How physicists understand matter

Gerald Feinberg

The Forces of Nature. By P. C. W. Davies. Pp. 231. (Cambridge University Press: Cambridge and New York, 1979.) Hardback £12; paperback £4.25.

PAUL DAVIES is a mathematical physicist with both interest and talent in writing about modern physics for non-specialists, His previous works in this genre include *Space and Time in the Modern Universe* and *The Physics of Time Asymmetry.* There he treated aspects of relativity, thermodynamics and comology. In his present volume, *The Forces of Nature,* Davies turns to the central concern of twentieth-century physics, the structure of matter, and the interactions (forces) acting among subatomic particles. The book uses relatively little mathematics, and, in most places, requires no previous knowledge of physics on the readers' part. The result is a broad and usually clear survey of the ways in which physicists now understand matter. However, *The Forces of Nature* is missing a certain spark that was present in Davies' previous books. Also, it is somewhat marred by a number of inaccurate or misleading statements. These do not distort the main thrust of what Davies is doing, but they do make his treatment of some subjects unreliable. As the book does not try to present original contributions to physics, it is style, clarity and accuracy that are of greatest importance, and I will concentrate this review on these questions.

As might be expected from an author whose own research is highly mathematical, *The Forces of Nature* is very much a theorist's book. The ideas of physics are described in detail, but the experimental methods that led to these ideas are given perfunctory treatment. This is especially true of experiments carried out over the past thirty years. I cannot help thinking that this disparity in the treatment of theory and experiment will give readers a distorted view of how physics has developed in the past, and how it may proceed in the future.

The Forces of Nature begins with a brief introduction to Newtonian mechanics, and to electrical, magnetic and gravitational forces. The discussion of the forces is very clear and precise, but that of mechanics is less so. In particular, the description of energy is so vague that a reader will have trouble knowing what the concept means. This introductory chapter concludes with a section on special relativity theory.

In his next chapter, Davies outlines the quantum theory of atomic structure as developed between 1900 and 1930. The essential feature of such an exposition is its treatment of quantum mechanics, perhaps the major intellectual achievement of the twentieth century. Davies approaches quantum mechanics through its wave aspect, which he explains very well, using analogies with musical instruments. He uses this discussion to indicate why electrons in an atom have discrete energy levels. However, the correct way of describing electrons in an atom, through the notion of a quantum state characterised by definite values of energy, angular momentum and spin, is not introduced clearly. As a result, Davies' discussion of the Pauli exclusion principle is vaguer than it need be. Furthermore, the distinction between fermions and bosons is described in such a way that one of the great achievements of quantum field theory, the connection between spin and statistics, seems a tautology. These problems could have been avoided with only a little more care.

Davies turns next to nuclear structure, and discusses the constituents of nuclei, nuclear stability, and alpha and beta radioactivity. These subjects, especially nuclear stability, are treated well. The description of beta radioactivity, with its distinction between neutrinos emitted in electron capture and antineutrinos emitted in neutron decay, leads into a discussion of antiparticles in general. Here Davies uses the Dirac hole theory, with its heavy reliance on the exclusion principle. This approach has some virtue in making the existence of positrons plausible, but it has two decisive disadvantages. One, mentioned as an afterthought by Davies, is that the hole theory does not apply to bosons, such as charged pions, which also have antiparticles. The other is that the hole theory obscures the fundamental symmetry between particles and antiparticles by making antiparticles seem like interlopers in a Universe composed of particles. That picture is, however, false, and the observed surplus of electrons over positrons, and of protons over antiprotons, is actually an empirical fact that needs explanation, which physicists are beginning to find in the early Universe. Although the hole theory did lead Dirac to predict antiparticles, it has probably outlived its usefulness and should be retired to the same honoured resting place for outmoded physical concepts as Maxwell's mechanical models of electromagnetic fields.

The notion of antiparticles next leads Davies to consider particle creation and annihilation, one of the more surprising consequences of the union of quantum mechanics and relativity. Davies approaches this through the use of quantum field theory, again skillfully using analogies with the behaviour of musical instruments. An emphasis on the field, rather than the particle aspect of relativistic quantum theory is not the rule among physicists today, most of whom think of quantised fields as no more than convenient mathematical tools for the description of interacting particles. Davies has an additional motive in emphasising fields, which is the desire to demystify the abrupt, unanalysable creations and destructions of particles, by treating these processes as more familiar changes in field amplitudes. However, the amplitudes of the fields are also quantised, and also change abruptly when the corresponding particles are created or destroyed. It is therefore no more accurate to think of transitions between states of a quantised field in classical terms than it is to think of transitions bestween particle states in that way. In both cases, transitions occur in a way that cannot be predicted in advance, although the transition can be measured after it does occur. It is not a difference here that impels us to use quantised fields. Davies does not mention recent work on solitons, and on vacuum excitations, which is a more basic effort to make the field aspect of relativistic quantum theory play a role separate from the particle aspect.

