

Heisenberg's program for a theory of elementary particles

INTRODUCTION TO THE UNIFIED FIELD THEORY OF ELEMENTARY PARTICLES. By Werner Heisenberg. 177 pp. Interscience, New York, 1967. \$7.00

by Arthur S. Wightman

Any student of modern physics worthy of the name recognizes the author as one of the founders of quantum mechanics. Students of the history of elementary physics know that for three decades the author has relentlessly sought a fundamental theory of elementary particles and, in the process, has developed important parts of the conceptual framework of existing theory.

A characteristic of the author's work on the theory of elementary particles is that he has attempted to find a grand scheme and then to fill in the technical and mathematical details. The scheme has evolved gradually over the years and has acquired additional elements under the impact of experimental and theoretical developments. For about the last 15 years it has included features sufficiently different from those assumed by others working in the field to set it somewhat apart. Thus an account of the theory describing its present state as well as the motivation of its distinguishing features is welcome.

The book, based on Munich lectures in 1965 "for the younger generation of physicists," is as nontechnical as possible for a subject whose essential points appear to bristle with technicalities. The book can be cursorily summarized as follows. Chapter 1: The variety and interrelations of the known elementary particles make it likely that they are to be regarded as excited states of some underlying "goo" (Urmaterie). The goo is described by field theory since that is the best way to ensure causality and relativistic invariance, and it does not appear to contradict experiment. Chapter 2: Field theory ought to be constructed with an indefinite metric in Hilbert space to gain the possibility of singularity-free propagators and

Green's functions. Otherwise the standard ideas of collision theory ought to be used. Chapter 3: The goo is described by a pair of fundamental two-component spinor fields, the two-valued index labeling the pair being related to isospin. These fields are coupled by a fundamental Fermi interaction. Chapter 4: For lack of a better method the consequences of the equations of the theory are evaluated in the new Tamm-Dancoff approximation. Chapter 5: In lowest approximation the equations of the theory are consistent with the appearance of low-lying excitations as follows. Bosons: $S = 0, T = 0$ and $S = 0, T = 1$ interpreted as η and π , respectively. $S = 1, T = 0$ and $S = 1, T = 1$, which turn out to be of negative norm (ghosts). Fermions: Two $S = 1/2, T = 1/2$ states: one massless, interpreted as the neutrino and electron; the other massive, interpreted as the nucleon. With a suitable choice of coupling constant, the predicted masses of the identified particles are not unreasonable. Chapter 6: Approximate calculations for scattering processes yield values for coupling constants of some of the preceding particles. For example, the pion-nucleon coupling constant is calculated

to be 12.5 as compared with the observed 14. Chapter 7: A degenerate asymmetrical ground state is introduced whose excitations (spurions) couple with the goo to produce strange particles. Chapter 8: The Goldstone theorem on the connection between broken symmetries and mass-zero excitations is extrapolated to provide a reason for the occurrence of photons and neutrinos. Chapter 9: Heisenberg argues that the principal successes of the bootstrap method and the dispersion theory ought to appear also in the present theory and that, in addition, it provides a rational account of the other phenomena not successfully treated elsewhere, for example, high-energy jets. Chapter 10: The general view provided by the theory is summarized. Heisenberg maintains that the theory has a cosmological element because it requires in addition to the field equation the degenerate vacuum.

The immense scope of the book is evident even from this crude sketch. Whatever one may think of the details, the courage and ingenuity displayed by the author in tackling so many difficult problems is impressive.

The crucial difficulty with the theory in its present state is that one does

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not really know which of its predictions are just that, and which are artefacts produced by the approximation methods used. This does not reflect a lack of skill in using quantum field theory. In fact, much of the ingenuity displayed by others who work in conventional quantum field theory is devoted to avoiding issues that the author runs into head-on. Examples of such unsettled issues are these: To what extent is the degeneracy and asymmetric character of the vacuum a consequence of the equations of mo-

tion? Are there also solutions without degeneracy and asymmetry? Do these phenomena appear only within a formalism that uses indefinite metric or are there analogous solutions in the conventional Hilbert space theory?

In the sense indicated by these questions the book is clearly premature, but it is premature in the grand style. It will no doubt serve as an inspiration for years to come.

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Within both cultures

THE PHYSICS OF MUSICAL SOUND. By Jess J. Josepfs. 165 pp. Van Nostrand, Princeton, N. J., 1967. Paper \$1.75

by Lawrence Slifkin

Although physicists often have a hearty appreciation of music, they exhibit little active interest in the physics of music and musical instruments. Delight in music is more or less universal, and the application of physics to musical phenomena appeals to one's curiosity; nevertheless there are few modern books on the subject. This neglect is especially surprising since most of the physical arguments, because of their essentially geometric nature, can be appreciated by a rather wide audience. Moreover, in the border region between physiology, psychology and physics there are many intriguing questions. Are "melodic" sequences pleasing when played backwards? What determines the time and pitch resolutions of human hearing? Why is the octave a special interval? How might one construct a time-varying visual analog to music?

In *The Physics of Musical Sound*, Jess Josepfs, a physics professor at Smith College and an expert on electronic sound reproduction, has prepared an introduction to the subject that will be instructive to both physics student and musician. One hopes that the integral equation appearing on the first page will not frighten off the non-technical reader, as there is very little mathematics in the remainder of the book. Moreover, brief summaries of the essential physics, in most simple terms, are introduced as needed so that one can honestly say that intelli-

gent curiosity is the only prerequisite to the enjoyment of this book.

Josepfs begins with a description of simple harmonic motion, leading naturally into a discussion of the physical characteristics of sound and the physiology and psychology of hearing. He then treats musical scales and tone quality. There is considerable discussion of stringed and percussion instruments, organ pipes and the human voice although little is said about the brass and woodwind instruments. Treatments of electronic sound reproduction and room acoustics are also included. In addition, many simple experiments are described whereby the

reader can perform his own investigations.

The style is rather business-like and often terse, in contrast to the somewhat more romantic presentation of Jeans' older *Science and Music* and to Benade's rather informal *Horns, Strings, and Harmony*. Occasionally Josepfs abruptly terminates the discussion just when the reader's interest has been aroused, as on page 154, where it is simply mentioned that the acoustical absorptances of a man and woman were evaluated. How different are they? And which is greater? The index is somewhat skimpy: For example, although the just scale, intermodulation distortion, phase effects and instrumental response are described, none of these terms can be found in the index. The book could be improved by removal of several obscurities and minor errors, mostly grammatical and syntactical. Furthermore, a book designed to stimulate further inquiry into the subject should surely have made deliberate reference to three other paperbacks currently available: those mentioned above and *Waves and the Ear* by van Bergeijk, Pierce and David.

These criticisms, however, are minor and readily corrected. *The Physics of*

RCA ELECTRONIC MUSIC SYNTHESIZER constructs tones according to specifications of frequency, intensity, growth, duration, decay, portamento, timbre, vibrato and deviations. Punched-paper records control the Synthesizer functions. (Photo: Columbia-Princeton Electronic Music Center.)

