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Microcosmic Foundations

All the properties of electron spin, including the proper amount of angular momentum, relativistic fine structure and even the gyromagnetic ratio, flow out of the Dirac formalism in an almost miraculous fashion suggestive of a magician's extraction of rabbits from a silk hat.

Encyclopaedia Britannica, Vol. 18, p. 930, 1970 edition

Modern techniques for understanding the behaviour of the cosmos appear to have rather abstract foundations. The large-scale phenomena of our universe have become the realm of Relativity. The small-scale world of the atom, is the world of wave mechanics. Here we find the physicist using terms such as electron spin, angular momentum, relativistic fine structure and gyromagnetic ratio to portray the properties he can observe by his experiments. Some of these terms are common to the language of the greater world around the atom, suggestive of true unification of our theories across the whole spectrum of our experience. However, in view of the above quotation, suggesting that some of these properties have their origins in the occult magic of Dirac, we need to exercise care before accepting all that modern physics has to teach us. We must be suspicious of mathematical formalism.

An occult-sounding term used by engineers is the word entropy. It is a measure of the thermal energy in a system which is unavailable for turning to good account and performing useful work in man's machines. The concept of entropy is the engineer's contribution to philosophy. Referring to this contribution, and speaking of the philosophy of science in the nineteenth century, Eddington wrote:*

* *The Nature of the Physical World*, A. S. Eddington, Cambridge University Press, 1929, p. 104.

It was in great favour with the engineers. Their sponsorship was the highest testimonial to its good character; because at that time it was the general assumption that the Creation was the work of an engineer (not of a mathematician, as is the fashion nowadays).

Then, later on page 209 of his book Eddington wrote:

Nowadays we do not encourage the engineer to build the world for us out of his material, but we turn to the mathematician to build it out of his material. Doubtless the mathematician is a loftier being than the engineer, but perhaps even he ought not to be entrusted with the Creation unreservedly. We are dealing in physics with a symbolic world, and we can scarcely avoid employing the mathematician who is the professional wielder of symbols.

All this, of course, has given the philosopher food for thought. Dana Scott* writing under the title: 'Existence and Description in Formal Logic', says:

It is curious that in ordinary mathematical practice having undefined functional values, a situation close to using improper description, does not seem to trouble people. A mathematician will often formulate conditionals of the form

$$\text{if } f(x) \text{ exists for all } x<a, \text{ then. . . .}$$

and will not give a moment's thought to the problem of the meaning of $f(a)$. More careful authors never use a description or a function unless it has been previously proved that its value exists. . . . More serious is the fact that it is quite natural to employ descriptions *before* they have been proved to be proper.

Scott then goes on to prove something in eighteen pages of mathematical symbology. I could not follow the analysis; it seemed too complicated, though it is surely undoubtedly valid. Jumping to his conclusions I quote one of his results from his page 197:

The operator O is eliminable in a theory T if and only if whenever two models of T are weakly isomorphic by a certain one-one function they are also strongly isomorphic by the same function.

As applied to the physics of crystals, isomorphism is the property of forming in the same or closely related geometrical

* The 16th essay in *Bertrand Russell: Philosopher of the Century*, edited by R. Schoenman, Allen and Unwin, 1967, p. 181.

configurations. In the logical derivation of this result, the operator O is something which has replaced the 'abstraction operator'. I do not confess the slightest understanding of the above conclusion. Nor am I encouraged by the final conclusion on page 199:

> This result on eliminability is not very satisfactory. . . . The author has no idea what kind of model-theoretic conditions would correspond to this uniform eliminability that we have when operators are introduced by contextual definitions. It seems like an interesting problem.

Perhaps an abstraction operator is involved in linking the three-dimensional world of our experience with the four-dimensional world of Relativity. Perhaps then it is difficult for the logician to satisfy himself that the method of Relativity is a valid method by which to reason an understanding of Nature. Or perhaps the logician is just confused by Relativity.

At this stage I wish to give my view that the mathematical theories of our universe, highlighted by Einstein's Relativity, have given too much rein to the mathematician. His skills in providing one of the tools needed by the physicist have been set aside and he has tried to become a philosopher in his own right. His apparent success has so affected the would-be general philosopher that mathematics appear nearly everywhere, superimposing a man-made vision of Nature and confusing us rather than recounting Nature's ordered structure with clear language.

