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A NEW INVESTIGATION INTO THE PROBLEM OF PERFECT DETERMINISM IN MODERN SCIENCE

I. Introduction

The problem of perfect determinism and its relation to causality has occupied an important place in almost all philosophies of the world. The development of Newtonian mechanics has provided a very precise meaning to this whole idea and hence the entire formalism has been given a mathematical shape by a simple abstraction of the real world activities. This idea of perfect determinism had established itself as the most fundamental law of nature which can be practically verified in several simple situations. However with the development of quantum mechanics (q. m. in short for later use), it was realized that this law of perfect determinism is no longer valid at the microscopic level because of the uncertainity principle and the fact that a quantum system cannot have a physically meaningful property independent of the measuring apparatus[1]. It is also found that the particular state in which a given quantum system could be found is not entirely under our control, but it could be predicted only with some probability. Furthermore, this probability is not because of lack of some information as in ordinary statistics but is an intrinsic part of our process of description and it can never be reduced by any means whatsoever. Essentially it is a result of the uncontrollable interaction between the measuring apparatus and the given quantum system.

However, the measuring apparatus is a device constructed by the human observer and the results of its interactions with the quantum system are also interpreted by the human observer who is the ultimate observer. So we find that indirectly even the characteristics and different states of the human observer comes into the process of quantum mechanical description. Bohm was the first who recognized the importance of the role of human consciousness in the quantum mechanical description. Ordinarily of course we do not talk of the involvement of the human consciousness in our day to day calculations of quantum mechanical problems, but it does come into the picture when we discuss the philosophical implications of q. m. But this problem has not received serious attention and has been avoided as much as possible.

We therefore make here an attempt to consider this problem of consciousness in an abstract way. Our analysis has become an abstract formalism because we are also interested in looking for a possibility of perfect determinism within q. m. We have introduced two abstract entities to deal with this problem.[2] The first is an abstract causal world described by the classical physics in which causality is perfectly obeyed and we have a state of perfect determinism, completely independent of any measuring apparatus or an observer. We call this entity A.

It may be noted that the assumption of this kind of reality or entity was considered to be irrelevant and physically meaningless by Heisenberg and others but it does not mean that they have completely ruled out the existence of this reality. This is so because Heisenberg very clearly asserted that the laws of nature which we formulate deal no longer with the nature itself but with our knowledge of the nature. It may also be mentioned that Einstein had a firm belief in the idea of existence of a reality where the law of causality is perfectly obeyed and there is state of perfect determinism.[3]

We then introduce a second abstract entity for which causality is neither obeyed nor violated and call it B. If we treat this new entity as an abstract observer then the interrelation between these two entities indicates that this new entity can be interpreted in two contradictory ways. According to one interpretation the entity B is physically meaningless because it is void of any physical properties but according to the second interpretation this new entity B can perceive the whole causal world in one single perception. The past, present and future of our causal world are perceived simultaneously. Thus we have described the properties of the Laplacian imaginary demon who can perceive the whole classical world.[4]

This paradoxical situation appears to be very much similar to the one which has been described in different schools of thought of the Indian philosophy whose main conclusion is that the true knowledge of this world is structured in the consciousness and hence can be obtained only by enlightenment. It is argued that an enlightened consciousness is capable of perceiving the whole causal world in one perception from one point of view but from the other point of view this enlightened consciousness is a null, void of any physical meaning in the terminology of this material world.

Although we have started from a very abstract formalism I feel that this attempt has put the problem of perfect determinism on a new footing and it provides a new insight into the whole problem. A fundamental question which should now be raised is "what new information can be derived from this formalism?". At this point we discuss this formalism in the light of the concept of knowledge in the Indian philosophy. This discussion leads us to suggest that although the present formalism may be some kind of asymptotic generalization of some unknown relation between the human consciousness and the world around us and the idea that knowledge is structured in the consciousness may have some real meaning. This suggestion is based on very remarkable quantitative facts mentioned in the ancient Jain literature[5] which indicates that this knowledge of consciousness can be developed to such an extent that one may start perceiving even the microscopic particles of matter. For this, I have given a table for measurement of length used by the ancient Jain saints in the appendix. A simple calculation from this table shows that the size of the smallest particles of matter as estimated by the ancient saints through their knowledge of enlightened consciousness lie in between the average size of the atoms and the average size of nuclei as determined in the modern physics. Thus in a way the present investigation gives a new dimensions to the problem of extra-sensory perception. Hence it is suggested that the whole issue requires a serious and a patient investigation with an open mind.

