

several things stand out: very excellent production and careful copy editing, including discussions following papers; about 70 lecturers from the US, one Canadian, two from the United Kingdom, and two Scandinavians—with the two-week meeting held in Bergen, Norway; and the very high price.

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S. Fred Singer is deputy assistant secretary in the Department of the Interior.

Light at the junctions

THE PHYSICS OF ELECTROLUMINESCENT DEVICES. By P. R. Thornton. 382 pp. Barnes & Noble, New York, 1967. \$14.50

by D. G. Thomas

This book begins with the brave statement that the study of electroluminescence is not one for faint hearts. One wonders sometimes whether there is a branch of physics, and particularly one that aspires to be useful, that can be tackled by faint hearts. But it is probably true that the subject of electroluminescence, that is, the direct conversion of electrical energy into visible or near-visible light by exciting a solid without significantly heating it, is one that had better be approached with a certain ebullience of spirit. The trouble is not the magnitude of the intellectual challenge, but rather the demands that are made on patience and imagination. There is great variety to the field, which spreads over the physics and chemistry of semiconductors. This book deals chiefly with the physics of the subject to omit any discussion of materials preparation. The author points out that materials preparation is extremely important, but a proper discussion would occupy too much space.

Generally speaking, a straightforward, elementary and reasonably critical account is given. The author presents an outline of the theory, such as it is, of the various subjects. The treatments are brief and not very deep; thus the theory of p-n junctions under forward and reverse bias are given, but for an appreciation of the problems that remain and of the approximations that have been made it would be necessary to refer to the original literature to which adequate references are supplied. Nevertheless the

summaries are a useful introduction to the main subject of the book, which consists of an account of various specific electroluminescent processes. The immensely detailed work on the "classical" electroluminescent system of zinc sulfide embedded in a plastic dielectric is summarized, and the author gives an appropriate critique. More attention is given to electroluminescence generated by the dc forward biasing of well defined p-n junctions, and this reflects the direction the field is taking today. Spontaneous emission from gallium arsenide, gallium phosphide, silicon carbide and various semiconductor alloys is dealt with quite competently as far as the subject allows it. There is a quite lengthy account of injection lasers, which, as the author writes, is a more satisfying subject as one can say a good deal about it that is both clear and relevant. It is unfortunate that at present these devices do not work continuously at room temperature, and only exceptional ones generate visible light. These limitations are pointed out in the book and comments are made upon their possible solutions. The book concludes with a reasonable discussion of the applications of electroluminescent devices and touches on the dismal subject of their possible failure.

There are a few 1966 references, but most of the work pertains to 1965 or earlier. Inevitably, therefore, in places the book is out of date. Thus the author states that efficiencies of electroluminescence from gallium phosphide are in the range 0.01–0.04% at room temperature, whereas in fact today they are roughly 100 times these values.

The field of electroluminescence is one of growing importance and almost certainly will have an impact on electronics technology because it can play a part at that point at which a man confronts his machine. The convenient visual display of information will clearly be valuable.

P. R. Thornton, who has spent three years in England at the Services Electronics Research Laboratory, an institution active in this field, and who now teaches material sciences at the University College of North Wales has given us a useful, critical and well written account of the physics of the subject. It is likely that it will find use for several years among those who are working in the field of electroluminescence and among those, pre-

sumably of stout heart, who propose to take it up.

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The reviewer has worked for several years at Bell Telephone Labs with emission of light from semiconductors.

Spinors and spaces

THE THEORY OF SPINORS. (Trans. from 1937 French edition) By Elie Cartan. 157 pp. MIT Press, Cambridge, Mass., 1966. \$8.00