Max Born* in his essay 'Reflections of a Physicist' writes:

> All our instruments consist of ordinary bodies and cannot be discussed but by ordinary language with the help of concepts of Euclidean geometry. It is of course left to the philosopher to analyse this macroscopic domain. But the physicist has enlarged it enormously by using magnifying apparatus: telescopes, microscopes, amplifiers, multipliers, etc. These produce data which, though consisting primarily of ordinary sense perceptions, cannot be conceived as meaningful structures with the help of the experience collected and the language learned in childhood. One has to apply abstract thinking. This is the domain of Russell's theory of empirical knowledge.

* The 11th essay in *Bertrand Russell: Philosopher of the Century*, edited by R. Schoenman, Allen and Unwin, 1967, p. 124.

For the physical world revealed here is a construction of the mind, armed with mathematics, from raw material obtained by the senses, armed by the magnifying tools of science.

Evidently, Born sees both the physicist and the mathematician as mere helpers who carry the brushes and paint to the great philosopher artist, busy at work transforming the visions of his mind on to a canvas which will portray Nature and Creation. But surely, this canvas has already been painted by Nature herself. It only needs the physicist to clean off the paint added for centuries by these many philosopher artists and then to examine, under his microscope of course, the fine detail and true beauty and majesty of what is there to be revealed.

When Eddington referred to the Creation being the province of the mathematician he had in mind the name of Dirac. Dirac graduated Ph.D. at Cambridge in 1926 in mathematics. Six years later in 1932 he was awarded a Nobel Prize along with Schroedinger for 'the discovery of new productive forms of atomic theory'. Yet, Dirac was an engineer turned mathematician. He graduated as a Bachelor of Science in electrical engineering at Bristol in 1921, and his engineering spirit may well account for his frank and objective way of expressing his ideas, thus making his work an easy target for our enquiry. Dirac's contribution to modern scientific outlook on the workings of the cosmic world is so great that he provides the focal point for study in this chapter and also in Chapter 10. Following the theme of our introduction, it will be the objective to question and criticize the reputed 'wizardry' of Dirac. But this attack has broader address. The viewpoints projected here can be levied against the works of numerous less-eminent contributors to the mathematical theories of physics. It is just that Dirac's work provides an exciting stimulus to critical and constructive review and adds to rather than detracts from the magnitude of his great contribution to the scientific thought of this century.

Dirac's main contribution concerns the properties of the electron, that fundamental entity of electric charge which is almost the sole performer in the practical applications of electricity. The history of science is well coloured by the early recognition of the existence of the electron and its eventual discovery when, near the end of the nineteenth century, it became possible to measure its charge/mass ratio, and then its singular charge. After this there seemed little further to be said about the electron. How it kept itself intact, restraining itself from exploding under the action of the mutual repulsive force of its charge, was the real problem. How it behaved in atoms and could be created or annihilated were to become problems. A concept known as 'electron spin' was to be invented by 1925.* Nevertheless, the electron had been discovered by the end of the last century and, thereafter, its properties were merely a matter for experimental investigation to afford the clues as to its origins. But when Dirac came to discover the properties of the electron he was not examining the electron at all. His interest focused upon certain mathematical equations characterizing the new concepts of wave mechanics which were at that time being projected in Continental Europe by de Broglie and others.

It will be remembered that at the beginning of Chapter 5 we mentioned de Broglie's award of the Henry Poincaré medal by the French Académie des Sciences on December 16, 1929, and the honour on the same occasion conferred upon Véronnet. Months previously Véronnet proposed his aether to the Academy, an aether containing 'etherons' whose motion determines the Planck constant. Four days previously, on December 12, 1929, de Broglie had been presented with the Nobel prize 'for his discovery of the wave nature of electrons'. In his Nobel lecture he had said:†

> A purely corpuscular theory does not contain any element permitting the definition of a frequency . . . I thus arrive at the following overall concept . . . for both matter and radiations, light in particular, it is necessary to introduce the corpuscle concept and the wave concept at the same time. In other words the existence of corpuscles accompanied by waves has to be assumed in all cases.

Centuries before, in the time of Newton, it had been recognized that light had a corpuscular nature, and yet that light

* Uhlenbeck and Goudsmit, *Naturwiss*, 13, 1925, p. 953.

