

example, the incisive criticisms of Pauli after Heisenberg's talk on his unified theory at the 1958 "Rochester" Congress in Geneva made it clear why Pauli detached himself—after a lengthy collaboration—from that theory.

Volume B also contains the full text of several books, some in English, such as *The Physical Principles of Quantum Theory*, written in 1930. There are the two editions of *Cosmic Radiation* (in German), the first published in 1943, the second in 1952. The progress of that field was so fast that the second edition is an altogether different book. Finally, we find in that volume *Introduction to the Unified Field Theory*, in English, a book that appeared in the US in 1966. It contains a detailed description of Heisenberg's heroic but unsuccessful attempt to construct a "world formula," the solution of which should describe all observed particle physics.

Series A and B are published by Springer-Verlag (New York) whereas series C is published by Piper (Munich). The five volumes in series C, a collection of writings addressed to a wider audience, are of a different character. They are concerned with philosophy—in particular Heisenberg's views of the philosophical consequences of quantum mechanics, with science politics in post-war Germany and with attempts to make modern physics understandable to the public. Volume CII includes the Gifford Lectures (1956) in German translation (they appeared first in English under the title "Physics and Philosophy"). In volume CIII we find *Der Teil und das Ganze*, written in 1969, which appeared in English under the title *Physics and Beyond*.

Among Heisenberg's philosophical and popular writings, volume CIV is from a historical point of view the most interesting. It contains the laudations and obituaries devoted to his older contemporaries (Einstein, Hilbert, Planck, Schrödinger and others), his main teachers (Sommerfeld, Born and Bohr) as well as some of his close associates (including Pauli, Rudolph Peierls and von Weizsacker). Here it is particularly regrettable that but for one piece—"The Significance of Sommerfeld's Work Today" (1968)—all these masterful biographical sketches are in German. (On the other hand, Heisenberg used his language with the highest literary skill, and it will be hard to find an adequate translator.) Incidentally, this volume contains also some surprising literary exercises, including a travel account written by Heisenberg when he was a

Boy Scout "eagle" and a humorous parody entitled "Nuclear Mechanics" contributed for Born's 50th birthday.

About his education Heisenberg is supposed to have said, "From Sommerfeld I learned optimism, from the people in Göttingen mathematics and from Bohr physics." Certainly Bohr's influence was the greatest. Describing one of his earliest discussions with Bohr (1922), Heisenberg quotes him as saying: "Of course we are greatly impressed by the fact that the present quantum theory is able to explain, for example, in the case of the Stark effect, so many details, but mathematics has only a limited number of forms which we can adapt to Nature, and it can happen to one that he finds the right forms by formulating entirely wrong concepts. But then the whole thing is still in a state of total mess and can thus not be extended to constitute a closed theory." This point of view accompanied Heisenberg throughout his life, and he in fact always found confirmation of Bohr's opinion: Clearing up concepts is even more important than a mathematical formalism that represents experiment correctly!

Heisenberg's own credo as a theoretical physicist is stated most clearly in his laudation of Peierls (given when Peierls received the Planck Medal in 1963). There he says, "I am using the term 'theoretical physics' with a very specific meaning, in a certain sense as contrasted with two apparently cognate types of physics, namely with either mathematical physics or with the phenomenological description of experiments.... I would like to circumscribe this approach with a few words: This kind of theoretical physics occupies in a remarkable way the middle ground between mathematical physics and a purely phenomenological description. The compelling power of statements in this [type of] theoretical physics does not stem from the fact that they can be proved. And it is also not merely based on experimental evidence. As far as proofs are concerned, I would like to quote Pauli, with a sentence from a discussion between him and a friend, the eminent mathematician John von Neumann. As von Neumann said to him 'Listen, I can prove that.' Pauli replied: 'Well, if the essence of physics was giving proofs, then you would be a great physicist.' In the case of theoretical physics, as we learned it primarily from Bohr, the essence neither consists of proofs nor in the mathematical description of experiments. Rather the convincing power of the mathematics employed comes from

what one calls physical insight or physical interpretation. The supreme requirement of this type of physics is to understand every formula that one writes down physically both as to its intellectual content and to its context."

Pauli was not only Heisenberg's fellow student in Munich, but his lifelong critic. The two men were, notwithstanding their fundamentally different characters and roles during the war, very close. After Pauli's death, Heisenberg summarized Pauli's philosophy brilliantly: "Pauli was an unusually penetrating, critical and productive physicist. Throughout his life he conserved the power to grasp most subtle connections intuitively, although he always focused that power with sharp, unforgiving critical spirit into a limited domain.... He was aroused by those mysterious structures of natural phenomena which can be seized intuitively long before they enter consciousness as rational images, but nevertheless he gave his confidence only to a rational formulation that was clear down to the last detail."

Much but perhaps not enough is found in these volumes about the problems that Heisenberg had to face during the Nazi period with the persecution of the Jews. Although the Nazi concept of Jewish physics was condemned by Heisenberg, he had to be prudent during the Nazi regime and he was not a heroic fighter, as were Wolfgang Gentner and Johannes Jensen. One could have wished a more explicit condemnation of the Nazi crimes in his articles written after the end of the war. In a talk given at the consecration of a bust of Einstein in the German Museum in Munich in 1958, he emphasized Einstein's role as a world citizen, but also ascribed some traits of Einstein's character to his birth in Ulm, Germany. Einstein wrote: "Another sort of application of the principle of relativity will amuse the reader. Today I am called in Germany a 'German savant' and in England a Swiss Jew. If I may come to be regarded as a *bête noire*, I shall become a Swiss Jew for the Germans and a German scientist for the English."