by Lawrence C. Biedenharn

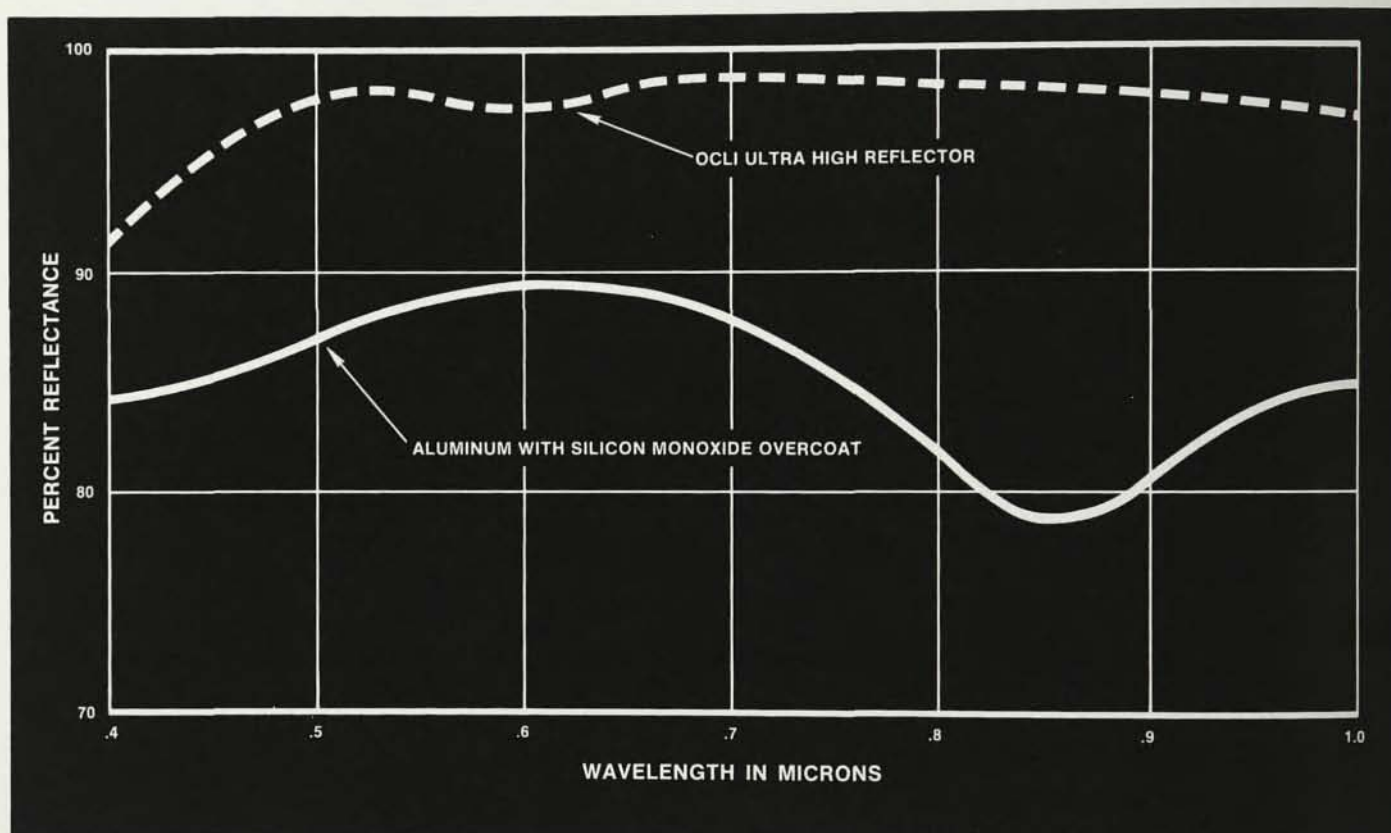
Elie Cartan was one of the great mathematicians of this century; for physicists he is probably best known for his fundamental work on Lie groups. It is probably not well known that Cartan developed the *general* theory of spinors in 1913, a dozen years before Wolfgang Pauli made the spin- $1/2$ system a commonplace in physics (the name "spinor" stems from this latter application).

The present book is a translation (the first in English) of Cartan's lectures on spinors in 1937—a classic of the mathematical literature. Cartan's purpose in these lectures is to develop the theory of spinors from a purely *geometrical* point of view, in contrast to earlier treatments, such as that of Weyl and Brauer. (A second motivation, for Cartan, was the desire to extend Paul Dirac's equations to general relativity; on this particular subject the present book is now somewhat out of date; the recent literature is cited in B. S. Dewitt, *Relativity, Groups and Topology*, Gordon and Breach, New York, 1965.)

The lectures were aimed at a general audience and develop the necessary techniques for linear representations of groups from the beginning by employing the (now familiar) method of infinitesimal generators. The work divides into two main parts: The first treats generalities on rotations and reflections in n-space, linear representations and the theory of spinors in 3-space; the second treats the theory of spinors in n-space including Minkowski space and Riemannian geometry.

Cartan's geometrical view of spinors can be best illustrated, for physicists nowadays, by reversing his order of presentation. Consider an arbitrary vector V in ordinary 3-space and the Pauli matrix vector σ . If we define a

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spinor by $\sigma \cdot \mathbf{V}\zeta = 0$, it is clear (for $\zeta \neq 0$) that this requires $\mathbf{V}^2 = 0$. This is Cartan's starting point: The spinor ζ is associated with the isotropic vector $\mathbf{V}$, that is, a (complex) vector of zero length. From this geometrical view, he develops all the familiar results of spinors, including the charge conjugation matrix C .

The particular advantage of this view is that it generalizes directly: Spinors in a euclidean space of odd dimension $n = 2\nu + 1$ are associated with totally isotropic subspaces of dimension ν . This leads very directly to the Clifford algebras and to linear representations of the general orthogonal group.

