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Review Article / Derleme

Some Critical Points in the Methods and Philosphy of Physical Sciences

Fiziksel Bilimlerin Felsefesi ve ve Metotlarındaki Bazı Kritik Noktalar

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ABSTRACT

Nowadays, it seems that there are not enough studies on the philosophy and methods of physical sciences that would be attractive to the researchers in the field. However, many revolutionary inventions have come from the mechanism of the philosophical thought of the physical sciences. This is, of course, a vast and very interesting topic that must be investigated in detail by philosophers, scientists or philosopher-scientists such as physicists. In order to do justice to it one has to write a book. For example, you may think mainly of the historical aspect that is how methodology and philosophy of physical sciences developed in the last century and how it influenced the development in science. One may also think of the topic of methodology and philosophy in physics treated by a philosopher, a scientist or a physicist, which would mean from quite different points of view. Another important question of this topic that needs to be answered is the question of what can be done in methods and philosophy of physical sciences in the near future.

The aim of the study: For a quarter of a century I have been interested in " Philosophy of Sciences " as a hobby and from time to time have given lectures on this subject to students of physics as an elective course, in which one of the main subjects of the course was "Philosophy and Methods of the Physical Sciences ," I would like to share my experience , knowledge and research results on these topics with distinguished science readers of public and to acquaint philosophical and methodological ideas that play an active role in the development process of physical sciences for those who want to do research to shed some light on this issue. In this direction, science of physics, relation between physics and philosophy-science, the philosophy and methods of classical physical sciences, philosophical comments of quantum theory, the methods and philosophy of modern physical sciences, Philosophy of Physics and the Methodology, how a scientist works to get a better understanding of the laws of nature, success through method, Einstein's methodology, impact of relativity, the conflicting views in the progress of modern physics, and the strategy adopted in the study of physical systems, have been examined.

Keywords: Scientific Method, Philosophy of Physics, Methods and Philosophy of Physical Sciences.

ÖZET

Günümüzde, Fiziksel bilimlerin felsefesi ve metotları konusunda yeterince ilgi çekici çalışmalar yapılmamaktadır. Oysa birçok devrim niteliğindeki buluşlar, fiziksel bilimlerin felsefi düşünce mekanizmasından çıkmıştır. Bu konu, kuşkusuz, filozoflar, bilimciler veya filozof-bilimciler gibi fizikçiler tarafından ayrıntılarıyla incelenmesi gereken çok ilginç ve geniş bir konudur. Onu hakkıyla yapabilmek için insanın bir kitap yazması gerekir. Örneğin, başlıca tarihsel görünüşü düşünebilirsiniz ki o: geçen yüzyılda fiziksel bilimlerin felsefesi ve yöntemleri nasıl gelişti, bilimin gelişmesini nasıl etkilediğidir. İnsan, aynı zamanda, bir filozofun, bilimcinin, ya da fizikçinin fiziğin yöntemi ve felsefesi konusunu, oldukça farklı bir görüş noktasından incelediğini düşünebilir.Bu konuda yanıtlanması gereken diğer bir önemli sorun, yakın gelecekte fiziksel bilimlerin felsefesi ve yöntemlerinde ne yapılabileceği sorunudur.

Bu çalışmanın amacı; çeyrek asırdan beri bir hobi olarak ilgilendiğim ve zaman zaman seçmeli ders olarak fizik öğrencilerine verdiğim "Bilim Felsefesi " dersinin ana konularından biri olan, "Fiziksel Bilimlerin Felsefesi ve Yöntemleri" konusundaki araştırmalarımı ve deneyimlerimi, bilgimi, kamuoyunun çok değerli bilim okuyucularıyla paylaşmak ve fiziksel bilimlerin gelişim sürecinde etkin rol oynayan, felsefi ve metodik düşünceleri tanıtmak, bu konuda araştırma yapmak isteyenlere bir ışık tutmaktır. Bu doğrultuda; fizik bilimi, felsefe-bilim ve fizik ilişkisi, klasik fiziksel bilimlerin felsefesi ve yöntemleri, kuantum kuramının felsefi yorumları, modern fiziksel bilimlerde benimsenen felsefe ve yöntemler, fizik felsefesi ve yöntemler, doğa kanunlarını daha iyi anlamak için bir bilimci nasıl çalışmalı, metod aracılığıyla başarı, Einstein' in metodu, görelilik kuramının etkisi, modern fiziğin gelişiminde çelişkili görüşler, ve fiziksel bilimlerin incelenmesinde benimsenen stratejiler " incelenmiştir.

Anahtar kelimeler: Bilimsel yöntem, fiziğin felsefesi, fiziksel bilimlerin felsefesi ve yöntemleri

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INTRODUCTION

There is not much interest on the philosophy and methods of physical sciences and there is barely any study that would attract our attention. Yet many revolutionary inventions have been the outcome of philosophical thoughts of the physical sciences. This is, no doubt, an interesting and vast subject that must be explained in detail by famous natural scientists or scientific philosophers. In order to do it properly one may have to write a thesis on it. For example, one may/can think of the historical appearance, which is related with how the philosophy of physical sciences and methods developed in the last century and at the same time how it influenced the development of science. One may, at the same time, think that a philosopher, scientist, scientific philosopher or physical philosopher can/may examine the methodology of physical sciences and its philosophy in a very different point of view. What kind of studies can be done in our country on the philosophy of physical sciences and methods might be another question that needs to be answered. We are expecting philosopher physicists and scientific philosophers to show interest in this matter.

