METAPHYSICS AND PHYSICS — A PLEA FOR A DIVISION OF LABOUR

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Study of science — rather physics — has generated by now a large number of theories, laws and experimental results of the physical world from microworld to macroworld through the ordinary world — the world of senses. There are, however, deeper significance behind all such knowledges required to be strictly analysed through the grammer of philosophy and not by common-sense-type philosophy. Such analysis forms what is called Philosophy of Science or Metaphysics. Herein lies the need of two distinct disciplines — Physics and Metaphysics.

Introduction

Physics is the most fundamental of the sciences for studying nature. Metaphysics can be defined as that which comes beyond physics, meta meaning after or beyond. The questions of metaphysics thus arise out of, but go beyond, factual or scientific questións about the world. The central part of metaphysics is ontology, the subject dealing with the nature of being.

In an earlier publication, we discussed on Physics, Mathematics and Philosophy[1]. In this paper we propose to further discuss the relationship of metaphysics to three areas of modern physics which continue to attract the interest because of an air of mystery surrounding them:

— interpretation of quantum theory; ultimate building blocks of matter;

— origin of the universe, big bang, space-time singularity at start;

— chaos theory and origin of complexity.

The aims of metaphysics and physics are related in the sense that they both strive to tell us something about the nature of reality or the external world. The methods employed, however, are entirely different, although the roles of logic and rational argumentation are basic to both the enterprises of philosophy and science. Science, in particular a

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basic science like physics, deals with factual, objective knowledge about what can be observed in the world we live in. This is done in terms of theories and natural laws. Philosophy, on the other hand, does not deal with factual, objective, verifiable knowledge at all. It rather examines the nature of knowledge itself and the limits of knowledge that we can have. It also analyzes concepts we use in science and in everyday talk.

We maintain that a philosophical treatment of questions arising out of science requires a special care not shown by all writers of popular science. Even competent scientists have been noticed to philosophize wildly. We will conclude that a division of labour among physicists and metaphysicians (or philosophers of science/analytical philosophers) would be beneficial for all. Let the physicists do physics — theoretical (mathematical) and experimental — properly and the metaphysicians take care of the interpretation of their results, including pronouncements on the nature of reality, world view, etc.

What is Metaphysics ?

'Metaphysics was regarded by Aristotle as a single comprehensive study of what is fundamental to all existence, all knowledge and all explanation.'[2] In the words of the English metaphysician F H Bradley :

> We may agree, perhaps to understand by metaphysics an attempt to know reality as against mere appearance or the study of first principles or ultimate truths, or again the effort to comprehend the universe, not simply piecemeal or by fragments but somehow as a whole.[2]

According to G E Moore, quoted by Strawson, the philosopher's main task — the metaphysical task — is that of answering the question :

> What are the most general concepts or categories in terms of which we organize our thought, our experience of the world.[3]

With the rising predominance of science, the discipline of the philosophy of science has come into existence. It examines critically the concepts and statements of science; these studies could also be included under the umbrella of metaphysics.

With regard to the relation between metaphysics and physics, or more generally between philosophy and science, and also about the task of philosophy, we find the following quotations form Wittgenstein's *Tractatus Logico Philosophicus*[4], most appropriate for our discussions in this paper :

> The totality of true propositions is the total natural science (or the totality of the natural sciences).
>
> Philosophy is not one of the natural sciences. (The word 'Philosophy' must mean something which stands above or below, but not beside the natural sciences).
>
> The object of philosophy is the logical clarification of thought.

Baker and Hacker[5] have shown how Wittgenstein's views on the nature of philosophy were opposed to Russel's. Russel considered philosophy to be a kind of science ; science and philosophy for him were akin in method and product. Wittgenstein from his early days maintained that the sciences were totally different in nature and pursued for very different purposes. Consequently, science is irrelevant for philosophy.

In summary, metaphysics is as old as philosophy and its scope almost as large as that of all of philosophy, excluding ethics. Metaphysics overlaps with other branches of philosophy known as epistemology, ontology and logic. Regarding the main task of metaphysics or philosophy in general, we favour the view that it is clarification of concepts and statements used in science as well as in connexion with our everyday experience. Metaphysics does not provide factual, objective knowledge as done by science. Rather, it critically examines the nature of this knowledge. When we remember this, many of the criticisms of metaphysics can be put at rest.

