say, basing on which we can gain right knowledge (*Pramana*) about everything: by empirical observations (*Pratyaksh**a***), by doing rational analysis (*Anumana*), by building analogous theoretical models (*Upamana*) and by taking recourse to the knowledge documented (*Shabda*) by previous authentic investigators (i.e. "statements of seers" in *vedic* era and "papers by peers" in scientific era) regarding the phenomena concerned. This is precisely the scientific method that is universally followed today. The *Vaisheshika* of *Kanada* classifies the basic categories and the fundamental substances (*Padarthas*) and enumerates their various attributes, interactions and functions, which is akin to the roles that Physics and Chemistry play in modern day sciences.

The *Samkhya* of *Kapila* enumerates in a still more elaborate manner and goes deeper still into the nature of the phenomenal world as an evolution from the "interplay" of *Purusha* and Prakriti, the twin primordial principles, the cosmic subject or observer (*Iswara*) and the cosmic object or energy (*Avyakta*) and lists a total of 25 basic entities. It further establishes that there are three primary all-pervading fields called *gunas* (*Sattwa, Rajas* and *Tamas*) that by their mutual interactions make up the entire phenomenal universe of things and beings inhabiting space-time. The Yoga system of *Patanjali* goes further and sheds light on how the individual can go beyond the clutches of the nature made up of the three *gunas* and can attain a blissful state of perfect knowledge and power (*Jnana and Siddhi*) called Samadhi by the practice of protracted meditation. The relationship of the Individual with God is now left to be rationally established.

The *Purva* (prior) *Mimansa* of *Jaimini* **(**disciple of *Vyasa***)** treats of the methods of sacrificial works or *Karma* for the attainment of any desired end and holds *Karma* as the sole determinant of the destiny of the individual. The *Vedanta* system or *Uttara* (later) *Mimansa* of *Vyasa* (also known as *Vadarayana*) codified in the *Vedanta sutras* or *Brahma Sutras* points out the methods of liberation (*Moksha*) of the individual by attainment of *Jnana* or knowledge of the Highest Self (*Brahman*), which is defined as Sat-Chit-Ananda, existence-consciousness-Bliss Absolute and irrefutably establishes the identity of the individual with the supreme Absolute at the most fundamental level. Thus the Indian philosophical quest for Reality begins in *Nyaya* and culminates in *Vedanta*. However, *Vedanta* has further developed into six distinct schools later on beginning with *Adi Sankara's Kevala Advaita Vedanta* [vi].

4. Essentials of the *Vaisheshika Darshana*

As is well known all of our western sciences have had their roots in the Greek philosophy and there are historical evidences to show that the Greeks had exchange of ideas with the so-called later-vedic philosophers of India. Further, all of our Modern sciences have benefitted from the Indian philosophies which went to the Europe via the Arab route during the

16th and 17th century AD and even before, when Indian texts on Mathematics and astronomy etc. were translated and made available in the Arab countries.

It turns out on closer scrutiny that one of the oldest systems of Indian philosophy, the *Vaisheshika Darshana* aphoristically developed by *Kanada* in the treatise ***Vaisheshika Sutras*** (VS), the aphorisms on particularities, has much in common with Modern physics and even in some respects goes beyond it conceptually. It would be interesting to find out the areas of agreement and difference between the two in regard to the various concepts such as the fundamental substances, their general nature, particular properties and also their interactions.

There are 10 chapters containing a total of 368 aphorisms in the *Vaisheshika Sutras* [vii] of *Kanada*.

The six **Padarthas** (categories) enumerated in the first chapter are **dravya** (substance), **guna** (attribute), **karma** (action), **samanya** (generality), **vishesha** (particularlity) and **samavaya** (inherence).

The 9 substances are **prithvi** (earth), **Apas** (water), **tejas** (fire or radiation), **vayu** (air), **akasa** (ethereal space), **kala** (time), **dik** (directions or dimensions), **Atma** (self or soul) and **manas** (mind). Substances are those which have attributes and actions.

