

A great creator of theoretical concepts teaches

Pauli Lectures on Physics

Wolfgang Pauli (C. P. Enz, ed.)

Six volumes. MIT Press, Cambridge, Mass., 1973. \$9.95 each

Reviewed by Ellen Yorke and Ivan Kramer

Victor Weisskopf concludes his foreword to this six-volume set of notes from Wolfgang Pauli's lectures given at the Swiss Federal Institute of Technology in the late 1940's and early 1950's with this wish: "May this volume serve as an example of how the concepts of theoretical physics were conceived and taught by one of the great men who created them." On the whole the wish is fulfilled. The logical structure of each branch of physics covered is clearly delineated. Generally Pauli is very careful to point out the assumptions and approximations that are needed to derive a particular result. The mathematics is rigorous but clearly explained and is generally at a level that a senior or a graduate student can follow. One is rarely made aware of the fact that these are lecture notes—the text is coherent and reads smoothly. An appendix to each volume clarifies some points, makes historical comments and updates the lectures with references to recent literature.

It should be stressed that these books are all highly theoretical. Practical applications of physics are omitted entirely or dismissed in a few sentences. There are no numerical examples, making it difficult for someone who is not familiar with the topic of the lecture to get a feeling for the scale of phenomena under discussion. There are no problems for the readers to work, and the few pictures are almost all schematic. For these reasons, none of these volumes would be suitable as a main text for even an advanced course. However, all are concise, clear, reference reading, particularly for graduate-level, theoretical courses. And all are a worthwhile addition to any physics library—departmental or private. Our review of each volume follows.

Electrodynamics, Volume 1. Pauli's approach to the presentation of electrodynamics consists of building up



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Maxwell's equations from experimental laws. To summarize, his presentation consists almost exclusively of a concise mathematical development and exposition of Maxwell's equations to their most general form. This approach is theoretical and mathematical as opposed to physical and practical, and therefore this book is of little use as an introductory book for physicists or engineers. At its best it supplements material found in standard textbooks, but cannot replace it.

The chapter on electrostatics and

magnetostatics is clear and is logically developed, but the presentation assumes a familiarity with gradient, divergence, and curl operators.

From a knowledgeable theoretician's viewpoint the chapter on steady-state currents contains much material that is novel and interesting. There is an excellent discussion of the different ways of mathematically formulating the Biot-Savart law, ending with Pauli appealing to experiment to decide the question. Unfortunately, there is no circuit analysis of any consequence in

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this text—the book is not a practical handbook for experimentalists.

Optics, Volume 2. This is an intensely theoretical book in which the bare bones of the structure of optics are clearly revealed. Geometrical optics is introduced via Fermat's principle, and the analogy between the principle of least time in optics and least action in mechanics is carefully explored. The scalar wave equation is used to discuss some standard examples of diffraction theory. More than half the book is a thorough discussion of the propagation of light in isotropic and anisotropic media starting from Maxwell's equations. There are *no* discussions of applied optics and no photographs of any of the phenomena. However, at each point it is made clear exactly how much understanding of the detailed nature of light and matter is needed to explain a phenomenon, and it is this logical clarity that gives this book its greatest relevance to the practitioner or physics student.

Thermodynamics and Kinetic Theory of Gases, Volume 3 and Statistical Mechanics, Volume 4. Volumes 3 and 4 are companion volumes that give a clear and crisp survey of the main points of these closely allied subjects. A pleasing feature of these books is that whenever several approaches to a topic exist they are all thoroughly discussed. Pauli always deals with the more phenomenological approach first and then the more axiomatic. The second law is first formulated in the "engineering" language of Clausius and Thomson and then in the axiomatic language of Caratheodory. A similarly dual approach is taken in the fairly long section on chemical equilibrium. Volume 3 concludes with a careful discussion of phenomenological kinetic theory, and volume 4 begins with a derivation of the Boltzmann equation. There is a discussion of the virial theorem, including applications—something rarely seen in a textbook.

Volume 4 is very meaty for its size. Even though these notes were taken in 1947, Pauli frequently discusses fluctuations and displays the richness and physical content of these phenomena, which are now recognized as being of such importance in understanding critical phenomena. All the results that are routinely covered in a statistical mechanics course are incorporated in Pauli's lectures—and some that are rarely mentioned. There is a thorough chapter on Brownian motion. The revelation of wave-particle duality in the energy fluctuations of black-body radiation is discussed, as is the experimental observation at high temperatures of the existence of zero-point energy in crystals.

The last few pages of this volume are

a hasty discussion of quantum statistics. This subject is taken up again in the Wave Mechanics lectures, and its lack in volume 4 is all that prevents the third and fourth volumes from being a self-contained set covering the most important theoretical aspects of thermal physics. They are excellent resource material and good sound reading for any physicist.