I have planned this paper in the following way. The classical ideas of causality and perfect determinism are discussed in section II. Section III deals with the concept of causality and perfect determinism in q. m. In section IV we discuss the properties of the two abstract entities and their interrelations in classical physics. As we have explicitly introduced an observer and have also attempted to search for the possibility of perfect determinism of classical physics within q. m., it has become somewhat difficult for us to differentiate between classical level and quantum level. With this background we discuss the implications of this formalism in q. m. in the light of the concept of knowledge in Indian philosophy in section V. The interesting evidence from Jainism is also discussed in the same section with some general remarks.

II

The Principle of Causality and the Concept of Perfect Determinism in Classical Physics :

The principle of causality is the most fundamental concept in classical physics and it appears directly or indirectly in all aspects of our description of nature. To fully appreciate the significance of causality, let us analyze the basic process of understanding a natural phenomenon in classical physics. As soon as we say that we wish to understand a given phenomenon occurring in nature; we have divided the nature into a large number of phenomena or parts and then we try to understand one of these phenomena (At least there will be two phenomena, one is ourselves and the other is the rest of the world or nature). Thus first we divide the nature into a large number of parts, secondly we identify these parts as roughly independent systems and we finally study the interrelations among these parts, and phenomena associated with them. I wish to emphasize that (i) the simple process of analysis of nature into a large number of parts, (ii) their identification and finally, (iii) the synthesis of these parts deeply involve the principle of causality and continuity. To illustrate this point, let us study the motion of a planet in the sky. For this we first isolate this planet from rest of the bodies in the sky and then identify it as having some definite properties which are different from those of others. We then study its motion in the space because of the forces acting on it due to the other bodies in the space (mainly gravitational forces). Now as soon as we isolate the given planet from rest of the bodies in the sky we have assigned a certain definite position to the given planet in the space. This position is in relation to other planets in the space and this assignment of relative position to the planet is based on their fixed locations in the space which in turn is determined by the gravitational interactions among them. It is now well-known that the gravitational interaction strictly follows the principle of causality and that is why we continue to identify the given planet as different from other planets and having some fixed position relative to other planets. If the gravitational interaction had not followed the law of causality, the mere isolation of the given planet from others would not have been possible. The process of identification of the planet also involve some fixed characteristics of the planets which makes this planet look different from others. Thus it has some fixed size, some definite colour, some definite shape and structure etc. Now all this information is obtained by the light reflected from the planet and it is well-known that the laws of reflections of light also follow the principle of causality. Lastly, when we study its motion due to the forces acting on it then all these forces must follow the principle of causality for a physically meaningful description of the motion. So this example illustrates the significance of the law of causality in our fundamental process of description of nature. This simple example can be generalized for description of other objects and processes (phenomena) occurring in nature and one can say that the law of causality and continuity are most fundamental and crucial for a physically meaningful and consistent (space-time invariance) description of nature.

Let us make these ideas more precise and give them a mathematical shape. For a complete description of the behaviour of a system, we need two distinct but slightly related elements. Firstly, we wish to have a space-time order of the events that describe this behaviour, that is we must tell what happens to the system at a given space-time point. In addition we are also interested in having a causal description of the events which tells us the reasons for the occurrence of these events. Now the very fact such a causal description is possible is based on a presumption that some causal factors exist within matter which are responsible for bringing about the events in the question... In classical physics these causes are nothing but the forces which exist among the particles of matter. These may either be internal forces or externally imposed ones. To be more specific, these forces are causes which can bring about a change in the velocity of the particles. The exact relation is given by the Newton's law of motion. So if the initial position and initial velocity and force (net force) acting on a particle is given then the Newton's law of motion completely describes the motion of the particle for all times. This idea can be then generalized for all the particles present in the world and one can say that if initial positions and initial velocities of all the particles are known at a given time and if the forces acting among them are also known then the future course of action (even the past also) of all the particles of the whole world can be determined by the Newton's laws of motion and we have a state of perfect determinism. Laplace was the first to discuss these ideas in some detail. He had also thought of an imaginary demon who can perceive this perfectly deterministic world.