Some authors and commentators [viii,ix] keep *akasha* as *akasha* and translate it as ether and translate *dik* as space, but this does not seem logical. The directions are clearly mentioned under the heading *dik* in the VS and thus they should mean directions or dimensions. This is reasonable since the astronomy of the Vedas give us clear indication that the directions were different (anisotropic space) in their contents and impact. The constellations, stars and planets are present in different directions and hence different direction needed to be spelt out.

Further, based on experimental observations e.g. in Michelson-Morley experiment, modern physics does not any more recognize the existence of a material ether. Currently, ether or space is not considered different from free space or vacuum. In Quantum field theories this vacuum becomes a material entity with many particle-antiparticle pairs continuously being created and annihilated in it. It serves as the source for all matter-energy in the universe. Therefore *akasha*, which is physical in *vaisheshika* must mean physical empty space or vacuum of science, as far as special Relativity is concerned, while *dik* should be taken to mean the directions in space. It is only in general relativity that space and time cease to be infinite and eternal entities and are determined by the energy density.

There are 17 attributes **rupa** (colour)**, rasa** (Taste)**, gandha** (odour)**, sparsha** (touch)**, samkhya** (number)**, parimana** (dimension)**, prithaktva** (distinctness)**, samyoga** (conjunction)**, vibhaga** (disjunction)**, paratva** (priority)**, aparatva** (posteriority)**, buddhi** (intellect)**,**

sukha(pleasure)**, dukha** (pain)**, ichha** (desire or attraction)**, dvesha** (aversion or repulsion) and **prayatna** (volition or will)**.**

The 5 types of action are: **utkshepana** (throwing up), **avakshepana** (throwing down), **akunchana** (contraction), **prasarana** (expansion) and **gamana** (movement).

In this system, time is the primary cause of everything but it exists only in and for the non-eternal substances (VS-2/2/6). For the eternal ones it does not exists. A substance has attributes and actions and is an inherent cause. The characteristic attribute of earth is odor, of fire is heat and that of water is coldness. Earth has color, taste, touch and odor; water has color, taste and touch; fire has color and touch; while air has touch only. These first four substances are atomic in character and form basic building blocks of the entire visible universe. Sound is a special attribute associated with space. Time, directions and mind and the self are eternal and not perceivable by the senses, but the eternal mind is atomic in character. Plurality of individuals results from difference in circumstances in which these atomic minds are placed. The self must exist as the ultimate perceiver through the mind (chapters-2&3).

In the 4th chapter it is mentioned that the eternal are those that are not produced from any causes. They are uncaused existences. The principle of causality is mentioned succinctly by Kanada: Everything (an object, an event or a process) has a cause (*Karanabhavat karyabhavaah*: VS-4/1/3) and the cause precedes the effect.

The 5th chapter deals with the causes of phenomena and states that gravitational force (**gurutva**) causes the downward movement (*gurutvat patanam*: VS-5/1/8 and VS-5/1/18). It is important to note that ***gurutva*** is mentioned as the cause of free fall of an object, without any connecting link or will involved therein, and not as an attribute (*guna*) of the moving object. The movement of the needle towards the magnet (magnetic force), circulation of water in plants i.e. Capillary/ electrostatic forces (VS:-5/2/7), flow of air (pressure/mechanical/electric force), assimilation of food in the body (vital/electric forces), movement of atoms (all fundamental physical forces, will force and karmic force depending on which atoms are being considered), and their mutual interactions are all said to be due to an invisible causative force called ***adrishta*** or "the unseen"(*Agnerurdhvajvalanam vayostiryakpavanamanunam manasaschaadyam karmadrishtakaritam* : VS-5/2/13). These are examples of the *karma-karanas* or the forces in Vaisheshika which bring about the karmas like *gamanam* etc. [x,xi,xii].

In the 6th chapter this ***adrishta*** is also said to be responsible for the desires arising in the mind and for the accrual of fruits (merits and demerits) of actions performed by individuals and is therefore the cause behind their births and deaths i.e. conjunction or disjunction of the soul with an atomic mind plus a physical body made up of the atomic first four substances (earth, water, fire, air).

