Book Reviews

Space-Time Structure. Erwin Schrödinger. New York: Cambridge Univ. Press, 1950. 119 pp. $2.75.

Those already familiar with any of the publications of this author will reach eagerly for this new publication of a great physicist, and they will not be disappointed. Throughout the book we find Schrödinger's familiar informal style; here we find those little details and aids to the memory in the exposition of the material by which the author manages to make the subject clear to the student. Here and there the text takes the form of a lecture, but even where this is not directly the case, the style of the book is so interesting that one has the feeling of being spoken to personally.

The general purpose of the book is to give (for those having some superficial familiarity with special relativity theory) a clear and up-to-date picture of the *mathematical* fundamentals of general relativity theory. Thus, this is a book on geometry rather than on physics. Possible physical applications of these geometric considerations are scarcely touched. No discussion is given of applications of the theory of gravitation to planetary motion or to other effects that form the experimental backbone of general relativity theory. Nor is there a discussion of cosmological problems, nor one of the place of spinors in general relativity. One could therefore wish for a second volume from this author dealing in the same lucid and entertaining way with these and other elaborations and applications of the theory.

Space-Time Structure is indeed a mere introduction to the subject—an excellent and easy-to-understand introduction, at that, which one can in good conscience give to individual students wanting to get acquainted with the geometrical methods of general relativity. But this book is equally important for those who studied the subject long ago. For them, it is not only a wonderful refresher but has an entirely new approach. Its originality lies in not following the historical evolution, but putting the affine connection ("principle of parallel displacement") ahead of a metric, instead of letting it follow. The parallel displacement is indeed the basis for the underlying idea of the theory of gravitation that a particle will follow in space-time the "straightest line possible." This affine connection by itself then does already provide a measure along the geodesic lines themselves. A general metric is introduced later for enabling us to take over special relativity theory for small regions surrounding arbitrary points in space-time. Even postulating the identity of both measures along the geodesics, one finds the equality of the affine connection to the Christoffel brackets only under two further special assumptions.

In the last chapter, Schrödinger reports on some generalizations of Einstein's original theory, such as the Einstein-Straus theory. Interesting, too, is the purely affine theory discussed on the last few pages of the book, in which a "metric" is *derived* from the affinity, instead of the other way around. In the discussion, a reference is given to some of Schrödinger's own recent work on this subject.

The reviewer regrets that no more references to further and original literature have been given. The lack of an index is less serious, as the study is brief and has a satisfactory table of contents. (The author probably thought that sufficient indices already appear in the equations!)

Many physicists will criticize the way in which Schrödinger considers his relation (11.11) between the gravitational field and the energy tensor T_{ik} of matter (and light). On page 99 it is stated that this is to be regarded as a *definition* of T_{ik}. If this is correct, then T_{ik} would not depend on matter field variables at all and, in a quantum theory of matter, would be independent of the numbers of particles and photons present. But the whole importance of Eq (11.11) is the part which Schrödinger denies it, *viz.,* telling us how the gravitational field *is* influenced by the presence of matter. For, although the left-hand member of (11.11) depends solely on the gravitational field, its right-hand member T_{ik} can and should be expressed in terms of the components of the matter and light field. Such definition of T_{ik} cannot follow from a discussion of the g_{ik} field alone, but requires such considerations of the matter field as the reviewer has given in *Physica* (7, 449, [1940]). A similar argument applies to the equation div $E = 4\pi\rho$ of electrodynamics, which is usually not even maintained as an identity but is replaced by an auxiliary condition imposed on the state vector.

Some other criticisms are the following:

The footnote on page 36 overlooks the special case $A\,B;_k = 0$, $AB \neq 0$. On page 41 it might have been added that one *can* enforce symmetry of the affinity by postulating the possibility of constructing arbitrary infinitesimal parallelograms. On pages 98 and 100, the statement that in general one should expect fourth order Hamiltonian derivatives of the curvature scalar density is incorrect, as this density is of only second degree in the differentiation operator ∂_k. Variation cannot increase this degree. Therefore, the reasons given on pages 100–101 for this missing of higher than second order derivatives are superfluous. On page 100, a short discussion of "free" scalars and vectors would have been welcome in connection with the problem of the possible "invariant meaning" of any three-dimensional volume integrals of components of vectors or tensors.

The number of misprints is relatively low. Some trivial printing errors appear in formulas on pages 6, 24, 25, 30, 31, and 100. The word "vanish" in the footnote on page 15 should read "are unity." In Eq (9.7), read ki or ik instead of kl in the Christoffel bracket symbol. In Eqs (9.8) and (9.10) factors $-\frac{1}{2}$ should be replaced by factors $+\frac{1}{2}$. This also affects the sign of Γ in the last equation on page 67. Line 23 on page 68 is confusing by its brevity.