Criticism of Metaphysics

Kant, as one of the founders of what we today understand by metaphysics, started off with the aim of correcting the serious defects of existing metaphysics of his time and formulating something new on a secure scientific basis. In the preface to his major work, *The Critique of Pure Reason*, he writes:

> This attempt to alter the procedure which has hitherto prevailed in metaphysics, by completely revolutionising it in accordance with the example set by the geometers and physicists, forms indeed the main purpose of this critique of pure speculative reason. It is a treatise on the method, not a system of science itself.[6]

In this century, the main criticism of metaphysics has been that it attempts to construct an all-embracing system that cannot be tested by observation. The philosophical movement known as logical positivism (later called logical empiricism) preached by the Vienna Circle, strongly repudiated any need for metaphysics. Metaphysics, we were told, made impossible claims and made unfounded speculations. Thus the terms 'metaphysical' became almost a pejorative term.

A distinctive feature of the Vienna Circle was its attempt to develop and systematize empiricism with the aid of concept of logic and mathematical thoery, in particular on the basis of early work by Russel and Wittgenstein. The members of the circle shared a science-based outlook in the spirit of Ernst Mach and were hostile to old-style-metaphysics. The abstract myths parading as reality, the grandiose claims and the conflicting results — these seemed to many to be the essence of the metaphysical enterprise and sufficient reason for condemning.

In more recent times, a criticism of 'old' metaphysics has come from the proponents of what may be called 'new' metaphysics. According to them:

> The primary error of all classical metaphysics is the belief in a meaningful structure independent of man. The new or modern metaphysics begins with a denial that there is such an independent meaningful structure. It denies that such a structure could exist without man. It denies that our fundamental categories can be explained by extraconceptual reference . . . Primordial reality is man's relation with the world. Primordial reality is not an object; it is not a physical object; it is not a mental process. It is a relation. The relation is meaningful, but neither man nor the world is meaningful, apart from the relation.[7]

Notwithstanding attacks on what is usually understood as metaphysics, we do not believe that the enterprise of metaphysics — which still continues to draw many people to a study of philosophy — has been proved to be without value. We cannot blame metaphysics for not delivering the kind of knowledge delivered by science. As already mentioned, we believe the roles of metaphysics and physics are completely different. In its function of providing a clarification and analysis of concepts of science, metaphysics can indeed make a very positive contribution towards our understanding of not only the world of our everyday experience, but of the invisible world of physics as well.

Scope of Physics

Physics is the most fundamental of the sciences. It deals with what we can observe directly or with the aid of instruments in the non-living part of our environment, with emphasis on basic principles and idealized examples. Assuming that there exist laws of nature, physics tries to discover them (invent or construct them, according to some physicists). Physics establishes theories which can be checked against specially contrived experiments or other observations. To arrive at the theories, a host of concepts and definitions are introduced. Above all, we should note — as Galileo already did in the 17th century — that mathematics is the language of physics and almost all discussion in theoretical physics revolves around mathematical equations.

If a certain theory is found inadequate, a better one is sought which gives a better agreement with experiment, has a wider application and is perhaps mathematically more elegant or simpler. As Karl Popper[8] has pointed out, a physical theory is neither true nor false, in the sense of corresponding to an external reality. A theory is only more or less successful in describing nature. Furthermore, a thousand corroborative experiments do not prove a theory (limits of inductive reasoning), but a single decisive experiment can falsify a well-established theory pointing to the need of further research. In fact, Popper goes on to say that the hallmark of a sound physical theory is that it should be falsifiable in some way or other. If we cannot think of any method to falsify a theory, it may not be a good theory after all. According to Popper, it is this property of falsifiability that distinguishes a physical theory from a metaphysical theory. A metaphysical theory cannot be shown to be true or false.

As already pointed out, physics and other sciences give us verifiable, objective knowledge about the world we experience. In the first place, they provide us with explanation and prediction of events in the observable world. On the nature of reality or the relation between appearance and reality, a physicist *as a physicist* — we submit — should not speculate. The line of separation between metaphysics and physics should be respected by physicists in our opinion.