Wave Mechanics, Volume 5. This is *not* an introductory textbook in quantum mechanics; rather, it is a mathematical summary of the basic structure of the theory. It is concise and sophisticated, often leaving the student to fill in background mathematics for himself.

The Schrödinger equation is pulled out of a hat with no justification given. The text is mathematical as opposed to physical, and there is no attempt to demonstrate how the final theory was developed.

Virtually all the discussions would be better understood and appreciated if the student knew quantum mechanics beforehand. There is a clear and concise development of the connection between Schrödinger's functions and operators versus Heisenberg's vectors and matrices.

There is a long section on the confluent hypergeometric function, the two-dimensional linear harmonic oscillator problem is solved in cartesian and polar coordinates, and the hydrogen-atom problem is solved *both* in parabolic coordinates and in spherical coordinates.

There are excellent discussions of classical versus quantum statistics, the connection between physical requirements of the theory and the mathematical requirements of operators, the relationship between quantum expectation values and classical equations of motion, symmetry classes and the exclusion principle.

Finally, for some reason when this text uses the symbol $\hbar$ it really means what every other text denotes by h .

Selected Topics in Field Quantization, Volume 6. This text represents a highly distilled, mathematically complete presentation of Lagrangian field theory.

The discussion of the Dirac equation cannot be understood unless the reader is already familiar with it. Field theory is of necessity very mathematical. That is why it is especially important to try as much as possible to keep track of the physics—no real attempt is made in this direction here. It is extremely advantageous to know the subject already and understand the value of a particular mathematical development to appreciate this book.

It is often hard to separate out the easy and important from the difficult and esoteric in this presentation. A

discussion of particles with zero spin follows a very long mathematical discussion on vacuum expectation values of expressions bilinear in the current. Pauli is best when he does not try to be as concise as possible and includes more discussion; but this is rare—a pity.

Since the contents of this book represent a series of lectures Pauli gave in 1950–1, it does not include any of the more modern field-theory formulations (LSZ or Wightman). Although the text devotes a small chapter to Feynman's approach to quantum electrodynamics, nowhere does he exhibit a single Feynman diagram!

In summary we have here a technical book written for a narrow audience. To appreciate it you have to think like Pauli (few do!). If you know what you want to do, Pauli will show you how to do it, but the necessity for doing it must be found elsewhere.

However, its mathematical completeness makes it a useful supplementary book to any of the better, standard treatments in the field.

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Acoustics: Historical and Philosophical Development

R. Bruce Lindsay, ed.

465 pp. Dowden, Hutchinson & Ross, Stroudsburg, Pa., 1973. \$24.00

This volume is a most impressive selection of classics in acoustics ranging from Aristotle to Wallace Sabine, with contributions from many of the great figures of physics throughout the entire period, including Galileo, Boyle, Newton, Euler, LaGrange, Laplace, Faraday, Green, Joule, Stokes, Helmholtz, Rayleigh. Each selection is introduced by R. B. Lindsay with an explanatory paragraph; illuminating footnotes provide essential continuity and clarification.

Sixteen of the papers have been beautifully translated into English by the editor himself from the Latin, French and German originals. Lindsay's fine "Story of Acoustics" has been reprinted as the first entry and provides an excellent historical introduction, especially for physical acoustics. His unobtrusive, but authoritative, scholarship is an essential ingredient to the usefulness of this impressive collection.

This introductory volume of the

"Benchmark" series on acoustics carries the reader to the year 1900, and ends with Wallace Sabine's great paper on reverberation, which initiated so many of the present developments in architectural acoustics. The progress in acoustics since 1900 will be presented in some ten additional volumes treating the specialized fields into which acoustics has grown in recent times. With few exceptions Lindsay's choice of historical material is excellent, although perhaps somewhat heavily weighted toward his own speciality of physical acoustics.

However, his choice of material from Vitruvius is not the most helpful. The choice is, of course, limited to the fifth book of this famous classic, but the omission of chapters III, VI, and VII, is unfortunate for these together with chapter VIII (which is included) provide the modern worker in architectural acoustics with the only surviving insights into the Greek contributions. Lindsay's choice of chapter IV on harmonics and Greek scales is understandable but his inclusion of chapter V on "Sounding Vessels in the Theatre" may well be misleading, especially since he provides no footnotes to explain, on physical grounds, why such sounding vessels could not have functioned as amplifiers of sound as Vitruvius claimed. Not a single bronze vessel of the type described has been found in spite of diligent search.

I find several serious omissions from the book. It would have been helpful to include Fourier's great contribution, even at the cost of selections by less prominent scientists, J. J. Waterson for example. To better balance the coverage, A. Kircher's famous tome "Murgia Universalis" might properly



Underwater acoustics apparatus of the 19th century. This plate from Colladon's "Experiments on the Velocity of Sound in Water" appears in Lindsay's *Acoustics: Historical and Philosophical Development*.

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