

on basic mathematical theory and general physical situations. Hence attempts are being made in the direction of invention of new approximate or exact methods.

The unified relativity theory naturally offers a virgin field for scientific exploration. Combined with the circumstance that the mathematical problems posed are extremely complicated, is the factor of an elegant generalized geometrical interpretation. This presents a definite challenge for the mathematically minded. On the other hand the physicist finds it appealing in the remarkable resemblance of certain concepts in the theory to the "ether strain" of Maxwell and Faraday, as well as in the universal nature of its goal, to describe all physical phenomena by a nonlinear field theory.

Once one passes beyond the realm of applicability of the elementary theory of shaped charge jet formation and penetration, the experimental and theoretical studies become extraordinarily difficult. This is due not only to extreme difficulties in observation but also to the presence of large, as yet unexplained, fluctuations in some of the phenomena. From the theoretical side it is due partly to the fact that the processes involved can but rarely be regarded as steady state ones. For these reasons, and for certain practical applications, it is handy to be able to summarize the formulation of the elementary theory in as concise a form as possible. Theoretical calculations along these lines are in progress.

The theoretical work of Professor Borowitz is mainly concerned with investigations in the field of fundamental processes of the ionosphere. The principal long-range concern is to investigate the collision and recombination cross sections of electrons with atoms and molecules and ions. At the moment the simplest three body scattering processes are being considered.

The elementary processes are of the utmost importance in determining electron, ion, and radiation densities in the upper atmosphere. Inasmuch as the physical situation existing in the ionosphere cannot be duplicated in the laboratory at the present time, the theoretical calculations offer the best hope of obtaining information.

Many of these problems have been examined in the past, but their complexity has prevented any but the crudest approximations to the answers from being made. In recent years, improved analytical techniques coupled with computational machines have made the outlook for better results promising.

The work is being performed by Assistant Professor Borowitz and Visiting Associate Professor Gerjouy under contract with the Geophysical Research Directorate, Air Force Cambridge Laboratories.

Professor Beers has initiated some spectroscopy in the longer microwave region where there is promise of obtaining interesting information concerning the structure of molecules although the number of lines is smaller and intensities are considerably weaker than in the "K" band and millimeter regions which are popular fields for research elsewhere. At the time of writing Professor Beers and two graduate students have just completed a spectrometer and results should be forthcoming in a short time.



Operations Research

Methods of Operations Research (First Edition Revised). By Philip M. Morse and George E. Kimball. 158 pp. The Technology Press of Massachusetts Institute of Technology and John Wiley & Sons, Inc., New York, 1951. \$4.00.

Professors Philip Morse and George Kimball have produced the most impressive account of wartime operational research that has appeared, so far as the reviewer knows, in either the United States or the United Kingdom. The origin of the book is clearly indicated by the first paragraph of the authors' Preface, which reads:

"In a sense, this book should have no authors' names or else several pages of names. Parts of the book were written by various persons during and at the end of World War II. What the undersigned have done is to collect the material, rewrite some in the light of later knowledge, expand some to make it more generally intelligible, add chapters on organization and general procedures, and cement the mosaic into what is hoped to be a fairly logical structure.

"Since the undersigned were members of the Operations Research Group, U. S. Navy, it is perhaps not surprising that the examples given are drawn chiefly from the work of this group, though an effort has been made to include examples from the work of other groups. Many persons have helped by discussions and editorial criticism, including members of other operations research groups in this country and in England. To mention a few would slight many others, so none will be named."

The perusal of the various chapters bears out this account of the book's origin. Much of the material has been taken directly from previously secret service reports. Naturally detailed references to these reports cannot be given. In a bibliography at the end of the book a comprehensive review of published work on operational research is given, and it would perhaps have been expected that where such published work is quoted verbatim detailed references would have been given. It is perhaps a pity that this was not done, as it is somewhat disconcerting to find in the book paragraphs taken almost verbatim, and without inverted commas, from one's own writings on the subject! This criticism is, however, rather trivial, and in no way detracts from the value of this excellent compilation of wartime results and experience.

As one who was closely associated with several of the

important developments in the organisation and methodology of operational research in the United Kingdom, I admire the soundness and general good sense of the presentation.

In particular, chapter 1 gives an excellent introduction to the subject in clear and readable form. Most of the factors which, in the authors' personal experience, are important to ensure the success of such work, are clearly emphasised. Again, the last chapter on "Organizational and Procedural Problems" seems to me equally sound and well judged.