'At the heart of the scientific method is the construction of theories. Scientific theories are essentially models of the real world (or parts thereof), and a lot of the vocabulary of science concerns the model rather than the reality. For example, scientists often use the word "discovery" to refer to some purely theoretical advance. Thus one often hears it said that Stephen Hawking "discovered" that black holes are not black, but emit heat radiation. This statement solely refers to a mathematical investigation. Nobody has yet seen a black hole, much less detected any heat radiation from it.'[9]

'Generally, the more science moves away from common sense, the harder it is to decide what constitutes a mere model and what is supposed to be a faithful description of the real world.'[9]

Beyond Physics

Since no boundary can be set to human curiosity, a physicist is bound to speculate beyond what can be empirically known. There is often a flexibility in the interpretation of physical theories. The same experimental observation, say the scattering of an electron beam through a double slit, can be explained by different theories about the electron[9,10]. The theories, in turn, can be interpreted in a number of ways. Under these circumstances, can a physicist go a step further and say that his theory describes accurately the ultimate reality — how things really are? Can he also propose a world view, a scientific world view based on his observations in the laboratory and mathematical calculations?

In our view, this kind of extrapolation of science is not justified. It should be left to a metaphysician or a philosopher of science — the label is not important. What is important is that the terms and expressions used in a physical theory (eg, quantum mechanics), including the ontological status of theoretical entities, should be carefully analysed and interpreted by one who is good at it.

A thoughtful physicist is apt to ask himself, sooner or later, questions, which we can call metaphysical, about his work. What are the ultimate building blocks of matter? What is an electron — a wave or a particle? Can there be a single electron? What are energy, force, mass, charge, spin, gravitational and electromagnetic fields? What exactly are quanta, quarks, neutrinos, elementary particles? What do we mean by Heisenberg's inequalities? Are they intrinsic indeterminacies or our subjective uncertainties? Are space and time finite or infinite? Does the subject play a role in physical theories? (eg, Copenhagen Interpretation of quantum mechanics). Is the big bang theory true?

These and many other questions arising directly from a study of the subatomic world or from a study of the universe as a whole are the staple of philosophy of science or metaphysics and should be dealt with philosophically. An amateurish treatment by writers of popular science, whatever service they might be rendering by spreading science, may be misleading and be less than useful.

Physical theories can be visualized for everyday world of our experience only in the range of mesocosm (intermediate ranges of space and time). In the field of microcosm, or when dealing with the universe as a whole, of which we do not have any direct experience, the terms and concepts of physics employed may not have a counterpart in our everyday world. In other words, a study of the microworld throws up a host of questions which cannot be dealt with using the vocabulary or concepts of everyday knowledge or even of physics texts. On the other hand, a good philosopher — who has read Kant, Wittgenstein, Strawson, and some philosophy of science — can with relative ease handle questions such as status of unobservable entities, provide a conceptual analysis and an explanation, as far as it can go. This kind of treatment of the metaphysical problems by a philosopher, would be preferable to wild and haphazard philosophization by scientists innocent of philosophy. To illustrate these remarks let us consider a few examples, which also have popular appeal, from modern physics.

Examples from Physics

Interpretation of Quantum Mechanics

The quantum theory — including its later development into quantum mechanics and quantum field theory — is the best theory we do now have to describe the microworld. In fact, not a single event has been observed which would contradict the quantum theory. On the other hand, an interpretation of quantum theory has been found to be so counterintuitive that an endless debate is still going on, for more than 60 years, on how best to understand what the theory means. For example, how to visualize wave-particle duality of an electron, what does the wave function of an electron represent and what does a superposition of states in quantum mechanics really mean, how does the collapse of a wave function take place on measurement, why can we not know simultaneously the precise position and momentum of an electron, what are hidden variables, what is Copenhagen Interpretation? These are some of the questions still being discussed by philosphers of science. The fact, that there is so much debate and lack of agreement, will not be surprising if we remember that in philosophy there are always bound to be alternative points of view, alternative styles of philosophizing realism, anti-realism, empiricism. One can chose an interpretation that one finds convincing; **none is true or false.**

As an example of philosophical puzzlement arising out of interpretation of quantum mechanics, let us look closer at the controversial topic of Heisenberg's Inequalities.