Defining the atom in chapter-7, Kanada mentions that they are eternal, a dimensionless point particle (**kana**), and hence have spherical symmetry (*Nityam Parimandalam*: VS-7/1/20), but are invisible. One can apply this definition to all the four ***nitya dravyas***. These atoms are to be known only from their effects (*Tasya karyam lingam*: VS- 4/1/2). The atoms of fire, air, water and earth combine via ***adrishta*** to form **dvanuka** (diads), **trayanuka** (triads), **chaturanauka** (tetrads) etc. and thus give rise to the four gross substances which are perceived by us. The subtle difference between objectivity and subjectivity of attributes are also discussed in the 7th chapter.

The last three chapters have very little to offer for a comparative analysis of *Vaisheshika* and modern physics, and therefore we just state for the sake of completeness their brief contents. In the 8th chapter the nature of perception, whether it is determinate or not, and the right means of establishing a fact are discussed. In the 9th the function of the intellect in drawing an inference is made clear. In the 10th the different possible types of inference are analysed.

We will now put the *Vaisheshika* classification of the essential categories and substances in a form (fig-1) that will help us connect it with modern physics.

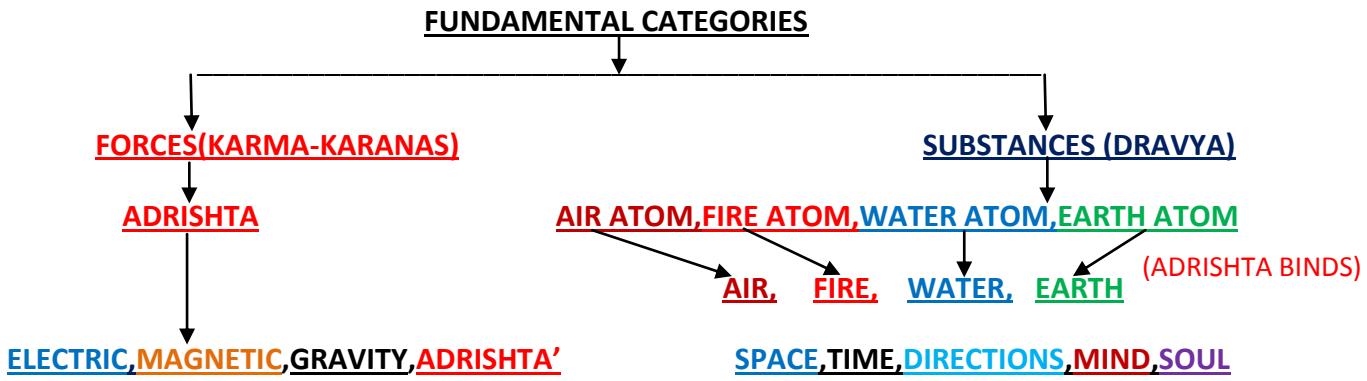

Figure-1: The Vaisheshika Classification

Firstly, it is to be noted here that we have separated out the electromagnetic part from the general ***adrishta*** and written the rest as ***adrishta'*** which is responsible for the rest of the functions ascribed to ***adrishta***. Therefore,

Fundamental Force = Adrishta ----------(1)

Adrishta → Gravity + Electric force+ Magnetic Force +Adrishta' ----------(2)

Adrishta' → Any other Physical forces + Will force + Karmic Force ----------(3)

The "Will force" is responsible for actions by the mind and the "Karmic force" is responsible for the fruits that are to come to the mind as its effects. These two and any other Physical force that is not explicitly mentioned in the VS by *Kanada* i.e. neither Gravitational nor Electric nor magnetic, make up the *Adrishta'* as can be inferred from the sutras regarding the actions of the atomic substances. (VS-5/2/13).

Secondly, we have put the substances in two distinct levels in order of their subtlety. The First four atomic substances make up all matter; the next five are at a subtler level. Space, time and directions are discussed in Physics, but the last two i.e. mind and soul are yet to convincingly occupy their rightful place in today's mainstream Physics, although there are indications that they cannot be left out in the cold any longer. Space, time, soul and directions in *vaisheshika* are non-atomic and infinite, while the mind is stated to be atomic.