† The quotations from the Nobel lectures presented here and elsewhere in this book are taken from *Nobel Lectures (Physics) 1922–1941*, Elsevier Publishing Co., 1965.

was transmitted by waves in the aether. It was a real step forward to discover that corpuscles had an associated wave nature. The inevitable physical constant of such an association is Planck's constant, the quantity relating energy and frequency of light quanta. Véronnet's aether was, therefore, very much in evidence from de Broglie's discoveries. For de Broglie to say that 'a purely corpuscular theory does not contain any element permitting the definition of frequency' and then go on to endow it with its own wave properties is to ignore the aether. Or it may be a way of recognizing the electron and the aether as a co-operative whole. It is a question of one's viewpoint.

Three years later on December 12, 1932, Dirac delivered his Nobel prize lecture under the title 'The Theory of Electrons and Positrons' including the words:

> It is found that an electron which seems to us to be moving slowly, must actually have a very high frequency oscillatory motion of small amplitude superimposed on the regular motion which appears to us. As a result of this oscillatory motion, the velocity of the electron at any time equals the velocity of light. This is a prediction which cannot be directly verified by experiment, since the frequency of the oscillatory motion is so high and its amplitude so small.

Dirac attributed this viewpoint to Schroedinger but Einstein also had proposed an explanation of de Broglie's wave formulations in 1925.* Einstein imagined the electron as belonging to a Galilean reference frame oscillating at a frequency determined from the electron rest mass energy and the Planck relationship, and being everywhere synchronous. Thus Dirac, Schroedinger and Einstein all seem prepared to recognize that particles of matter may have a superimposed cyclic motion, as if belonging to some unseen reference frame which is oscillating at a very high frequency, which for electrons happens to be the frequency at which they are annihilated or created.

One is tempted to argue from this that the aether which we spoke about in Chapter 4 as having a system of negative particles oscillating in harmony in a continuum of opposite charge is exactly in keeping with these wave mechanical ideas. If an

* Paper at p. 3 of *Berlin Sitz.*, 1925, but see also reference by Sir Edmund Whittaker in *History of the Theories of Aether and Electricity, 1900–1926*, Nelson, London, 1953, p. 215.

electron is swept into the negatively charged system and shares its oscillations it can well display wave properties. Certainly, the ideas proposed for the origins of the earth's magnetism must gain support from this link with de Broglie's wave mechanical theories.

However, we must return to the mathematical techniques which led to the bold discoveries of Dirac. We will omit the mathematics in the following quotation from his Nobel prize lecture and capture those words (paraphrasing some) which will show how his argument is developed:

> We begin with the equation connecting kinetic energy and momentum of a particle in relativistic classical mechanics. . . . From this we get a wave equation of quantum mechanics, by letting the left-hand side operate on the wave function. . . . With this understanding the wave equation reads . . . but a wave equation must be linear in certain terms and this is not. . . Let us try a new equation . . . this involves four new variables which we use as operators . . . now assume certain relationships between these variables . . . this is linear and it makes the equations equivalent to a certain extent . . . the new variables which we have to introduce to get a relativistic wave equation linear in . . ., give rise to the spin of the electron . . . the variables also give rise to some rather unexpected phenomena concerning the motion of the electron. These have been fully worked out by Schroedinger. It is found . . .

Here the quotation develops into the one already presented. Dirac invented a mathematical equation, found it could be adapted to fit the observations and then concluded that the terms in his equation actually give rise to physical phenomena. He has provided the mathematics needed to fit the facts. All that remains is for someone to provide the physics which will fit this mathematics. All we need is enough understanding of the aether and we might find what is needed. But, oddly enough, the modern physicist thinks the work is already finished. He is not interested in the physics and is quite content with his mathematics.

Dirac himself had more to say. His eye for symmetry allowed him to extract more from his mathematics. Continuing from his lecture:

We now make the assumptions that in the world as we know it, nearly all the states of negative energy are occupied, with just one electron in each state, and that a uniform filling of all the negative energy states is completely unobservable to us. Further, any unoccupied negative-energy state, being a departure from conformity, is observable and is just a positron.

The positive electron or positron had just been discovered earlier that year by Anderson and Millikan, working in California analysing cosmic radiation. Dirac's mathematical scheme thus explained the positron as well. One might wonder how a physicist or an engineer can come to terms with the idea of negative energy, particularly when it is attributed to the fundamental sub-stratum of our universe and is not merely a change in energy due to displacement from an arbitrary position. However, be that as it may, Dirac's theory commanded attention and was taken as meaningful by those best able to judge. Dirac did, however, not claim that his mathematics could explain the neutral particle, the neutron of the atomic nucleus, which had been discovered by Chadwick that very same year, 1932. It is interesting to note that when Chadwick received his Nobel prize for this very discovery in 1935 he said about the neutron:

A structure of this kind cannot be fitted into the scheme of the quantum mechanics, in which the hydrogen atom represents the only possible combination of the proton and the electron.