These relations, introduced by Heisenberg in 1925, constitute a central theorem of quantum mechanics. They are also called the Uncertainty Principle of Heisenberg. According to it, one cannot know — even in principle — simultaneously the position q and momentum p (mass × velocity) of an electron. The product of the uncertainties of q and p is of the order of h, the Planck's constant ($h = 6.62559 \times 10^{-34}$ JS). That is

$$\Delta p \times \Delta q = h.$$

Stated differently, the electron does not have a precise position and a precise momentum at the same time. This is a rather simplified statement of the principle, but the main point is that its interpretation has caused a lot of controversy among scientists and philosophers of science for over 60 years. Are the Heisenberg's relations — uncertainties (our ignorance) or indeterminacies (objective quantum mechanical indeterminacies) or something else?

According to Mario Bunge[11,12] they are neither uncertainties nor indeterminacies. These mathematical relations follow from basic postulates of quantum mechanics. They should be understood as saying that at the quantum level (for micro-objects like electrons) the mean standrd deviations of, say, the position and momentum of an electron are inversely related so that if one is large the other is small. Subjective uncertainties do not have a place in physical theories according to Bunge and others. Bunge[12] says :

> both the — uncertainty and the indeterminancy interpretations rest on the tacit hypothesis that micro-objects are point like. But this hypothesis does not belong to quantum mechanics.

If an electron is point-like, then of course it has a definite position at all times even if we are unable to compute or measure it for some reason or other. Bunge suggests that electrons are neither (classical) particles nor (classical) waves, they are objects of a kind unknown to classical physics. They might be called quantons, for instance. They are extended objects with no definite shape or boundary. They have no sharp position. Normally the quanton has a non-vanishing spatial half-width and a non-vanishing momentum half-width. This explanation by Bunge allows us to view the most famous inequality in modern physics in a new light without astonishment (how is it possible that a particle cannot have a precise position and momentum at the same time?).

Cosmology

Similar to our study of the microworld — the world described so successfully by quantum mechanics — a study of the world in the largest scale, the world of stars and galaxies, including the question of the beginning of the world (or, of time itself), poses serious philosophical questions, despite the availability of good scientific theories. When we try to think of the universe as a whole and its origin, we are confronted with the age-old problems of space and time.

As an example of counter-intuitive theory which explains our observations in a far better way than older theories of physics, we can cite Einstein's General Theory of Relativity. It replaced Newton's Law of Gravitation and the assumptions of absolute space and absolute time. In Einstein's theory space and time were combined into a four-dimensional space-time. Instead of an universal gravitational force, attraction between two bodies was explained by the assumed curvature of the space-time caused by matter. Later, in the late 1920s, the observation of red-shift in spectra of stars and galaxies led to the conclusion that the universe is expanding in all directions at a uniform speed. When did the expansion start? Expanding into what? How will it end? Can we call these points in time the beginning and the end of the world, or even of time?

There are several scientific, mainly mathematical, models of cosmology available today. A widely accepted picture, called the inflationary theory in combination with the Big Bang theory, says that after a fleeting moment of inflation in the beginning, the evolution of our universe started with a Big Bang 15 billion years ago. This is nowadays preferred to a stedy state theory of the origin of the universe, where matter is assumed to be continuously created. There is also a model in quantum cosmology where the world is assumed to start from nothing or a vacuum, just as one treats vacuum fluctuations in quantum field theory. The world is assumed to start with a space-time singularity at time $t=0$. Time and space are assumed to begin at that moment, so to say.

What was there before the Big Bang ? Why was there a Big Bang ?

The wellknown scientist Emilio Segre, when asked about his view on the origins of the universe both on a scientific level and a metaphysical level, replied —

> I have no opinion on the origins of the universe. I have some knowledge of present cosmology, Big Bang, and so forth. I know that such theories are subject to change with time, although, each one leaves a residue which is incorporated in the next one. The origin of the universe does not seem to me to be a scientific question. Scientific theories are usually validated by experiment, consistency tests, and predictive power, all of which are hardly applicable to the origin of the universe. On a metaphysical level each individual may have his own opinions ; I do not know how to prove or disprove them.[13].

