Foundations of Physics, Vol. 14, No. 8, 1984

Book Review

Seventeen Simple Lectures on General Relativity Theory. By H. A. Buchdahl. John Wiley and Sons, New York, New York, 1981, xiii + 174 pp., $49.50 (cloth).

Many of us who teach find that often the best way to clarify a subject for ourselves is to teach it to others: Self-clarification beforehand is thereby forced on us, and further clarification may result from the questions and comments of those we teach. Hans Buchdahl—highly regarded as an active researcher and expositor in the field—tells us with admirable frankness in the preface of his new book of the uncertainties and perplexities he encountered while reading the standard textbooks on general relativity and also of realizing that he was far from alone in being perplexed, even among specialists. Writing the seventeen "simple" lectures was part of his determined effort to isolate and confront these difficulties, if not necessarily always to resolve them. And indeed the most characteristic feature of this book is that it abounds with questions—salutary shakers of complacency to those who have some prior acquaintance with the subject. These lectures constitute neither a textbook nor an introduction to general relativity: They are intended as a basis for a critical review of the subject. They are discursive, loosely structured, and make no claim to be comprehensive. Perhaps the qualifier "simple" is meant to convey some of that flavor. It must not be taken to mean "easy"! For, although there are many excursions into the realm of philosophy of science, and the ratio of text to equations is unusually high, there is also much physics and mathematics to be found here.

An incomplete list of these "hard" topics might run as follows: variational approach to the field equations, linearized theory, Schwarzschild–Kruskal space, gaseous spheres (interior solutions), Reissner–Nördstrøm space, axially symmetric metrics (the Weyl form, a Curzon solution), Minkowski space as the only static, asymptotically flat and regular space, Kerr space (derived!), the Weyl tensor and a sketch of Petrov classification, exact and linearized plane gravitational waves, the

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energy pseudo-tensor, and some cosmology. Many of these more or less standard topics are treated in fresh and elegant ways. I particularly enjoyed the discussion of the gaseous star and the more general spherically symmetric solutions, and the interesting inequalities on the mass, radius, etc. that result.

What of the questions opened and perplexities aired? Here are some of them: What is a regulative principle, a theory, a metatheory? When is a theory a generalization of another? Special relativity theory: why special, why relativity, why theory? Same for general relativity theory. What is a geometry? Linguistic confusions: the phrase "physics has become geometry" rejected. Improper and proper form invariance; four distinct meanings of "absolute"; the principle of absolute form invariance; can the demand for covariance ever be physically nonempty? (The author's answer is yes.) On the redundancy of direct equations of motion. (The author seems to hold that it was *a priori* evident that the equations of motion must follow from the field equations.) What do the linear equations approximate? Obscurities surrounding the pseudo-energy tensor. Substantivalism and relationism with reference to Mach's principle.

This list is far from complete. The book is full of interesting comments, asides, warnings, unanswered questions, etc. that should all stimulate thought and provoke discussion. My one criticism concerns its slightly unhelpful format. There are no titles to the lectures, much overrun of topics from one lecture of the next, no headings or subheadings in the text, not a single diagram (particularly disappointing in the discussion of the Kruskal and Kerr spaces), not a single reference, and of course no problems or exercises. But there *is* a list of 46 books which the author found helpful in preparing the lectures, a full synopsis of the lectures in lieu of a table of contents, and a sparse but adequate index. In sum, this is an unusual book, and one that should find many friends. It would serve extremely well as a basis for a seminar course, as background reading for a standard course, or just for private pleasure for no course at all.

Wolfgang Rindler
The University of Texas at Dallas
Richardson, Texas 75080

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Book Review

Ludwig Boltzmann: Man–Physicist–Philosopher. By Engelbert Broda. Translated, with additions, from the original German by Larry Gay and the author. Ox Bow Press, Woodbridge, Connecticut, 1983, viii + 169 pp., $22.60 (cloth).