With this classification scheme in mind we will now try to see how far the Vaisheshika tallies with the classification scheme of modern physics for fundamental entities (particles) developed in the 20^{th} century. It is quite surprising that in many respects they are in agreement in regard to the basic concepts and entities involved.

5. "Fundamental Entities" in Modern physics

In Modern physics, the universe is conceived of as an objective phenomenon being acted out by some "fundamental entities" in the arena of space-time (3 space dimensions +1 time dimension) and we are presently in such an era that these "fundamental entities" have come together to form not only inanimate things but also animate living beings, that have evolved in course of time up to the human stage. The universe is believed to have begun with a big-bang (for some unknown reason !) with all its contents (fundamental entities) in a hot soup confined in a very small region $\approx (\ell_p)^3$, with $\ell_p \simeq 2\text{x}10^{-32}$ cm, and has expanded continuously to reach the present vast size in an estimated span of about 14 billion years .

The "fundamental entities" are called elementary particles and their mutual actions are carried out by four fundamental forces, namely, Gravitational force, Electromagnetic force, Strong nuclear force and Weak nuclear force. The current understanding is that in the beginning all the forces were unified as one fundamental force and afterwards there were only two forces, the Gravitational force and the Grand Unified (GUT) force which comprises of the Electromagnetic, weak and the strong forces. As the universe expanded and cooled further, the GUT force gave rise to the strong force and the electroweak force. The electroweak force later on gave rise to separate electromagnetic and weak forces and we are currently in this phase of the universe, where all forces appear to us as separate manifestations of the one unified force between any pair of fundamental particles. These forces are carried by a class of particles called

Gauge Bosons and the elementary particles that go to form all matter are called Fermions [xiii]. We write:

Fundamental Unified Physical Force → Quantum Gravity ----------(4)

Quantum Gravity → Gravity + GUT forces ----------(5)

GUT force → (Electro-Weak) + Strong → Electromagnetic+ Weak+ Strong ----------(6)

Two classes of Fermions called Quarks and Leptons, each coming in three doublet families in order of their attributes (masses and other characteristic properties) have been discovered. In all, there are six quarks and six leptons (and their antiparticles) that form all the material particles. The gross material substances made up of fermions are in the form of solids, liquids, gases etc. and they are all, in general, made up of molecules. The molecules on their part are made up of atoms and the atoms are made up of three kinds of particles: the proton and the neutron that together make up the nucleus, around which the electrons are distributed in space with various energies. The proton and the neutron are not fundamental and are made up of three quarks each, while the electron is a lepton and is itself an elementary particle. The proton and the electron are stable charged particles having equal and opposite charges while the neutron having no electric charge decays into a proton, an electron and an anti-neutrino in about 14 minutes. Every atom being electrically neutral has equal number of protons and electrons.

