The Will and the Plan in Science

by V. Appa Row, M.A.

(Professor of Mathematical Physics, Presidency College, Madras)

Published in 1931
Theosophical Publishing House, Adyar, Chennai [Madras] India
The Theosophist Office, Adyar, Madras. India

A lecture delivered during the Students' Week-end, Easter 1931 at the Theosophical Headquarters, Adyar.

WHEN I was asked to talk to you on "The Will and the Plan of the Logos in Science: in Physics", I felt I was not competent to speak on it. On further inquiry, I found I was to give you the march of scientific thought and progress in Physics, particularly within the last few years. The fundamentals of physics have been given a very rude shock during recent years, and much speculation has been made by scientists and astronomers on the change brought about. Among them I should mention to you Sir Oliver Lodge, Sir Arthur Eddington and Sir James Jeans.

Lodge's *Beyond Physics or the Idealization of Mechanism*, " being a survey and attempted extension of modern physics in a philosophical or psychical direction," is a recent production. The main object of the book is to find a place for life and mind in the world of physics as a primordial ingredient of the Universe. I am not to deal with such aspects of physics, and I believe I can never do that. The province is more metaphysical than physical. Life and mind are not to be explained in terms known to physics. Therefore the question is pertinently asked, *viz*., " Is it that our make-up is such that, we cannot be scientific, that we are perforce only religious?"

Sir Arthur Eddington and Sir James Jeans deal with mind and consciousness in relation to physics and have written very interesting books, *The Nature of the Physical World* and *The Mysterious Universe*. These books stand on a very firm physical basis and give food for philosophic speculation. I can confidently recommend these two books to those among you who have not already read them. They are certain to be read widely. The new line of philosophic thought based on the concepts of modern physics is very well depicted in these two books. A pure scientist may find it very difficult to agree with certain conclusions there, but I dare to say that he will at least be very much interested to read them.

My main endeavour is to try and give you, as far as I can, material from the science of Physics in its progress in recent years, from which it will be perhaps possible for you to infer the existence of a plan in the physical world.

The work of a physicist or a scientist is not to try and find out the " why" of things but the "how" of things. He starts with what is known as a working hypothesis, which is useful in so far as it logically and consistently explains observed experimental facts, and which is also useful in predicting some more verifiable facts. As soon as a set of facts, which are not explainable under the existing hypothesis, is

come across, another hypothesis or theory is formulated. Thus you should not be surprised to find that theories in physics are not unchanging. One thing however stands out, that the new theory is an improvement in so far as it is more comprehensive than the one rejected, and hence more useful in throwing more light on the explanation of the "how "of the physical phenomena. In seeking truth through physics it is customary to talk or explain in terms of certain fundamental concepts. You will find that electricity or electric force is the fundamental concept of modern physics. In explaining what it is we use terms which can be only explained ultimately in terms of electricity. Thus is created a cycle of concepts within which we have to wander and have our explanations. This is more or less analogous to the explanations of words we find in a dictionary. Thus it is clear that we have to reach some fundamental concept in physics behind which we do not and cannot go. This, in essence, is the explanation in physics, and we are to be content with it.

Progress in physics has resulted in recognizing matter and radiation as the two ultimate entities of the physical universe. We will first consider the progress of ideas regarding matter, and then of ideas regarding matter and radiation taken together.

Matter

That every piece of matter is an aggregate of minute indivisible particles is a very old conception. This smallest particle was supposed to possess all the properties of matter and was called the " atom". This is the atomic theory of the ancients. Now we all know that such a particle is called a "molecule" but not an atom. As knowledge grew and the ideas of the laws of chemical combination crystallized, it was recognized that a physical molecule is built of chemical atoms in definite proportions. Different substances were subjected to chemical analysis, and it was slowly realized that all of them are made of certain fundamental substances called elements. Spectrum analysis helped the classification a good deal, and it was soon understood that the diversity of matter as we find it in the Universe is after all a composite of these elements — hydrogen, helium, carbon, oxygen, etc. Chemistry was thus able to establish that 92 elements are the ultimate constituents out of which the whole world is built. This is a very great achievement, and it tended towards the belief that the building up of matter is a simple and logical process — simplicity in diversity. Mendelejeff, the great Russian chemist, classified the chemical elements thus far known, arranged them in the order of atomic weights and, by comparing the physical and chemical properties of the elements, was able to find a periodicity in these properties. The marvels of Mendelejeff's periodic table are very well known. Every element was given a definite place in the table. Certain gaps were discovered and those were the places to be occupied by elements to be discovered thereafter. Many such gaps were subsequently filled up by the discovery of new elements, whose properties wonderfully fitted into the periodic table as previously predicted by the genius of Mendelejeff. The maximum number of the elements in the table was fixed at 92 and up till now not one more could be added to the number.

