ON THE PROBLEMS IN THEORETICAL PHYSICS – AN OUTLINE

R Sashikanth

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R. Sashikanth
Assistant Professor and Head of the Department
Department of Physics and Space Sciences
Gandhi Institute of Technology and Management,
Gangapada, Bhubhaneshwar,
Odisha, India.
E-mail : astrophysics1827@gmail.com, spaceweather@rediff.com
spaceweather@yahoo.com, spaceweather066@gmail.com

Abstract : The current paper falls under the category of a series of papers on *The General Theory of electromagnetic field.* The various problems in theoretical physics include those of electrodynamics, electromagnetism, Newtonian laws, Quantum mechanical laws, Maxwell-Lorentz equations etc which serve as some examples. This paper discusses some important aspects of theoretical physics in the framework of mathematics being used as a very important tool for explaining the natural physical laws. Hence, this paper fulfills the purpose of an introductory overview about the different problems in theoretical physics and the various inter-connectivities.

Keywords : Theoretical Physics, Godel's Incompleteness theorem, electromagnetism, quantum mechanics, Special relativity, General Relativity, Maxwell – Lorentz equations, Pulsars, chandrasekhar limit, Black holes, white dwarfs, Maxwell's displacement current.

1. Objective of Research

The objective of this theoretical research is to outline the various problems in theoretical physics. Many brilliant ideas in theoretical physics had given rise to revolutionary branches in physics and opened up new worlds of exploration. The structure and topography of theoretical physics is also explored briefly in this current paper. The main objective for this exploration is to eliminate the misconception that theoretical physics is just another branch of abstract mathematics. In addition, the use and abuse of logical reasoning is examined in the view of theoretical physics.

2. Introduction

It is a well known and well established fact that physics is an experimental science. Mathematical methods were used as a very useful tool to obtain the quantitative formulation of the natural physical laws and this was clear from the great works of Isaac Newton and other founders of contemporary physics. Newton was very much successful in applying the mathematical techniques to mechanics and hence the motion of bodies like billiard balls, planets and other macroscopic objects were predicted with good accuracies. The natural phenomena include both the macroscopic and microscopic domains. The physical laws consistent with one domain turn out to be definitely not the same for the other domain. Even stalwarts like Einstein had put lot of efforts to unify the macroscopic and microscopic domains – like trying to unify gravity and quantum mechanics. Early attempts were made to understand and unify the four fundamental forces in nature– gravitational force, electromagnetic force, weak nuclear force and strong nuclear force. Many theories like string theory, loop theory, knot theory, m- theory (membrane theory) came to the rescue, but still the unification appears a long way to go. The reasons can be multifold as the mathematical tools used might require huge modifications. It is true that much advancement had been achieved in trying to understand the fundamental forces of nature, but still many problems persist and new problems spring up to add up to the old set of problems. As old problems are solved with brilliant solutions, newer and newer problems are arising. This had inspired a brilliant mathematician Kurt Godel to formulate his famous " Godel's Incompleteness theorem".

3. Theoretical physics – a branch of mathematics ?

The last century had witnessed the huge applications of mathematical methods and techniques to physics and was found to be so extensive that a new branch of physics itself arose which goes by the name of *Theoretical Physics.* People often jump to quick conclusions regarding considering theoretical physics as a branch of mathematics. However, on a careful and refined analysis, it becomes quite clear that although the similarities are many in both, still there are differences between mathematics and theoretical physics. Partly, this might be due to a famous statement made by one of the most important stalwarts in Quantum mechanics – Paul

Adrein Maurice Dirac, which says " Physical equations should have mathematical beauty". Paul Dirac was a brilliant and strategic expert in using the mathematical techniques in bringing out the secrets of the quantum world. Dirac's relativistic wave equation for an electron serves as a serious case for the marvelous application of mathematical methods to quantum mechanics. Even Heisenberg's matrix mechanics, Max Born's probabilistic equations etc are some of the good examples in this regard. At this juncture, one can safely conclude that theoretical physics is no different from mathematics.

3.1 Problems facing theoretical physics

These are of two kinds – (a) The expression of physical laws in the form of quantitative relations, and the establishment of underlying correlations among the various experimentally established facts.

(b) The application of mathematical methods and techniques of investigation to find new physical laws and the prediction of new, as yet not experimentally observed connections between the various physical phenomena.

Hence, theoretical physics, in its methodologies looks like a mathematical science and appears a physical science, when the content is seen. Moreover, it is quite clear that the general theoretical viewpoints concerning the essence and the underlying theme of the various physical processes are embodied and made complete in theoretical physics.

3.2 Illustration through lucid examples

Lucid examples are indeed necessary to portray a crystal clear analysis of the situation. Let us try to understand this by means of a simple, yet a good example which accurately fits in the scenario. Researchers who established the planetary atomic model and the presence of discrete energy values in atoms and similar facts on an experimental basis, made a paramount contribution to the theoretical physics. However, we cannot confine theoretical physics to the mere qualitative model representations of the atomic structure. This is the juncture, where theoretical physics seeks to formulate the most general quantitative natural physical laws, expressing the underlying theme and essence of as wide a range of phenomena as possible. The Newtonian laws in Mechanics, The Maxwell – Lorentz equations in the laws of the electromagnetic field and the Quantum mechanical laws serve our purpose as some lucid examples in this regard.

3.3 Logical Reasoning – Is it the basis ?

Definitely, logical reasoning cannot be the basis of the general physical laws. Mere logical reasoning is sure to sidetrack the observed or experimental facts. Many a time, logical reasoning can come to the rescue, but still is inaccurate and insufficient, when it comes to the basis of the natural physical laws. Hence, the most general quantitative relations of theoretical physics are not 'derived', but they represent a generalized formulation of the observed physical regularities. On the other hand, the quantitative expression of the natural physical laws appeared as a result of the scientific predictions as is seen from most cases.

