Book Reviews

General Education in Science. I. Bernard Cohen and Fletcher G. Watson, Eds. Cambridge, Mass.: Harvard Univ. Press, 1952. 217 pp. $4.00.

General education is a religion that is fast acquiring the status of an established church. This book is a contribution to its ecclesiastical literature, being 15 essays prepared by competent educators for the Harvard Workshop in "Science in General Education" (1950). Although understandably exhortatory in tone, each essay has merit as an indication of honest effort to say something significant about science teaching and its needs.

When one has lived for years, as I have, in *sin*—the sin of specialization—the reading of this book is likely to arouse mixed emotions. First, there comes the spirit of proud defiance, then of contrition, and finally of conversion as one evangelist after another preaches the gospel of integrated education. If there is backsliding, it is but an indication of the utter depravity of the old ways into which one has heedlessly fallen.

The 15 defenders of the faith are united in their opposition to "the traditional specialist's courses" in science. In their concerted aim to make science intelligible to more nonscientists and to make scientists better citizens, historians, and philosophers, their purpose is noble. On how to attain their desired goal, each man's suggestions are worth considering: surely, any program that includes among its aims the cultivation of *better thinking* by students deserves attention! General education hopes to liberate liberal education, to have students "know the scientific enterprise as a whole," to divest science of its priestly robes, to disengage it from its beautifully deceptive aura, to restore to it a history and a philosophy, to debunk it of its fictitious "scientific method," to release it from the "curse of coverage," and replace coverage by well-chosen case histories, in the study of which the student is led into scientific thinking, or a reasonable facsimile thereof. If the movement avoids playing the role of a Don Quixote, it may have in it the strength to accomplish what has always seemed to this reviewer as the avowed but unattained purpose of education generally. New ideas, new slogans, and new blood should be welcomed in any process as important as education, since each generation reviews the faults of the past and tries to modify its own course in directions that give promise of satisfactory advancement. One detects frequently the note of humility as these essayists recognize the vastness of the task undertaken.

In a short review, it is not possible to give many of the quotable statements the volume contains, nor to write adequate criticisms of each man's contribution. The place of science in our civilization and the reasons for believing that changes in science education are much overdue are viewed from various angles by Messrs. Dubos, French, Sears, LeCorbeiller, Goudsmit, and Fuller. The part played by philosophy in the teaching of science is treated by Kemble and Frank; by history, in three essays by Cohen, Nash, and Kilgour. Two sane and realistic contributions by the biologists Castle and Erikson appealed to your reviewer as particularly acceptable. The book concludes with two chapters by Dyer and Watson on the difficult problem of evaluating the results of the new approach to science teaching. Throughout the "commercials," there are valuable suggestions and stimulating ideas.

If, two decades from now, science teaching has taken on a new complexion, if it serves the populace better, makes more civilized scientists and more science-minded citizens among the laity, it may come to pass because of the efforts of these men, and others, who honestly and earnestly seek for better ways to do this perennial job of educating that has never been done well enough. Much as they tend to blame the present sorry plight of the world, so far as education is responsible for it, upon the growth of narrow specialization, most of them frankly admit that general education is not a proved panacea for all our ills, but that it still stands in the position of a promising experiment. Education is still likely to remain a process that depends primarily upon the teacher's breadth of interest, devotion, and ability to share with students his best insights.

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Physics and Mathematics

Astrophysics: A Topical Symposium. Commemorating the fiftieth anniversary of the Yerkes Observatory and a half-century of progress in astrophysics. J. A. Hynek, Ed. New York: McGraw-Hill, 1951. 703 pp. $12.00.