However, if we look at the concept of force more closely then we find that really speaking this is a redundant concept because once the initial positions and initial velocities of all the particles of the system (the whole world) are known at any given instant of time and if differential equations of motion are also given then both the past and the future of the entire world are perfectly determined. The space-time order of the events is therefore determined for all the time but this determination is not conceived of as being the result of the operation of anything like causes. So except as a convenient term for showing the effects of a large number of accelerations the concept of force is simply not required at all. Of course this concept is practically useful when we study an isolated system.

In the next section we shall discuss the concept of causality and perfect determinism as modified in q. m.

III

The Ideas of Causality and Determinism in Quantum Physics :

With the advent of q. m. the ideas of causality and perfect determinism of classical physics had to be drastically modified. This drastic modification was a result of the following factors which had to be incorporated in q. m.

In contrast to classical physics where the measuring apparatus was found to play no role in our description of a system, quantum mechanical discoveries indicated that a quantum mechanical system, for example an electron; cannot be even described independently of a measuring apparatus. Thus we cannot even think of any intrinsic character of a quantum mechanical system like an electron. So electron takes properties which are partly governed by the electron itself and partly determined by the nature and state of the measuring apparatus. Thus the same electron can behave as a wave as well as a particle depending upon the nature of the measuring apparatus and we can not assign any reason for this dual behaviour. As the measuring apparatus is arranged by we people and it is once again we people who interpret the observations of the measuring apparatus, our own state of consciousness plays an important role in the description of a quantum mechanical system. Bohm was the first to raise this problem. These ideas can be generalized and one can say that at quantum mechanical level no system can ever have any intrinsic character of its own, it simply shows some properties which are partly determined by the measuring apparatus. Since in general a system can interact with an infinite number of systems (measuring apparatus), it can show infinite attributes. That is why we treat this world as an indivisible whole and therefore we can not divide this world into two or more than two parts having some intrinsic characteristics. It may be noted that this idea of unity of the world in q.m. is much more stringent one than what we have in classical physics. There also we have a unity of the world in the sense that all parts of the world are interrelated among themselves through different kinds of forces.

In addition, the principle of causality breaks down in q. m. because a quantum mechanical system can take either a wave-like character or a particle-like character and we do not know the reasons for this dual behaviour. So the effects or the results of the experiments are known to us but we cannot assign any reasons for this dutal behaviour.

Let us discuss the other aspect of the quantum mechanical description which throws more light on the actual status of causality in q. m. This deals with the famous uncertainity principle. According to this principle it is impossible to determine simultaneously the exact position and exact linear momentum of a microscopic particle perfectly. This is so because when we attempt to measure its position accurately by a position measuring apparatus then its linear momentum becomes uncertain and when we attempt to measure its linear momentum accurately by a momentum measuring apparatus its position becomes uncertain. It means that one cannot even think of finding the present position and present momentum (hence present velocity) so there is no question of determining the future position and future velocity of the particle at any time. We can only mention the probability that the given particle will take a given value of either position or velocity (momentum) at a given time in the future after undergoing an interaction with some system or otherwise. Again we cannot assign any reason for this indeterminism except that it is just a result of our process of description of nature. Thus here again we find that although some effects are known to us but no suitable causes can be searched for them. It is a simple matter now to generalize this behaviour for a system having a large number of particles.

