methods of observing steps one atom high on growth surfaces. The steps had exactly the form that Frank had predicted. Later, Forty used the same techniques to observe the paths over which individual dislocations had moved in crystals of silver. Thus dislocations—like electrons, charged ions, and magnetic domain walls—have ceased being only elements in a theoretical picture and have become laboratory observables.

Next to the studies of crystal growth, the most direct evidence for dislocations and their behavior has come from research on crystal grain boundaries, in particular, boundaries between grains or subgrains that have only a small difference in orientation. Experiments have verified the dislocation theory of the structure, energy, and motion of grain boundaries.

There are other results of dislocation theory which (like the theory itself in its early stages) have as yet no direct experimental verification but are nevertheless widely used because of their simplicity and the absence of conceivable alternatives. One of the most important such concepts is the so-called Frank-Read mechanism which explains how a single dislocation initially present a solid can (1) produce a large amount of slip on a single slip plane and (2) multiply and produce the substantial number of additional dislocations that accumulate inside a crystal during deformation.

Of practical metallurgical problems, probably the most successful experimental-theoretical attack has been made on the interaction of dislocations and impurity atoms as illustrated, for example, by the hardening effect of carbon in iron. A. H. Cottrell and his co-workers at the University of Birmingham, England, have led dislocation theory into this difficult but important area. It is one of the discouraging features of working on dislocations that centuries of empirical metallurgy have uncovered practical results whose discovery would otherwise have been the worldly reward of pure science. In this respect dislocation theory is less fortunate than nuclear theory and semiconductor electronics.

One of the least understood and most practical problems is the nature of work hardening (the fact that slip increases the resistance to further slip). This is known to be somehow tied up with the strong interaction between dislocations, which get tangled up with one another and thereby are immobilized. However, the details of the process remain obscure, and it is seldom possible to make definite predictions to compare with experiment.

This brief discussion has touched on only a few salient aspects of a fascinating and expanding subject where theory and experiment have just begun to bridge a long standing gap in our knowledge of solids. Not the least appealing feature of the subject is that so much can be explained with simple pictorial ideas that presuppose no more physics than is acquired in an undergraduate course.

Suggested References

W. T. Read, *Dislocations in Crystals*, McGraw-Hill Book Co., New York, 1953.

A. H. Cottrell, *Dislocations and Plastic Flow in Crystals*, Oxford, New York, 1953.

Books

Meson Physics. By Robert E. Marshak. 378 pp. McGraw-Hill Book Co., Inc., New York, 1952. $7.50.

One purpose of a book review is to help the reader make an intelligent decision concerning his purchase of the book. However, for specialists in the field of meson physics, that decision was made the instant they learned that the book was to be published; members of this group naturally sent in their orders at once. Professor Marshak's contributions to the field have been extensive, both in research and through his Rochester Conferences.

As a theoretical physicist, the author stresses the theoretical aspects of the subject, and arranges the material according to its theoretical interest. Fortunately for those who know a microsecond more intimately than they do a matrix element, the author writes as one who has spent many an hour explaining theoretical concepts to his friends in the laboratory down the hall. The book is strictly for professional physicists; there is not a single paragraph of historical introduction. The opening paragraph assumes a knowledge that π and μ mesons exist, and that the Conversi experiment gave unexpected results. It mentions photon-nucleon, and nucleon-nucleon production of π mesons, and gives an order of magnitude estimate for the unobserved production of μ meson pairs by gamma rays. Books at this level often start with an "easy chapter", but from the reviewer's personal experience, all this accomplishes is the sale of the book to some unsuspecting undergraduate students, who are pleasantly surprised that they can understand the first chapter. Marshak's approach is more candid; he implies that if you can't understand what he is talking about in the first few pages, the book should be of no interest to you. However, if you can understand, or perhaps just follow, what is discussed in the first sections, the book is a gold mine of information on all phases of meson theory and experimental results.

Meson physics differs from most other branches of physics in that the theory came before the experiments. One should rather say theories, since theoretical predictions are commonly made for mesons of various spins, parities and coupling schemes. Now that the spin and parity of the meson are known, one might at first suppose that a great theoretical simplification could take place; it should no longer be necessary to carry along all calculations for vector mesons, and mesons with even parity. But when one remembers the heavier mesons that are still so little understood, one sees the usefulness of having the theory available in all its diversified glory. Marshak's book presents the theory of the generalized meson, and the results of experiments on π and μ mesons. (Heavy mesons are discussed briefly in the last chapter.)