One of the important consequences of quantum field theory is the notion of virtual particles, and their effect on the properties of 'real' particles. Any existing configuration of particles spends part of its time in other states, which may consist of any combination of particles with the same value of conserved quantities, such a charge, as the original configuration. Davies gives a mostly clear exposition of this idea, both for the electromagnetic field, and for the fields associated with pi mesons. Along the way, he introduces the Feynman diagrams that are now universally used by physicists to symbolise various creation and annihilation processes. However, Davies does overstate the significance of virtual particles in one respect, when he says that the real particles produced in various collision processes are simply the virtual particles already present in the projectile and target. This picture is only true for special cases, such as the emission of very low energy photons in a collision between charges. It is not true for the production of high energy particles in collisions, in which case some of the emerging particles must be imagined to have been created in the collision process itself. William Blake's vision of "a World in a grain of sand" may be qualitatively satisfied by the existence of virtual particles, but it should not be taken as quantitatively sound.

The subject of the next section of*The Forces of Nature* is the profusion of subatomic particles discovered in recent years, and the phenomena of strong and weak interactions that they undergo. This description is fairly thorough and easy to follow. One important part of the theory of subatomic particles treated in this section is the set of symmetry principles that these interactions satisfy. Davies' discussion of the basis of these principles is curiously Aristotelian, relying on the invariance properties of empty space. Although he is able to draw correct conclusions from this analysis, past experience should make us cautious about the extent to which such a style of argument can be trusted. It would be just as easy to infer Aristotle's form of inertia as Galileo's form from Davies' arguments.

The final section of *The Forces of Nature* deals with recent developments, such as the quark theory of hadrons, and the unified theories of weak and electromagnetic interactions. The discussion here is very up-to-date, and includes the discovery of the upsilon meson, and of parity non-conservation in deep inelastic electron scattering. There are also nice discussions of spontaneous symmetry breaking and of some reasons why quarks may not be observable. Once again, some things in the text are misstated, such as the mechanism by which charged pion decay occurs in the quark model.

A general stylistic objection to the book is that over and again Davies resorts to the phrase "it can be shown," or the like, a device that will probably annoy others as much as it does this reviewer. But on the whole, *The Forcers of Nature* is a considerable achievement in popular science writing. It is most likely to appeal to readers with an abstract turn of mind, who like deductive reconstructions of physical phenomena. □

Gerald Feinberg is a Professor of Physics at Columbia University, New York.

Einstein's ideals

Eugene Wigner

Albert Einstein, The Human Side: New Glimpses from His Archives. Selected and edited by Helen Dukas and Banesh Hoffman. Pp.168. (Princeton University Press: Princeton, New Jersey, and Guildford, UK, 1979.) $10; £4.95.

THE purpose of this book is to acquaint the reader with Einstein's social ideas, with his emotional life, with his convictions concerning the objectives man should strive for. And he surely abided by the ideals he put forward in his letters as well as any person could. The book is almost completely restricted to these aspects and contains hardly any information about Einstein's scientific accomplishments. It deals with what the authors call the human side.

As far as Einstein's own direct contributions to the book are concerned, these are almost completely restricted to letters which he sent out and a few which he drafted but did not send off. It does contain also two vitae — one written when he was 17, the other when he was a member of the Prussian Academy of Sciences, in Berlin at the age of 53 — and these are interesting to compare. Most of the rest of the book is due to two of his admirers: his almost life-long secretary Helen Dukas and his past friend and collaborator Banesh Hoffmann. They call themselves Selectors and Editors of the letter collection, but their contribution is actually much greater. It includes also the description of Einstein's relationship to the addressee of the letter, Einstein's attitude towards him or her, the motives leading Einstein to write the letter and the circumstances under which it was written. All this is done very clearly. They have also written a very nice introduction to the book.

Most of Einstein's letters were originally written in German and some were sent in that language. Others were drafted in German then translated into English by Einstein himself, but in some cases only the original German draft is available. In both these cases translations have been made by the Selectors and Editors, and in some cases this has been a difficult task. A particularly difficult case is that of the poems written by Einstein for inclusion in the letter. But whenever the letter's English formulation was not by Einstein himself, the German original is reproduced in the second part of the book ("German Originals", pp. 119-163). In a few cases, one must admit, the translation is less lively than the original, but it is good even in these cases.

The book does give the reader a vivid impression of the breadth of Einstein's interests, of his modesty and desire to help his fellow men and please them, of his convictions about what is good and what is evil. As to the first question, even the writer of this review, though he knew Einstein since about 1925, was not aware of all his interests. Besides all branches of physics, it also included music — his favourite composers were Bach and Mozart but he did have an affectionate regard for some of the later ones. His love of his violin was well-known to all his acquaintances. But in addition to these well-known interests, he showed great fondness towards the great philosophers of the past, and many of his letters are enlivened by philosophical remarks which give pleasure to the interested reader of the book and must have given even more pleasure to the original receipient of the letter. "The concept of a soul without a body seems to me empty". "What I see in Nature is a magnificent structure that we