A reconciliation of theories of the very small and the very large scale is one of the most important single issues in physics today. Many people today are unaware that back in the 1930s, Sir Arthur Eddington, the celebrated astrophysicist, made great strides towards his own 'theory of everything'.

In 1936 and 1946 Eddington's last two books were published. Unlike his earlier lucid and authoritative works, these are strangely tentative and obscure – as if he were nervous of the significant advances he might be making. This volume examines how Eddington came to write these uncharacteristic books – in terms of the physics and history of the day – and what value they have to modern physics. The result is an illuminating description of the development of theoretical physics in the first half of the twentieth century from a unique point of view: how it affected Eddington's thought. This will provide fascinating reading for scholars in the philosophy of science, theoretical physics, applied mathematics and the history of science.

Eddington's search for a fundamental theory

A key to the universe

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C. W. Kilmister
Formerly Professor of Mathematics, King's College London

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Preface

Most physicists have no difficulty in seeing physics as a single subject. Yet this view, which was straightforwardly tenable until the end of the nineteenth century, is radically inconsistent with the situation since then. There has been a divorce between the theories of the very small and the large scale. Amongst those worried about this the response has been to search for a 'theory of everything'. This phrase has many closely related connotations and to determine which, if any, is the correct one is an inspiring and useful task, not least for the unexpected by-products. So far, however, it has proved a task without any successful outcome. In this book I draw attention to an alternative. Unnoticed by many today, Eddington in the 1930s made great strides towards a different solution of the enigma.

It is half a century since I first succumbed to the Eddingtonian magic – I paraphrase Thomas Mann's phrase to try to do justice to my youthful if uncritical absorption in *Relativity Theory of Protons and Electrons*, which Eddington had published five years or so earlier, in 1936. I had already enjoyed his authoritative *Mathematical Theory of Relativity* with no more difficulty than that produced by the complex mathematical techniques which were new to me. Looking back on it, it surprises me that I could take in without a qualm so many of the unorthodox philosophical views in that book. But *Relativity Theory of Protons and Electrons* was a different matter. Another clutch of mathematical techniques was not enough to obscure a radically new position.

It was very much a book of the 1930s. In the first part of that decade, when the book was gradually coming together, the situation in theoretical

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physics had become very puzzling. On the one hand, the discoveries of special and general relativity in 1905 and 1915 had been wholly absorbed and largely understood. But understood only within the macroscopic bounds set by the theories themselves. They were confidently expected to explain cosmology in due course, they were known to describe more local astronomical phenomena more closely than Newtonian mechanics and for ordinary mechanics they reduced to Newton's system. On the other hand, the microscopic world had undergone two revolutions. One was at the turn of the century when Planck and Einstein initiated the so-called old quantum theory, a tool-bag of rules for calculating the frequencies of sharp lines in atomic spectra. The second was in 1925–6 when the manifold confusions into which the old quantum theory had fallen were, it seemed, removed not by one but two initiatives, an algebraic one (Heisenberg, Born, Jordan and Dirac) and an analytic one (Schrödinger). The fact that the two were then proved to be substantially equivalent and so were both called *the* new quantum theory was held to confirm their rightness. The puzzling character of physics was that there seemed to be no relation at all between the macroscopic and the microscopic theories, even to the extent that the new quantum theory was consistent with Newtonian mechanics instead of with special relativity (let alone general relativity).

At first Eddington was content to see the two sides as simply two alternative ways of looking at the world, wholly independent of each other. He played no active role in developing the new quantum theory. But in 1928 Dirac's publication of his equation for the electron, an equation which was a natural development of the new quantum theory and yet was consistent with special relativity, alerted Eddington to the problem, a problem that he soon came to see as an opportunity. The realisation came in a personally painful way, for the equation contradicted a folk-belief, strongly held by Eddington amongst the majority, that relativity had in its possession a mathematical device (the tensor calculus) which could churn out all possible equations consistent with its tenets. Dirac's equation was not of this form.

Eddington set to work at once in a way that was characteristic; he employed a number of illuminating models to guide his mathematics. The principal such model was Maxwell's electrodynamics and the way in which Maxwell, by combining the hitherto related but separate theories of magnetism and electricity, was led to the prediction of the value of a physical constant (the speed of light in vacuum) from the known scale constants that related electric and magnetic units. This model was then interpreted in an enormously generalised way. The theories to be linked became relativity and quantum theory, separate indeed but scarcely related at all. The much harder task of joining them would, if carried out successfully, bring even more in the way of prizes. As the work went on the prizes took the form of four physical constants, but now of the dimensionless kind, the most striking ones being the so-called fine–structure constant $e^2/\hbar c$, for which Eddington finally settled on the value 1/137 and the proton–electron mass ratio m_p/m_e for which he gave 1848. At first Eddington's contemporaries were interested but then scepticism took over. In the absence of any other plausible unification of relativity and quantum theory, for quantum electrodynamics was still far in the future, the problem came to be simply ignored, and Eddington's attempted solution with it. Meanwhile Eddington had progressed to a new position. The two theories were not to be seen as parts of a single whole, as in the Maxwell model, but as alternative descriptions which could, just occasionally, apply to the same situation and the results compared. Out of such a comparison could come numerical values of physical constants.

In 1941 much of this background was unknown to me and I was just fascinated by the book on its own terms. As time went on I learnt more and more of the difficulties and the task became that of reconstructing Eddington's work in such a way as to avoid them. In 1945 *Fundamental Theory* appeared after Eddington's death. It was a disappointment to me, for it did not seem to address the real obscurities of the earlier book. I spent a good deal of time clearing up the algebraic aspects of the theory but when this had been done the basic ideas were not much clearer. Yet they continued to dazzle: flashes of insight grouped round a frame of numerical results. I kept returning to Eddington's work and puzzling over it between the other enterprises that filled my working life. I owe a debt of great gratitude to Ted Bastin who often gave me guidance and help over Eddington during this forty-five years.

Eventually I realised that the time was passed in which I personally could hope to unravel the whole enigma. Yet the problem tackled by Eddington, if without complete success, the seemingly unbridgeable gap between quantum mechanics and relativity, particularly the general theory, remained, and I write that in full knowledge of the recent attempts at 'quantum gravity' of all kinds. A problem still pursued me but now it was a different one. How could it have come about that Eddington, such a lucid writer both professionally and in popular science, wrote two such obscure books at the end of his life? This book is an attempt to get behind

Eddington's printed page to answer that question. I found that it needed answers on many levels. The history of science, general history, Eddington's personal circumstances and his peculiar philosophy of science all had their part to play. I had to range over much of twentieth century physics and over Eddington's other work. There was virtually no documentary evidence to go on beyond his printed papers and books, so the reconstruction of his development has been an imaginative journey and the book an intellectual biography. At the end of it I was excited to find a clear picture emerge of how the two books came about.

I have tried throughout to keep technical details to a minimum and to explain most of the physics from first principles, so that the story is as accessible as possible. Yet this is not only a popular book; it is also meant to stimulate others to the task that I have laid down and, if I am fortunate, to give them the benefit of my experience.

Lewes, East Sussex C. W. K.