The exposition and organization of the lectures are remarkable; the style is precise and economical but very clear and a pleasure to read. Physicists will probably find the viewpoint and method slightly unfamiliar, but the work is quite accessible and is recommended primarily for broadening and enriching one's viewpoint, rather than for a first treatment.

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Lawrence C. Biedenharn is a professor at Duke University in theoretical physics. His research interests include nuclear physics and the application of symmetry techniques to particle theory.

Sound in the sea

CHARACTERISTICS OF SEA REVERBERATION. By Victor V. Ol'shevskii. 159 pp. Trans. from Russian. Consultants Bureau, New York, 1967. Paper \$19.50

by Peter G. Bergmann

Underwater acoustics has been cultivated by all naval powers ever since the French physicist Paul Langevin developed some echo-ranging gear toward the end of the first world war. Underwater sound has also been employed as an oceanographic research tool for locating commercially valuable schools of fish and for determining the depth of the ocean as part of navigation. Typically, research in underwater sound proceeds partly as a branch of acoustics, partly as an oceanographic specialty.

Reverberation occurs when a beam of underwater sound emitted to observe a reflector (such as a submerged object, or the ocean bottom) is scat-

tered, usually incoherently, back into the receiving equipment, so that the desired reflected signal is obscured and contaminated by the back-scattered sound energy, whose frequency characteristics will differ from those of the signal only insofar as the Doppler effect may shift signal and scatter by different amounts. Obviously, reverberation cannot be overcome by increasing the power of the emitted beam in contrast to background that is independent of the emitted sound power.

Victor Ol'shevskii's survey is concerned primarily with the mathematical treatment of reverberation, which lends itself readily to the application of such standard theorems as the Wiener-Khinchin relationship between correlation function and power spectrum. The treatment given appears concise, without omitting any of the important techniques of statistical analysis now available. In a concluding section Ol'shevskii also summarizes experimental procedures suggested in the taking of data on reverberation.

On the whole this book appeals primarily to the reader who is himself engaged in underwater acoustics or at least in a neighboring discipline. The presentation is clear though this reviewer suspects a few lapses, perhaps unavoidable, on the part of the translator. The half-tone reproductions of sound traces lack the sparkle possible with a superior photoengraving technique but are probably adequate to demonstrate the principal characteristics of underwater sound signals and of reverberation. The absence of an index is probably not too serious in a relatively brief survey, and there is a bibliography with a total of 58 references, selected from both Soviet and US journals.

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The reviewer is professor of physics at Syracuse University.

Bohr and the new theory

SOURCES OF QUANTUM MECHANICS. (Reprint collection) Edited with historical introduction by B. L. van der Waerden. 430 pp. North-Holland, Amsterdam, 1967. \$14.00

by Robert L. Weber

In a 59-page introduction, B. L. van der Waerden presents a valuable his-

torical study and an interpretation of the importance of the papers selected for this source book, from the years 1917 to 1926. These papers are divided into two sections. The first part, "Towards Quantum Mechanics," includes papers written before July 1925 judged necessary to an understanding of the discussion of matrix mechanics. These papers are by Albert Einstein, Paul Ehrenfest, Niels Bohr, Ladenburg, H. A. Kramers, John Slater, Max Born, John Van Vleck, Werner Heisenberg and Kuhn. In the second part, "The Birth of Quantum Mechanics," are papers written from June 1925 to January 1926; they contain the complete development of matrix mechanics. These papers are by Heisenberg, Born, Jordan, Paul Dirac and Wolfgang Pauli.

The editor has added considerable interpretation, with benefit of hindsight, through his conversations with the authors and by inclusion of correspondence among the principals. One might wish that this correspondence were given in English translation, as are the papers. This volume is devoted strictly to the development of matrix mechanics. As stated in the preface, papers on other topics, Zeeman effect, spin and statistics, quantum field theory, as well as papers by Peter Debye, Arnold Sommerfeld and John von Neumann, were omitted. Papers on wave mechanics are said to be reserved for a projected second volume. Van der Waerden's own authorship of a quantum theory of wave fields gives promise that the study will be continued.

The theme of this collection is that Bohr's correspondence principle was the guideline in the transition from the old to the new quantum theory. This thesis has governed the selection of papers, quotation from correspondence, and even those areas of Bohr's work that are examined.

Editor and publisher are to be commended for making available in attractive form these important papers.

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Robert L. Weber is a professor at Pennsylvania State University.

NEW BOOKS

ELEMENTARY PARTICLES & FIELDS Muons. By A. O. Weissenberg. Trans. from Russian. 347 pp. North-Holland,