Another physicist, Charles H Townes, a Nobel Laureate, says on the same topic,

> I do not understand how the scientific approach alone, as separated from a religious approach, can explain the origin of all things. It is true that physicists hope to look behind the Big Bang and possibly to explain the origin of our universe as, for example, a type of fluctuation. But then, of what was it a fluctuation and how did this in turn begin to exist? In my view, the question of origin seems always left unanswered if we explore from a scientific view alone. Thus I believe there is a need for some religious or metaphysical explanation if we are to have one.[13]

Louis Neel, also a Nobel Laureate in physics, says quite modestly, 'A hypothesis is of interest only if it is possible to verify its consequences by discovering new phenomena or new directions. This means that all hypotheses concerning the origin of the universe do not belong to physics but to metaphysics or to philosophy and that physicists as such are not qualified to deal with them.'[13]

From these quotations we see that the basic questions of cosmology are far from being solved. Although a certain model has been accepted to explain astronomical observations as closely as possible, cosmologists are carrying on their reseraches to fine-tune the existing theories and to deal with the troublesome singularities. Notwithstanding success in all these efforts, the metaphysical questions remain open and one should not overlook this.

Chaos Theory and the Origin of Complexity

Leaving aside the two worlds of very small and very large sizes, the microworld and the universe as a whole, both of which lead a physicist into metaphysical problems, we find that equally open questions arise when he studies the observable, daily world of moderate size around him. We mean the existence side by side of order and disorder, periodic and chaotic behaviour, simple and complex systems. In a recent meeting on chaos theory[14], Professor G Hausler of Erlangen pointed out that the title 'chaos theory' or 'chaos research' is slightly misleading. One should rather use the term 'non-linear dynamics' beacuse a non-linear system can reveal both a chaotic and orderly behaviour, depending on the values of the parameters chosen in the equations describing them.

Chaos in a system can be defined as random fluctuations that are deterministic in origin. Non-linearity is a necessary but not a sufficient condition for chaos. An excellent example of a non-linear sytem is a coupled system with feedback, such as a videocamera looking at a monitor coupled to it. Both symmetric patterns, illustrating 'fixed points', and chaotic pictures are seen on the monitor depending on the nature of noise introduced in the circuit.

Using a slightly technical language, let us consider a dissipative non-linear system whose motion may be described by a trajectory in phase space. Depending on the value of the control parameter, the trajectory will tend, with the passage of time, towards one of the following alternatives:

a point attractor — a stable final state;

a periodic attractor — a closed curve in phase space;

a quasi-periodic attractor — non-repetitive periodic motion;

chaotic, strange or fractal attractor — eg, Lorenz attractor.

By attractor we mean a region in the phase diagram to which a point, representing the motion of a system, is attracted. The actual source of chaos is the property of the non-linear system of separating initially close trajectories exponentially fast in a bounded phase space.

The predictions of chaos theory have found corroboration in different physical sciences — physics, chemistry, hydrodynamics, meteorology, animal populations etc. The numerical constants in the equations controlling the onset of chaos, was found to be the same in widely different types of systems, showing a universality of the phenomena. This is an example of a good marriage between physics and mathematics.

In the last two decades or so, the chaos theory and the related field of fractal geometry have become a most fruitful area of interdisciplinary research, mainly due to the availability of high speed computers. Computers were used for numerical solution of non-linear equations as well as for presentation of fractals — beautiful repetitive patterns on the colour monitor. H O Peitgen, wellknown author of many books in this field, writes :

> Chaos and Fractals represent together an attempt at a mathematical solution of the problem of complexity. For dynamical complexity, ie, complexity arising from a evolution in time, in connection with the theoretical or experimental predictability of strictly deterministic processes, chaos theory is relevant. It explains the nature of chaos, its measurable properties, and the transition of a

system from order to chaos. For complexity of structures and patterns, which we see in nature and which arise ultimately as an interplay of laws of nature, fractal geometry is the relevant topic. Almost always chaos shows a fractal trace. And often behind a fascinating fractal pattern, there is a chaotic process. Fractal geometry is the geometry of chaos.[15]

Peitgen also writes in the same book,

> Mathematics is the answer of man to the phenomenon of complexity in the world. Mathematics is the ruling power in the jungle of phenomena.