My main aim, as a theoretical physicist, in this review of related work:

As a theoretical physicist who every now and then lectured on scientific philosophy as an elective course and who is interested in it as a hobby, I have figured out from intensive questions and feed back at the conferences, seminars, papers presented at international physics conferences and articles released in my home country that this subject has not been studied or investigated enough by physicists. My goal is to share my research and review of related work with esteemed science readers, attract their attention, and shed some light on the subjects of interest on philosophy of physical sciences.[1-15]

After this introduction, before presenting a synthesis of various views and thoughts given in literature on 'Some critical points in philosophy of physical sciences and methods' I thought it would be useful to define some crucial scientific notions like, physics, relations between physics and philosophy and science. After answering the question 'Do physical sciences, a crucial part of philosophy and science, have a philosophy and method of its own' contradictory philosophical views will be discussed in the developmental period since 17th century.

As a final point, it is examined that some critical points in the philosophy and methods playing important role in the process of development of modern physical sciences in the 20th century, such as some new theses on philosophy of physics, philosophical interpretation of quantum theory, some methods and philosophy adopted in the modern physical sciences, how a scientist would study to get a better understanding of the laws of nature, success through method, Einstein's method, influence of the theory of relativity, the conflicting views in the progress of modern physics, and some strategies adopted in the examination of physical sciences.

What is physics that play an important role in the development of science, philosophy, technology, and various branches of science?

Physics, the basic science of nature, is a whole that consists various branches of science which, through trial or theoretically, examines the interaction among the inorganic matters of the perceivable universe either formed in laboratory or that man encounters directly in nature. The vast field that comprises every event including the movements of stars and galaxies, the basic particles forming quark and electron, is the subject of physics. Yet, physics is limited with the most general and basic appearances of the matters and events. Physics is not only descriptive like mathematics but also it plays an integrative role between theory and experiment. [3,6,7,9,10]

Relation between physics and philosophy-science:

The classical period of philosophy starts at the end of 16th century. According to the prominent philosopher and mathematician Descartes, philosophy is like a tree whose roots are of metaphysics, and stem of physics, and branches are of medicine, mechanics and ethics.

Descartes says "ethics is the highest science because it requires other knowledge to be known". He sees philosophy as the perfect expression of physics and metaphysics. He says' God determines all the rules of physics ' , and according to him God's knowledge is the mandatory condition of all other knowledge.

Descartes who says 'Cogito ergo sum' (I think therefore I am) and who gives priority to mathematics due to the definiteness and clarity of its proof wants to restore mathematicians to prove that God's existence is as clear as 2+2=4.

Leibniz thinks Descartes' clarity principle is the source of many errors and he proposes **causality principle** in which he negatively says there's nothing without any reason and positively he says everything has a reason. [3]

Do physical sciences, inseparable parts of philosophy and science, have methods and philosophy of their own?

The research methods of classical physical sciences resulted basically from experiment and philosophical views. Part of the philosophical views is general and the others are related with nature. The philosophy and methods of physical sciences offer various and mostly contradictory but gradually formative forms. For a long time a priori and theoretical attitude has been accepted as superior to experimental knowledge. In the ancient Greek and middle ages when Aristotle's views were dominant in a system where physics could inspire from metaphysical views, physics was thought to content with little directly perceivable data that would form a whole. Like Descartes we can see this theoretical dominance in Galileo who is considered to be the first founder of experimental physics in 17th century; but these physicists have brought a new understanding of physics depending on mathematics and contradicting with Aristotle's' qualitative physics. On the other hand in the same period an experimental physics movement by English physicist Francis Bacon started. Bacon gave knowledge a practical aim. To him you should not only know the nature but also be effective on it. Due to his distrustfulness to reason he proposed to apply experiment and observation of events as the criterion of truth and the method of induction as the sampling method because the facts were hidden behind 'idol's wrong ideas whose masks must be taken off.

These two tendencies, particularly with the efforts of Pascal, Huygens, Hooke, Marotte and Newton, started to be consistent in mid 17th century. The supporters of this trend/movement who considered physics as a whole formed in induction through open principles, appropriated to give these principles to the inspection of experiment. Yet those who defended the superiority of the facts considered them as assumptions that might cause suitable results to pass through experimental tests but mostly far away from the facts. Newton who built classical mechanics on axioms and principles is one of them even though he says 'I don't propose any assumption'. Finally in spite of all revolutionary results, experimental method is merely one of the two basic tools in the methodology of physical sciences. The other is the mathematical method used in the formation of physical explanation. The association of this method with the experimental one is a dazzling period of development that has started in physics. The component that gives classical physics and modern science its real power is this association called **hypothetic- deductive** method developed by Newton. This method has the explanatory nature that provides suitable mathematical hypothesis to infer observational facts.