This volume, most appropriately bearing the subtitle *A Topical Symposium,* was composed to commemorate the fiftieth anniversary of Yerkes Observatory and half a century of progress in astrophysics. The contributors, who all at one time or another were connected with Yerkes, were each asked "to survey his field, to describe its growth during the past fifty years, to examine its particularly challenging problems; and to address a hypothetical first-year graduate student, well versed in fundamentals but by no means a specialist." It is amazing, even when one takes into account the galaxy of contributing astrophysicists, to what degree practically all of them have succeeded in doing exactly this. The result is a most stimulating survey of practically the whole field of astrophysics, and this volume can certainly be used as a textbook for graduate courses in the subject. The fact that the various contributors have clearly indicated the many problems with which astrophysics is still confronted should assist research workers in the field, and for a long time to come this book should provide a powerful stimulus to astrophysicists.

The material is divided into an introduction followed by four large sections. In the introduction, which surprisingly bears the title "On the Development of Astrophysics during the Last Half Century," Strömgren gives a survey of the state of astrophysics around 1900. Only by a comparison of the situation then with the present is it possible to see the great heights reached by astrophysics in as short a period as 50 years.

The four main sections deal, respectively, with "Spectroscopic Astrophysics," "Physics of the Solar System," "Physics of Binary and Variable Stars," and "Physics of Cosmic Matter." The division seems to me rather artificial and not always understandable. For instance, although one can easily see why Greenstein's chapter on interstellar matter is classified under physics of cosmic matter, it is difficult to understand why Chandrasekhar's contribution dealing with the structure, composition, and source of energy of the stars should also fall into the same category, and one wonders whether, in that case, all chapters could not have become part of this section of the volume.

In the first chapter of Part One Keenan and Morgan give a historical survey of the classification of stellar spectra, showing how this branch of astrophysics has developed and discussing what spectra offer special problems of classification. In the next chapter Aller describes how stellar spectra are obtained, how spectral lines are formed, and what information can be obtained from the spectra. Aller restricts himself to "normal" spectra. In the third chapter Struve reviews the fascinating problems posed by some "peculiar" spectra. He has chosen for discussion the following 8 topics: Be stars, close binaries with gaseous rings, spectra with peculiar line intensities, Wolf-Rayet stars, T Tauri variables, stars with extended atmospheres, novae, and emission lines in long-period and Cepheid variables. As could be expected from this author, the chapter is extremely stimulating and full of pointers to as yet unsolved problems. The fourth chapter is devoted to a discussion by Swings of molecular spectra. As this field is still developing fast, Swings devotes most of his account to suggestions of possible astronomical observations, laboratory and theoretical investigations, and desirable theoretical astrophysical investigations. Part One closes with a chapter by Strömgren in which he discusses how spectroscopic astrophysics has progressed during the past 50 years.

Part Two, treating the physics of the solar system, contains three chapters. In the first of these Pettit discusses the sun, its radiation, sunspots, chromospheric phenomena, prominences, the corona, and related topics. There follows a discussion by Bobrovnikoff of our knowledge, and in many cases our lack of knowledge, of comets. The last chapter contains an extremely interesting, but rather controversial, paper by Kuiper on the origin of the solar system. I hope to discuss this theory in detail elsewhere in the near future, but, interesting as Kuiper's considerations are, it is regrettable that he—who has contributed so largely to the recent increase of knowledge about characteristics of the solar system—did not give us instead an account of the physical nature of the planets. As an alternative, I feel that it would have been valuable to have given a critical survey of developments in the field of theories on the origin of the solar system, which would, at the same time, have been more in accordance with the general aim of the volume. During the past 50 years there have been proposed such widely diverging theories as the different tidal theories, Birkeland's and Alfvén's electromagnetic theories, and von Weizsäcker's and Kuiper's versions of Kant's cosmogony, to name only a few, and a critical survey would have been of the utmost importance.

Physics of binary and variable stars are dealt with in Part Three. Van Biesbroeck opens this section with a chapter on the visual binary stars and stellar parallaxes, and Hynek discusses spectroscopic binaries and outlines the problems connected with any theory about the origin of binary stars—a problem justly described as a pivotal one in cosmogony. In Chapter 11 Pierce discusses briefly how eclipsing binaries provide us with information on the physical properties of the stars. Cecilia Payne-Gaposchkin ends this part with an account of our present knowledge about the intrinsic variable stars. She discusses in turn all 5 main groups of the Great Sequence, classical Cepheids, cluster variables, RV Tauri stars, long-period variables, and semiregular variables.