Other comments on the same topic, quoted in a German weekly[16] run as follows: Fractals have nothing to do with reality. Nobody has ever produced the structure of a natural cloud with the help of fractals. Apart from misleading similarities between fractals produced by a computer and the solutions of chaos (non-linear) equations representing phenomena in the world of experience, there is really no justification for thinking that chaos and fractals are identical, or that fractals are building blocks of chaos, or are tamed chaos. Connecting closely the phenomena of fractals and chaos, may lead to some wild extrapolations in the popular mind. One might wrongly start believing that scientists and mathematicians have at last found out that instability and disorder in society (chaos) are just a harbinger of ultimate order and beauty (fractals). No such 'redeeming world view' can be obtained from chaos theory or from any other scientific theory, in our opinion. For instance, the chaos theory tells us that for an open, dissipative dynamical system, interactions between its parts may lead either to synergetic effects and self-organization processes or to a state marked by fixed points and attractors. To attach a metaphysical label to the attractors as teleological goals, appear to us as far-fetched.

If the mathematics and physics of chaos are now well understood, what then are the metaphysical problems, if any, related to chaos research? In our view these problems are not as serious as in the cases of quantum theory and cosmology. Perhaps they are not full-blooded metaphysical problems at all. We would, however, still like to record our concern in this matter as follows.

Firstly, as Prof Hausler mentioned in the lecture cited above, we need to demystify the popular perception of the chaos theory; the new theoretical insights have in no way proved the edifice of modern physics to be invalid. Secondly, chaos research is based on exact scientific and mathematical concepts and we should not expect chaos theory to provide global teleological views. There is a tendency to apply mathematical models to social, political or economic matters. When doing this one should not forget that social systems by their very nature, cannot be expected to behave like a wellcontrolled physics experiment. There are too many unknown, unquantifiable parameters in a social system such as a group of people, a nation etc, to make any predictions about the onset of disorder, riots, stock market crashes with the same confidence as one might expect in the case of a pendulum or a water pipe. Already in the case of weather predictions, one cannot predict more than a few days in advance because of the underlying non-linear equations of meteorology susceptible to chaotic evolution.

The unpredictability of non-linear chaotic system is of a different kind than that seen in quantum mechanics. In the latter, the uncertainties (eg, Heisenberg's Inequalities regarding simultaneous knowledge of position and momentum of an electron) are built-in in the theory and are because of their statistical nature, irremovable. The 'particles' of quantum mechanics, thus, have no fixed trajectories. In the chaos theory, by contrast, the trajectories are in principle uniquely determined, but for all practical purposes, they are so sensitively dependent on initial conditions that no prediction is possible. In neither case, however, are the age-old metaphysical questions of causality and determinism, affected ; only, the limits of what we can know from physics becomes clearer on a closer look at the underlying theory. At best we can say, in physics, like causes have like effects, rather than same causes have same effects, because of the unavoidable uncertainty.

Conclusion

Physics, as the most fundamental of the sciences, aims to describe the non-living world around us. It uses a set of concepts and mathematics for this. Physics depends on models and theories for explaining observations and for predicting new observations. Theories are corrigible. An assumption is generally made, often unconsiciously, that nature obeys rigid laws expressible in mathematical terms. The main aim of science is to find theories and laws of nature which can be corroborated by observation and are independent of the observer.

There exist good theories to explain the inanimate world in the smallest or the largest scale, or in the intermediate range. While good agreement between mathematical predictions and results of careful experiments can be found, an interpretation of the underlying concepts and equations of physics has proved to be problematical.

These problems are metaphysical or philosophical in nature. A philosopher of science or metaphysician will remind us that metaphysical questions cannot be answered in a 'yes or no', 'true or false' manner. A physicist as a physicist, should not draw unjustified conclusions from the exciting new results of modern physics.

We have tried to show how the situation becomes particularly confusing in the fields of the microworld — treated by quantum mechanics and cosmology — treated by the inflationary and Big Bang models. Similarly, in the world of medium size, we face problems which arise from non-linear equations of motion; order and disorder lie side by side, regular and chaotic behaviour alternate, we see growth of complexity.

In each case, we urge the obvious course: judge each individual problem on its merit; clarify the language and concepts used, remember the separate roles of physics and metaphysics and their limitations and let there be a division of labour. Even if all questions are not answered, we are bound to come out, after following the prescription, with a clearer understanding of what we can know of how things are.

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