As is known, scientific method starts with observation, but it does not contend with it. Observation is reinforced with experiment and description is completed with mathematical explanation. Then from this explanation some results are reached at through mathematical methods and they are compared with facts. However what these facts prove right might be conditions that may include more than the facts tell. It is possible to have different observations than theory or mathematical explanations proved right. Newton is brave enough to go to an abstract theory but a cautious one who wouldn't consider a fact right if not proved with facts.. The same attitude is seen in A. Einstein.

Mathematical method helped physics have its preventive power. Physics owes its physical scientific success to mathematical deduction that combines observation and experiment. G. Galileo is the first person who noticed the importance of mathematics in physics. Galileo's words '**The book of nature was written in mathematical language**' have been proved beyond all his expectations in the following centuries. Actually with their requirement and universal features the natural laws seem to have the characteristics of mathematical laws. Mathematical law has been a tool to explain not only the facts but also the prologs. It gives the physical scientist the power of predicting the facts. When compared with the power of hypothetic-deductive method, the inductive reasoning, reasoning achieved with simple generalization remains very poor. 'What is the source of this power? An answer to this question might be 'Between everything in nature there must be a strict order suitable to explain every phenomenon with mathematical relations.' **This order is called causality principle**.

From the perspective of classical physical sciences the idea that everything that happens in nature has strict causality is the thought of modern ages. There is no trace of such an idea in ancient and Middle Ages. The determination of classical physical sciences is very distinctive. Its root must be looked for in the success of mathematical method in physics. Because it is impossible to interpret physical laws as mathematical relations and to find certain prologs from deductive methods and use them, we must think there is a mathematical order and casual relations behind the apparent disorder. According to French mathematician Laplace 'If we cannot know or catch this order it is because of our insufficiency'. [3,9,10,14]

The philosophy of classical physical sciences:

We see two conflicting philosophical movements in 17th century. One is renaissance naturalism and the other is mechanical philosophy founded by Descartes.
Renaissance naturalism depended on the belief that nature was a mystery no man could ever understand. Idea-material and spirit-body couldn't have been thought as different quantities. Ariosto's form principle had a similar role in a more elegant nature philosophy.

The mechanical nature philosophy founded by Descartes tells to abandon the research method through intuition and declares that nature does not have non analytic mystery and that it has a known structure for reason.

We can say that Descartes' mechanical nature philosophy is a definite break off from the dominant notion renaissance naturalism represented and from Ariosto's in a similar way. In this sense Descartes was the speaker of the 17th century with an ardor of making a new start and was illuminating new developments. [13]

From the 17th century on in the developmental process of physical sciences there have been two contradictory philosophical views challenging:

One of them is rationalist philosophy. No existing thing can have an explanation contrary to that of the human mind can accept. It puts forward that the world, namely the elements that form the universe and the world in time are bound to comprehensible causality and constant laws. Historically reasoning is bound to struggle for the autonomy of science against religion. Leibniz, Spinoza, Kant, and Descartes are those who fought for this.

The second one is experimental philosophy. Experimental philosophers build the basis of experimental philosophy questioning dogmatic reasoning. Asking whether reason can think and solve everything they reconsider the knowledge theory. They start to examine the thoughts and refute the existing conceptions directly and determine the limits. F. Bacon, Loke, and Hume are among the famous defenders of this view. With the end of 18th century we see the philosophy of physical sciences got into a tight corner. The amazing knowledge systems created by human mind seemed incomprehensible. The physical scientists were ignorant of this dead-end in philosophy. They made observations and built their theories and rode quite high. Yet no sooner than later they found themselves in dead-end at the end of 19th century. [5,6,7]

The new physics resulted from the crisis of classical physics; finally, it has brought the crisis in philosophy to solution.

One of the two points in the application of classical physics to events found insufficient occurred in the behavior of objects moving at high speeds such as elementary particle and the second one in the objects of very small atomic size events. Classical mechanics left its place to special relativity theory by Einstein in 1905, and the examination of smallest-dimensional events to quantum mechanics developed by Bohr, Schrödinger, Heisenberg, Dirac, and other distinctive physicists in 1920. A theory that ensured both relativity and quantum principles for both very fast and very small particles was needed. This theory was called quantum field theory developed in 1930-40s by Dirac, Pauli, Schwinger, and Feynman and hasn't been considered a complete one today. [5,10,14]

Two different philosophical views have been put forward on the application of classical physics to atoms: positivist philosophy and realistic philosophy:

Positivist philosophy was a positivist movement and was only dealing with perceivable facts. For this reason it opposed to the atomic model of the matter. It was influenced by the philosophical movement by A.Comte who thought explanations beyond physics were theoretically impossible and useless. This movement managed to save physical sciences from incomprehensible judgements and to direct them to the nature of the matter. However it prevented the development of physics in 19.th century in many ways. It particularly delayed the truth on molecules and atoms being known. It prevented also development of statistical mechanics. This scientific positivism has been used by A. Comte (1798-1857) as a social scientist and philosopher, and scientists Ernst March and Marcellin Berthelot.