This year marks the 140th anniversary of the birth of Ludwig Boltzmann, without doubt the greatest theoretical physicist of Austrian birth and one of the great physical scientists of the nineteenth century. In 1955 Professor Engelbert Broda of the University of Vienna authored a small book with the title *Ludwig Boltzmann, Mensch, Physiker, Philosoph,* presenting a brief sketch of Boltzmann's life with emphasis on his scientific and philosophical achievements. The volume here under review is a translation of the original German edition by Dr. Larry Gay of South Yarmouth, Massachusetts, with the collaboration of Professor Broda, and with certain changes and additions. Although this is not a full scale biography (something which is badly needed in view of Boltzmann's importance in the development of nineteenth century physics), it is a very welcome sketch in English of the great physicist and his professional contributions.

The atomic theory is now so thoroughly entrenched in all branches of science that it is not easy now to recall the lively struggle over the establishment of the atom as a basic entity in modern physical science that took place only a century or less ago, a controversy in which distinguished scientists, like Ernst Mach and Wilhelm Ostwald, not only refused to believe in the existence of atoms but felt it was far more efficient to construct physical theories on a purely phenomenological basis, with principal emphasis on the role of the concept of energy from a macroscopic point of view. It is appropriate to remember the vital role played by Boltzmann in his vigorous defense of atomism, both through his theoretical researches in the statistical molecular theory of gases and his more purely philosophical writings.

This volume is essentially a series of vignettes set forth without following the temporal sequence of the events in Boltzmann's life. The three

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sections into which the work is divided concentrate respectively on aspects of Boltzmann as a man, as a physicist, and as a philosopher. The principal events of his life are summarized in three pages of the first section. This is followed by brief accounts of his teaching career and his thoughts thereon, as well as on his love of beauty and his rather peculiar naiveté. The section concludes with a reference to his tragic death by suicide in the summer of 1906. There is no doubt that Boltzmann suffered from intermittent depressions, though it is not at all clear how much of his trouble was due to a feeling that his work was not appreciated and how much stemmed from a more deep-seated physical cause. It is difficult to understand how a scientist in normal health could feel so deeply frustrated by the failure of the significance of his views to be understood by his contemporaries as to lead him to take his own life. The problem in Boltzmann's case remains a mystery to the general scientific community. A full-scale biography would naturally be expected to go into the matter as thoroughly as possible.

To the reader with predominantly scientific interests, the second and third sections on Boltzmann as a physicist and philosopher will offer the greater appeal. They constitute the bulk of the volume. All students of classical theoretical physics are, of course, acquainted with the Maxwell–Boltzmann distribution of velocities of the molecules of a gas in equilibrium, in what is now called classical statistics. This was the first serious mathematical development in what eventually was called statistical mechanics. Boltzmann's famous H-theorem had a profound impact on this development, for it showed that the Maxwell–Boltzmann distribution is the only one that does not change with time for a gas in equilibrium. If for any reason the distribution should be altered by an external disturbance, when left again to itself, the gas will revert to the Maxwell–Boltzmann distribution in an extraordinarily short time. In the case of hydrogen, for example, the time is of the order of magnitude of 10^{-10} sec. Boltzmann later showed the close relation between his H-function and the entropy of the gas. Even better known is Boltzmann's famous relation between the entropy S of a gas in equilibrium and the statistical probability W, namely $S = k \log W$, in which k is the so-called Boltzmann constant or the gas constant per molecule (a universal constant of nature, with the value 1.38×10^{-16} erg/deg). This equation is inscribed on Boltzmann's tombstone in the Central Cemetery of the City of Vienna—a very fitting memorial; but what would Boltzmann with his sense of humor have made of it?