We shall make this situation more clear and precise by discussing the complementary nature of the causal description and the space-time description. It is found that in q. m. energy and momentum are to be treated as fundamental variables in addition to other fundamental variables like space and time because in q. m. energy and momentum are not reducible into space and time variables as is the case in classical physics. In q. m. energy and momentum are treated as causal factors inherent in matter which are related with the space and time variables in such a way that the causal factors and the space-time variables behave in a complementary way. This means that if we wish to make our causal description very precise then the space-time description becomes very poor and if we wish to make our space-time description very precise then the causal description becomes very poor. Thus matter should be regarded as having opposite potentialities for developing either comparatively well defined relationships between comparatively poorly defined events or comparatively poorly defined causal relationships between comparatively well defined events but not both together. Which of these potentialities is more fully realized in a given experiment depends partly on the system with which the object in question interacts.

After describing the correct status of the principle of causality and perfect determinism in classical physics and their modified versions in quantum mechanics, we shall now proceed to discuss the properties of an observer who can still think of a perfectly deterministic world. That is, we shall investigate the properties of the Laplacian demon who perceives a perfectly deterministic world.

IV

Definition of the Abstract Observer and its Interrelation with the Classical World :

Our first abstract entity is nothing but the world as described by classical physics. In this world the principle of causality is strictly obeyed at all levels. We further assume that such a world exists independently of any external observer. We call it the entity A. This is same as the Laplacian world and we have a state of perfect determinism.

We then define our new entity B. This is an entity for which causality is neither obeyed nor violated. The principle of causal connection points out that for every effect there is a definite cause behind it (or a large number of causes behind it) and every effect in turn becomes a cause of some other effect. Now when we say that causality is violated then it can have the following two different meanings : (i) when the causality is violated then this can mean that temporally the role of cause and effect has been reversed so that first we have an effect and then there is a cause. This is the situation believed to be existing in the case of tachyons (particles moving faster than light). They are assumed to be moving backward in time so it is said that causality is violated by tachyons. (ii) Violation of causality can also mean that there may be some effects (causes) whose causes (effects) may not be known to us or no physically reasonable causes (effects) can be searched for given effects (causes). This is the situation which we have found in quantum mechanics where we have found that there are some uncontrollable fluctuations in the predictability of the state of a system in a given measurement process. These fluctuations are such that we can not assign any kown factors or causes responsible for it.

Let us now take the help of this discussion to understand the meaning of the term causality which is neither obeyed nor violated. From the above discussion it is clear that when we define an entity for which causality is neither obeyed nor violated then for this entity neither cause precedes an effect nor an effect precedes a cause. Or we can say that since the simple notion of cause and effect implies a temporal relation, for this entity there is neither a cause nor an effect. We can also say that cause and effect have both merged into each other. That is, this entity is neutral with respect to cause-effect relationship. Still another method of understanding this entity is that as the cause-effect relation implies a change in the observable state of a system with respect to time, this entity is neutral with respect to time. In addition since different observable states of a system are characterized by a change in the spatial co-ordinates of the system (or a part of it), we can say that this entity is neutral with respect to the spatial co-ordinates also.

Let us now study the interrelation between these two entities. As the world described by classical physics does not recognize any measuring apparatus or an observer, our formulation is somewhat different from the standard classical physics. Furthermore, since the role of a measuring apparatus or an observer is extremely important in q. m., our analysis is quite similar to the theory of quantum phenomena but different in the sense that we are talking about a perfect determinism within q. m. Thus our formulation is somewhere in between classical physics and q. m. It is found that the interrelation between these two entities can be given the following two different interpretations :

(a) **First interpretation :** As our new entity B is neutral with respect to the cause-effect relationship, physically it is of no use because no observable conclusions can be drawn in terms of our familar concepts. Hence in relation to the classical world, it is just a null, void of any physical meaning at all. Hence we can not discuss this relation further. However, there is another interpretation of this interrelation which we now discuss.