As the founder of positivism and the great priest of man's religion A. Comte wanted to reorganize the society through an intellectual reformist way. He proposed this task to be given to social sciences, the top of positivist experimental sciences. A positivist A. Einstein denied the basic hypothesis (absolute universe, absolute time and mass) proposed by Newton and instead he proved that a relative time defined with positivist procedures and non-absolute universe and a mass that changes in very high speeds might be possible.

The second philosophical view, that takes both the perceivable truth and unseen truth into consideration. This philosophy which we can consider as the successor of atomic view considered the seen event related to matter's internal reason and took not only the perceivable truth into consideration but also the unseen truth.

Physical facts always have two sides, the event and the pure knowledge process develops in two levels: Experimental and theoretical level.

According to Boltzmann what govern the nature is not man's ideas but things that form the idea and surround the man permanently. Boltzmann was looking for the true and suitable image of physical truth of science with the help of models. Physical reality school supporters were unknowingly defending materialistic philosophy.

In the framework of classical physical theories Boltzmann's explanation of 2nd laws of thermodynamics and the kinetics theory of gases with statistical method depending on the atomic structure of matter is a good example of two-level development of knowledge.

Actually both views result from two contradictory physical understanding that spread to all physical sciences. Some philosophers and scientist defended that science wouldn't reach the truth. According to Henri Poincare "what causes a theory to be preferred to another is merely due to coming to an agreement". According to Vienna school (Carnap, Franck, Neuranth) that existed in 1930s and which was very influential at the time 'science was merely a language; metaphysics must totally be excluded from science.' This way of thinking was the propulsive power of current movement that had many supporters and defended science wouldn't be able to reach the truth of objects.

According to this movement, science must contend with models that do not contradict with experiment and that give possibility to certain envisages. In the meantime various physicists showed realistic approach. Prominent names about old quantum mechanics are adopted realistic approach by A. Planck, Einstein, Louis de Broglie and, in the more general sense, science philosophers Karl Popper and Mario Bunge.

We see mathematics contributed greatly to theoretical physical sciences and physical sciences contributed to mathematics from 17th century on. The main influence of this great development in positive sciences is certainly on scientific philosophy.

In the historical developmental process there have been some factors preventing the development of physics. Prejudices in physics, conceptual mistakes, and theoretical drawbacks are the main ones. As A. Einstein said "To relieve a prejudice is harder than smashing the atoms".

At the top of the drawbacks that prevent the development of physics come the ideas that the world is the center of the universe and concepts like absolute space, absolute time, absolute mass and Ether, that had been put aside by Einstein in the beginning of 20th century. The supporters of these views couldn't accept that they would be denied if they had kept the quality of being a basic principle for them.

Whereas, on the one hand measurements, its definiteness, and agenda of error evaluation concern, on the other hand, adopting a theory or determining the conditions that must be provided to prefer another theory, have been the driving force of these changes. This second problem has been the subject matter of new debates and extensive research in 1960's. The studies of Karl Popper and his friends, who considered the determination of theories are related to social and psychological behaviors, are greatly echoed in scientific world. Popper points out that even when the facts that confirm a theory are too many, they may not be enough to secure its being real and that only one contradiction might cause the theory to be unsuccessful. Besides Popper maintains that a physical theory that is closer to real "work" conditions may be verified through various tests and so that the truth will be closer to reach at. Standard theory that has been developed in high energy physics and which has had successful results is an example of this.

Physics has shown great development both theoretically and experimentally in recent years. At the same time it has gained more protective characteristics.

Certainly this branch of science aims at a rational synthesis relieved of metaphysics that causes uneasiness and drawbacks. It has gained a scientific characteristic that is ready to arrange and correct itself and to sail to new horizons with chemistry and mathematics.

Scientific productivity and diversity and usual yet unfamiliar and ultimate creativity of human mind have developed with integrative means. These things that do not almost fit to each other and that cannot be reduced to one another are in great harmony. They are the components of man's distress, eye catching brilliance, power and weakness, death and transitory existence, and immortal success.

In the end of 19th century when the thought that physics reached its ultimate level was accepted by almost all the physicists, from the last quarter of 19th century on new observations in physics couldn't be explained through classical physical theories, such as black matter radiation observed by Gustav Kirchoff in 1859; Henri Becquerel's discovery of radioactivity fact on uranium salts in 1896; hydrogen atoms spectrum in apparent zone. All these could have been explained with the development of quantum theory. [1,3,4,5,6,7,9,10,19,20,24]

Philosophical comments of quantum theory:

We observe that two different philosophical views have been put forward in the comments of quantum theory. One of them is the official comment defended by Bohr, Heisenberg, Pauli, Born and others (This group is called Copenhagen school). We call it **positivist explanation**. The other is the **Realist explanation** defended by Einstein, Shrödinger and others (This group is called Berlin School). According to positivist view the observer, the observed system and the measurement process are in the fundamental level. As long as no measurement is conducted, the system can be defined as a linear mixture of the probable conditions. By measurement, the system might collapse into a probable state.