About the year 1895 while conducting experiments on the discharge of electricity through the vacuum tube, Sir J. J. Thomson and his collaborators contributed the next great advance in the idea of the constitution of matter. The passage of electricity through gases at reduced pressure was studied. In particular the phenomenon of cathode rays — a beam of light starting out of the cathode of the discharge tube — was thoroughly investigated. It was shown that the cathode rays were not rays of light as ordinarily understood but were composed of a stream of minute electrically charged bodies called electrons, coming out of the cathode. The materials of the experiment were varied but the same

electrons were found to be the product of the discharge. The electron was soon recognized to be the ultimate constituent of all matter. The older conception that the chemical atoms were the ultimate smallest constituents of the Universe was abandoned. Further investigation revealed the existence of another kind of particles called protons to be co-existent with the electrons in a discharge tube. The mass and the electric charge of the electron and the proton were determined. The electron was found to carry a definite negative electric charge, and the proton to carry an equal amount of positive charge. The electron was found to have a mass 1,844 times smaller than that of the proton. Protons and electrons thus came to be recognized as the two final constituents of matter, out of which the Universe is built. This is certainly a very great step towards the law of simplicity of the structure of the Universe.

Structure of the Atom

It has thus been established that the 92 chemical elements of the periodic table, from Hydrogen to Uranium, are built of electrons and protons only. If so. what then constitutes the difference in the elements ? How are the different properties of the elements and the periodicity of their properties to be explained ? Can a consistent and logical structure peculiar to each chemical element be conceived to explain all the known facts about them ? These questions naturally arose and were to a great extent solved.

A structure of the atom which increases regularly in complexity as the atomic weight increases has been conceived by Rutherford, Bohr and Sommerfeld. In considering the structure, the place which any element occupies in the periodic table turns out to be very significant. The place is expressed as a number called the atomic number, and the atomic number of hydrogen is one and that of Uranium 92. This number *n* represents in the structure the number of free electrons that go round the centre. The centre of the orbits of these free electrons is conceived to be built up of 2*n* protons and *n* electrons, into a central nucleus or core. The nucleus possesses a resultant charge of n units of positive electricity. The whole atom with the nucleus and the *n* free electrons or n negatively charged particles has therefore no resultant electric charge. Each atom is conceived as a miniature solar system, and has its mass almost concentrated in the nucleus. Between the nucleus and the surrounding electrons it is all hollow. With such an image of the structure of an atom all the known properties of the elements in the periodic table have been wonderfully explained. Thus a logic and a system in the structural conception of atoms has been successfully developed with mathematics as the basis. *It must be anyhow remembered that these various structures built up out of electrons and protons are not all real or actual but only conceptual.* The whole thing is based on a working hypothesis which is found to be immensely useful. The intricacies of mathematical reasoning and the mathematical symbolism associated with it are so entrenching that there is no escape from it. You might conclude that a great mathematician is at the bottom of all atomic constitution, with a regular and a graded plan.

So far the structure of an atom only is considered. We have yet to consider the structure of molecules, and the structure of crystals as well. The knowledge of the structure of molecules is not yet very much advanced. The newly discovered Raman Effect has been found to be a very powerful tool in the elucidation of the mysterious inside and construction of molecules. Work is rapidly progressing and theoretical physicists are busy applying mathematics to the experimental facts regarding molecules. The structure of crystals has been studied by the chemist and much system has been brought into the study. In very recent years a powerful impetus has been given to this study by X-ray analysis of different elements and compounds, and as a result the crystal structure revealed is amazingly architectural with

wonderful symmetry about it. These different structures explain in their own and peculiar way the diverse properties of the different crystals. The whole thing again is a mathematical and logical concept which we cannot escape. Judging from the beautiful structures of the various crystals one may be tempted to conclude that Nature is verily a great geometrician and architect.

Matter and (Energy) Radiation

Matter is the stuff of which bodies are made. Besides this concept of matter which is very ancient, another which is akin to it, namely mass, was introduced into physics by Newton. The conception of the mass of a body is the outcome of Newton's laws of motion. The mass of a body is determined by its weight, or by the force required to give the body a definite acceleration. In the nineteenth century matter and mass were supposed to be identical, and so also the two great laws of the conservation of mass and the conservation of matter.