Nor so widely known is Boltzmann's interest in Maxwell's electromagnetic theory and the part he played in promoting this theory throughout the continent. Boltzmann was a great admirer of Maxwell and of the use of the field concept in electricity. We should not forget in this connection the Viennese physicist's beautiful theoretical derivation (1884) of

Josef Stefan's experimentally established law expressing the density of electromagnetic radiation as a function of the absolute temperature ($E/V = CT^4$). Boltzmann's derivation was an ingenious combination of thermodynamics and radiation theory, which proved extremely useful in the later development of the quantum theory of radiation. In the section on Boltzmann as a physicist, stress is also laid on his contributions to the foundations of mechanics (1899), which may have had some influence on Einstein and other relativity thinkers.

Some 45 pages are devoted to Boltzmann's role as a philosopher. His opinions on the methodology of physics undoubtedly justify this amount of attention. It seems clear that Boltzmann had essentially the operational point of view before Bridgman; he had little use for the idealistic tendency in the philosophy of science. He firmly believed in the existence of an external world and that the reality of atoms as existing entities would ultimately be experimentally verified. How pleased he would have been had he lived for another 15 years! Though firmly committed to the deductive method for the construction of physical theories, he held it was unwise to use the word "truth" in connection with the conclusions thereof. Theories are *successful* to the extent in which they provide a satisfactory explanation of observed phenomena. Boltzmann's philosophy was very broad in range. This is shown, for example, by his enthusiastic reception of Darwin's theory of evolution.

Boltzmann was fond of scientific controversy, as shown, for example, by his strong attacks on the views of the "Energetics" school of Helm and Ostwald. These scientists attempted to base the whole of science on the concept of energy interpreted from a phenomenological point of view, discarding completely any need for bringing atoma into physical theorizing. In a number of masterly papers, Boltzmann clearly demonstrated the impracticability of the claims of the energetikers.

Here the reviewer would like to take mild exception to the translators' use of the word "energism" for the German term "Energetik." Actually the word which has long been in standard use in English in the description of the ideas of Helm and Ostwald and their followers is "energetics." This indeed was the word used by W. J. M. Rankine in his famous paper published in the *Proceedings of the Philosophical Society of Glasgow* in 1855. This point of view was later taken up and elaborated by Ostwald. The word "energetics" in both the Merriam-Webster and the Oxford English Dictionaries is defined in accordance with the use by Rankine and Ostwald. In both dictionaries the word "energism" is given a quite different meaning. The matter is mentioned here since readers of this generally excellent translation of the Broda book may be misled by the unfortunate usage.

The volume is much enlivened by the frequent quotations from Boltzmann's letters and papers. The bibliographical notes at the end of each section have been considerably increased in number over those in the German original, and they provide the interested reader with the chance to explore for himself the original sources. The interesting introductory comments in the original German edition by the late Professor Hans Thirring of the University of Vienna have been appropriately replaced in this volume by an appreciative statement by Professor Harold J. Morowitz of Yale University.

A very attractive feature of the book is the inclusion of 18 plates of photographs of Boltzmann, his famous contemporaries, and some of his successors in the field of theoretical physics.

To sum up, the volume provides fascinating reading and can be highly recommended to all who are interested in the history of science. May it serve as a stimulus for the production of a full-scale biography, which Ludwig Boltzmann richly deserved!

R. Bruce Lindsay
Brown University
Providence, Rhode Island 02912

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Book Review

A First Course in the Mathematical Foundations of Thermodynamics. By D. R. Owen. Springer-Verlag, New York, New York, 1984, xvii + 134 pp., $26.00 (cloth).

D. R. Owen is one of the authors who have extended phenomenological thermodynamics in order to cope with such areas as viscous fluids, tensile deformations, and systems exhibiting memory. This led him to write the significant *précis* reviewed here.

It is my lifelong interest in "elementary intrinsic reversibility versus macroscopic factlike irreversibility" that prompted me to read this book, which (as should have been expected) does not bring much news in this particular respect. Its interest lies elsewhere.

Abstractness and generality in the reasoning characterize phenomenological thermodynamics, and this exposition of the subject does conform to the tradition: rigor in reasoning and in formalization are its main features, the level being "advanced undergraduate."