The realist view contrary to the positivist one says "The observer's existence does not influence the events and physical laws; there is an objective world, the events keep happening even without observer. If measurement is not conducted the system will still be in one of the probable state, yet we do not have enough knowledge which one it is in. Measurement gives us this information". There are other comments apart from these two comments such as Paris School leaded by Louis de Broglie. [11,14]

Philosophy of physics and methodology:

In a recent major effort to provide an overview over the state-of-the-art of the philosophy of physics, the editors Jeremy Butterfield and John Earman, two of the most eminent contemporary philosophers of physics, specify the following central tasks. First, philosophy of physics is concerned with the interpretation of physical theories, which in many cases can inform philosophical discussions e.g. on realism, the concept of probability, or the nature of space–time. Second, philosophy of physics is concerned with'foundational issues in fundamental physics', which Butterfield and Earman regard as currently 'the most interesting and important problems in the philosophy of physics'. M. Kuhlmann and W. Pietsch's articles provide a detailed analysis in the form of eleven theses, delineating both the nature of the questions asked in philosophy of physics and the methodology with which they are addressed. These eleven theses have been given only their headlines in the following : [28,32]

(i) Philosophy of physics explores three main issues: methodology, fundamental concepts, and ontology.

(ii) The boundary between physics and philosophy of physics is blurry.

(iii) Philosophy of physics is interested in foundational problems of physical theories.

(iv) Philosophers of physics often engage in inquiries that are very similar to those of physicists working during periods of scientific crisis.

(v) Philosophy of physics also encompasses text-based methodologies.

(vi) While embedding in a mathematical framework is important, philosophy of physics explicitly goes beyond the purely mathematical content of physical theories.

(vii) Philosophy of physics takes a more pluralistic, non-partisan approach to physical concepts and theories than physics.

(viii) Philosophy of physics is historically informed.

(ix) Philosophy of physics is interested in all physical knowledge, including non- fundamental and also abandoned theories.

(x) Philosophy of physics makes normative claims about the methods of physics, and is interested in the scope and limits of physical knowledge.

(xi) Philosophy of physics has an eye on the social boundary conditions under which research in physics is carried out and tries to situate physics within the broader spectrum of human knowledge.

The methods and philosophy adopted in the modern physical sciences

Now, I shall attempt to give you some detailed idea of how a scientist works, how he or she sets about trying to get a better understanding of the laws of nature, by using the methods and philosophy of physical sciences.

One can look back over the work that has been done by many great scientists in the past. In doing so one has the underlying hope at the back of one's mind that one may get some hints or learn some lessons that will be of value in dealing with present-day problems. The problems that scientists had to deal with in the past had fundamentally much in common with the present-day ones, and reviewing the successful methods of the past may give us some help for the present.

One can distinguish between two main procedures for a scientist. One of them is to work from the experimental basis. For this, one must keep in close touch with the experimentalists. One reads about all the results they obtain and tries to fit them into a comprehensive and satisfying scheme.

The other procedure is to work from the mathematical basis. One examines and criticizes the existing theory. One tries to pinpoint the faults in it and then tries to remove them. The difficulty here is to remove the faults without destroying very great successes of the existing theory.

There are these two general procedures, but of course the distinction between them is not hard-and -fast. There are all grades of procedure between the extremes, and which procedure one follows depends on the subject of study. For a subject about which very little is known, where one is breaking quite new ground, one is pretty well forced to follow the procedure based on experiment. In the beginning, for a new subject, one merely collects experimental evidence and classifies it.

For example, let us recall how our knowledge of the periodic system for atoms was built up in the last century. To begin with, one simply collected the experimental facts and arranged them. As the system was built up one gradually acquired confidence in it, until eventually, when the system was nearly complete, one had sufficient confidence to be able to predict that, where there was a gap, a new atom would subsequently be discovered to fill the gap. These predictions all came true.

In recent times, there has been a very similar situation for the new particles of high energy physics. They have been fitted into a system in which one has so much confidence that, where one finds a gap, one can predict that a particle will be discovered to fill it.

In any region of science where very little is known, one must keep to the experimental basis if one is not to indulge in wild speculation that is almost certain to be wrong. I do not wish to condemn speculation altogether. It can be entertaining and may be indirectly useful even if it does turn out to be wrong. One should always keep an open mind receptive to new ideas, so one should not completely oppose speculation, but one must take care not to get too involved in it.

One field of work in which there has been too much speculation is Cosmology. There are very few hard facts to go on, but theoretical workers have been busy constructing various models for the universe, based on any assumptions that they fancy. These models are probably all wrong. It is usually assumed that the laws of nature have always been the same as they are now. There is no justification for this. The laws may be changing, and in particular quantities which are considered to be constants of nature may be varying with cosmological time. Such variations would completely upset the model-makers.

With increasing knowledge of a subject, when one has an established base to work from, one can go over more and more towards the mathematical procedure. One then has as one's underlying motivation the striving for mathematical beauty. Theoretical scientists accept the need for mathematical beauty as an act of faith. There is no compelling reason for it, but it has proven a very profitable objective in the past. For example, the main reason why the theory of relativity is so universally accepted is its mathematical beauty as well as its correlation to the known empirical facts. The idea of mathematical beauty in the laws of nature stems from the fact that the nature of the physical world may be expressed through mathematics (following, for example, Jean's Maxim: "The Great Architect of the Universe now begins to appear as a pure Mathematician"). [2,4,8,25,26,27,28]

Success through method:

With the mathematical procedure, there are three main methods that one may follow;

(I) To remove inconsistencies,

(II) To unite theories those were previously disjoint,

(III) To formulate phenomenological theories by using experimental data.