In the beginning of the nineteenth century mechanical energy, heat, light, electricity and magnetism were conceived to be all different from one another. The experiments of Joule and others first proved that mechanical energy and' heat are inter-convertible. Very soon Faraday and Maxwell did pioneer work and were responsible to a very large measure for the great triumph and conclusion of the nineteenth century, that all the various forms of energy are inherently one, and are different manifestations of the same energy generally called radiation. They were all conceived to be electromagnetic waves of varying wave-lengths. They range from the longest waves used in wireless telegraphy to the shortest cosmic rays. All energy is thus a great array of radiations, and energy like mass and matter is conserved. This was the condition of the thought about physics at the end of the nineteenth century. The mass of a body as originally conceived by Newton was thought to be fixed and unalterable. But conflict soon arose when J. J. Thomson showed theoretically, that a moving electrically charged body has a greater mass while in motion than when it is stationary. With the discovery of electrons — negatively charged particles having tremendously high velocities — theory could be substantially supported by experimental facts. Einstein with his theory of Relativity could calculate the addition of mass due to the energy of motion, and as a net result it was concluded that the total mass of a body is the sum of (i) the mass of the body when at rest — otherwise called matter or rest-mass — and of (ii) the mass due to energy of motion or energy-mass. Total mass=Rest-mass or matter + energy-mass.

A great transition of ideas was thus brought about by relativistic physics in the beginning of the present century. The three different laws of conservation of matter, mass and energy had to be knit together into one combined concept. Matter and energy are therefore conserved together, and the mass of a body includes both its matter and the energy associated with it. The principle of conservation of mass has come out to be the most fundamental. Energy is thus considered as a form of mass. Radiating bodies are considered to lose mass equivalent to the radiation emitted. Radiation can only be at the expense of mass. Sun and stars are therefore continually losing their mass. In short, modern astrophysics is inclined towards the conclusion that annihilation of matter is the only satisfactory explanation for the enormous radiation of stars. All this is tantamount to saying that matter and energy are essentially one and that we can realize a single and ultimate entity in the building up of the physical universe.

It is possible to approach the same realization of this single and ultimate entity in a totally different manner. Matter is made of electrons and protons which are identified as particles carrying unit electric

charges of the negative and positive kind respectively. Energy is supposed to spread in a continuous manner in the shape of waves. So let us now consider particles and waves in the place of matter and energy. The properties of particles and the properties of waves are very well known in physics to be distinct and different from each other, as is evident from the controversy of the corpuscular and the wave-theory of light. The chief characteristic of light or radiation in general is the phenomenon of diffraction and interference that which produces the halo round the moon. The phenomenon of interference of light — wherein light added to light can produce darkness — is the stronghold of the wave-theory of light, and it is because this phenomenon could not be explained by the older corpuscular theory of light of Newton that it had to be given up in preference to the wave-theory of Huygens and Fresnel. But in the last decade of the previous century, experimental evidence accumulated enough to doubt the total validity of the wave-theory of light. Light had to be considered corpuscular or particle-like in character if certain facts were to be explained. This point of view resulted in the epoch-making statement of Max Planck in 1900 of his famous quantum theory of light. Light or radiation in general is under this theory radiated out in quanta or bundles. The continuous character of the wave had to give place in certain phenomena to the discontinuous process of quantum radiation. The unit of light energy or quanta is called a proton, the unit of energy. Much light was thrown on many dark spots in experimental physics by this new venture in the physical theory of light.

Putting it in other words briefly, radiation behaves sometimes like waves and sometimes like particles or quanta. A duality of function for light has been consistently observed. This is only one side of the question. Waves and particles are the two distinct entities we started with, and we have known that waves have a duality of behaviour sometimes like waves and sometimes like particles. It is natural to expect the same from particles also. Why should not particles also behave sometimes like particles and sometimes like waves ? No evidence in this direction was available till very recently. A stream of rapidly moving electrons was sent through an extremely thin film of gold one-millionth of an inch thick and a phenomenon exactly like that of diffraction of light was observed. [Davison and Germer of America were the first to show this.] Concentric rings of varying diameter were discovered on the other side of the film where the electrons crowded in alternate rings, and this is exactly like having bright and dark concentric rings alternating. This is a clear evidence that electrons — particles — also behave like waves. These experiments were repeated with films of other substances like mica and the results were confirmed by many experimental physicists in America, Great Britain, Germany, France and Japan. Very recently an exactly similar phenomenon was observed with a stream of moving protons — positively charged particles — by Dempster of Chicago. Thus it is experimentally proved beyond doubt that electrons, and protons as well, behave in a dual capacity. So, particles behave like waves and waves behave like particles. Is it worth while then to view them still as separate and distinct entities ?