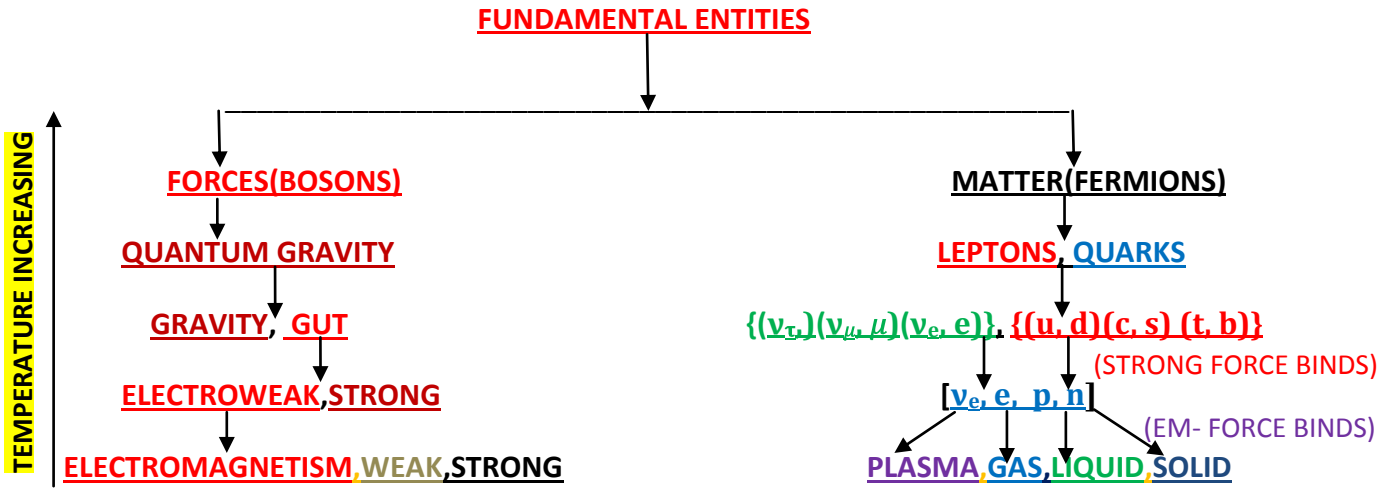

Figure-1: The Particle Physics Classification

All the gauge bosons are massless except for those responsible for the weak interaction. The electromagnetic interaction between charged particles like the electron and proton is carried by bosons called photons. It is the photons or the electromagnetic forces that bind the protons and electrons together to form the atoms, atoms together to form molecules, and

molecules together to form substances. Similarly the strong interaction and the gravitational interaction are mediated by massless gauge bosons called gluons and gravitons respectively. All the massless particles always travel with the speed of light ($c = 3x10^8$ m/s) according to the theory of Relativity. These gauge bosons are the action agents of modern physics that make up the phenomenal universe appear as it appears to us.

We have presented these observations in the above scheme (fig-2) for purposes of comparison with the *Vaisheshika* view. We have separately listed the lightest lepton pair (ν_e, e) and the nucleon pair (p, n), below the quarks and leptons since only these four fundamental particles take part in the formation and decay of the nuclei, atoms, molecules and finally, of all substances available to us in the four states of matter viz. solids, liquids, gases and plasma.

6. Comparative Analysis of Vaisheshika and Modern Physics

We now note the agreements and differences on various issues between Modern particle physics and the *Vaisheshika* view and try to see how far the criteria of indivisibility and eternality of the atomic substances can help us connect the two and also draw some interesting conclusions regarding the nature of the fifth atomic substance, the mind. We discuss everything under two heads viz. fundamental substances and fundamental forces.

(a) Fundamental substances:

(i) Atomicity: The fundamental material particles of all four material substances are atomic (particles or ***anu***) in both the schemes. But in Particle Physics which is based on quantum field theories (QFT), the particles are the quanta of the corresponding fields and they obey their respective field equations. *Kanada* is the first ever atomist or particle theorist in the world. For him atoms meant the indivisible and eternal fundamental constituents in the universe.

(ii) Fundamental Material Particles: The statement that the invisible and indivisible particles (*anu*) of air, fire, water and earth by joining together through *adrishta* form the entire physical universe is something that needs a deeper analysis on the basis of the tremendous amount of scientific knowledge gained through the centuries gone by since the days of *Kanada*. The basic criterion is the *indivisibility* or *eternality* of the fundamental particles. What could be these indivisible fundamental particles of *Kanada*?

The very first and the grossest level of understanding is that these fundamental substances may stand for the four generic states of matter: gases (air), plasma (fire), liquids (water) and solids (earth), since these are what we find in the physical universe apart from radiation. Note that electromagnetic radiation can be included in plasma as an essential constituent since there are mutually interacting ions and electrons in it and it is known that

flame or fire is also in plasma state emitting heat and visible radiation. Air also has lots of free electrons and radiation in it. It seems that at this level everything is pretty mixed up as stated by *kanada* in VS-2/1/1, 2/1/2 and 2/1/3). But, what are the primary atomic (*anu*) constituents in each of these four? They are the real fundamental constituents.

We therefore consider the fact that these are made up of invisible "atoms" that are indivisible. If we take them **literally**, the next level of indivisible units would be the molecules that make up the substances. For plasma we would have molecular ions, electrons and radiation. But, as is well known molecules are not **spherical** and **indivisible** as demanded by *Kanada* for the *anu*. Thus they don't meet the requirements.