There are many examples where the following of method (I) has led to brilliant success. Maxwell's investigation of an inconsistency in the electromagnetic equations of his time led to his introducing the displacement current, which led to the theory of electromagnetic waves. Planck's study of difficulties in the theory of black-body radiation led to his introduction of the quantum. Einstein noticed a difficulty in the theory of an atom in equilibrium in black-body radiation and was led to introduce stimulated emission, which has led to the modern lasers. But the supreme example is Einstein's discovery of his law of gravitation, which came from the need to reconcile Newtonian gravitation with special relativity. In practice, the method (II) has not proved very fruitful. Present physics recognizes four basic forces in nature. In order of increasing strength they are the gravitational, the weak nuclear, the electromagnetic and the strong nuclear forces. The greatest ambition of physics is to unify the general theory of relativity, which describes the gravitational field, with quantum field theories, which provide a context for dealing with the other three known forces. If this will be achieved, all four basic fields of force would be described by the common concepts of a dynamic geometry of space-time. However, Einstein spent many years trying to unify them, without success. So far all attempts to unify them have mainly made their incompatibility more apparent.

Nevertheless, a number of recent developments (including super gravity, super symmetry ...) demonstrate that Einstein's grand aim of achieving such unification is not impossibility. The new Weinberg-Salam Theory (they won the Nobel prize for physics in 1979) is based on the so-called SU(2)xU(1) gauge group (often called quantum flavor dynamics, QFD), which describes and unifies all known weak and electromagnetic forces. It seems that a direct attempt to unify disjoint theories, where there is no definite inconsistency to work from, is usually too difficult, and if success does ultimately come, it will come in an indirect way. There are many good examples in physics to support this view.

In contrast to the method (II), method (III) has proved very fruitful in the physical sciences. In physics, there are so many good examples of phenomenological theories developed by distinguished physicists. One good example is the Bohr Theory of H-atom in atomic physics. When Bohr had put forwards his theory, he had calculated nothing. He had just guessed his results. He knew the experimental situation in chemistry, he knew the valences of the various atoms, and he knew that his idea of the quantification of the quantization of the orbits or rather his idea of the stability of the atom to be explained by the phenomenon of quantization, fitted somehow with the experimental situation in chemistry. On this basis, he simply guessed what he then gave us as his results.

Finally, Bohr's conjectures were proved by means of rigorous mathematical calculations based on quantum mechanics.

Whether one follows the experimental or the mathematical procedure depends largely on the subject of study, but not entirely so. It also depends on the man. This is illustrated by the discovery of quantum mechanics.

Two men were involved in quantum mechanics at the same time, Heisenberg and Schrodinger. Heisenberg was working from the experimental basis, using the results of spectroscopy, which by 1925 had accumulated an enormous amount of data. Much of this was not useful, but some was, for example the relative intensities of the lines of a multiplex. It was Heisenberg's genius that he was able to pick out the important things from the great wealth of information and arrange them in a natural scheme. He was thus led to matrices' representation in quantum mechanics.

Schrodinger's approach was quite different. He worked from the mathematical basis. He was not well informed about the latest spectroscopic results, as Heisenberg was, but had the idea at the back of his mind that spectral frequencies should be fixed by eigenvalue equations, something like that fix the frequencies of systems of vibrating springs. He had this idea for a long time, and was eventually able to find the right equation, in an indirect way.

Heisenberg and Schrodinger gave us two forms of quantum mechanics which were soon found to be equivalent. They provided two pictures, with a certain mathematical transformation connecting them. [2,27]

Einstein's methodology:

When a golden age started in theoretical physics in the beginning of the twentieth century, there was an unknown physicist, the creator of the relativistic mechanics, Albert Einstein. His lifelong works in physics had made a profound effect on the methodology and philosophy of science.

Einstein himself was a philosopher-scientist. Admirably, he actually used philosophy to create what is now a significant portion of modern science, making contributions which are today utilized in almost every "practical" domain of our society.

Einstein's methodology may be best demonstrated by the following passage taken from Philip Frank, Einstein his Life and Time:

"Since Einstein was chiefly interested in the general laws of physics or, more precisely, in deriving logically the immeasurable field of our experience from a few principles, he soon came into contact with a set of problems that are usually dealt with in philosophical works. Unlike the average specialist, he did not stop to inquire whether a problem belonged to his field or whether its solutions could be left to the philosophers"

He regards philosophy as the removal of borders between science and science-based philosophical inquiry. Thus Einstein's methodology may be considered as modern scientific skepticism which leads to a critical examination and to a cautious selection of some of their kernels in the light of new advances in human knowledge. [14,15,29]

Impact of relativity:

In order to understand the atmosphere in which theoretical physicists were then working, one must appreciate the enormous influence of relativity. Relativity had burst into the world of scientific thought with a tremendous impact, at the end of a long and difficult world war. Everyone wanted to get away from the strain of war and eagerly seized on the new mode of thought and new philosophy underlying quantum mechanics and relativistic physics. The excitement was quite unprecedented in the history of science.