Part Four contains only two chapters, but both are extremely interesting. Greenstein deals with interstellar matter, discussing the whole field of emission nebulae, reflection nebulae, interstellar reddening, interstellar grains (I always wonder at the reluctance of so many astrophysicists to use the term "smoke particles," introduced by van de Hulst), interstellar hydrogen, galactic radio noise, interstellar molecules, stellar evolution, and interstellar polarization. The last chapter is one by Chandrasekhar on the structure, composition, and source of energy of the stars. As we have learned to expect from Chandrasekhar, this contribution is original, clear, and comprehensive. In fact, if I should have to state my preference for one of the chapters of the book, this would be the one I should choose. Chandrasekhar deals with the following problems: physical conditions in the interior of a star, source of stellar energy, composition of the stars, structure and composition of the white dwarfs, and stellar evolution.

It can be seen from the account given here that this volume covers an extremely wide field, and the editor must be congratulated on achieving such a great amount of uniformity. Any review of a book of this kind must of necessity have a strong personal flavor, and the special stress on certain chapters and more casual mention of others are due purely to personal interests. However, it should be clear from the foregoing that there is enough choice in the volume to satisfy practically anyone who is at all interested in astrophysics. The contributions that appealed most strongly to me were those of Chandrasekhar, Struve, Swings, and Bobrovnikoff—partly because of their subject matter and partly because of the clarity with which existing problems were mentioned.

The volume promises to become a classic in the field, and one can only be envious of all astronomers who belong to the family of Yerkes scientists, since a school boasting a group of people like the contributors to this book must necessarily produce a never-ending line of outstanding astrophysicists. It will be of the greatest interest to see how much of the material presented in this topical symposium will still be considered correct when the second volume appears to commemorate the Yerkes centenary.

The book contains three indexes—name, star, and subject—which should enhance its usability. It is to be regretted that its price is practically prohibitive so far as European astrophysicists are concerned, but with present-day exchange rates and costs of book production this could hardly have been avoided.

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Studies in Large Plastic Flow and Fracture: With Special Emphasis on the Effects of Hydrostatic Pressure. P. W. Bridgman. New York–London: McGraw-Hill, 1952. 362 pp. $8.00.

This is an important book for those interested in the mechanical strength of solids. Its principal purpose is to consolidate and discuss a large amount of experimental material gathered by Professor Bridgman and his small group of assistants at Harvard University during and following the recent war. Actually, various experiments done prior to that period are included—some from as far back as 1912. A list of 42 publications and government reports is given as the source material. A few results postdating the publications are included. The information on fracture strength and resistance to plastic deformation thus provided is outstanding and unusual, both with respect to the variety of materials studied and with respect to the extreme range of essentially static conditions of plastic strain and of stress.

The substance of the book is a series of deformation studies some of which employ hydrostatic pressures as large as 400,000 psi. For each, the author's narrative of the experimental work is followed by his analysis of the results and his reflective comments in some detail. The experimental work and numerical results are of major permanent value, and readers will find the presentation of these features clear and remarkably interesting. Pertinent colorful detail is included in sufficient amount so that one feels he is witnessing these rare experiments. For example, when a brittle solid with an internal cavity is subjected to large hydrostatic pressure, failure at the walls of the cavity generally begins with forceful ejection of tiny spicules. In a later chapter, it is found that shear fractures can be made to occur under nearly hydrostatic pressure such that they heal immediately, but not without a variety of strange noises voiced in protest against the Bridgman shear strains of 10,000 radians or more.

The numerical results are frequently of arresting interest. One might expect plastic distortion, whether under compressive load or not, to result in growth of internal strains and an accompanying decrease in density. However, commercial samples of tool steel, stainless steel, copper, and brass all show an increase of density under one-sided compressive deformation. On the other hand, soapstone, marble, and cast iron, subjected to similar stressing, flow very little but decrease in density. Complexities associated with internal flaws or cavities apparently are of dominating importance in measurements of this type.