Certainly not, is the only answer that reason forces on us. Matter and radiation or particles and waves must be considered to have merged their duality of behaviour into a unity. This duality may be considered as the manifestation of a single and ultimate entity. When this single entity chooses to manifest itself like waves, and when like particles, and how it does it, all this is too much to say now. What determines the particular choice in the behaviour of the entity is not known. Perhaps it is a "Lîlã" [Lîlã, a sanskrit word meaning “play” or “sport”, is used in Hindu mysticism for one aspect, that of joy, of the creative energy of God — Ed] of the ultimate entity.

The New Natural Philosophy

This realization of unity in the diversity of the physical world in this clear and scientific way set many physicists and astronomers — not to mention mental and moral philosophers — to think of its inner meaning. All of them naturally began to philosophize about the facts in physics which were presented in an entirely new aspect. It is as if physics has once again to be significantly understood as " natural *philosophy* ". Some of the lines of thought that prominently branch out of such a new philosophy of physics are worth mentioning.

Waves and particles are regarded as two complementary rather than contradictory aspects of a single entity. The first attempt to conceive unity in this duality was made by Louis de Broglie in 1924, when he introduced the composite concept, Material-Waves. A definite wave-length is associated with every particle. This idea was confirmed by experiment, and calculations fit in with facts observed by Davison, Germer, etc. The idea of material-waves was developed wonderfully by a band of brilliant mathematicians, Schroedinger, Heisenberg and Dirac. Their theories are based on fundamentally different philosophical ideas. But curiously the mathematical content of their theories is one and the same. The results worked out explained not only all the previously known facts but many of the outstanding difficulties. Schroedinger started with the inherited classical conception of waves, *viz*., continuity, and began explaining atomic events. Heisenberg *abandoned* them — avoided the *pictorial imagery in the theory of the atom* — and started only with quantities that can be measured by experiment, *viz*., frequencies and intensities of spectral lines. In spite of these fundamentally different basal ideas behind the theories, the Wave-Mechanics of Schroedinger and the Quantum-Mechanics of Heisenberg proved to be equivalent, as regards the results. One very important view-point, that both the theories agreed to, is in regard to the interference and diffraction of light. Optical intensity is regarded solely as a measure of the probability for the incidence of light quanta at the given time and at the given place concerned. The greater this probability the greater is the brightness.

Principle of Causality Knocked Down

At this stage Heisenberg enunciated a great principle called *the uncertainty principle or the principle of indeterminacy.* This has become a household phrase throughout the modern universities and ranks in importance with the principle of Relativity.

"Classical theories assume the possibility of observation, without perturbation of the object under investigation." Modern quantum theory denies this possibility, and hence Heisenberg says: " Every experiment destroys some of the knowledge of the system, which was obtained by previous experiments." It is not possible to determine accurately both the position and velocity of a particle. Both are possible if much accuracy is not wanted. But aiming at accuracy of one will lead to a corresponding inaccuracy in the determination of the other. There is a positive uncertainty in the accurate determination of one of the two, and both cannot be determined equally very accurately. The most significant result in this principle of uncertainty is that the product of the two uncertainties is a constant, and is of the order of the quantum of action " *h*," Planck's universal constant. So it follows from this that experimental measurements are inevitably uncertain, and that this principle strikes at the root of the old ideas of determinism, and causality. Probability has taken the place of determinism, and is measured by the degree of chance. The old theories were based on the belief that the laws of macrocosm hold good in the atomic microcosm as well. The principle of indeterminacy is a negation of this old belief which brought in

a good amount of confusion into the understanding of physical facts. This new principle of Heisenberg asserts that it is not possible to have an exact knowledge of the present, and hence an exact knowledge of the future, and that nothing is predetermined in the atomic world. But in the macrocosm, where the probabilities are high, you can still talk about determinate quantities.

Is there in Nature any other law than a purely statistical one ? Can non-statistical laws be completely ruled out from Nature ? Such are the questions that engage the attention of the physicist now. Interest now centres round such questions. Physics has thus very unexpectedly justified itself being called Natural *Philosophy*. No wonder therefore that physicists, at least some of them, are busy discussing about determinism and free will—idea's exclusively belonging to the realm of mental philosophy. It is a remarkable instance of the unity of thought and of the simplicity of Nature and its workings, “that a study apparently so remote from human emotion as atomic physics, should have so much to say on of the great problems of the soul”.