Chapter 2 gives a survey of probability theory of a fairly conventional type, which is useful but can also be found in many other textbooks. My own attitude to probability theory is a somewhat cautious one. In a sense, of course, probability theory in the form of the simple laws of chance is the key to the analysis of warfare; in addition simple fluctuation phenomena have to be understood by all workers in this field. My own experience of actual operational research work has, however, shown that it is generally possible to avoid using anything more sophisticated. In actual operational research, where possible executive action is in mind, results which depend, say, on the application of a "chi squared" test are usually so much on the borderline as to be of little use. In fact the wise operational research worker attempts to concentrate his efforts on finding results which are so obvious as not to need elaborate statistical methods to demonstrate their truth. In this sense advanced probability theory is something one has to know about in order to avoid having to use it. An analogy from experimental physics is the view, often attributed to Rutherford, that no experimenter wanted to know much about the theory of errors, for if he were a good experimenter he would go back and improve his apparatus and do the experiment again. In operational research one can seldom or never do experiments again, but one can and does concentrate on obtaining results of such decisiveness as to make common sense rather than elaborate probability tests their sanction.

Chapter 3, under the title "The Use of Measures of Effectiveness", gives a useful and readable account of the analysis of many parts of the air and naval war against submarines, with special emphasis on sweep rates, probabilities of sighting, exchange rates and the comparative effectiveness of various forms of attack.

Chapter 4, under the title "Strategical Kinematics", delves rather heavily into what may be called "a priori" warfare of the type originated by Lanchester. Lanchester, of course, displayed remarkable originality in his famous book and, as one of those who can claim to have been partly responsible for reviving interest during the war in his work and relating it to modern operational research, I feel it should have a place in any such textbook. However, the more elaborate developments in the form of the general Lanchester equations given in this book are rather outside my field of experience, and I am not able to judge whether or not they are of any use in actual operational research.

The following three chapters, "Tactical Analysis",

"Gunnery and Bombardment Problems", and "Operational Experiments", are straightforward and useful, though in several cases I would have preferred somewhat less mathematical analysis and rather more experimental fact and practical example.

Though explicable from the above-quoted origin of the book, it would have been an added asset to the book if examples had been drawn from a wider field. Admittedly most of the now accepted methodological and organisational procedures of operational research originated in the early part of the last war, in connection with the sea and air war in Europe. It is still true, however, that very valuable results were subsequently achieved in other fields. There is, for instance, almost no reference to any work on land warfare, and hardly any to the highly documented and controversial subject of long range air bombardment. As is well known, the long-range bombardment of cities, factories and communication systems played a very important role in the Allied war effort, and has been extremely well and accurately documented in the numerous reports published by the U. S. Strategic Bombing Survey. These reports provide a great amount of invaluable material for use in operational analysis and provide, incidentally, excellent examples for many of the principles outlined in the various chapters of the book. However these reports are not mentioned in the text nor in the bibliography.

Various references are made to the possibility of applying such methods to peacetime use but no attempt is made actually to do so. In this the reviewer considers the authors' judgment to be sound—it was better to concentrate in this book on what was achieved in the war than to make immature sallies into the industrial or peacetime field. For one thing must over and again be emphasised: original operational research on any important war problem demands a large background of factual knowledge and experience, which may appear only implicitly if at all in the analysis. Some of the deceptively simple conclusions of great technical or strategic importance—results which can be demonstrated in a few lines of writing and a few simple arithmetical expressions—can only in fact be made on the basis of a profound knowledge of the factual environment. Innumerable other facts have to be known in order to know that they need not appear in the analysis.

Thus, if one attempts to apply operational research to the civil field, it will be necessary to build up a similar deep knowledge of the factual environment before one can attempt to get useful results. For those, however, who are interested in applying these methods to peacetime problems, a detailed knowledge of what was achieved in war cannot but prove extremely valuable. Morse and Kimball's book has for the first time made available to the public a connected and weighty account of many of these achievements. The authors have therefore certainly performed a very valuable service in compiling and writing this book.