(b) **Second interpretation** : As for this new entity causality is neither obeyed nor violated it can neither be a cause of bringing any change in the perfect causal world nor the perfect causal world can bring about any change in this new entity B. Therefore this new entity B can be treated as a field which pervades every part of the causal world A like the hypothetical ether without any resistance. Moreover this entity B pervades every space-time point of the causal world A. But in contrast to the ordinary ether which pervades the ordinary world only spatially, our new entity B pervades the perfect causal world spatially as well as temporally. So if we treat this new entity as an abstract observer then this observer is there in contact with each space-time point of the perfect causal world. Hence it is capable of perceiving all interelations existing among different space-time points of the causal world. Furthermore since it is one single entity pervading the whole causal world both spatially as well as temporally, this observer perceives all correlations among different space-time points individually and simultaeneously. As qualities of a particular system are nothing but the corresponding correlations of the system with other systems present in the causal world, this observer can perceive all qualities of all the systems of the perfect causal world and that also in one single perception.

Thus if we consider the world as described by the classical physics then our new abstract obseiver B can perceive the whole classical world perfectly and deterministically. But as shown earlier if we consider the whole world then the concept of causality is redundant in classical physics and only the spatio-temporal relations are significant hence the space-time coordinates of all the particles are known at all the times. However if we look at the first aspect of causality which says that the concept of causality is required even while considering the divisions of the world into different parts and their identification as roughly independent systems hence this interpretation would indicate that there is nothing like divisions of nature into different parts and phenomena etc., for this observer. This observer rather perceives the whole world as a single entity without any sub-divisions. But simultaneously it is also capable of perceiving an infinite subdivisions of the world. Thus the new abstract observer is clearly having a highly dualistic behaviour which is quite paradoxical.

These ideas appear to be very similar to the concept of knowledge in the Indian philosophy (specially Sāṁkhya darshan and Jaina philosophy).[6] It is mentioned in almost all schools of thought in the Indian philosophy that the true knowledge of this world is structured in our consciousness (an entity completely different and independent from this material substance) and so this true knowledge can be acquired only when one relinquishes this material world and isolate oneself from this material world. This isolation is then described in such a way that from one point of view this pure consciousness has dissociated itself completely from the material world but from the other point of view this pure consciousness (subject) has completely merged into the materialistic world and hence it can perceive the whole materialistic world and its different parts directly, completely individually and simultaneously. Such a perception is called an absolute perception.

Thus using the scientific terminology we have clarified the age old problem of the absolute knowledge, a perfectly deterministic causal world and the qualities of an abstract observer who can have such a perception. It should be quite clear that this observer will perceive the reality as it is irrespective of whether the reality is classical or quantum mechanical or something else. In addition our abstract observer is very similar to the Laplacian imaginary demon who can perceive the whole classical world simultaneously in one perception. Thus our formalism describes the properties of the Laplacian imaginary demon.

A fundamental defect of this formulation is that nothing has been said about the nature of this perception and the information transfer from the causal world to the observer. This problem is very similar to the problem of conception of the ultimate knowledge, ultimate perception and ultimate observer in the modern science. However we conclude this section by stating that a mere postulation of a perfectly deterministic causal world and a suitable observer to observe such a world leads us to a paradox.

But still we shall discuss this topic further. First of all we shall study the implications of this formulation in the light of some quantum mechanical problems using the ideas of the Indian philosophy. An interesting feature of the Jain philosophy is then discussed which will indicate the real significance of the present work. This is done in the V section which contains some general remarks also.

V

Our Formulation; Quantum Mechanical Problems and Indian Philosophy (A Quantitative Analysis) :

Quantum mechanical discoveries have shown that our knowledge about the reality has to be essentially quantum mechanical. But this conclusion is based on the following assumptions: (i) the measuring apparatus, (ii) the transfer of information from the measuring apparatus to our brain, (iii) the analysis of this information in our brain and (iv) working of our brain are all four following the laws of classical physics. Thus at some stage of our description we have to take help of the ideas of classical physics. This is highly objectionable because many have argued that neurobiological processes in general and the thought processes in partcular might be following the quantum mechanical laws. It is also not correct to treat the above three factors from a classical level when we realize that ultimately the whole nature is following q. m. Thus our quantum theory is still not a complete theory in itself.