This was in spite of the fact that Fermi had been at work suggesting in 1934 that the neutron and the proton were the same particle in two different quantum states. But we have more to quote from Dirac's lecture, and it is particularly important in view of our account of the creation of the solar system as presented in Chapter 5.

If we accept the view of complete symmetry between positive and negative electric charge so far as concerns the fundamental laws of Nature, we must regard it rather as an accident that the earth (and presumably the whole solar system), contains a preponderance of negative electrons and positive protons. It is quite possible that for some of the stars it is the other way about, these stars being built up mainly of positrons and negative protons. In fact, there may be half the stars of each kind. The two kinds of stars would both show exactly the same spectra, and there would be no way of distinguishing them by present astronomical methods.

Now, this is only speculation. Symmetry has meaning in mathematics but we have to be cautious in physics. Dirac's mathematics pertain to an aether as much as they do to the systems of matter we can see. If the aether had regions with polarity of charge inverted, would the boundaries between these regions be stable? Boundary conditions are of vital importance to the physicist. The mathematician can examine his ideal regions, his singularities, and forget the practical boundary problems. This is where Relativity fails, as we shall presently see. The chances are that with the aether of mixed polarity there would be an over-riding tendency towards uniformity rather than symmetry. Aether in which positrons and anti-protons predominate might be squeezed out of existence as the boundaries move to convert it to aether pervaded by electrons and protons. We are speculating, of course, but we are thinking in physical terms, not mere mathematical notions of symmetry. Perhaps, then, it is in the sun and all the other stars that this fight between the aethers is raging. The polarity inversion may be occurring at the spherical boundaries between aether at the solar surface and hence energy may be unleashed from the aether itself as by-products of the basic particles of charge are produced to create and illuminate the universe. It is not our task to pursue this here. We have examined how Dirac approached the problem of explaining the properties of electrons. What he discovered may, or may not, be an answer. It may only be itself a philosophical problem. In any event, Dirac became the man most competent to speak about the origins and the nature of the electron. It is, therefore, of particular interest to see what he has to say about the electron a little later in 1938 when he is examining electron radiation properties. It is the question of energy radiation which is attracting attention at the present time. Hence the importance of this question. But we will come to that in Chapter 10. First, we will digress a little to philosophize about physics. This diversion seems appropriate because ideas of the cosmos have been our prime concern in the previous chapters. Now we are turning away from these grand matters of our direct experience and what we can observe in astronomical telescopes to the uncertain realm of the microcosmos, the physics of what we cannot see. We want neither occult techniques nor fiction, but, instead, experimental techniques and fact. We must be able to distinguish fact from fiction to make certain progress in our endeavour.

For those equipped to understand the language in which the physical nature of our environment is currently portrayed, physics is a most fascinating subject. The secrets of our origins and destiny are undoubtedly contained in the ultimate solution of the fundamental problems of physics. Concepts such as space, time, energy, matter and electric charge all play a prime role in the physicists' world, but the secrets of the reality contained in these concepts will not be discovered merely by thought processes. Man must examine and re-examine the system of Nature which has revealed them and reach his conclusions without adding unnecessary complexities contributed only by his mind. The fundamental nature of things is likely to be simple, just as complex products result from random or selective aggregations of simple constituents. However, although it is said that truth is stranger than fiction, one can but wonder at both the strangeness and the truth of modern physical theory. If the reader who is well versed in physical theory can honestly say that he understands the accepted explanations for the physical nature of phenomena then he will have little interest in this book. But few physicists can really be wholly satisfied with the representative works of modern physical theory. Doubt and uncertainty must confront the majority and this book may provide some appeasement if not inspiration to those interested in thinking about physics.