There is one point of historical interest on which the reviewer would like to touch: this is the question of to what extent operational research is new. The novelty, in

the writer's view, lies not in the application of scientific method to such complex phenomena as war, since scientific method has already been often successfully applied, in the form of social studies, to the equally or still more complex phenomena of society. The novelty, in my view, is in the organisational level at which the work was done. The essential point is that the work was carried out in close contact with executives and had an immediate practical relevance. This fact coloured the whole organisation and personal relations of the people concerned. The authors do bring out clearly the very important point of the relation between the operational research workers and the executives, and the fact that they have two different tasks to do and that these must never be confused. I personally am convinced that both the organisational patterns evolved empirically for the operational research groups during the war and the methods they developed are directly applicable to very many peacetime problems. The single proviso is, of course, that the groups must build up that intimate background of knowledge of the whole field of activity of what they are investigating before they attempt to give advice to busy and usually harrassed executives.

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A Portrait of Newton

Isaac Newton. By E. N. Da C. Andrade. 111 pp. Chanticleer Press, New York, 1950. \$1.75.

Printed in a size that will enable the reader to carry it in his jacket pocket, this short biography of Isaac Newton will appeal to all physicists who are intrigued by the personalities of great discoverers. In a certain real sense, Professor Andrade has not written so much a biography as a portrait of Newton. The limitation of space and the adulatory tone of the book do not allow for a full critical analysis of all that Newton did and all that Newton was. In this connection we must remember that Newton is one of the most enigmatic figures in the history of modern science. The intensity of his creative effort during a short period of his youth continued to bear fruit until he forsook the career of scientist for one of public service in the Mint. Of this we are given a simple lucid account by Professor Andrade in a book that is gracefully written and that provides a more intimate portrait of Newton the man and Newton the creator than is to be found in many larger works.

In this book the reader will find more than a picture of Newton the physicist. Professor Andrade does not neglect Newton's other activities and presents Newton the alchemist, the theologian—wrestling with problems of the Trinity and a kind of Unitarianism, and the critic of the Bible for whom every aspect of human existence and the universe provided material for a great hermeneutic exercise on "the meaning of it all". Here too are presented Newton's abhorrence of controversy and the difficulty his contemporaries had to get anything out of him, his dislike of women, and his generosity on occasion.

Professor Andrade has written a number of studies on various aspects of science in the seventeenth century, especially in England, and possesses one of the finest private collections of books in older science. Not only does he know the science of the seventeenth century well, but he has—in addition—consummate literary skill which he has exhibited in splendid nontechnical accounts of modern physical science and also in verse. As a literary venture, this small book is a gem, evoking memories of other short biographies of English men of science by Englishmen, such as Tyndall's *Faraday as a Discoverer*. Yet, on the critical side, it must be pointed out that the character of the book is also its weakness; while Newton's predecessors are mentioned briefly, as are some of his contemporaries, one gets the impression a little too much that Newton—so to speak—did it all himself. A number of minor slips mar the text; e.g., all the learned men of Kepler's time did not write in Latin (Galileo, for one, wrote also in Italian); Newton was not the first to extend gravity from the surface of the earth to the moon; etc. But these are minor matters and critics can be too carping in reviewing books for general reading that make no pretence of advancing scholarship.

For the busy physicist who wishes to spend a few hours in his study or on a train in reading a most pleasant and engaging book, Professor Andrade's *Newton* can be highly recommended. Handsomely printed and beautifully illustrated, it is a volume in a series entitled "Personal Portraits", edited by Patric Dickinson and Sheila Shannon; let us hope that other members of the series will be forthcoming on such figures as Boyle, Hooke, Priestley, Cavendish, Clerk Maxwell, J. J. Thomson and Rutherford, and that they will be as excellent in their way as this one is.

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Briefly Noted

Physics in France

The French Bibliographic Digest, No. 7, *Physics* (87 pp.) was edited and published this year by the Cultural Division of the French Embassy, 934 Fifth Avenue, New York City. Copies may be secured without charge by writing to the above address.

For those having some special interest in French physics books published during the period between 1940 and 1948, the booklet is certain to be of considerable value. Others, provided they bring with them at least a casual curiosity, will find this pamphlet rewarding—if for no other reason than its introductory essay, a review of wartime and postwar French physics written by Ives Rocard, professor of physics at the Ecole Normale Supérieure de Paris. Professor Rocard's summary of the period places particular emphasis upon the effects of the German occupation on French research and pays homage to several of the more notable French physicists whose lives were lost during the war, some in the campaign of 1940, some in concentration camps or during