Exploration of various stress laws for plastic flow and fracture supplies continuity and background motive for most of the author's experiments. The serious limitations of these laws are analyzed and discussed. As necessary supplements or replacements, the author draws attention to energy considerations, creep, inhomogeneous and nonisotropic strain hardening, and localized distortions resulting from flaws or corners. Thus he provides a wide variety of measurements that can be employed to check theoretical relations, shows that existing relations do not serve well for representation of his data, and suggests numerous plausible viewpoints which deserve trial in future explanatory efforts of workers in this field.

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The Algebra of Vectors and Matrices. Thomas L. Wade. Cambridge, Mass.: Addison-Wesley, 1951. 189 pp. $4.50.

This book gives a lucid elementary exposition of the algebra of vectors and matrices, set in a framework of modern algebra. The opening chapter explains and illustrates the basic concepts of groups, integral domains, fields, and rings. Vectors and vector spaces are dealt with in the next three chapters. The vector products are defined in space of three dimensions, but examples of their utility are rather meager and could well be expanded. The linear dependence of vectors receives adequate treatment, first in three, then in n-dimensional vector space.

The remainder of the book is concerned with matrices. The treatment is simple and straightforward, and the theorems are all well illustrated with examples. The prerequisite mathematical background is only a course in analytic geometry and a knowledge of the usual theorems on determinants given in college algebra. The more advanced parts of matrix theory, such as the minimum equation of a matrix, are sensibly omitted, but references to more complete texts are always given. Among the topics dealt with in some detail are the characteristic equation, roots and vectors of a matrix, the Hamilton-Cayley theorem, elementary transformations, reduction of a matrix to the diagonal form, and the solution of systems of linear equations. A whole chapter is devoted to theorems dealing with the concept of rank and various theorems on linear dependence. Finally, the theory of matrices is applied to the study of bilinear and quadratic forms and their reduction to canonical forms.

On account of the importance and elementary character of the proofs, it is a matter of surprise that the author has omitted two basic theorems on symmetric matrices—namely, that their characteristic roots are real and that the characteristic vectors corresponding to distinct roots are orthogonal. In fact, the theorem on the reality of the roots is not even explicitly mentioned, although in dealing with the reduction of symmetric matrices it is tacitly assumed. But, on the whole, the author has shown excellent judgment as to the inclusion or exclusion of material for an admittedly elementary book—a book that should prove a most welcome introduction to a branch of algebra with manifold important applications.

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Linear Transformations in n-Dimensional Vector Space: An Introduction to the Theory of Hilbert Space. H. L. Hamburger and M. E. Grimshaw. New York: Cambridge Univ. Press, 1951. 195 pp. $4.50.

In the introduction to his book *The Theory of Groups and Quantum Mechanics,* Hermann Weyl included the following comment:

> It is somewhat distressing that the theory of linear algebras must again and again be developed from the beginning, for the fundamental concepts of this branch of mathematics crop up everywhere in mathematics and physics, and a knowledge of them should be as widely disseminated as the elements of differential calculus.

That some progress toward this goal has been made in the more than 20 years since this was written is mainly due to the subsequent appearance of several fine treatises, elementary and advanced, dealing with this subject. The book by Hamburger and Grimshaw is a valuable addition to this steadily growing branch of mathematical literature. It introduces the ideas and methods of the theory of linear transformations in Hilbert space (the "operators" of quantum mechanics) by using them to present the more elementary theory in a finite dimensional space. Its principal results—the spectral representations of Hermitian transformations and the canonical representations and commutativity properties of general linear transformations—are developed in great detail. No use is made of determinants since there would be no analogous treatment in Hilbert space.