The second fundamental problem in q. m. which we have discussed earlier is about the unity of nature at the quantum level. This means that the whole world should be treated as one single unit which therefore can not be divided into different parts having distinct characteristics.

Lastly the quantum mechanical variables (complementary pair of variables) like position and momentum for a given system like an electron can not be specified simultaneously with a perfect accuracy. Hence it is advisable to have a reasonable balance between both the complementary pairs of variables describing the system in order to have a reasonable description of the system with a similarity with classical physics.

These problems in q. m. leads to ask us the following questions:

(a) If we allow all the above four factors to behave in a quantum mechanical way then can we regain the perfect determinism of the classical physics? (b) If we talk about the indivisible unity of nature then how far and to what extent can we go in differentiating the measuring apparatus or the observer from the object 2. (c) Can the present analysis provide us with some new ideas if we study these problems in the light of the concept of knowledge in the Indian philosophy?

As far as answer to the question (a) is concerned then it is quite obvious that it will not be possible to arrive at a concept of perfect determinism by allowing the above four factors to behave in a quantum mechanical way because by adding more uncertainties, we cannot get certainity out of it.

When we come to discuss the question (b) then also it is not difficult to conclude that for anydescription to be physically meaningful in our ordinary terminology, we have to make a division between the object and the observer at some point of our description. The line of demarcation may change from one description to the other. So we have to sacrifice the utopian view of the perfection, completeness and absolutism.

If we discuss these two problems together then we can make our position very precise. The basic assumption of all scientific theories is that all physical laws must be invariant under space-time transformation and independent of all human observers. Hence we have to assume all the above four factors to follow classical physics and we have to make a well defined division between the object and the measuring apparatus or the observer. As we do not have any other alternative approach to deal with these fundamental problems we are forced to adopt this artificial condition. But this is a serious restriction and a self-contradiction which needs some serious philosophical investigations.

Now we know that evolution and adaptation are two most fundamental characters of the biological systems and we have acquired the present state of the scientific brain through several stages of evolution and adaptation. I feel that too much emphasis on the invariance of the physical laws under the space-time transformation is just a part of the so-called scientific conservatism and it is a convenient device forced on us by our practical problems of lack of other suitable method of logical description. Thus I wish to emphasize that one must keep one's mind open and look for other approaches where some other laws are operating and some other conditions are more fundamental than the condition of invariance under space-time transformation.

It is in this spirit that we now come to discuss the question (c). As has been shown earlier it is remarkable that the idea of indivisible unity of nature has occupied an important place in the Indian philosophy. Hence it is mentioned that unless a subject merges completely into the object (nature) it is not possible to acquire the complete, perfect, absolute and true knowledge of this world. That is why it is specified that one who has understood onself has understood the whole world. This is essentially correct because in general an individual interacts with all the other systems present in this world, hence it implies indirectly that one who has understood oneself must have understood the whole world. It appears that in a very advanced state of meditation, one's awareness or the consciousness gets less localized and more globalized and this seems to be the meaning of merger of the consciousness into the materialistic world. In this state a person develops a very advanced state of eqanimity to all contradictory properties of nature (like our complementary variables). This kind of behaviour appears to be a macroscopic manifestation of quantum nature of our behaviour.

All this discussion look quite interesting and can be made really significant by giving the following quantitative proof of the reality of their ideas of knowledge through consciousness.

It has been mentioned in the Jain philosophy that the knowledge acquired through mind and other sense organs is a very limited knowledge and is restricted by space and time. Beyond this illusory knowledge there is another knowledge which can be acquired by oneself through spiritual enlightenment. For this knowledge space and time are no restrictions and it easily penetrates them. The purity of the consciousness can be improved and it can be developed to such an extent that one can even start perceiving the microscopic particles of matter. In appendix we have given a table used for the measurement of length by the ancient Jain saints. It indirectly gives a rough idea about the size of the smallest particle of matter as estimated by the ancient Jain saints through their knowledge of the consciousness. Their estimated value roughly lies in between the average size of the modern atom and the average size of the modern nuclei. Although this comparison is very crude but is still very significant if we note that this table is based on the literature which is as old as 2000 years. So if this agreement is not a mere coincident then it gives a very serious evidence about the reality of the so called inner intuition or the knowledge of the consciousness. Hence this problem must be further investigated with an open mind.