The Mathematics of Projectiles in Sport

Neville de Mestre

Cambridge U. P., New York,
1990. 174 pp. \$22.95 pb
ISBN 0-521-39857-6

In his preface, Neville de Mestre writes that the first seven of the eight

chapters of his book encompass material he presented to mathematics students at the Royal Military College in Australia and at the Australian Defence Force Academy. In these chapters, he primarily addresses the mathematics of exterior ballistics for students who have a substantial background in classical mechanics and mathematics including differential equations and their numerical solutions; for example, there are important references to Runge-Kutta procedures but no description of this approximation method. In his last chapter, which constitutes about 25% of the book, he uses the techniques developed to describe the trajectories of shot and shell to address the paths of missiles projected more peacefully in sport. The book is written in the form of a textbook, with a set of exercises at the end of each chapter.

The spirit of the book is mathematical: It emphasizes analytic approximations and numerical methods for solving the relevant differential equations while the physical bases of the equations are considered minimally. The approximation techniques, which are elegant and interesting for their own sake and occupy much of the book, will appear to be misplaced to those who just want answers and have minimal access to computers. My obsolete PC had sufficient power to solve the problems that were posed by the most naive of iteration methods—never mind application of the intelligence de Mestre provides.

The transition to sports elements—usually balls, but shuttlecocks and javelins, as well as human long jumpers and even motorcycles are considered—is not wholly successful. In general, I found de Mestre's comments on individual sports interesting, sometimes amusing (as in his claim that many rugby passes are illegal), but by no means definitive; certainly some of his statements about baseball are at best arguable. The parameters used to describe the effects of the air on moving objects can be used to gain some insight into the trajectories of many sports missiles, but the approximations used are not always adequate for calculation of the accuracy of interest to sports fans. For example, the drag on a baseball traveling at 40 m/sec is understated by almost a factor of two. And though the inadequacy of the discussion of the Magnus force—and hydrodynamics in general—can be blamed on the references consulted by de Mestre, the resultant errors are troublesome. The graph presented in Chapter 8, which shows the variation of the lift coefficient as a function of

spin and velocity for a smooth rotating sphere, predicts that a table tennis ball thrown with spin will curve in the opposite direction from that which is observed.

These caveats are of minor importance for those who would use the book as a text, but I doubt that there is a substantial American clientele for a course on this subject. Those who are interested primarily in the sport aspects will find—as I did—matters of interest, but the book will not teach one to calculate accurate baseball trajectories.

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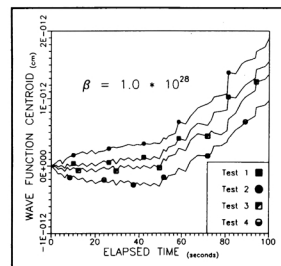
Unification of Fundamental Forces: The First of the 1988 Dirac Memorial Lectures

Abdus Salam
Cambridge U. P., New York,
1990. 143 pp. \$14.95 hc
ISBN 0-521-37240

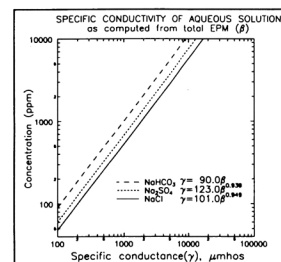
This engaging little book consists mainly of a personal history by Abdus Salam of unification in physics, supplemented by two contrasting lectures by Werner Heisenberg and Paul Dirac. My reactions to the book were molded by the circumstances in which I read it: on a train through Central Europe, two days after the end of the Gulf War, immediately after reading an English newspaper article making light of the demise of the French intellectual and shortly after a visit to Salam's International Centre for Theoretical Physics in Trieste. Salam's book distracted me from the beautiful scenery and set me musing about the conditions and relations of the Western and Eastern scientific traditions.

Salam's history of unification takes us from the Al-Biruni, who lived in what is now Afghanistan and was apparently the first to assert explicitly that physical laws are the same in different parts of the universe, to the possibility that superstrings might provide a "theory of everything," and ends with a humbling quotation from the Holy Koran. The stages in between are not reviewed in great scholarly detail but are entertainingly illustrated by apposite anecdotes, such as the travails of a journalist interviewing Dirac, the story of how Theodore Kaluza started working on the theory of swimming and Dirac's "minus two fish" solution to the Cambridge Archimedes problem. I particularly enjoyed the tale of an encounter between Dirac and Richard Feynman at a Solvay conference and the perspective on the fundamental

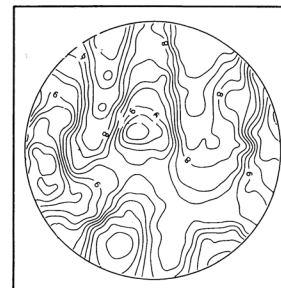
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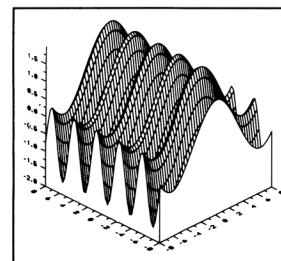
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