Neither the material nor its treatment is new. Nevertheless, even the specialist in this field will find novelty in some results and proofs, and in the organization of the material. Of special interest are the instructive notes, mostly historical and bibliographical, and the copious references. To the nonspecialist the book will not be easy reading. Although it is intended as an introduction to a more advanced theory, the authors pay little attention to didactical demands. Motivation of developments is brief or nonexistent, there is practically no illustrative material, no excursions to other fields, no signposts to guide us through the more complicated proofs. The authors state in the preface that they chose, for the greater part of the book, a concrete vector space in preference to an abstract space, so that the ideas may be more readily grasped. But not only does this choice necessitate duplication and circumlocution, but, by stressing the arithmetical against the geometrical aspect, it may actually produce the opposite effect.

Whatever objections one may have to these features of the book, its positive qualities are such that it deserves the widest use.

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The Classical Theory of Fields. L. Landau and E. Lifshitz: trans. from the Russian by Morton Hamermesh. Cambridge, Mass.: Addison-Wesley, 1951. 354 pp. $7.50.

This book gives a systematic presentation of the theory of electromagnetic and gravitational fields. The entire treatment is relativistic. The first chapter covers the fundamentals of the special theory of relativity, that being the only part of relativity needed in the first two thirds of the book, which deal chiefly with the electromagnetic field. The second chapter treats relativistic mechanics. The last third of the book, devoted to the theory of the gravitational field, requires the general theory of relativity. Four-vectors and tensors and space vectors are used in the mathematical treatment.

Although physics is kept in the foreground, the treatment is deductive and mathematical. It is seldom that the authors refer to experiment except in general terms. All the fundamental laws of motion and field equations are derived from the principle of least action, with the integrand of the action integral S initially unknown. The form of the integrand of S in each case is inferred from a consideration of the kind of quantities that must appear in it, arguments concerning scalars and four-vectors or tensors, and similar general considerations. Sometimes these arguments appear not to be quite sufficient, and a little outside aid must be brought in. Nevertheless, the book goes far toward creating the impression that relativity theory and the principle of least action with the integrand of S initially unknown suffice to derive the fundamental laws. These derivations, however, are not quite complete deductive proofs in all cases. Thus, in getting the Lagrangian L for a free particle, a comparison is made with the L for Newtonian mechanics in order to determine a constant that turns out to be mc.

From arguments involving relativity the authors conclude that the electron and all elementary particles are geometrical points. They also state, however, that "electrodynamics as a logically closed physical theory presents internal contradictions when we go to sufficiently small distances." For the electron they obtain a distance $R_0 \sim e^2/mc^2$.

> This dimension [the "radius" of the electron] determines the limit of applicability of electrodynamics to the electron, and follows already from its fundamental principles. We must, however, keep in mind that, actually, consideration of quantum phenomena already set much higher limits than the limits of application of electrodynamics which have been presented here [so-called "classical limit"].

The treatment of general relativity is quite elegant. The physics is kept in the foreground rather than the geometry of space-time. The discussion of time, synchronization of clocks, and simultaneity in the general theory is thorough and excellent. The last part of the book deals with the application of general relativity to the universe as a whole.

For a reader with a background of knowledge of advanced Newtonian mechanics, this is an excellent and readable volume. It is a valuable and unique addition to the literature of theoretical physics.

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Proceedings of a Second Symposium on Large-Scale Digital Calculating Machinery. Annals of the Computation Laboratory of Harvard University, Vol. XXVI. Harvard Univ. Press, 1951. 393 pp. $8.00.

Howard H. Aiken is to be congratulated on the appearance only two years later of this record of the second symposium held by the Navy Department Bureau of Ordnance and Harvard University at the Harvard Computation Laboratory in September 1949. The claim that the volume will function both as a progress report and as a preview of the future is more than borne out.

The field covered includes computing machinery both from the theoretical and from the practical standpoint; the analytical and numerical methods that are developing because large-scale machinery makes them practicable; and an account of the solution of various problems in physics, mechanics, and economics that has been made possible, as well as of proposals for solution of still larger problems.