Against this background of excitement, physicists were trying to understand the mystery of the stability of atoms. Schrodinger, like everyone else, was caught up with the new ideas, and so he tried to set up a quantum mechanics within the framework of relativity. Everything had to be expressed in terms of vectors and tensors in space-time. This was unfortunate, as the time was not ripe for a relativistic quantum mechanics, and Schrodinger's discovery was delayed in consequence.

Schrodinger was working from a beautiful idea of de Broglie connecting waves and particles in a relativistic way. De Broglie's idea applied only to free particles, and Schrodinger tried to generalize it to electron bound in an atom. Eventually he succeeded, keeping within the relativistic framework. But when he applied his theory to the hydrogen atom, he found it did not agree with experiment. The discrepancy was due to his not having taken the spin of the electron into account. It was not then known. Schrodinger subsequently noticed that his theory was correct in non-relativistic approximation.

The moral of this story is that one should not try to accomplish too much in one stage. One should separate the difficulties in physics one from another as far as possible, and then dispose of them one by one. [15,29]

The conflict views in the progress of modern physics:

With the development of quantum mechanics one had a new situation in theoretical physics. The basic equations, Heisenberg's equations of motion, commutation relations and Schrodinger's wave equation were discovered without their physical interpretation being known. With the non-commutation of the dynamical variables, the direct interpretation that one was used to in classical mechanics was not possible and it became a problem to find the precise meaning and mode of application of the new equations.

This problem was not solved by a direct attack. People first studied examples, such as the non-relativistic hydrogen atom and Compton scattering, and found special methods that worked for these examples. One gradually generalized and after a few years the complete understanding of the theory was evolved as we know it today, with Heisenberg's principle of uncertainty and the general statistical interpretation of the wave function.

However, Einstein found these broadly accepted interpretations of the quantum mechanics "fundamentally unsatisfactory" by declaring that "GOD DOES NOT PLAY DICE". In spite of this fact, it is not so well known that the development of quantum physics, too owes a great debt to Einstein. Surely, every student of modern physics knows of Einstein's contributions to quantum physics. A biographer of Einstein even declares, "No physicist had more to do with the creation of quantum physics than Einstein". He, who was initially in fact, one of the chief architects of the quantum theory, refused to accept its final form. He rejected the theory, not because he was too conservative to adapt himself to new and unconventional modes of thought, but, on the contrary, because the theory was in his view too conservative to cope with the newly discovered empirical data. Einstein has also been proceeding on different lines, lines of pure geometry. He should think naturally that further problems of physics should be solved by geometrical ideas. His great adversary, Niels Bohr, declared in 1961 that "were it not for Einstein's challenge, the development of quantum physics would have been much slower".

The early rapid progress of quantum mechanics was made a nonrelativistic setting, but of course people were not happy with this situation. A relativistic quantum theory was set up by Dirac who introduced the two-valued quantities, now called spinors in agreement with the general principles of quantum mechanics, and also accounted for the spin of the electron, although this was not the original intention of the work. But then a new problem appeared that of negative energies. The theory gives symmetry between positive and negative energies, while only positive energies occur in nature.

As frequently happens with the mathematical procedure in research, the solving of one difficulty leads to another. You may think that no real progress is then made, but this is not so, because the second difficulty is more remote than first. It may be that the second difficulty was really there all the time, and was only brought into prominence by the removal of the first.

This was the case with the negative energy difficulty. The difficulty is removed by the assumption that in the vacuum all the negative energy states are filled. One is then led to a theory of positrons together with electrons. Our knowledge is thereby advanced one stage, but again a new difficulty appears, this time connected with the interaction between an electron and the electromagnetic field.

When one writes down the equations that one believes should describe this interaction accurately and tries to solve them, one gets divergent integrals for quantities that ought to be finite. Again, this difficulty was really present all the time, lying dormant in the theory, and only now becoming the dominant one.

The difficulty of the divergences in quantum electrodynamics proved to be a very bad one. No progress was made for twenty years. Then a development came in 1947, initiated by Lamb's discovery about the shift of the 2S-state of hydrogen upward in energy. The problem of the Lamb shift was solved by Bethe while he was travelling in a train, which fundamentally changed the character of theoretical physics.

A feature of the calculations leading to the Lamb shift should be noted. It involved setting up rules for discarding the infinities. One finds that the parameter (e) denoting the charge of the electron in the starting equations is not the same as the observed value for this quantity. If we keep the symbol (e) to denote the observed value, we have to replace the (e) in the starting equations by e+5e, where 5e is small corrections which can be calculated. This procedure is known as renormalization.

These rules, which are precise, so as to leave well-defined residues that can be compared with experiment. But still one is using working rules and not regular mathematics.