On lines 12 and 15 of page 76, read "but impossibly" instead of "or possibly." On pages 104–105 the use of the indices of $T^m{}_n$ and of the asymmetric tensor $t^m{}_n$ is contrary to that in Eq (11.21).

As for the notation: The arguments on page 7 in favor of x_k instead of x^k and on page 45 for c_a and $h_{\rho a}$ instead of c^a and $h_\rho{}^a$ are not very convincing. This notation leads to atrocities such as $(dx)^k = d(x_k) \neq (dx)_k = g_{ki}(dx)^i$, and it fails to show the correct vector character of the local and world coordinate differentials, which would be better shown by a notation using $dy^a = h_\rho{}^a dx^\rho$.

Also, the use of $A_{;k}$ and $A_{,k}$ is hard on the eye. $\nabla_k A$ and $\partial_k A$ would not have required use of a magnifying glass. The tensors on page 23 could then have been written in the easier-to-memorize forms $\partial_{[k}A_{i]}$, $(\frac{1}{2})\ \partial_{[l}\phi_{ik]}$, and $(\frac{1}{6})\partial_{[m}A_{ikl]}$, in which less harm is done when a student inadvertently tries to apply these theorems to tensors lacking the required antisymmetry.

All these little details do not alter the fact that this book is a very welcome and important contribution that deserves wide attention.

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Bees: Their Vision, Chemical Senses and Language. Karl von Frisch. Ithaca, N. Y.: Cornell Univ. Press, 1950. 119 pp. $3.00.

Professor von Frisch, of the University of Munich, has crystallized in delightfully clear English his 40 years of monumental research in interpreting the senses and language of the honeybee. His book will appeal to scientists, teachers, and laymen. Von Frisch has successfully reduced a complex subject to a clear, easy-reading text. He exemplifies scientists who place clear thinking and perseverance ahead of great physical resources for successful research. Students who expect to enter scientific fields will gain from it a desirable attitude of mind.

Bees are shown to have a sensitivity range between orange-yellow and ultraviolet or to light waves between 650 and 300 mμ. The response of bees to the influence of floral colors and color patterns is clearly demonstrated. They respond more strongly to their olfactory sense and to taste than to color, yet these senses collectively affect their behavior pattern. Bees distinguish between sweet, sour, salt, and bitter, although their threshold of tastes for these differ quite strongly from those of man.

The "language of bees" is shown to involve sensory behavior in respect to color or light quality, odor and taste perception, and the well-known bee dances. The author shows how these dances serve to communicate to other members of the colony that not only is food available in the field, but also what plant species is producing it, in what direction from the hive these plants are to be found, and how far the bees must travel to reach this food source.

The author was able to establish that bees apparently have the faculty of analyzing the polarized light in the sky. When they perceive a point of light from any direction in the sky, they can orient direction just as accurately as when they see the sun. The author discusses in the appendix the structure of the ommatidia in the compound eye in relation to an artificial eye he constructed from triangular pieces of polaroid to simulate the 8 visual cells observed in a bee ommatidium.

Students of bee behavior will recognize the general validity of the basic conclusions drawn from the experiments, for they have all observed many situations that fit this behavior pattern. Von Frisch would be the first to assert that there is much more to learn about the sensory mechanisms and their associations in the now well-established principle that bees have a positive language.

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Muscular Contraction: A Topic in Molecular Physiology. W. F. H. M. Mommaerts. New York-London: Interscience, 1950. 191 pp. $4.20.

The author of this monograph has presented an account of recent developments in the field of muscle biochemistry, emphasizing description of the actual experimental discoveries and discussion of the immediate interpretations of these discoveries.

The book begins with an outline of muscle metabolism which presents a very clear picture of the history and present status of carbohydrate metabolism and high-energy phosphate bonds in supplying energy for muscular contraction. Subsequent chapters present rather exhaustive accounts of work on the structure, activity, and interrelationships of the muscle proteins. Such topics as the structure of the muscle fibril, molecular sizes and shapes of muscle proteins, and viscosity and birefringence of flow are discussed. Experimental methods and results of the various investigators are described, and interpretations are made both from the data of that investigator alone and from correlation of all work presented in that section of the text.

Although at first glance the book may appear to be a duplication of one or more of the monographs of Szent-Györgyi, there is actually little overlapping. Szent-Györgyi's summaries are chiefly concerned with his own work, whereas this monograph devotes most of its space to the work of others, referring the reader to Szent-Györgyi for details and discussion of the theoretical background of his work.

The book is written so that a person seeking an introduction to the field can obtain it without wading through the pages of detail which will, however, be of great value to those who must for various reasons be more familiar with the latest developments of the problem.

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