A peculiar feature is that, throughout the book, "universality" of the argument is constantly blended with explicit reference to the ideal gas as a workable model and as a means for obtaining quickly the relevant formulas, essentially via "products of systems" *à la* Carnot. This marriage of abstractness with a familiar, simple model is an attractive feature of the book.

Throughout the volume one single system of independent thermodynamical variables is used: volume V (or length, in the case of filaments) and temperature θ. Therefore ideal gases are defined via two universal formulas: $pV = R\theta$ and Mayer's, together with an arbitrary function $c(\theta)$. The temperature scale is defined later as the thermodynamical one, but "self-reference" obviously is an alternative possibility. So, Chapter I presents "classical thermodynamics" along these lines.

The transition from the classical to the extended thermodynamics is presented in Chapter II: Paths go into processes, these being obtained by applying "process generators" to states. Process generators are endowed with

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a semi-group property. Systems with perfect accessibility are such that any two acceptable states can be reached from one another. An "action" is a real-valued function on processes, such as work or heat exchange, these being primitive, undefined concepts together with ordered temperatures.

Chapters III and IV discuss the first and second law via cycles, via an equality, and via an inequality, respectively. Product systems *à la* Carnot are used, one of them possibly being a perfect gas. Thus the first law is deduced with $J \equiv R/(C-c)$ and the second law with an "accumulation inequality" replacing Carnot's one. Of course much more sophistication is needed for the second law. First, "hotness levels" and arbitrary temperature scales are introduced, these obeying an order prescription, and parametrization of paths is often necessary. Serrin's explicit reference to the temperature level at which heat is exchanged is crucial in this derivation.

Chapter V deals with energy and entropy in the extended context, making use of the "action" concept previously introduced. A "Clausius property at state σ_0" is defined via an inequality attached to a cycle, and an "upper potential" (generalizing a thermodynamical potential) is defined, allowing one to write down an inequality for *open* processes. Via a product operation implying a perfect gas, an entropy function is then defined. Finally, using "actions" with either a conservative or a dissipative property, the energy and a Helmholtz-like free energy are defined.

Chapter VI applies these concepts to homogeneous filaments, either elastic, viscous, or "elastic-plastic," and discusses phase transitions. Chapter VII treats the case of viscous homogeneous fluids.

So, on the whole, this very significant book extends the range of phenomenological thermodynamics both at the conceptual level and in broadness of possible applications. It is a modern *précis* on the subject.

O. Costa de Beauregard
Institut Henri Poincaré
Paris, France

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Book Review

Fundamental Interactions: Cargèse 1981. Edited by Maurice Lévy, Jean-Louis Basdevant, David Speiser, Jacques Weyers, Maurice Jacob, and Raymond Gastmans. Plenum Press, New York, New York, 1982, 712 pp., \$89.50.

The Cargèse Summer Institute has become an important school for particle physics, reflecting in-depth treatments of the central problems in the field. The 1981 school was particularly impressive in its coverage of theoretical advances in quantum chromodynamics, confinement, etc.; experimental reviews of the many results in e^+e^- interactions; and, lastly, a forward look at the physics at the future high-energy hadron colliders.

Particle physics in 1981 had just completed a decade of great progress. Theoretically, the $SU(2) \times U(1)$ standard model for electroweak interactions had emerged and much progress through quantum chromodynamics had been made on a theory of the strong interactions. Experimentally, the dramatic discoveries of neutral currents in the weak interaction and the J/ψ bound state of a charmed quark–antiquark system were followed by much quantitative information on these phenomena, plus evidence for gluons, the discovery of yet another state (Υ), etc. At the time of the school at Cargèse, much of this information was being put into perspective and new information from the next generation of $\bar{p}p$ and e^+e^- colliders was being eagerly anticipated.