In this field much information is in the air rather than in the literature. The reason for this seems to be that, although rapid advances are being made, many of the main ideas are not new, and no one likes to undertake the task of giving proper credit for them! Under these circumstances symposia such as this perform a large and valuable service in promoting exchange of information among the experts, as well as providing a means of disseminating it widely.

Besides a discussion by B. L. Moore, assistant director of the Harvard Computation Laboratory, of the Mark III machine, which was on view at the symposium, there are papers on the Bell Computer, Model VI, on Whirlwind, on the Raytheon machine, on a General Electric digital computer, on the 603–405 computer, and on Louis Couffignol's machine at Paris, as well as a paper on automatic computing machine development in England. In addition, there are several papers on machine components and on the general theory of machines, and a discussion of the future of computing machinery by Louis Ridenour.

The session on numerical methods is noteworthy as containing the paper on mathematical methods by D. H. Lehmer in which he gives his famous rule for producing pseudo-random numbers—that is, long series of numbers random enough for practical purposes. The papers on problems in physics, aeronautics and applied mechanics, and the economic and social sciences, seem to support the view that although aircraft dynamics has been the mainstay and mainspring of the machines, and offers a vast field of future work, their use for problems in physics has only just begun, and for problems in economics is almost entirely in the future.

Anyone interested in machine computing must read these papers.

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Progress in Cosmic Ray Physics. J. G. Wilson, Ed. Amsterdam: North-Holland Pub.; New York: Interscience, 1952. 557 pp. $12.00.

Progress in Cosmic Ray Physics is a collection of eight survey articles by different authors on selected branches of cosmic ray study. The authors are among the foremost investigators in the fields they have surveyed, and a large portion of the work described is their own. This has an advantage over single authorship in assuring thoroughness of knowledge and accuracy of reporting on each topic. Furthermore, the task of writing the book is divided among numerous persons, and each chapter is more easily written because of the author's maximum familiarity with the subject. Only by such division of effort is it possible for men actively engaged in research to produce a book, and only by such means can the time of authorship be made small enough to permit publication before much of the material is obsolete. The present volume, issued early in 1952, represents the state of knowledge as of the early months of 1951.

The subjects covered, with the authors, are as follows:

I, Properties of nuclear interactions revealed by analysis of stars seen in photographic emulsions, by Camerini, Lock, and Perkins; II, Masses and decay schemes of heavy mesons, by C. C. Butler—a survey, including numerous cloud chamber pictures, of evidence regarding the charged and neutral V-particles and the τ meson; III, The qualitative nature of the coupling properties of elementary particles as revealed by nuclear physics and cosmic ray experiments, by L. Michel; IV, The chemical composition, flux, and energy spectra of primary cosmic rays found by studies of emulsions exposed in balloons at high altitude, by B. Peters; V, The primary energy spectrum and atmospheric absorption of cosmic rays, determined from counter and ion chamber measurements of the geomagnetic effects of cosmic rays at various altitudes, by H. V. Neher; VI, The intensities, genetic relations, and energy balance of the components of cosmic rays, by Puppi and Dallaporta; VII, The nature, intensity, and interactions of cosmic rays observed underground, by E. P. George; VIII, Observations and analysis of time variations of cosmic ray intensity, by H. Elliot.

Naturally, cosmic ray physics cannot be divided into branches that are independent of each other; the subjects listed above overlap considerably. Yet each chapter is self-contained. This adds to the clarity of individual sections, but, as a result, some topics are discussed more than once—for instance, the primary energy spectrum of cosmic rays appears in Chapters IV, V, and VI. The overlapping material is not even perfectly consistent in all cases. This reviewer finds such repetitions and differences in point of view helpful, and considers them to be one of the advantages of the multiple-author collection of articles over a perfectly coherent account by a single author.