Perhaps the real measure of our understanding of physics is our ability to convey such understanding to the younger generation. Let us then consider what is perhaps the first physical phenomenon to be introduced to the child without the back up of assured knowledge about its nature and cause. Magnetism should arouse tremendous curiosity, both in our childhood and in later years, if we really care about Nature's properties. The magnet has aethereal powers. It attracts iron and exerts its influence across empty space or even through material bodies. Yet how do we explain magnetism to a child? We cannot. We only demonstrate it. How do we explain magnetism to an adult? If he is conversant with the terminology of physics and he researches in the textbooks on the subject he will find it hard to discover an explanation that can evoke understanding. He will find it has some dependence upon what is termed an 'Exclusion Principle' for which we are indebted to a scientist named Pauli. This principle in its turn can be demonstrated in its application in physical theory. Its use can, therefore, be understood, but how can one understand the physical reason for the applicability of the principle without going deeper into the problem? We must be careful not to translate one problem into another and then think we have explained something. Progress results if we translate two problems into one common one, and then only if the common problem is one of physics and not merely one of mathematics. So-called principles do tend to be more mathematical than physical, and one can hardly explain mathematics by physics.

Looking through one of the most significant treatises on magnetism (dated 1966) we find the following statement:*

> About a generation has elapsed since it became recognized that the major agency responsible for ferro- and antiferromagnetic behaviour of materials is the Pauli exclusion principle, which makes the spatial and momentum distributions of a group of electrons dependent on the relative orientations of their spins.

This statement will undoubtedly be endorsed by physicists working in this particular field. They can even explain what it means, but they are unlikely to say more than is said in the rest of this treatise on magnetism. One can understand what they say, but does this mean that one understands magnetism itself? Many words and ideas are used in the explanation and they have no direct connection with what is observed in Nature. By some mental exercise one can forge links between Nature and certain principles and notions of man's own and then apply these to explain something else. But how do we know the

* Page 1, Vol. 4, *Magnetism*, Rado and Suhl, Academic Press, New York, 1966.

links thus forged are sound? Are these links founded in fact or fiction? Perhaps it does not matter, except that man has developed some linking concepts which are, to say the least, rather weird and complex. The nature of magnetism is, hopefully, not as complicated as the above-mentioned treatise suggests. Physics has become so complicated that the future must see attempts to scrap much of the presently accepted work and try again to find something less complex. In the meantime the newcomer to the subject should try to adapt his viewpoint to extract what is of value in recorded physics. The facts of experiment unadulterated by theoretical correction have to be sifted from the data available. Theoretical introductions to the facts of the subject are to be viewed with special caution.

The ultimate understanding of Nature will have to be one which relates natural phenomena to a minimum number of physical concepts. In the days before the discrete particle nature of electric charge it was the object of natural philosophy to portray phenomena in terms of mechanical principles. Before Newton's time there was a more direct reference to basic features of experienced phenomena. Fire, earth, water were typical elements on which physical theory was founded. With the discovery of the electron we could advance to efforts to relate all physics to fundamental electric charges and their mutual interactions. Yet, surprisingly, there has been little of lasting acceptance to emerge from these attempts at physical unification. The object remains as a challenge but inspiration has not matched the task. And yet, Nature should be simple and it should not be difficult to understand its fundamental structure.

In this book we shall forge ahead in this enquiry to the point where we even find a way of explaining mass itself in terms of electrical action. We will arrive there by asking questions and finding simple answers, by not accepting too readily what others have accepted too readily. We will move first to an explanation of the nature of the physical force interaction between two bodies, taking note of some words in Newton's *Principia* (1687):

That one body may act upon another at a distance through a vacuum, without the mediation of anything else, . . . is to me so great an absurdity, that I believe no man, who has in philosophical matters a competent faculty for thinking, can ever fall into.

The reader may be sceptical about what has been said in this chapter. We have criticized the abstract methods of Dirac, made reference to de Broglie's endowment of electrons with a wave property and come to Newton for support in advocating the existence of a real aether. Progress in physics may, indeed, require the physicist to backtrack in his ideas. As recently as March 1971, de Broglie wrote at page 149 of *Physics Bulletin*:

Everything becomes clear if the idea that particles always have a position in space through time is brought back. . . . The movement of the particle is assumed to be the superposition of a regular movement . . . and of a Brownian movement due to random energy exchanges which take place between the wave and a hidden medium, which acts as a subquantum thermostat.

Now, if de Broglie has to appeal to a hidden medium which exchanges energy with matter, and this in 1971, is not there purpose in reviving the aether with real fervour? We are now half way through this text on Modern Aether Science. The role of the aether in large-scale, cosmic phenomena has been presented. More will be said about this in Chapter 16. Now, however, whether prompted by de Broglie or Newton, the role of the aether on the microcosmic scale has been introduced and we are ready to see where this takes us.