The lecturers and contributors to this volume represent some of the most important and knowledgeable members of the field of elementary particle physics. The book includes contributions from B. de Witt, G. Segré, E. Fahri, A. Martin, G. Wolf, K. Berkelman, M. Davier, G. Altarelli, P. Sikivie, G. Preparata, M. Jacob, D. Treille, F. Englert, G. 'tHooft, and S. L. Glashow. The format is sets of lectures on both theoretical and experimental subjects aimed at young active students of the field.

Several parts of the book are particularly worth noting. The coverage of e^+e^- physics is very thorough and well presented. Since the initial discovery of the J/ψ simultaneously in pp collisions at Brookhaven and in e^+e^- annihilations at SPEAR, the great potential of studying the e^+e^- system has

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been appreciated. New e^+e^- facilities at higher energies were built and produced a great deal of physics in the later part of the 1970's. In this volume, G. Wolf does an excellent job of reviewing these results and summarizing our understanding of the resulting physics. For example, he describes the fact that e^+e^- annihilation generally results in "jet" formation. He defines and describes these jets and shows experimental evidence. With further analysis he demonstrates the evidence for "gluons" which come from three-jet events. He compares data with predictions from quantum chromodynamics (QCD) and discusses some anomalies like the prolific baryon production at these energies.

Another important topic in e^+e^- interactions is the study of states involving the fifth quark (e.g., the b-quark). The Cornell e^+e^- machine, CESR, is particularly suited for these investigations. K. Berkelman reviews the production of the Y, which is the bound $b\bar{b}$ state. He discusses the spectroscopic information and also evidence for decay into three gluons. In addition, Berkelman discusses production of B-mesons, that is, states containing a b-quark. This is a rich area of great current interest.

Finally, on e^+e^- physics, M. Davier reviews the future of the field. Large machines are being built at CERN (LEP) and at SLAC (SLC) to make available e^+e^- energies high enough to directly produce the Z° and W-bosons. These machines will be available for physics in the late 1980's. M. Davier describes the capabilities of such machines for Z° and W physics. In addition, he discusses the possibilities for completely new physics, such as production of Higgs Bosons.

Two subjects of great current interest are well covered in this book. G. Segré discusses the electroweak interactions. He discusses the "standard model" as background for other contributions and then covers a discussion of the mass matrix, CP violation, and conjectures about W, Z bosons, Higgs particles, etc. A contribution by G. Altarelli reviews theoretical aspects of perturbative quantum chromodynamics. He first discusses the results emerging from using a leading logarithmic approximation and continues with an analysis of the "running" coupling constant and describes structure-function physics beyond the leading logarithmic approximation.

Since 1981, the major advance in particle physics has been the discovery of the W and Z at the CERN $\bar{p}p$ collider. M. Jacob anticipates these discoveries in his article on "Physics at Collider Energies." In this article, he gives a general discussion of the character of $\bar{p}p$ annihilations at these high energies, production of the weak bosons, and other phenomena at large P_t. He concludes with the prophetic remark

> "If the weak vector bosons exist as expected in the present electroweak theory, they should be found..... Much should have been learned already when these notes appear in print."

Finally, this volume contains contributions from two of our most prominent particle theorists: G. 't Hooft and S. Glashow. The "Confinement Phenomena in Quantum Field Theory" are discussed by 't Hooft. He describes how confinement can be understood as a result of local gauge invariance and the topological properties of gauge field theories. Glashow discusses various developments in particle physics, but concentrates on the problem of whether the neutrino has mass. This problem is still unresolved.

Overall, I find this compendium of contributions quite useful. They represent well our understanding of particle physics in the early 1980's. An important question in a volume like this is how soon it will become dated. This varies, of course, from contribution to contribution, but the nature of these articles is different from Conference Proceedings. The depth of these presentations, plus the fact that they put many of the developments of the 1970's into perspective, should make it useful for many years.

Barry Barish
California Institute of Technology
Pasadena, California 91125

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