The selected branches of cosmic ray study do not include the whole range of current investigation; limitations of space made it impractical to try to cover all the subjects of interest. Perhaps the most important topic left out is the study of extensive showers in the atmosphere. The same limitations of space have restricted the amount of data and discussion that could be presented in each chapter; and, particularly in the first chapter, on nuclear interactions of the cosmic rays, this restriction seems regrettable. The editor offers the hope, however, that a second volume will be forthcoming, in which topics thus far omitted will be discussed and developments since the date of preparation of the first volume can be added. It is doubtful, however, whether any book can keep pace quite satisfactorily with the physics of elementary particles, of which one or two new types have already been discovered since the present one was written.

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The Design and Analysis of Experiments. Oscar Kempthorne. New York: Wiley; London: Chapman & Hall, 1952. 631 pp. $8.50.

The revolution in methods of designing experiments initiated by R. A. Fisher in *Statistical Methods* (1925) and *Design of Experiments* (1935) is presumably well known to readers of SCIENCE. Beginning with papers on "Complex Experiments" (1935) and "Design and Analysis of Factorial Experiments" (1937), by F. Yates, it launched much activity in exploration of combinatorial arrangements that would give designs suited to manifold purposes. The time is ripe for a stocktaking of what has been achieved. In 1950 Cochran and Cox' treatise covered the requirements of experimentalists, and H. B. Mann summarized the basic mathematics from a mathematician's point of view. But neither of these attempted to encompass the great amount of work that has been done on the level of mathematical statistics. Kempthorne now gives us a comprehensive account of the methods used to develop designs, and of computational procedures for analysis of results, in a book that maintains the high standard of the Wiley publications in statistics. It will be a pivotal landmark in development of the subject.

Par excellence, it is a book for experimental statisticians; they, however, will look to statistical journals for critical reviews. The potential value to others is difficult to assess.

The first 12 chapters (233 pages) are described in the preface as introductory. Although the methods described have been used in statistical laboratories for some years, no comprehensive account has previously been published. To many this will be the most valuable part of the book. Computational methods are described in detail from an elementary level. On the contrary, proofs are given in matrix notation, with no condescension to mathematical immaturity. As knowledge of matrices is rapidly becoming essential for understanding of much statistical literature, students will welcome having a presentation of least squares theory in this form. Some sections, however, seem rather more clumsy than they need be; with very little extension the path might have been made easier for students just learning these methods. The last section, in particular, seems to have been made unnecessarily difficult by ill-defined shifts of notation.

A discussion of randomization tests and the "finite model" will be novel and illuminating to many students. Divergent points of view, which have been topics of severe controversy, are drawn skillfully together.

Chapters 13–29 run parallel to Cochran and Cox' book, but at a more mathematical level and with little actual duplication. They cover factorial experiments, incomplete blocks, and, finally, two chapters on groups of experiments and treatments in sequence.

Exponents of complex designs have used mathematical tricks and specialized notations that are tremendously helpful once they have been mastered, but that make much of the literature obscure to the uninitiated. Readers new to the subject will find these fully explained. Only very occasionally are extensions indicated without adequate explanation (e.g., the $3^2\ 2^2$ design on p. 363 appears incomprehensible). Exposition is generally clear and free from ambiguity. An important feature is that practical aspects are always kept in view. Frequent warnings are interspersed against uncritical use of elaborations, with risk of the empirical model departing too far from reality, or of losing sight of the main objectives in a maze of intricacies, which may have the fascination of a chess problem but do not produce most profitable experimentation. The more complex arrangements are introduced with the healthy remark: "The advantages which accrue from using the simpler types of experiment will become evident from the descriptions that follow."

For a first edition, breaking new ground, a high level of accuracy has been maintained. Inevitably, one could make criticisms of detail—object to an example, to confusion of notation, and so on—but this is not the place to argue these. This is an important book. All who want to master its subject matter will be grateful for its thorough exposition and the drawing together of so much material between two covers.

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Chemistry and Biochemistry

Physical Properties and Analysis of Heavy Water. Isidor Kirshenbaum. Harold C. Urey and George M. Murphy, Eds. New York–London: McGraw-Hill, 1951. 438 pp. $5.25.