Most theoretical physicists nowadays appear to be satisfied with this situation, but not physicists such as Dirac. Dirac believed that theoretical physics had gone on the wrong track with such developments and one should not to complacent about it. Time will show if Dirac is right, but there is the important fact that the discovery of particles and antiparticles by Dirac has changed our whole outlook on atomic physics completely. Generally one can say that every state consists virtually of all possible configurations by which one can realize the same kind of symmetry. Now, as soon as one knows that one can create pairs according to Dirac's theory, then one has to consider an elementary particle as a compound system; because virtually it could be this particle plus a pair or this particle plus two pairs and so on, and so all of a sudden the whole idea of an elementary particle has changed. Before Dirac, every physicist had thought of the elementary particles as unchangeable units which are just given in nature and are just always the same thing.

The next step in this direction was the idea of multiple productions of particles. If two particles collide, then pairs can be created; then there is no reason why there should only be one pair; why should there not be two pairs. If only the energy is high enough one could eventually have any number of particles created by such an event, if the coupling is strong enough. Thereby the whole problem of dividing matter had come into a different light. So far one had believed that there are just two alternatives. Either you can divide matter again and again into smaller and smaller bits or you cannot thus divide matter infinitely and then you come to smallest particles. Now all of a sudden we saw a third possibility; we can divide matter again and again, but we never get to smaller particles because we just create particles by energy, by kinetic energy and since we have pair creation this can go on forever. So it was a natural, but a paradoxical concept to think of the elementary particle as a compound system of particles. [2,27]

The present physics needs further modification:

It may be noted that there are many serious difficulties (of unsolved problems) remaining in physics, such as Divergences of Quantum Electrodynamics, connected with photon (or point charge), Unification of Fundamental Forces, Quantized Hall Effect in Low Dimensional Physics, Energy Loss in Condensed Matter and so on.

It seems clear that the present physics is not in its final form. Some further changes will be needed, just about as drastic as the changes made in passing from Bohr's orbit theory to quantum mechanics. Someday a new quantum mechanics, a relativistic one, will be discovered, in which one may avoid these infinities occurring at all. It might very well be that the new quantum mechanics will have determinism in the way that Einstein wanted. This determinism will be introduced only at the expense of abandoning some other preconceptions that physicist now holds. So under these conditions, Einstein will likely turn out to be correct. [26,27,30]

The Strategy Adopted in the Study of Physical Systems

Before closing my article on the "methods and philosophy in the physical sciences", I shall attempt to add a prescription about how the physical scientist should work. This would however be dangerous, because the prescription ought to be different for different scientists. But, one can look back over the first class work done by many great scientists in the past. The strategy that they adopted may be summarized as follows: The main feature of the strategy is that physical sciences are uncompromisingly based on experiment.

1) One should not stick too much to one special group of experiments; one should rather try to keep in touch with all the developments in all the relevant experiments so that one should always have the whole picture in mind before one tries to fix a theory in mathematical languages.

A really good theory developed by this way, may suggest new and interesting experiments which can be used to confirm it. But beyond this, such a theory goes, to suggest new areas of interest.

2) One should be somewhat skeptical about the work of others. In other words, one should adopt an attitude of not entirely disrespectful skepticism towards works in the same field.

3) One should always keep an open mind receptive to new ideas.

4) The analysis of a physical system tends to be carried out in terms of the properties of simpler systems. In investigating a system a scientist seeks to treat separately each factor influencing its behavior. Each of these factors is related in some important way to the original system, but has fewer factors that are vital to its behavior. Being simpler, systems can be investigated to the extent that properties are well understood.

To study physical sciences one must have a good level of mathematics. You may have heard the saying that mathematics is the language of the physical sciences. In fact, mathematics is essential in order to be able to trace quantitative logical connections in studying physical systems. The rules governing all such connections are the subject of mathematics. Thus, most of the rules and procedures of mathematics are directly applicable to the understanding of physical sciences. However, we must stress that this does not mean that mathematics is physical science or vice versa.

Consequently, when we obtain a result from a mathematical argument, we will be interested principally in both the physical meaning of the steps used to obtain it and the experimental verifiability of the result.

All these characteristic features of the strategy used in the study of physical systems are one of the most powerful inventions of the human mind. Its fruits have completely transformed the way the human race lives, the way its members think and the world they inhabit.

In many years the use of the strategy of the physical sciences has spread to all fields of science. Indeed, some fields, such as psychology and economics, are considered "scientific" to the extent that they make use of scientific strategy or parts of it. The strategy is most successfully applied in physics, however, because it is especially suitable for the relatively simple systems which are the main concern of physics. Put briefly, physics is the simple science because it studies the simplest systems. For this reason physics forms the foundation of all other sciences.[22,26,27,31]

The strategy adopted in the study of physical systems may depend on attitude of physical scientist. Some scientists prefer to solve one difficulty at a time. This may be right, but it was not the way the others looked at the problems. Niels Bohr used to say "If you have a correct statement, then the opposite of a correct statement is of course an incorrect statement, a wrong statement. But when you have a deep truth, then the opposite of a deep truth may again be a deep truth". Therefore, I feel that it is perhaps not only a deep truth to say, "You can only solve one difficulty at a time", but it may also be a deep truth to say, "You can never solve only one difficulty at a time, you always have to solve quite a lot of difficulties at the same time", and with this philosophical remark perhaps I should close my paper on the "Methods and Philosophy in the Physical Sciences".

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