Further on, we may take the next subtler level of "atoms" i. e. the elements of the periodic table that are most abundantly present, by number of units (and not by mass percentage since we are trying to pin down the fundamental atoms in the substance as the *anu* for that) since the more the number of a particular type of atoms in the substance the more it can be said to be composed of that type of atom. But the "atoms" of the periodic table are also neither all **spherical** nor **indivisible** and hence they also don't fit in with *Kanada's* requirements.

Therefore, we have to come to the still more elementary constituents, the electron, the proton and the neutron apart from the photon that is also necessary for the formation of atoms, and also possibly, the neutrino, that is emitted by the neutron in the beta decay process.

Now, if we take radiation as fire then it is obviously composed of photons. Even if plasma is taken as fire, then there are almost equal number of ions and electrons, but there are also a large number of photons present. Thus, the physical *anu* for fire can be taken as the photon and it is indivisible as a unit of specific energy $\epsilon = h\nu$ (Planck-Einstein formula).

For the atomic constituents of air, we have neutral molecules, atoms, ions and electrons making it up. Which one is to be taken as the *anu* for air as postulated by kanada? We'll address this question after we addressed the issue of the "atoms" for water and earth.

Similarly, for the atomic constituents of water if we take into account the isotopic abundance of the oxygen, we get an excess of protons over neutrons (two hydrogen atoms per every oxygen atom with 99% of Oxygen being the even-even ^{16}O). Thus water can be represented as made of comparatively larger number of protons compared to neutrons. So proton could be Kanada's "atom" for water. But protons are not indivisible as each proton is known to be made up of three quarks: two up and one down. Thus they also don't qualify as "atoms" and going by number abundance again, the *anu* for the water may be the up quark which in particle physics is taken to be elementary having no parts and thus satisfies Kanada's

requirements, at least as long as it is not proven to be a composite of some other fundamental particles.

Similarly, for the earth having maximum iron-abundance (core, mantle and crust all included) and since all isotopes of iron have excess neutrons over protons and since for silicon also, 92.2297% being the even-even ^{28}Si, only ^{29}Si and ^{30}Si contribute to proton-neutron number difference and they have excess neutrons. Thus, the earth "atom" of Kanada could be the neutrons. But again neutrons are not indivisible as each neutron is known to be made up of three quarks: two down and one up. Thus again going by number abundance we can say that the down quark would be the atom for earth provided it is not subsequently proved to be a composite of some more fundamental entities.

Thus we may assume that any one of the two remaining elementary particles at our disposal-- the electron and the neutrino, must be *Kanada's* "atom" for air, and then the other may be associated with the fifth atomic substance, the mind! Note that **indivisibility** is the main decisive criterion in this analysis of the fundamental atomic constituents of the material world. Indivisibility follows from eternality, which is an essential characteristic of *Kanada's* atoms (VS: 7/1/20). We put these observations in a tabular form in table-1 below for an appreciation of how indivisibility leads us to the various mutual identifications in a gradational manner.

TABLE- 1
KANADA"S ATOMS (FUNDAMENTAL PARTICLES)

STATE OF MATTER	SUBSTANCE (DRAVYA)	MAJOR CONSTITUENTS (TAKEN LITERALLY)	ATOMIC LEVEL (LARGER NUMBERS)	FUNDAMENTAL PARTICLE LEVEL (LARGEST NUMBER)
PLASMA	FIRE	CO_2,H_2O,PHOTONS, IONS,ELECTRONS	O,C,H,→ PHOTONS	PHOTON(γ)
GAS	AIR	N_2,O_2,CO_2,CO, ELECTRONS, IONS	N,O,→ ELECTRONS	ELECTRON (e)
LIQUID	WATER	H_2O	O,H,→ PROTON	UP QUARK (u)
SOLID	EARTH	Fe, SiO_2 (CORE, AND MANTLE INCLUDED)	Fe, Si, O,→ NEUTRON	DOWN QUARK (d)

(iii) Space: In both schemes space (vacuum) is physical and invisible, but in Vaisheshika space is infinite, while in physics it depends on the particular cosmological model in general relativity.