This book by Kirshenbaum, with Urey and Murphy as editors, constitutes a valuable addition to the National Nuclear Energy Series.

The first chapter gives a number of useful tables listing all the known physical properties of D_2O. In the second chapter one finds a discussion and description of the theory and experimental data for isotopic exchange equilibrium constants; in particular, there is included considerable information for deuterium exchange in the hydrogen ammonia system, that has never before been published. The next 300 pages contain detailed descriptions and directions for hydrogen-deuterium analysis, as well as for the isotopic analysis of oxygen by a number of different methods. Of these, approximately 200 pages are devoted to the mass spectrometer, and about 100 more to the methods involving the measurement of the density of water. Both the mass spectrometer and the density methods are described in great detail, so that the book contains a wealth of experimental observations and recommendations concerning techniques. Nowhere else can such a body of useful information be found.

The author draws freely on many unpublished Manhattan Project reports, so that one can find for the first time details of much of the secret work done during the war. In fact, this reviewer learned the disposition and utilization of some apparatus constructed for the Manhattan Project at Northwestern University in 1942; aside from the fact that the apparatus had been taken to and installed in the laboratory at Trail, B. C., we never knew whether any practical use had been made of it. The last chapter of the book contains a good review of present knowledge concerning the natural abundance of hydrogen and oxygen isotopes.

As Kirshenbaum himself did much of the work discussed in the book, he was amply qualified to write of it in an authoritative manner. With Urey and Murphy as coeditors one can feel sure that no important methods have been omitted and that the opinions expressed are entirely sound. The author and the editors are to be congratulated on an excellent and useful job well done.

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Light Hydrocarbon Analysis. Analytical methods compiled and tested for the Office of Rubber Reserve, Reconstruction Finance Corporation, by the Butadiene Committee on Specifications and Methods of Analyses. O. W. Burke, Jr., C. E. Starr, Jr., and F. D. Tuemmler, Eds. New York: Reinhold, 1951. 639 pp. $15.00.

The foreword, by E. R. Weidlein, states ". . . this presentation constitutes a valuable contribution to scientific knowledge." The preface states that the Committee on Butadiene Specifications and Methods of Analyses is completing its war emergency assignment with the publication of this book. The titles of the 9 chapters are: "History and Function of the Committee on Butadiene Specifications and Methods of Analyses," "Butadiene Production Processes," "Butadiene Specifications and Applicable Test Methods," "Schemes of Analysis," "Sampling and Handling of Light Hydrocarbons," "Safety Precautions for Handling Light Hydrocarbons," "Analytical Methods," "Preparation of Samples of Known Composition for Test Programs," and "Evaluation of Accuracy and Precision of Methods." In addition to numerous informative tables, photographs, and drawings, there are 114 appendix tables (one to a page, mostly in fine print) which present analytical data on various test samples. These data are both chemical and physical, including distillation, spectral, and data from combination methods.

Abbreviations used are seldom defined, although the meaning of RFC and the letters designating the various government rubbers is given in pages 1–3. Probably a good many foreign, and at least some American, readers might like to know what ORR, O.R.R., L.H., L.M., psia, DD, etc., stand for.

The 54 procedures as set forth in Chapter 7 (363 pp.) have "L.H." numbers. (The abbreviation "L.H." presumably, is for "light hydrocarbons" and facilitates cross-referencing.)

The three-page index is totally inadequate for a work of this magnitude. For example, it fails to list diamylamine, an important component in the reagent for 1,3-butadiene (p. 163). A few of the tables, such as Table 76, are scarcely legible. Methods are referred to without stating what they are—e.g., the gravimetric method (p. 467) for 1,3-butadiene (L.H. 510, p. 27). The book contains about 70 references to the scientific literature. Many more would be useful.

This book will be of interest to the large number of investigators who were, or still are, connected with butadiene analysis. It contains a large amount of miscellaneous information (only part of it still useful) under a misleading title. A more appropriate