3.4 Theoretical physics eclispsing some important discoveries

This appears a bit weird at first sight as to how theoretical physics could eclipse some significant discoveries. Theoretical Physics has, at its disposal, a quantitative formulation of the general physical laws, making use of which new laws are established, by the means of the mathematical methods and tools. It can be said in this regard that theoretical physics had achieved huge successes in comparison with them that even some examples of scientific prediction as Leverrier's discovery of the planet Neptune in the nineteenth century had been eclipsed and appeared to be of minor importance.

3.5 Role of Theoretical Physics in the development of new and exciting branches of Physics

The examples being provided will indeed prove, as an undeniable fact, the key role played by theoretical physics in the development of some exciting and revolutionary branches of physics. Some examples will justify this : the discovery of displacement current by James Clerk Maxwell and the consequent establishment of the transverse electromagnetic nature of light (proving that light as an electromagnetic wave); the foundation of the special theory of relativity by Albert Einstein and in particular the establishment of the mass-energy relation; the development of the General Relativity by Albert Einstein and the establishment of gravitational force as warping of space-time; the Max Planck relation between energy and frequencyof the radiation and the explanation of Photo-electric effect by Albert Einstein; the prediction of the existence of the wave like properties of sub-atomic particles like electrons, protons etc by quantum mechanics (De-Broglie, Erwin Schrodinger, Heisenberg, Dirac etc,.) ; the prediction of the existence of anti-particles for particles by Paul Dirac's theory etc. The role played by theoretical physics in the recent development of nuclear physics and in the application of atomic energy is well-known.

3.6 Methods of calculation in theoretical physics

It is definitely much necessary to stress that the various methods of calculation employed in the calculation of the parameters in theoretical physics are of a special character. Moreover, theoretical physics is not a branch of mathematics. The distinction between theoretical physics and mathematics is as follows: In theoretical physics, one does not try to find the exact physical laws defining the behavior of even relatively simpler systems. A more precise, accurate and exact calculation of all the possible effects and interrelations would even make the most simpler problems totally insoluble in nature. The necessity of taking into account, the essential reasons and rejecting the unessential ones must be borne in mind at every stage of investigation in theoretical physics. Quite often, one finds that the various relations and equations in theoretical physics are so rigorous, tedious and complicated that one must practically and carefully proceed always by the means of approximate calculations. One must also proceed from the available experimental data in order to figure out the possible approximations and carefully reject the unjustifiable approximations which do not make physical sense at all. At the same time, the formulae and relations, which in principle cannot be checked through experimental means are sidelined in theoretical physics (Sometimes, these very formulae turn out to be radical, generating new possibilities and should not be ruled out !). All the various efforts of the theoretical and experimental physics are directed to explaining the existing relations in an objective sense, i.e. the physical laws of nature. A Physical theory explaining the known facts but unable to predict new ones is always considered unsatisfactory. On the other hand, the highest appraisal of the validity of a physical theory is the experimental confirmation of the facts predicted by it. In its turn, the elucidation of new phenomena observed experimentally serves as a stimulus for further development of theoretical physics. Hence, the experimental and theoretical physics make a single and inseparable whole.

4. Innovations and new branches in Physics

Many experimental phenomena and their various results of observation had led to new and exciting branches of physics. Numerous experiments were conducted in the 1800s on electricity and magnetism separately. Some of the stalwarts included Guass, Faraday, Henry, Ampere, Edison, Coulomb, Heaviside etc. It was not until the time of James clerk Maxwell, people realized that electricity and magnetism could be unified. Maxwell introduced a more realistic ‘ displacement current’ , that was the triggering point in electromagnetism and this was indeed needed to prove theoretically that light is an electromagnetic wave. Max Planck was working to solve the Black-body radiation problem where he could account for the Wien’s law at shorter wavelengths and Rayleigh-jeans law at longer wavelengths. This is itself the basis for the explanation of the photoelectric effect, compton effect and eventually quantum mechanics sprung up. Another serious case of interest is the Chandrasekhar limit which is a ground breaking discovery. Subramanya chandrasekhar worked on many topics which he stated as ‘left incomplete’ such as the mathematical theory of black holes, ellipsoidal figues of equilibrium, which was much necessary to understand the Pulsars (Pulsating radio stars). His outstanding works on many areas of theoretical physics (and astrophysics) paved the way to a greater understanding of many of the celestial and natural phenomena. Same is the case with Einstein’s General Relativity which explained gravity as the warping of space-time. Theoretical physics is an integral part of science and hence is inseparable.

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Conclusion

Some important problems in theoretical physics had been outlined and examined from various perspectives like logical reasoning etc. The key role played by theoretical physics in revolutionizing physics is highlighted in this paper. It is also clear that theoretical physics is much supportive to experimental physics in all respects. Theoretical physics and experimental physics must go hand in hand to have a good understanding of the natural physical laws governing the natural phenomena.

Limitations and Further Scope

The current paper highlights the various problems in theoretical physics. The further scope is to explore and identify the hidden problems in theoretical physics. The author strongly feels that radical ideas should be encouraged in order to find new solutions to the new set of problems in theoretical physics.

Research Highlights

1. The problems facing theoretical physics are outlined.
2. Examples are provided for a clear cut understanding of the situation.
3. Mere logical reasoning certainly cannot be a basis for the general physical laws.
4. Theoretical physics had given rise to exciting branches of physics and had eclipsed some important discoveries too.
5. The methods of calculation in theoretical physics are explained in a bit detailed manner.

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