(iv)Directions: The directions are an unusual inclusion in vaisheshika since in Physics they are assumed to be automatically understood to be included in space as its inherent property. But, the dimensionality of space (i.e. the independent directions in space), are not fixed by Standard model and thus it must be separately listed as "substance". Further, the inhomogeneity and anisotropy of space with respect to any observer needs to be taken care of. There are 10 directions in all -- 8 directions at 45^0 angular separations on a plane (East, North-east, North, North-west, West, South-west, South and South-east) plus the two normals to the plane called up and down. This covers the three-dimensional character of space.

(v)Time: Time, like space is included as an independent substance in Vaisheshika. In physics, time remains outside and is thought of in conjunction with space as forming a four-dimensional continuum called space-time, according to the theory of Relativity. Thus, space and time are independent variables on which the field operators depend and thus they are fundamentally different from the particles.

(vi) Mind: The vaisheshika has **mind** as another eternal indivisible **atomic** particle since it tries to explain phenomena involving living beings as well. This is a notable difference and science is yet to tackle directly the issue of the mind, although there are indications that very soon we may see an era of scientific study of mind and mental phenomena, so far restricted to the field of psychology in humanities. It is a pity that in this era of inter-disciplinary studies, the mind is not even discussed in Biology or so-called life sciences where it has a direct bearing. Only recently the mind has come to be discussed at some length by some authors through the interpretation and measurement problems of Quantum Mechanics. So whether the inclusion of the mind as a fundamental ***anu*** is an advantage or a handicap for Vaisheshika remains to be decided by science of the future.

The next big question is that if at all the mind exists as an atomic entity whether it is another physical atomic substance like the other four or is it fundamentally different from them? If yes, in what way does it differ and how are we to infer its presence from a modern physics perspective? We see that the only stable indivisible fundamental particle left is the lightest lepton, the electron neutrino (ν_e), the companion of the electron. It interacts weakly and is therefore very difficult to detect. Sometimes it is reported by scientists to be travelling faster than light. It has a lot of cosmological and astrophysical significance in the calculation of matter density in the universe and in neutron stars etc. Characteristics like these and more somewhat match with what is said of the mind by some seers. Can we identify the atomic mind of *Kanada* with the neutrino and say that what appears as the gross mind *dwelling in* each of us is but a neutrino (or a bunch of neutrinos, somehow bound together by *adrishta* in the neurons of the CNS and the brain)? This is a question for future research to answer.

(vii) Soul: Similarly, the inclusion of a soul as a fundamental substance in the universe is open to debates among scientists since so far no scientist has seen a soul or done any experiment on it. So no scientific statements can be made in regard to it. *To believe without experimental observation would surely be blind belief, but to disbelieve without sufficient reasoning would amount to "blind disbelief" and both are unscientific attitudes towards a hypothesis*. Is the infinite soul getting associated with a group of neutrinos (atomic minds) and appearing as individuals like us, as *Kanada* probably means? At the present moment, it would be better to leave it for future science to decide whether the soul exists and whether it is needed to be conjoined with the atomic mind and then with a body, to form what is an 'observer' or individual perceiver.

(b) Fundamental Forces:

(i) Gravity: The gravitational interaction is mentioned separately as a force in both vaisheshika and the standard model of particle Physics. . In Physics, Gravitation is responsible for curvature of space-time and is described by General Relativity and has not been successfully quantized yet. Interestingly, Gravity is kept out of the mention of the various forces in vaisheshika sutras (VS-5/2/13) and mass or weight (*gurutva*) is not also mentioned as one of the attributes of the substances. Only some of the later *Vaisheshika commentators* have added *gurutva* (mass) to the list of attributes [v].

The mass of a substance as a fundamental attribute of course is equally problematic in Physics. Gravity as a Newtonian classical force looses its relevance in general relativity where it is replaced by curvature of spacetime. In particle physics based on Quantum Field Theories which use only Quantum theory and Special Relativity, it appears as a property of fundamental particles only as a result of Yukawa coupling to the Higgs Boson which takes up a non-zero VEV (Vacuum Expectation Value) following spontaneous symmetry breaking.