The first three chapters discuss the production of π mesons in increasingly complex collisions: photon-nucleon, nucleon-nucleon, and general-nuclear. The next four chapters deal with the properties of π and μ mesons, and with the interaction of π mesons and nuclei. The experimental data for these chapters came largely from the high-energy accelerator laboratories. The last two chapters discuss the very-high-energy processes which are probably secure in the hands of the cosmic ray physicists, together with some of their new heavy particles which are just showing up in the laboratory at Brookhaven.

The author and the publisher are to be congratulated for making available to the meson physicist a book so complete in its coverage of theory and experiment, and so thoroughly up to date. A measure of this journalistic achievement can be had by comparing three dates. The latest reference in the book is to the Copenhagen Conference of June, 1952; the book was in the hands of its readers in January of 1953, and this review appears in the November 1953 issue of *Physics Today*.

Luis W. Alvarez
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The Nature of Some of Our Physical Concepts. By P. W. Bridgman. 64 pp. Philosophical Library, Inc., New York, 1952. $2.75.

This book, a reprint of three lectures delivered in 1950 at the University of London, attempts a deeper analysis of the operations involved in some of our physical concepts. Observation shows that physicists usefully employ concepts whose meaning cannot be found by the instrumental operations of the laboratory. Nearly all the concepts of theoretical or mathematical physics are of this character. A simple example is the ψ function of wave mechanics. The author calls the non-instrumental operations by which these concepts are defined "mental" operations. The special mental operations performed by the theoretical physicist in his mathematical manipulations are called "paper-and-pencil" operations. The author suggests that it is important to consider also verbal operations.

The structure of our language and of our thought makes certain demands which we try to satisfy by introducing appropriate concepts and then giving them an instrumental definition. For example, the second law of thermodynamics leads us to localize entropy in space. This leads to the formal and verbal demand that there exist fluxes of entropy to account for the changes of localized entropy. It is formal because we have not as yet any instrumental method of giving meaning to the flow of entropy across boundaries. The author shows that in certain cases instrumental operations can be discovered which will define the flow of entropy. By the use of this and similar concepts it is possible to bring certain irreversible processes within the scope of thermodynamics. One such process is the thermo-electric effect in metals.

The author's viewpoint is stimulating and provocative. It seems to bear out recent work in linguistics which shows that the concepts we use to think with are molded by the language we speak. It is clear that a further investigation of the connections between language and thought would be profitable.

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The Comets and Their Origin. By R. A. Lyttleton. 173 pp. Cambridge University Press, New York, 1953. $5.00.

In this book R. A. Lyttleton, one of the most competent astrophysicists of the present day, reviews the present observational evidence and modern thinking on the subject of comets. The five chapters logically divide the subject, the first two being descriptive of observed properties, the dynamical and the physical. The nature of the orbits, and the sizes, masses and spectra are summarized. The arguments are given which lead to the conclusion that comets are swarms of closely associated small particles.

The third and fourth chapters, on the origin and formation of the comets and the formation of their tails, represent the description of the newer contributions to the subject. In the chapter on formation, Lyttleton sets forth in detail the calculations of the accretion theory, and shows with simple mathematics how a star passing through a cloud of interstellar matter will sweep out a tunnel, some of which matter will form loose aggregates with elliptic velocities. These aggregates constitute the comet. The tail is dust and gaseous debris produced not mainly by solar action on the nucleus of the comet, but by collisions and friction due to internal motion, which is shown to be greatest at perihelion.

The last chapter is entitled "Relation of the Present Theory to Earlier Ideas", and is, in this reviewer's opinion, the least interesting part of the book. The chapter could have been strengthened if, instead of attacking the views held in 1560, or even a century ago, more space had been devoted to discussing the theories of the 1920's and 1930's. Since the definition of "Modern Astronomy" (or Modern Physics) is "That part of the subject which has developed since I was a Graduate Student", most of us would like to see a logical summary of the idea-building which has taken place during this time-interval.

On the whole, the book is a welcome addition to the scant literature in the field. The style is good, readable and clear, the illustrations are spectacular, and the printing and binding are the usual high quality Cambridge jobs. It should be on the list of required reading for any serious student of astrophysics.

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