It is interesting to note that the characteristics acquired by a human being from the various practices required to achieve this kind of knowledge are very similar to the conditions laid down for the successful implementation of the modern experiments in the field of ESP. [7]

Lastly it may be noted that a very important condition mentioned in the scriptures about these ESP phenomena is this that all these spiritual practices are meant for one's own enlightenment and for the search of true knowledge of the nature and peace. Any supernormal faculty developed during this process is not to be treated as a very great achievement. If it is there it should be entirely used (if necessary) for the benefit of the individual or the society and should never be exploited for the material gain or the fame. This condition seems to be an indirect evidence of the fact that the neurobiological processes are quantum mechanical in nature and hence they can be made to behave whichever way an observer wishes. Hence there is a warning for avoiding its misutilization. This condition should be compared with the space-time invariance condition for the physical laws. Knowledge of these laws on one hand have open several new frontiers of knowledge but has simultaneously produced highly destructive weapons which are capable of destroying the very life on this planet which had investigated these laws.

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APPENDIX

Table of Measurement of Length as Found in the Jaina Literatrue[5]

(1)	Infinitely many parmāṇus	=	1 Avasannasanna skhandha
(2)	8 Avasannasanna units	=	1 Sannasanna skandha
(3)	8 Sannasanna units	=	1 Trutreṇu
(4)	8 Trutreṇu units	=	1 Trasareṇu
(5)	8 Trasareṇu units	=	1 Rathareṇu
(6)	8 Rathareṇu units	=	1 Uttama bhogbhūmi bālāgra
(7)	8 U. b. b. units	=	1 Madhyama bhogbhūmi bālāgra
(8)	8 M. b. b. units	=	1 Jaghanya bhogbhūmi bālāgra
(9)	8 J. b. b. units	=	1 Karma bhūmi bālāgara
(10)	8 K. b. b. units	=	1 Likṣā
(11)	8 Likṣā units	=	1 Yūkā
(12)	8 Yūkā	=	1 Yava (Barley corn)
(13)	8 Yava units	=	1 Aṅgula (Finger breadth)
(14)	6 Aṅgula units	=	1 Pāda
(15)	2 Pāda units	=	1 Vitasti
(16)	2 Vitasti units	=	1 Hasta (Forearm)
(17)	2 Hasta units	=	1 Rikku or Kisku
(18)	2 Kisku units	=	1 Daṇḍa or Dhanus (Bow)
(19)	2000 Daṇḍas units	=	1 Krośa
(20)	4 Krośa units	=	1 Yojana

Here a *parmāṇu* has been defined as the smallest particle of matter having no length, no breadth and no height. This is defined as a particle which can be only thought of but is not practically perceivable. The particle which is perceivable is a group of *parmāṇus*. The smallest of such skandha is an avasannasanna skandha. Let us therefore estimate its size by roughly taking the average size of a finger to be equal to 2 cm. We can therefore write the following simple formula by using the above table :

Size of one avasannasanna skandha $= 8^{-12} \times 2$ cm. $= 2.91 \times 20^{-10}$ cm. This value lies in between the average size of an atom which is of the order of 10^{-8} cm. and the average size of a nuclei which is of the order of 10^{-13} cm. Now it is not possible for us to do further comparison between these results because we do not know whether their avasannasanna skandha correspond to our atom or to our nuclei, we also do not know the actual meanings of most of the terms (objects) used in the above table. But even this rough agreement between these two widely different conjectures should be taken seriously because we must realize that this table is based on the literature which is as old as 2000 years and also the size of the microscopic particles of matter has been guessed by the so called knowledge structured in the consciousness.

NOTES

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