Thus, it is quite surprising why *Kanada*, dating prior to 600BC, neither included mass or *gurutva*, the most conspicuous and palpable attribute of objects, in the list of attributes and nor did he include the action of gravity as *karma* by *Adrishta* in the same way as he did for others (VS-5/2/13).

(ii) Electromagnetism: Though not explicitly named, from the various separate listings of its actions we infer the existence of electromagnetism in *Kanada's* scheme (VS-5/2/13) as part of a more general force called *Adrishta* responsible for the interaction amongst the *atomic substances.*

(iii) Nuclear Forces: The nuclear forces are not separately mentioned by Kanada but, the physical part of the *Adrishta'* can mean the nuclear forces when Electromagnetism is separated out. If it be argued that Kanada does not explicitly mention about the nuclear forces, it is to be noted that even twenty years after their discovery someone like Einstein did not believe in the existence of nuclear forces till his very last and continued to find a unified field theory of only

electromagnetic and gravitational forces. And in case of *Kanada*, we are talking in times preceding 600 BC!

(iv) Adrishta: The *Adrishta* (or unseen force) is probably the ultimate unified force that was ever proposed and can ever be proposed by anyone in any tradition of scientific investigation that explains all phenomena involving mind and matter. This is a novelty in all Indian philosophies which try to explain the entire gamut of experiences, not restricting themselves to only the physical part of it as is done in western science.

(v) Quantization of Force Fields: Leaving aside Gravity, which is a classical field yet to be quantized consistently, the other three fundamental forces in Particle physics are quantum fields just like the material particles themselves and this is where Vaisheshika does not have anything to say. The nature of the forces remains obscure in vaisheshika and the only description is that they are invisible operations by the unseen or *Adrshta*.

(vi) Spontaneous Symmetry Breaking: As per the standard model the four forces which were one unified force in the beginning, say at the big bang by some mechanism evolved into the separate GUT forces and gravity as the universe expanded and cooled. Then, upon further expansion and cooling the strong force separated out from the electroweak force and then the electroweak further separated into the electromagnetic and the weak forces by the process of spontaneous symmetry breaking (SSB). The Higgs mechanism is responsible for the generation of masses of particles through the spontaneous change in the VEV (vacuum expectation value) of the Higgs field. In Vaisheshika no such mechanism for *Adrishta* is provided explicitly for the separation of the forces into distinct interactions, though the division into the different forces is quite visible. Although the masslessness of the ultimate "atoms" of *Kanada* may be inferred indirectly from their indivisible character, how they become massive is not clear and the only recourse is again to the *Adrishta* that combines them in various ways to manifest mass and the gross substances.

7. Discussion and Conclusion

We have made a detailed analysis of the Vaisheshika view in relation to modern particle physics and have tried to pin down the indivisible "atomic" constituents or *anu* for the four material substances.

The substances such as space, time and directions are more or less the same as far as non-relativistic descriptions are concerned. But once relativity enters space and time lose their absoluteness and become relative. Even the 3-dimensionality of space that we infer from the directionality cannot be taken as absolute since many higher dimensional theories have come up and are awaiting experimental confirmation in near future.

The fifth atomic substance, the mind, remains untouched in modern physics and thus, as of now, nothing definite can be said of it. When this is the case with the mind, then about the

infinite and eternal soul, the less said the better. We are still too far off from it as far as our sciences are concerned.

We have tried to align the vaisheshika view along the most recent scientific advancements in the understanding of the ultimate constituents of the physical universe and have found it tallying in some respects and differing in others. Since Science is always in a flux and the last word on anything has not yet been said, it is for future research to prove or disprove *Kanada's* proposals which don't match with modern science and in those areas where it does match, whether they can really be said to be settled final truths. In view of this, it remains to be seen whether *Kanada* is given the credit that is long overdue to him or he continues as the longest-overlooked particle physicist in the history of the human race.

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